ANALYSIS OF COST AND TIME OVERRUN OF HYDRO POWER PROJECTS

A DISSERTATION

Submitted in partial fulfilment of the requirement for the award of the degree

of

MASTER OF TECHNOLOGY

in

ALTERNATE HYDRO ENERGY SYSTEMS

By

VINAY SHANKAR

DEPARTMENT OF HYDRO AND RENEWABLE ENERGY

INDIAN INSTITUTE OF TECHNOLOGY

ROORKEE-247667 (INDIA)

JUNE 2019

DECLARATION

I hereby declare that the report which is being presented titled **“ANALYSIS OF COST AND TIME OVERRUN OF HYDRO POWER PROJECTS”** in partial fulfillment of the requirements for the award of the degree of **Master of Technology** in Alternate Hydro Energy Systems, submitted in **Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee, Uttarakhand, India**, is an authentic record of my own work carried out during period from July 2018 to June 2019 under the supervision of **Prof. S.K.SINGAL**, Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee.

I have not submitted the matter embodied in this report for the award of any other degree or diploma.

Place: Roorkee

Date: 12 June, 2019 (**VINAY SHANKAR)**

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Prof. S. K. SINGAL
Department of Hydro and renewable Energy
Indian Institute of Technology
Roorkee -247667

ABSTRACT

With increasing number of hydroelectric projects in India and across the globe, delays in commissioning and cost overrun has been a regular feature of these projects. Almost all hydro projects barring few, have been victim of time and cost overrun owing to various reasons. There are various studies conducted for risk management of hydro projects but so far there are not many studies conducted on time and cost overrun specifically for hydroelectric projects in context of India.

This study was started by preparing a report identifying the prominent causes behind delays and cost overrun in hydroelectric projects based on the literature review. As per the gaps identified, exclusive study has been done for hydroelectric projects regarding overruns considering only completed projects. This study analyses the reasons for cost as well as time overruns of hydroelectric projects across India to get an idea about range of cost and time overrun incurred to hydroelectric projects. Further analysis has to be done to draw comparison based on ownership, project location and installed capacity. This study is an attempt to analyse the arguments often given for government owned hydro projects to have lackluster record of overruns as compared to privately owned. The comparisons made here, have underlined motive to identify the poor performing sectors as compared to others. The present study has limited objective of bringing a comparison of overruns between them, not about the aspects of the reasons behind them. The comparison indicate that privately owned hydro projects do have better track record in most of the comparison criteria whereas state government owned projects shows a dismal track record. In terms of project location, south India projects have highest values of overrun but north India projects take the lead in having least value for overrun among north, south and north-east India located projects. Similarly, based on capacity, small hydro projects show better resource utilization while projects completion and at the same time, medium capacity hydro projects lag behind.

As cost and time overrun are generally interdependent so an attempt is also made through this study to find a relation between cost overrun and time overrun based on data available. The relation obtained through non-linear regression shows that time overrun as well as inflation does impact cost overrun and have positive relationship with cost overrun. In developing this type of analysis, it is hoped to create diligent method to predict or estimate the probable cost overrun value for better estimation of cost.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my guide **Prof. S. K. Singal,** HRED, Indian Institute of Technology Roorkee for his valuable guidance, support, encouragement and immense help. I would like to thank, Mr. N.A. Kakroo, JKSPDC and Mr. Mohit Shukla, SJVN for providing me the help with data. I would also like to thank my colleague Ayush Jain, M.Tech AHES, Indian Institute of Technology Roorkee for his timely help.

Moreover, I would remain grateful to all faculty members and staffs of Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee and also would like to extend my heartfelt thanks to all my friends who have helped me directly or indirectly for the completion of this report.

Date: 12 June 2019

Place: Roorkee **(VINAY SHANKAR)**

TABLE OF CONTENT

DECLARATION **i**

ABSTRACT **ii**

ACKNOWLEDGMENT **iii**

TABLE OF CONTENT **iv**

LIST OF TABLES **vi**

LIST OF FIGURES **vii**

NOMENCLATURE **ix**

CHAPTER 1 INTRODUCTION 1

1.1 GENERAL 1
1.2 DIFFERENT TYPES OF HYDROPOWER PROJECTS 1
1.2.1 Based on infrastructure 1
1.2.2 Based on capacity 4
1.3 COST ESTIMATION OF HYDRO POWER PROJECTS. 4
1.3.1 Cost Components of Hydro Power Projects 5
1.4 SCHEDULE OF A HYDRO POWER PROJECT 8
1.5 DELAYS AND OVERRUN 10
1.5.1 Cost overrun 10
1.5.2 Time overrun 11
1.5.3 Current scenario for ongoing projects 12

CHAPTER 2 LITERATURE REVEW 15

2.1 LITERATURE REVIEW 15

2.2 GAPS IDENTIFIED 21

2.3 OBJECTIVES OF THE STUDY 22

2.4 PROPOSED OUTLINE OF THE STUDY 22

CHAPTER 3 ANALYSIS OF COST AND TIME OVERRUN 25

3.1 GENERAL 25

3.2 COMPARISION OF COST OVERRUN . 36

3.2.1 Based on percentage of projects 36

3.2.2 Based on average cost overrun 40

3.3 COMPARISON USING PER MW COST OVERRUN 42

3.3.1 Per MW cost overrun (based on Ownership) 43

3.3.2 Per MW cost overrun (based on location) 44

3.3.3 Per MW cost overrun (based on Installed capacity) 44

3.4 COMPARISON USING TIME OVERRUN 51

3.4.1 Based on percentage of project 51

3.4.2 Based average time overrun 54

3.5 COMPARISON USING CAPITAL TIME WASTE FACTOR 57

3.5.1 Based on ownership 62

3.5.2 Based on location 64

3.5.3 Based on installed capacity 64

3.6 SUMMARY OF COMPARISON ANALYSIS 65

3.6 REGRESSION FOR TIME OVERRUN AND COST OVERRUN 67

CHAPTER 4 CONCLUSIONS AND RECOMMENDATIONS 77

REFERENCES 79

LIST OF TABLES

TABLE NO	TITLE	PAGE NO
1.1	Expected Time consumption for various activities for SHP	8
1.2	Top 10 delayed HEP in India (as of March 2018)	13
1.3	Major reasons for slippage in hydro power project	14
3.1	Project details with cost overrun	29
3.2	Comparison of cost overrun based on ownership	36
3.3	Average cost overrun based on ownership	40
3.4	Average cost overrun based on project location	41
3.5	Average cost overrun based on installed capacity	41
3.6	Project data with time overrun	46
3.7	Time overrun data based on ownership	51
3.8	Average time overrun with respect to Owner	54
3.9	Average time overrun with respect to region	55
3.10	Time overrun comparison installed capacity wise	56
3.11	Data for capital time waste factor	58
3.12	Capital time waste factor based on ownership	62
3.13	Comparison summery with respect to ownership	65
3.14	Comparison summery with respect to Location	66
3.15	Comparison summery with respect to installed capacity	66
3.16	values of regression coefficient	69
3.17	Value for actual and expected cost overrun	71

LIST OF FIGURES

FIGURE NO	TITLE	PAGE NO
1.1	Run-of-River based project	2
1.2	Reservoir based hydropower project	3
1.3	Pumped storage based project	4
1.4	Generic examples of Timeline for the development of a HEP	9
1.5	Amount & no. of Cost overrun projects	14
3.1	Outline of proposed analysis	26
3.2	Cost overrun based on ownership	36
3.3	Percentage of project with various cost overrun	37
3.4	Comparison of cost overrun and installed capacity	38
3.5	Percentage of projects having cost overrun	39
3.6	Percentage of projects having cost overrun based on installed capacity	40
3.7	Average cost overrun based on ownership	40
3.8	Average cost overrun based on project location	41
3.9	Average cost overrun based on installed capacity	41
3.10	Comparison of Cost overrun vs inflation during the delay of the project	42
3.11	Per MW cost overrun at 2019 price level are (Ownership)	43
3.12	Per MW cost overrun at 2019 price level are (Installation zone)	44
3.13	Per MW cost overrun at 2019 price level are (Installed capacity)	45
3.14	Time overrun plot based on ownership	51

3.15	Comparison of time overrun wrt ownership	52
3.16	Time overrun with respect to project location	53
3.17	Time overrun with respect to installed capacity	53
3.18	Average time overrun with respect to Owner	54
3.19	Average time overrun per project and per MW (zone wise)	55
3.20	Average time overrun per project and per MW(capacity wise)	56
3.21	Capital time waste factor based on ownership	62
3.22	Capital time waste factors based on ownership	63
3.23	Capital time waste factor based on location	64
3.24	Capital time waste factor with respect to installed capacity	64
3.25	Plot of cost overrun vs time overrun	67
3.26	Plot of cost overrun vs product of time overrun and inflation	68
3.27	Showing residual plot of non-liner regression	70

NOMENCLATURE

LIST OF SYMBOLS

SYMBOLS	DESCRIPTION
Ca	Actual cost at commissioning
Ta	Actual time taken for commissioning
To	Original anticipated time for completion
Co	Original expected cost for completion
PL	Price level
S	denoting location zone of projects in south India
N	Denoting location zone of the project in north India
NE&E	Denoting location zone of the project in north east and east India
C	Expected cost overrun from the relation
T	value of multiplication factor, actual time for project completion is of initially anticipated time of completion
i	Average inflation factor

CHAPTER 1
INTRODUCTION

1.1 General

In 21st century, with ever increasing population, energy demands are also increasing exponentially. With more impact on green energy in recent times there has been a significant emphasis on hydropower projects in recent decades be it large or small.

India has total estimated hydro power potential of 150 GW and of these 44963 MW as Major Projects and 4418 MW as SHP has been installed by Jan 2018[2]. India installed its first HEP Sidrapong Project (130 KW) in Darjeeling in 1897. Currently there are approx. 7134 projects[2] which are running and 48 projects (above 25MW) are under various stages of construction across India. Most of the projects lie in NE region, Himachal Pradesh and Uttarakhand. A large part of the estimated potential is yet to be exploited.

Life cycle analysis of hydropower shows as cleaner electricity technology with a low carbon footprint and it has the highest payback ratio. But cost and time overruns are diminishing those advantages. Time and cost are two lifelines of any construction of any hydroelectric project and failure of these two directly impacts the success of the project. And going by the recent trends, clearances and resettlements have costed dearly to these two. Time overruns generally make a project less lucrative for investors and sometimes it becomes a burden. Similarly cost overrun not only increases the generation cost of energy but also dents the economic feasibility of the projects (World Commission on Dams, 2000)[13].

1.2 Different type of Hydropower Projects

1.2.1 Generally based on infrastructure HEP (Hydroelectric projects) are categorized into

1) Run of River (ROR)
2) Reservoir based
3) Pumped storage

1.2.1.1 Run of river scheme

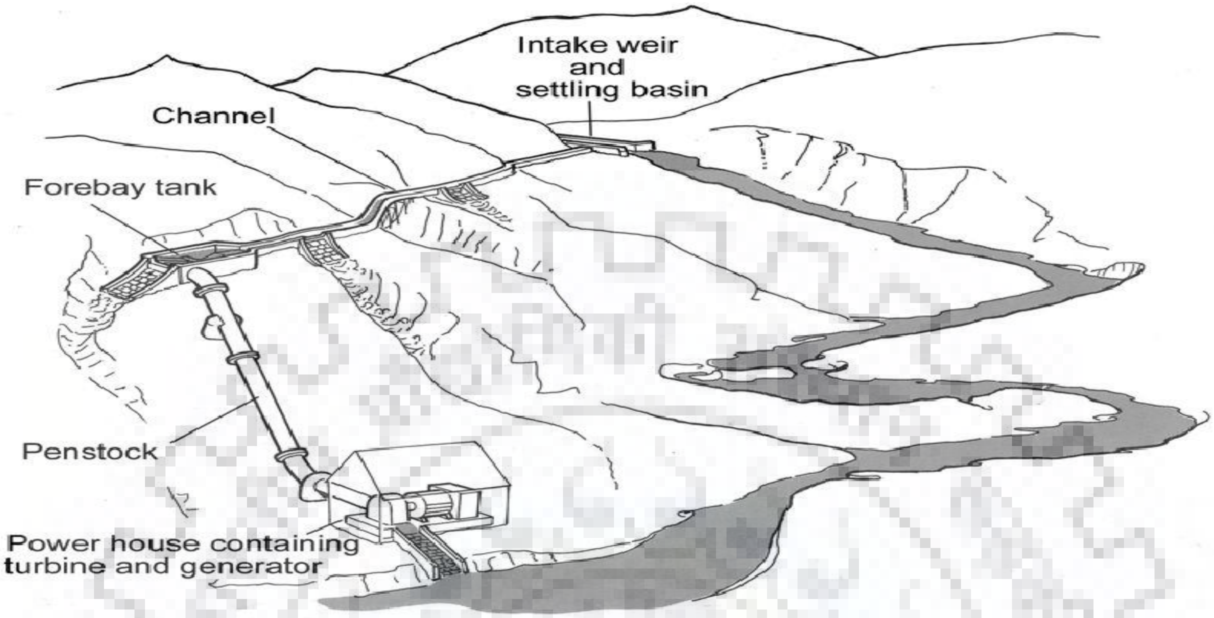


Fig:1.1 Run of River scheme[1]

As illustrated in Fig:1.1,In this type of project a portion of river water is diverted through a channel or penstock to powerhouse where it passes through turbine and power is generated. Water is again supplied back to river downstream through tail race channel. Typically, this kind of project have diversion weir to take out the water required for the energy generation. Such projects are dependent upon the flow in the stream as no storage or limited storage upto few hours are available through ponding.

Similarly, instream based scheme is a sub type of ROR (run of river) in which project is installed in stream itself, no need of diversion of water of any kind is required in this case.

1.2.1.2 Reservoir based Project

As illustrated in Fig:1.2, in this type of scheme water is stored behind a retaining structure for the continuous supply during lean water supply. As there is surplus water and flood like situation in many areas during rainy season and very less availability of water during lean season so surplus water during rainy season is stored to be used during lean season. Water is supplied to turbines through intake to generate electricity. It is installed to ensure reliability during lean period and avoid fluctuations of water in stream. Sometimes, these are used as multipurpose projects to control flood and for water storage.

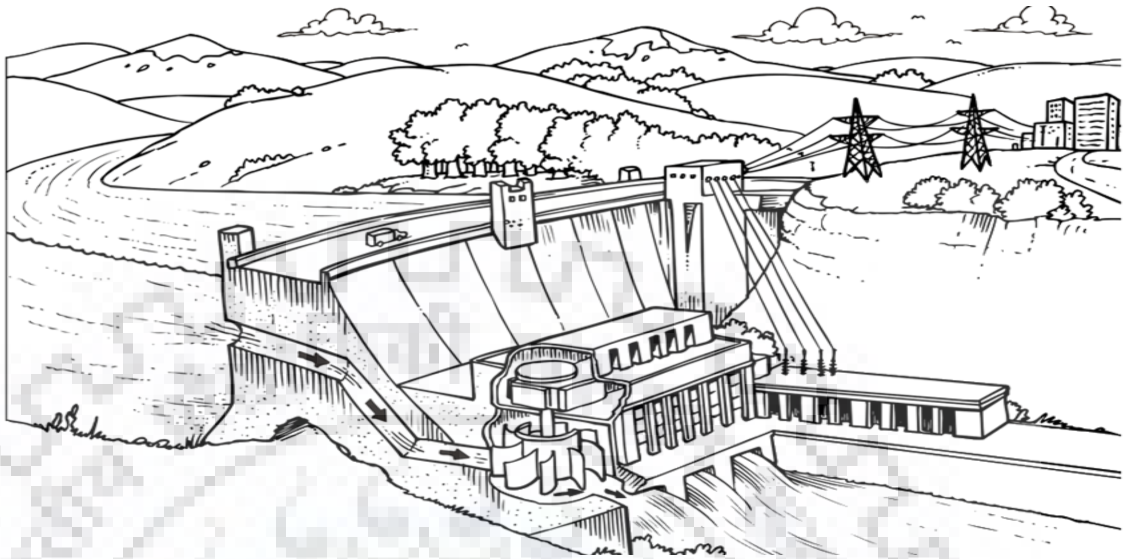


Fig:1.2 Reservoir based hydropower project [1]

1.2.1.2 Pumped storage Project

As shown in Fig 1.3, this type of scheme works like a battery, storing the water when energy demand is low hence using cheap electricity and utilizing the stored water in upper reservoir to generate electricity when demand is peak i.e. cost of generated electricity is more. It stores energy by pumping water uphill to a reservoir at higher elevation from a second reservoir at a lower elevation. When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir. During periods of high electrical demand, the water is released back to the lower reservoir and turns a turbine, generating electricity. Currently when solar based projects are at peak but they are unable to generate electricity during nighttime and we haven’t yet developed the ability of battery storage for large power hence this type of pumped storage scheme come handy where nowadays, surplus power generated using solar power is being used for storing water in upper reservoir to generate electricity during peak time or in night thus acting as virtual battery. As of June 2018, India has 6.8GW of installed capacity from pumped storage scheme[44].

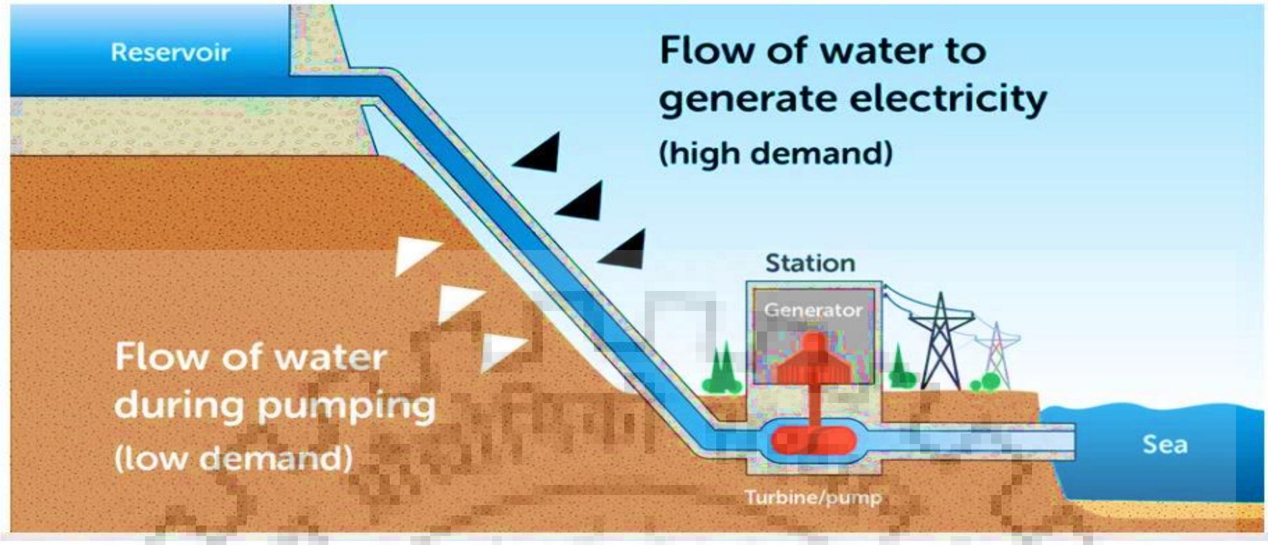


Fig:1.3 Pumped storage-based project [1]

1.2.2 Based on capacity

Based on capacity installed, hydro projects in India are categorized in

- Large: >100 MW
- Medium: 25 – 100 MW
- Small: 1-25 MW
- Mini: 100 KW - 1MW
- Micro: 5 – 100 KW
- Pico: < 5 KW

1.3 Cost Estimation of Hydro Power Projects

The complexity in cost and time estimation in hydro power projects can be understood with the knowledge that there is nothing like fix formula to set up a hydro power plant. Each one is different from anther and every part has to be custom made for each project. So, there might be similarity between two projects but even a slight variation in any of the factors can completely change the cost economics and schedule planning. In general, the geology varies considerably across India and specially the hydro power concentrated zone north and north eastern sides of country have young Himalayan geology which is comparatively unstable and has complex geological formation. So, these factors make execution of hydro power projects even more challenging and these factors completely rule the scheduling timeline in most of the hydro power projects. There are various case studies in which just due to geological surprises projects have been completely stalled or cost have been manifold.

1.3.1 Cost Components of Hydro Power Projects:

Cost estimation for any project is necessary to maintain the continuous and smooth flow of fund for uninterrupted development of the project. Cost estimates play a major role for further work to be taken based on available fund.

As per IS:4877-1968[3], detailed itemized cost of each component of the project is prepared with available precision and detail and rates for various components of civil structures are generally adopted as per prevailing government schedule of rates.

Generally, cost of a hydro project consists of Direct charges (for works, establishment, tools & plants, receipt & recoveries), Indirect charges (capital value of land revenue, audit & account charges etc.) and Misc. charges (financing cost, Local Area Development Cost (LADA), Interest during construction (IDC) etc.). Among all these three components shares large chunk namely Civil works, Electromechanical Works (E&M) and Transmission & Distribution Works(T&D). As these three components share most of the overall cost of HPP so is the risk associated with them. Failure or non-completion of any would affect whole project consequently delays and cost overrun.

1.3.1.1 Cost of civil works include:

- Earthwork and excavation
- Dam/Reservoir work
- Intake structures
- Conduit works and Penstocks
- Energy dissipation works and filter works
- Desilting arrangements
- Spillways
- Surge tank
- Powerhouse building
- Tail race channel

1.3.1.2 Electro-Mechanical works includes:

- Turbine and accessories
- Gates, cranes and hoisting equipments
- Draft tube arrangement
- Power cable and control cables
- Transmission lines
- Sub stations and equipments
- Switchyard
- Transformers

1.3.1.3 Other costs include

- Preliminaries like pre-construction and construction stage surveys and investigation.
- Land acquisition or land revenue
- Temporary building for manpower and store
- Tools and plants
- Audit and accounts
- Engineering design
- Roads and communication
- Miscellaneous like vehicle, security, compensation etc.
- Local area development cost (LADA), Financing charges (FC), Interest during construction (IDC) etc.

Based on 'Benchmark costs For Small and Large Hydro Projects' a report by AHEC[4], civil works comprises of around 45-55 % of total cost, E&M works comprises of 20-30% of total cost & T&D works comprises of 5-10% of total cost

1.3.1.4 For estimating cost of civil works, unit costs of labour, materials and equipment has to be determined. The cost of civil works associated with the power station building are largely dependent on head. Higher head needs less expensive powerhouse building.

Civil works cost comprises of diversion structure, water conductor system, powerhouse building, desilting arrangement, reservoir etc. The cost of each component is determined by computing quantities of various items and multiplying by prevailing item rates.

1.3.1.5 Electro-Mechanical Equipment is determined by the operating head on the hydraulic plants and selection of turbine type to optimize the generation. As the head falls, not only the size of runner diameter increases, but also cost of generator increases due to reduction in shaft speed. It is understood that site-specific equipment design has been avoided by standardized equipments to reduce the cost. The cost of electromechanical equipment depends on unit capacity, head, type of equipment and number of units. The cost is determined taking the prevailing market prices obtained from different manufacturers into consideration. These costs include cost of turbine, generator, valves, controls switchyard and other accessories but excluding cost of transmission line.

1.3.1.6 Transmission & Distribution Cost depends on the amount of power to be evacuated from the powerhouse, voltage level, types of conductor, types of poles and the length of transmission line. The cost of transmission line is assessed per km basis depending on capacity of the line such as 11 kV, 33 kV, 132 kV and 220 kV, etc. The cost of executing transmission line has to be shown as a separate item as providing transmission line for power evacuation may be the responsibility of the state utility.

1.3.1.7 Apart from these major costs other costs include cost on land acquisition, report preparation, Environment Impact Assessment, special tools & plants etc. which under normal circumstances remains more or less same.

As a thumb rule overall cost of a hydro power project generally varies between ₹ 5-10 crore / MW. Cost variation depends upon site to site, availability of resources, labour charges etc. (also see Benchmark cost for Hydropower Projects, AHEC)[4]

Cost estimates of a hydro power plant is based on detailed itemized cost of each component without adjusting inflation for the construction period with some physical contingencies for fluctuations.

1.4 Schedule of A Hydro Power Project

A proper schedule is maintained to complete the project stipulated time interval. For this proper timeline is forecasted for every activity using PERT or any scheduling technique for its journey from concept to construction and finally commissioning. As hydro power projects are generally complex in nature and various activity and parts are interdependent so a time bound management become necessity for scheduled completion of the project.

Hydro Power Projects are generally implemented in four stages. First stage is Pre-Construction activities which consist of pre-feasibility study which is done to have an overview about the feasibility of the proposed project. Then comes detailed investigation and surveys which deals with hydraulic investigation, geotechnical, topographic survey, power load demand assessment(in case of stand-alone projects), meteorological and environmental surveys. After all these surveys, preparation of DPR (Detailed Project Report) takes place, which contains all the survey reports, all necessary permission from various authorities, tendering and award of contracts, acquisition of land, detailed construction drawing etc. Second stage is construction stage which comprises of construction of diversion weir, intake, reservoir, channel, penstock, powerhouse building, forebay etc. after detailed drawings and design is completed along with awarding tender. Then third stage is Electro-Mechanical works which deals with procurement of E&M equipment and its installation, laying of switchyard, erection of machines and control panel etc. Then the last stage is Testing and Commissioning.

Table: 1.1 Expected Time consumption for various activities for SHP [5]

	Activities	**Time Taken**
A.	**Administrative**	
	Advertisement	Yearly
	Allotment	6 months to one year
	Signing of implementation agreement	1-3 months
B.	**Pre-implementation**	
	Detailed investigation and surveys	4 months - 2 years
	Pre-feasibility report (PFR)	1-3 months
	Detailed Project Report (DPR)	3-6 months
	Approval of DPR	4-6 months

	Activities	Time Taken
	Land Acquision - Forest Land Acquision - Civil Land Acquision - Private	6-12 months 4-12 months 4-12 months
	Clearance for Environment	4-12 months concurrently
	Power purchase agreement	2-4 months concurrently
	Clearance from different authorities	6 months concurrently
	Preparation of plan for resettlement and rehabilitation	Normally not involved
	Financing	3-6 months concurrently
C.	**Implementation**	
	Construction License	2-3 months concurrently
	Engineering design & construction design	3-6 months concurrently
	Equipment supply	8-16 months concurrently
	Civil work construction	10-18 months concurrently
	Resettlement and rehabilitation	Normally not involved
	Commissioning	12-24 months concurrently

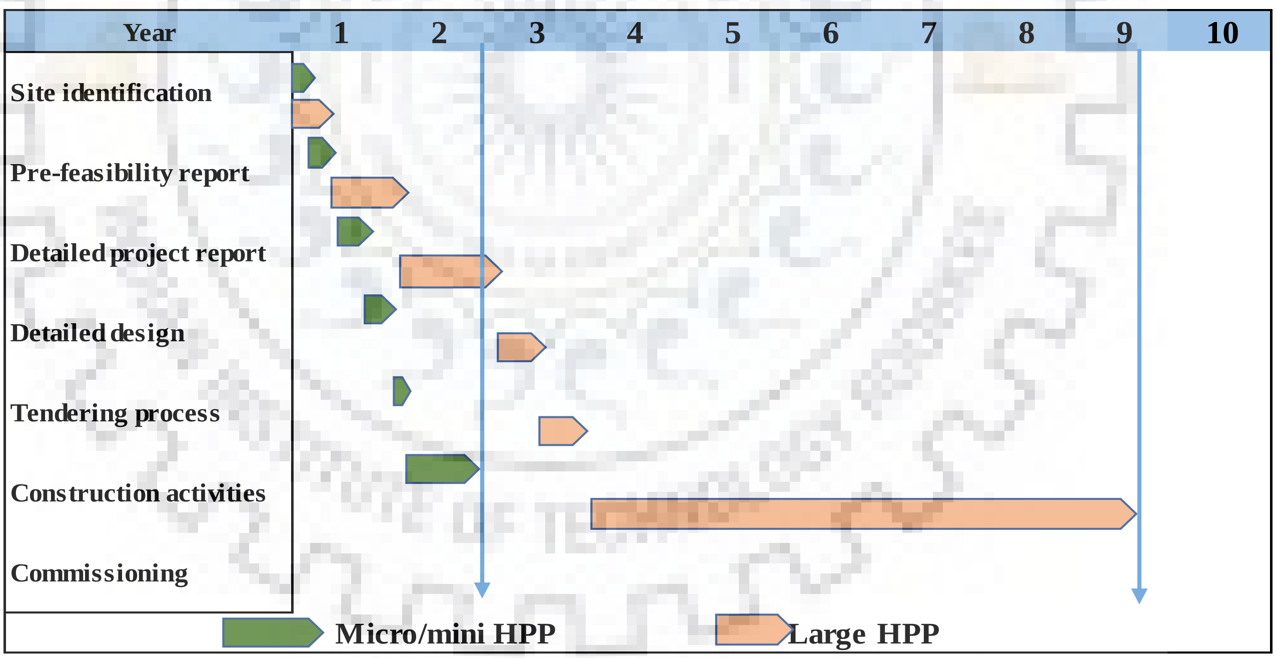


Fig:1.4 Generic example of Timeline for the development of a HEP [5]

1.5 Delays and Overrun

Delays in project implementation and the attendant cost escalation have been a regular feature of the hydro power sector in India and across the globe. Normally, the construction of a major hydro-power plant is expected to be completed within eight to ten years, and that of a mini hydel project in two to three years. However, India experiences, longer time and higher cost overruns in the case of both major and mini hydel projects, is baffling. A 'classic' example is the Kakkad hydroelectric project of 50 megawatt (MW) installed capacity; the project was sanctioned as early as in 1976 with an original cost estimate of. ₹1,860 lakhs; this project was proudly presented as the least-cost hydroelectric project in the State of Kerla. It was scheduled to be commissioned in 1986 but took twenty-three years for the Kerala power system to tap the energy potential of this project (major construction works on it started only in 1979), at an estimated cost of ₹.153.5 crores, about 725 per cent above the original one.

1.5.1 Cost overrun

Cost overrun can also be termed as budget overrun, cost increase, or cost escalation. Cost overrun is a variance/difference between initially estimated or projected cost and final cost at the completion of the project. Final costs are described as the total costs actually spent on construction project as determined at the project completion time while, projected or initial costs is known as the planned or predicted costs at the project approval time.

Actual costs are defined as real, accounted construction costs determined at the time of project completion. Estimated costs are defined as budgeted, or forecasted, construction costs at the time of decision to build. The year of the date of the decision to build a project is the base year of prices in which all estimated and actual constant costs have been expressed in real (i.e. with the effects of inflation removed) local currency terms of the country in which the project is located.

The cost overrun value for a particular project is calculated by dividing the difference of actual cost and estimated cost by estimated cost in terms of percentage given by Eq. 1.1, It gives us an idea about by factor cost has escalated in terms of estimated cost.

$$\% \, \textbf{Cost Overrun} = \frac{\textit{Actual Completion Cost} - \textit{Estimated completion cost}}{\textit{Estimated completion cost}} \, \textbf{X 100} \qquad \text{Eq. (1.1)}$$

The start of the implementation period is taken to be the date of project approval by the main financiers and the key decision makers, and the end is the date of full commercial operation.

Time overrun and cost overrun in construction projects can also be called is slippage of project schedules. Time overrun can also be defined as the time increased to finish the construction project after scheduled date which is affected by internal and external causes surrounded the construction project.

Projects with a poor cost and schedule performance are also likely to have a poor environmental and social track record. A greater magnitude of cost and schedule overruns is thus a robust indicator of project failure (Flyvbjerg, 2003)[7].

Time delays, cost overruns and change orders are generally due to factors such as design errors, unexpected site conditions, increase in project scope, weather conditions and other project changes.

1.5.2 Time overruns

The average time overrun of hydropower projects is estimated at six years, which is considerably long considering the steps being initiated by the government to provide an impetus to green projects in the country. As per the CEA, seven projects are facing delays of 10 years or more (as of November 2017). Of these, the 400 MW Maheshwar hydroelectric project (HEP) in Madhya Pradesh has had the highest time overrun of around 17 years. The primary concern of the Maheshwar HEP is the R&R of the local communities that are likely to get displaced as a result of its construction. The project has faced strong resistance from the Narmada Bachao Andolan in the past. Further, the project promoter, Shree Maheshwar Hydel Power Corporation Limited, has been facing financing issues, which also led to the takeover of the company's control by lenders in 2016. The project is currently stalled.

Meanwhile, NHPC Limited's 100 MW Uhl III HEP in Himachal Pradesh has been held up for 11 years due to delays in the transfer of forest land and the award of contracts, and the poor structure of the head race tunnel. North Eastern Electric Power Corporation Limited's 60 MW Tuirial project in Mizoram was commissioned in November 2017 after being delayed by 11 years due to challenges such as poor approach roads, slope failures and agitation from local communities. Other projects facing delays of nearly 10 years include THDC India Limited’s 1,000 MW Tehri pumped storage project in Uttarakhand, NHPC’s 800 MW Parbati II in Himachal Pradesh and 2,000 MW Subansiri Lower in Arunachal Pradesh. Several other projects are facing delays ranging from five to nine years.

1.5.3 Current Scenario for Ongoing Projects

The hydropower segment in India has consistently fallen short of achieving the prescribed capacity addition targets every year since 2008-09. During the Twelfth Plan period (2012-17), around 5,479 MW of capacity was added against the targeted addition of 6,247 MW. In 2017-18, about 278 MW of hydro capacity has been added till October 2017 against the annual target of 1,305 MW. The low capacity addition can be attributed to delays in land acquisition, resettlement and rehabilitation (R&R) issues, lengthy environmental approval processes and geological surprises that hamper project development. As per the Central Electricity Authority (CEA)[2] , around 38 hydropower projects aggregating 11,650.5 MW are facing delays with significant time and cost overruns, as of November 2017.

Delays have become common in the hydropower sector due to land acquisition challenges, long gestation periods and R&R issues. However, the biggest impediment to project commissioning remains the multitude of clearances and approvals required. In addition, weather fluctuations often slow down the pace of work, thereby aggravating the problem. Further, rehabilitation concerns amongst local communities and subsequent agitations continue to act as roadblocks in the commissioning of hydropower projects. In addition, most new hydropower sites are located in remote hilly areas with little or no infrastructure facilities such as roads, thus making the transport of men and machinery difficult. Apart from these, issues pertaining to water sharing between states, geological factors and delays in the award of contracts have been responsible for commissioning delays, which have exceeded 10 years in some cases.

Due to the cost-intensive nature of hydropower projects and unanticipated contingencies, the cost overruns of these projects are also significant. Since hydropower projects are financed by a huge amount of debt, project delays lead to significant cost escalation on account of the interest component of the loan. The interest during construction is calculated till the time the project gets commissioned and starts generating revenue. The process of obtaining clearances from several authorities and various geological factors such as floods and landslides lead to delays in project commissioning, thereby increasing the duration for which interest is calculated and the overall project cost.

Most hydropower projects under construction have experienced cost overruns with an average breach of about Rs 18.5 billion. Of the delayed projects, 23.07 per cent have registered cost overruns exceeding Rs 36.5 billion. Further, four projects have witnessed exceptionally high cost overruns accounting for 54.71 per cent of the total cost overshoot. These are the Subansiri Lower HEP, Maheshwar HEP, Parbati II HEP and Teesta Stage VI HEP (500 MW) with cost overruns of Rs 111.49 billion, Rs 65.51 billion, Rs 44.79 billion and Rs 42.58 billion respectively.

Table:1.2 Top 10 delayed HEP in India (as of March 2018) [2]

Top 10 delayed projects as of March 2018(in terms of time overrun)								
Project	**State**	**Capacity (MW)**	**Original commissioning schedule**	**Anticipated commissioning schedule**	**Delay (Months)**	**Original cost(Rs billion)**	**Anticipate cost (Rs billion)**	**Cost overrun (Rs Billion)**
Maheshwar	M.P.	400	2001-02	2018-19	204	15.69	81.21	65.52
Uhl III	H.P.	100	2006-07	2017-18	132	4.31	12.81	8.50
Pallivasal	Kerala	60	2010-11	2020-21	120	2.22	2.84	0.62
Tehri PSS	Uttrakhand	1000	2010-11	2020-21	120	16.57	39.39	22.82
Parbati II	H.P.	800	2009-10	2019-20	120	39.19	83.98	44.79
Subansiri Lower	Assam	2000	2009-11	2020-21	120	62.85	174.35	115.50
Swara Kuddu	H.P.	111	2010-11	2019-20	102	5.58	11.81	6.23
Teesta Stage IV	Sikkim	500	2012-13	2021-22	102	32.83	75.42	45.59
Rangit IV	Sikkim	120	2011-12	2019-20	96	7.26	16.92	9.66
Thottiyar	Kerala	40	2012-13	2020-21	96	1.36	1.50	0.14

As given in Table:1.2, it can be seen that cost overrun is about 4 times the initial estimated cot in case of Maheshwar HEP and delay is about 17 years and similarly in every case the delay is huge so considering this Table 1.2, it can be safely assumed that delay has very critical effect on cost overrun.

Hydro Power projects are having overruns not only in government funded projects but also in privately funded projects too. According to data given in CEA second quarterly report of 2018 for ongoing projects, following bar charts have been plotted for Variation among different type of promoters:

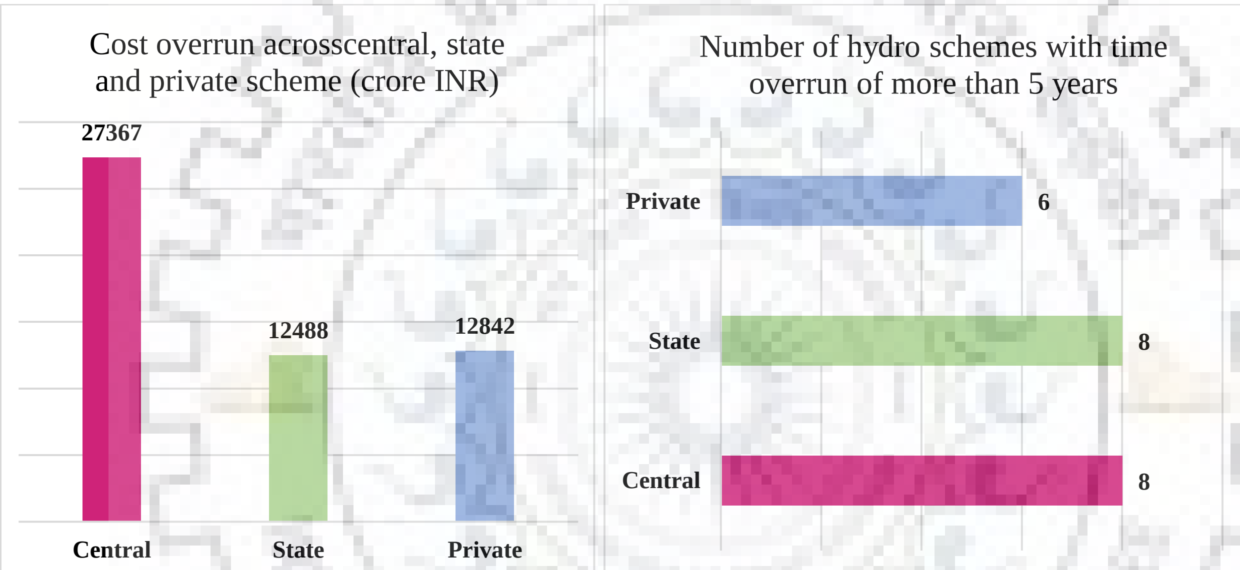


Fig: 1.5 Amount & no.of Cost overrun project [2]

Table:1.3 Major reasons for slippage in hydro power projects [2]

Major reasons for slippage in hydro capacity additions (as a percentage of total observed instances)							
	Geology, hydrology and topography	**Critical electrical and mechanical works**	**Delays in clearances**	**Local issues, law and order problems**	**Contractual disputes**	**Enabling infrastructure**	**Land acquisition**
Central	21	8	16	24	16	11	5
State	8	14	14	16	35	3	11
Private	35	12	12	19	8	8	8

CHAPTER 2
LITERATURE REVIEW

2.1 Literature Review

2.1.1 A study by (**Flyvbjerg et al., 2003**)[7] found that cost overruns may not always be accidental, and can, in a sense, be strategic. That is, project sponsors can misrepresent costs and benefits of a project in order to motivate stakeholder involvement and then commitment. It is also mention in this study that projects are consistently approved on the basis of underestimated costs, overestimated revenues, undervalued environmental impacts, and overvalued economic development effects. This misinformation intentionally distorts risk assessments and conceals the true risk of projects from investors, taxpayers, and regulators until it is ‘‘too late’’ to abandon a project. Contractors eager to have their projects accepted may produce overly optimistic assessments at the genesis of a project expecting that it will be too far along to back-out by the time its viability can be more accurately assessed.

This study also compared the mean cost of escalation for various infrastructure projects like nuclear reactors, railway network, bridges and tunnels, roads, mining projects, thermal power plants, wind farms, transmission projects along with hydroelectric projects. For hydroelectric projects value of average cost overrun came out to be 71% for 61 projects considered.

2.1.2 **Benjamin et al., 2014** [8] conducted study for 401 power plant and transmission projects in 57 countries which included 61 hydroelectric projects representing 113,774 MW of installed capacity worth $271.5 billion of investment. These projects experienced a total of $148.6 billion in cost overruns. Study suggested that costs are underestimated in three out of every four projects (75.4 %). Among all the power projects Hydroelectric dams had the longest mean construction time of all projects, as well as the largest total cost overrun amount per project and the reason given by this study behind ne possible explanation for why hydroelectric projects suffer the largest mean cost overrun of any project is that they are, on average, more materials intensive than other energy sources. Though this paper gives comparison between various power project cost and time overrun but it does not specify the causes and factors nor it gives suggestions for the same.

2.1.3 **Sambu, N & Irdus, A** [9] conducted a detailed survey for numerous projects and 113 causes for delay and cost overrun were gathered from the questionnaire surveys from three main components of projects i.e. Contractor, Consultant and Owners. All the causes were compiled into six different cases. This study mainly focuses on opinion of the three parties responsible for the projects and it primarily highlights non-cooperation between parties, wrong resource estimates and continuous change in drawings as responsible for cost and time overrun. This study falls short on detailed study of each factor responsible and quantitative impact of each on both cost and time.

2.1.4 **Aibinu & Odeyinka, 2006**[10] identified several factors as main contributors to contractor's responsibility for the delay, these delays are financial problems, equipment fault, planning and scheduling problems, shortage in equipment and materials, slow mobilization, maintenance problems and shortage of labours. And owner's cash flow problems, variation orders and slowness and delay in decision making as contribution to owner's responsibility. This study assesses the causes of delays by focusing on actions and inactions of project participants and external factors. The study analyzed quantitative data from completed building projects to assess the extent of delays, and data obtained from a postal questionnaire survey of construction managers to assess the extent to which 44 identified factors contributed to overall delays on a typical project they have been involved with.

2.1.5 **Chan and Kumaraswamy 1997**[11] categorized the factors affecting cost and time overrun in three categories namely contractor's responsibility, consultant's responsibility and owner's responsibility. Poor site management and supervision, insufficient project planning and scheduling are identified as contractor's responsibility whereas delay in design information, lack of designs team experience and mistakes and contradiction in design documents as consultant's responsibility and unrealistic duration of the contract, low speed of decision making and owner initiated variations as owner's responsibility.

2.1.6 **Dinesh Kumar R, 2016)** [12] focused on to find out the most significant factors causing delays in Indian construction projects through literature review and questionnaire survey. From the literature review 103 causes of delays categorized into 8 types of groups, 8 effects of delays were found and also rankings given by the authors for the delaying factors. Further, the Questionnaire survey is conducted with the participants (contractors, owners, consultants and others) of Indian construction industry in order to determine the top 20 significant factors with respect to Indian context and finally recommendations are given to avoid delays in construction project. In this paper, Relative Importance Index method is adopted to determine the relative importance of the various causes of delays. Inadequate contractor's work & experience & also poor risk management and ignorance is the most prevalent reason behind delays of the project as it has max relative importance index in this study.

2.1.7 (**World Commission on Dams (WCD) 2000)**[13] , reported that the average cost overrun for hydropower projects was about 21%. However, it was noted that performance in sub-region of Latin America, Central and South Asia with cost overruns averaging 53%, 108% and 138% respectively. In the report of WCD the cause of cost variations are categorized as Poor development of technical and cost estimates and supervision by sponsors, Technical problem that arose during construction, Poor implementation by suppliers and contractors & Change in external conditions (economic and regulatory). Further, discovery during construction are less favorable site conditions than those estimated in the engineering designs and construction plans can be a significant contributor to cost overruns and time delays of the projects.

2.1.8 **'The Report on Hydropower Project Cost Overrun'**[14] by Bhutan Electricity Authority, study suggests that the bigger the project, the more likely the project will experience cost overruns. According to this study the prominent factors that contribute to the cost overruns in hydropower projects are change/error in design mostly civil works due to geological problems, engagement of ineligible contractors, strong political interference in the construction of hydropower projects and corrupt practices. It also outlines the BEA's role and accountability regarding cost overrun of the hydro projects.

2.1.9 **Shibani A., Kumar A., (2015)**[15]**,** analyzed the survey conducted by them, showed that the most five factors causing time delay in construction projects from perspective of importance were: low productivity of labours, poor communication and coordination between parties, different ways of bribes, financing delay of the project, change orders during work and unskilled labours .This paper also indicates that the most five factors causing cost overrun were: additional works by the owner, inaccurate review of the plans and contract document, poor feasibility planning and cost control during work, resources constrains such as (financial budget, lack of reserved resources for the contractors), fluctuation of materials prices. It also suggests owners, contractors and consultants to be more responsible about their work and their responsibility to prevent any delay or cost increasing which could be achieved by encouraging the labours by giving rewards to increase their productivity, good management, improve the communication and coordination among them.

2.1.10 **Joy (1994)**[16] identifies overruns of upto 1382 percent in some of the projects. While assessing overruns in public sector Mega projects ongoing in India in 1991, out of the 27 projects, 16 of these were in the power sector. The cost overruns ranged between 2 to 10 times, while time delays in construction ranged from 1 to 7 years with possibility of further overruns.

2.1.11 **(Naveenkumar.G.V, & Prabhu.V, 2016**)[17], studied to determine factors affecting time and cost overruns on construction projects in our country. The objectives of the study were achieved through valid questionnaire. The study clarified that “Less outcome of labour", “Delaying in Bill settlement”, “Lack of maintenance of the equipment” “Poor procurement programming of materials, Strikes, riots and other external factors was the most critical factor that influence project delay. The study illustrated that "delay in preliminary handing over the site" was one of the most important factors that may lead to cost overrun. Also it clarified that contractor's delay of material delivery and equipment has led to cost overrun. The study also clarified that prices inflation highly contributes to cost overrun.

2.1.12 **Kannan and Pillai 2002 A**)[18], discussed the costs of inefficiency in the context of the Kerala power sector at the project implementation stage. In this paper, project wise analysis has been done for 16 hydro projects in Kerla since 1985. Time and cost overrun profile of each is found along with detailed cause behind the overrun. A comparative analysis has been performed in the paper for all the projects along with the loss of revenue if project have been completed on time. Moreover for better analysis and measure, a combined effect of both time and cost overrun is used which is called ‘Capital x time waste factor’ (also see Morris 1990) is obtained as the difference between the actual capital x time (CaTa) and the originally planned capital x time (CoTo) measures as a percentage of the latter (where Ca and Co are the actual (or latest) and originally planned estimates of capital cost and Ta and To are the corresponding period of commissioning). The capital x time waste factor for the nineteen projects ranges from 148 per cent for the Kallada project to 2,766 per cent for the Vazhikkadavu diversion. it shows the enormous waste of capital x time resources in hydro power project implementation in Kerala. This paper also lists various causes of delays and case study of Idukki Stage I, 390 MW project. In its previous paper Kannan and Pillai (2001 b), they have provided analysis of political economy of corruption and its hand in cost and time overrun.

2.1.13 **Ram Singh(2009)**[19] in his study **'**Delays and Cost Overruns in Infrastructure Projects: An Enquiry into Extents, Causes and Remedies', analyzed 1035 projects belonging to seventeen infrastructure sectors completed during April 1992-March 2009, each project is worth at least Rs 20 Crore and publicly funded. He found that the project cost and the project time vary significantly from project to project, across sectors as well as within each sector. He also analyzed the data for cost and time overrun according to year of project implementation and found that over the years there has been some decline in the magnitudes of estimation errors only with respect to project cost. That is, some learning seems to have taken place over the years. Moreover, there is no indication of any significant decline in the frequency of delays. Also, regardless of their source, delays are one of the crucial causes behind the cost overruns & bigger projects have experienced much higher cost overruns compared to smaller ones. He also concluded that , the longer is the implementation phase, the higher are cost overruns in absolute as well as percentage terms. Compared to other sectors, projects from road, railways, urban development sectors, as well as those from civil aviation, shipping and ports, and power sectors have experienced much longer delays and significantly higher cost overruns. Also compared to other states, projects located in southern states, Andhra, Karnataka, Kerala and Tamil Nadu, have experienced somewhat shorter delays and lower cost overruns. Performance of rich states is not significantly better than that of the poorer states.

2.1.14 **'Study on project schedule and cost overruns, 2018'**[20] by Ministry of Statistics & Programme Implementation (MoSPI) GoI, lists out various reasons behind time and cost overrun across the infrastructure sector. Some issues like land acquisition or delay in regulatory approvals may impact in pre-planning stage while issues like contractual conflict, design changes etc. may impact in implementation stages. It states Land/site handover is the most primary cause of various projects across the sector for cost as well as time overrun. Moreover, it also points out that majority of the projects are delayed by internal factors which can be controlled at the project level through proper planning and project management. The study also highlights the severe skill shortage and the growing demand-supply gap for qualified construction professionals affecting the infrastructure sector in India. Project owners feel this is a long-term issue which not only makes the projects more expensive and riskier, but also results in compromise on quality as well as timelines.

2.1.15 (**Ansar et al. 2014**)[21] is most cited study in this field, found overwhelming evidence that budgets are systematically biased below actual costs for hydropower projects—excluding inflation, substantial debt servicing, environmental, and social costs. They used multilevel statistical techniques and were able to fit all the data and designed a model to predict cost and schedule overrun. This model takes into account 36 possible variables which affects time and cost for 245 hydro projects as reference sample. Variables like size of head, capacity, length etc., economics of estimated cost and inflation contingency, time of start and commissioning as well as country variable like political regime, GDP per capita income etc. In this study avg. cost overrun for various large hydro projects by geographical location is found although there was no evidence for schedule estimates to have improved over time. This study also makes it possible to predict the cost overrun before construction begins. Using Reference Class Forecasting (RCF) it gives a curve between uplift required in cost estimates vs chances of cost overrun.

2.1.16 **Ameh O.J. & Osegbo E.E., 2011**[22] studied relationship between cost overrun. time overrun and productivity on construction sites and attempted to find the relationship between the above mentioned three factors in case of construction activities. Predictive model from the study was developed using regression technique o\for the collected data to find the relationship. In this paper, causes for low productivity was also surveyed using questionnaire from various people involved in construction activities.

2.1.17 **Ludovique c. et.al.(2016**)[23] in their study 'Cost overruns and delays on energy mega projects: when bigger is worse' estimated the probability distribution function for time and cost overrun with the international database of 400 power projects with special emphasis on hydro projects in Brazil. This paper used class reference forecasting for cost and time estimation. to compare a particular project. At the same time, it is established that the distribution that best fit the hydroelectric plants costs overrun is the gamma distribution and for time overrun it is log-normal distribution. Emphasis was specifically laid to performance of larger energy projects. This paper conclude that large projects are more fragile as an investment and more prone to overruns as these involve uncontrollable risks that can not be anticipated and adequately mitigated.

2.1.18 **Hariharan S. and Sawant P.H., 2012**[24] in their study 'Analysis of Relationship between Time and Cost Overruns in some Infrastructure Projects' in a study conducted by NICMAR India, tried to find a correlation between cost and time overrun for infrastructure projects in India consisting of all kinds of projects. In this paper Pearson's correlation is used and validated using F-test to show a strong correlation between them. At the same time no clear cut relation was developed between both. As conclusion this paper attributes specifically bidding process to be main culprit for time overrun whereas inexperience and improper forecasting for the cost overrun.

2.2 Gaps Identified

From the detailed review of the literature on Reasons for time and cost overrun of construction projects, it can be seen that cost and time overrun are most prevalent across all kinds of construction project not only HEP. The motive was to find the available literature to consider it as reference point to make way for further study in this. Based on this, following gaps have been identified:

- Previous studies are focused mainly on identification and management of reasons behind the cost and time overrun, not much has been reported on analysis and pattern of these overrun.
- Comparison between various factors for both types of overrun and trend has not been reported earlier.
- No exclusive study has been done for analyzing the relationship between cost and time overrun of hydroelectric projects in India.

2.3 Objective of the study

Keeping literature review and gaps identified in view, present study has been carried out with the following objectives:

- Collection of available data regarding initial and final cost as well as time of commissioning of hydroelectric projects.
- To adopt a methodology to analyze the gathered data for cost and time overrun for various hydroelectric projects across India.
- Using adopted methodology, drawing comparison for time and cost overrun between various factors based on ownership, region, installed capacity etc.
- To develop a relationship between cost overrun and time overrun for hydropower projects.

2.4 Proposed outline of the study

Keeping in view of above objectives, following works are to be done in the methodology listed below:

- **Literature Review**

  Going through various available research publications to understand the various reasons behind the cost overrun and time overrun and get an idea about the reasons for the same. Based on the literature review, gaps have been identified. With the help of gaps identified, objectives have been set for current study.

- **Gathering of required data**

  For the proposed study, data has been obtained for various hydroelectric projects across India which consist of following parameters:

  - Hydroelectric project name and Location
  - Installed capacity
  - Owner(Central/state/ Private)
  - Final approval date

- Initial estimated cost
- Initial expected completion time
- Final completion time
- Final cost

The above data has been gathered though direct source like visiting the project or requesting through email or through indirect source likes CEA reports, power ministry report, project reports from respective project websites, tariff orders from CERC or state electricity regulatories etc.

- **Analysis and comparison of gathered data**

  From the gathered data, % cost overrun and % time overrun are calculated and comparison is made based on following parameters

  - Percentage time overrun and percentage cost overrun
  - Per unit MW cost escalation (adjusting inflation as per 2019 price level)
  - Method of Capital Time waste factor as per Kannan and Pillai (2002)[18]

  Comparison are drawn between:

  - Central vs Private vs State owned projects
  - State wise/Region wise
  - Capacity wise (Small/Medium/Large)
  - Time overrun and cost overrun

A mathematical relationship between time overrun and cost overrun has been developed using regression and checking for its suitability.

- **Dissertation writing and submission**

  Thesis report is prepared for the current study in the standard format and submitted.

CHAPTER 3
ANALYSIS OF COST & TIME OVERRUN

3.1 General

India is a developing country. For a vast country with 130 crore population, energy demand is touching a new high, every day and hydro power being one of the crucial parts to mitigate this energy demand, government has been focusing on developing more projects in this sector. But with increasing projects, comes a new challenge to properly commission it as per schedule, which has not been the case lately for hydro power. With overrun in both cost and schedule, it not only, pushes back the demand supply gap but also hampers the economy as a huge amount of money is invested in them and makes the project look like bad investment. So, it becomes the need of the hour to study and analyse the overrun to get a new perspective and ways to, if not mitigate then control it.

3.1.1 As per the objective, gathered data is used to find out some values which will help in analysis for the sake of this study. Following sources have been utilised for these gathered data, details of which for each individual data source has been listed in APPENDIX I.

- Visiting JKSPDC Jammu, UJVNL Dehradun, IREDA New Delhi, SJVN Shimla and BBMB office, Nangal
- Using AHEC source data for 'Benchmark cost of small and large hydro power projects'
- Using tariff and petition orders on CERC and state regulatory websites.
- Using CEA quarterly reports for hydropower projects
- Browsing through govt data depository like data.gov.in and pppindia.gov.in
- Going through various CDM (Clean Development Mechanism) reports from cdm.unfccc.int
- Going through world bank and ADB available documents for various invested hydro projects by them.

3.1.2 Gathered data for hydroelectric projects comprises of initial cost estimate and actual cost along with initial estimated completion and final commissioning time has been tabulated to get:

- Difference between initial cost (C_o) and actual cost (C_a) and hence percentage cost overrun,
- Actual time taken (T_a) and Original time for commissioning (T_o) of project is calculated.
- Using difference between T_a and T_o to find percentage time overrun for that hydroelectric project.
- Per MW (megawatt) cost overrun (in crore) is calculated as of 2019 price level (adjusting inflation between commissioning and 2019)

3.1.3 The brief outline of the proposed analysis

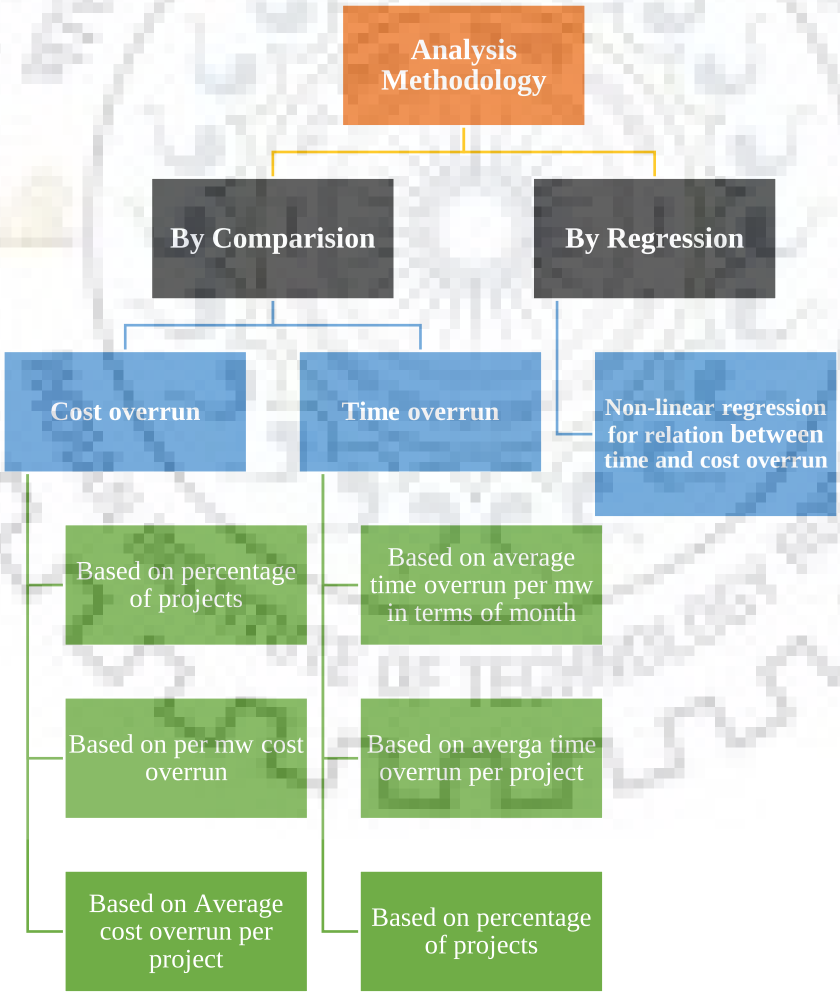


Fig 3.1 Outline of proposed analysis

The above mentioned comparison is to be made based on following criteria

- Ownership (central government/state/private)
- Project location (North India/south India/ North-east and east India)
- Installed capacity (small, medium/large)

3.1.4 Following considerations are held, while analyzing the data:

- Sample of data available is 61, which is not so good pool to draw a strong conclusion
- In case where clearance date/DPR approval not available, financial closure or construction start date(whichever is latest) is taken as project initiation.
- While considering projects which has been completed more than 4-5 years ago, while comparing per MW cost overrun, inflation is considered.
- In case where only year is available as scheduled or actual date then march sept is taken as month by default for calculation of number of months.
- It is debatable if the data available for this study represents the whole picture, but effort has been made to diversify the data availability as much as possible.
- Any type of comparison or analysis with respect to any criteria is only considered if at least 15 data sets are available for that criteria.

3.1.5 An Overview of the gathered data

- A total of 62 project data has been gathered of which 19 are central government projects, 23 are state owned projects and 20 are privately owned projects installed mainly in north , north-east and south India.
- Data were gathered with details consisting of information like initial estimated cost, actual completion cost, project clearance date, project estimated completion date, project actual completion date.
- Data gathered aggregates to 11621 MW consisting of 6109 MW of central government projects, 981 MW of private entity projects and 4531 MW of state government owned projects.

- Projects together have 73371.02 crore INR investment at 2019 price level with 43583.84Cr of central government projects, 7392.5cr of private entity projects and 22394.63cr of state owned projects
- For comparison in per MW cost overrun, 2019 has been taken as base year to get rid of disparity due to inflation for projects installed during different years. Moreover, for analysis of relation between cost overrun and time overrun inflation during time overrun period is also considered. For inflation data[25] government published data has been used along with various reliable online sources available for inflation calculator.

Table:3.1, gives details for Name of project with its owner, initial estimated cost and final cost, date of initial commissioning and final one, along with calculated % cost overrun and per MW cost overrun (as per 2019 PL) in crore.

Table: 3.1 Project details with cost overrun

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Samal SHP (Orrisa Power Consortium Ltd.)	20	Odisha	Private	97.6	116.47	18.87	19.334	5.57	13.764	2.385
Kolab HEP (Meenakshi Power Ltd.)	37	Odisha	Private	161	240.53	79.53	49.40	104.94	-55.54	4.401
Dikchu (Sneha Kinetic Power Projects Pvt. Ltd.)	96	Sikkim	Private	639.57	1140	500.43	78.24	17.98	60.26	5.705
Doyang HEP (NEEPCO)	75	Nagaland	Central	384.75	758.7	373.95	97.192	35.96	61.232	16.065
Teesta-III (Teesta Urja Ltd.)	1200	Sikkim	State	5705.55	11382	5676.45	99.49	42.50	56.99	5.177
Teesta Low Dam-IV(NHPC)	160	W.B.	Central	1061.38	2193.08	1131.7	106.63	56.99	49.64	7.915
Teesta Low Dam-III (NHPC)	132	WB	Central	768.92	1628	859.08	111.73	85.48	26.25	8.953

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Pare (NEEPCO)	110	Arunachal Pradesh	Central	573.99	1262.27	688.28	119.91	30.59	89.32	6.585
Tashiding (M/s Shiga Energy Pvt. Ltd.)	97	Sikkim	Private	465.95	1045.44	579.49	124.37	6.85	117.52	6.539
Chujachen (Gati Infrastructure Ltd)	99	Sikkim	Private	448.76	1044.5	595.74	132.75	42.18	90.57	8.278
New Umtru (MePGCl)	80	Meghalaya	State	226.4	599	372.6	164.58	54.59	109.99	4.902
Jorethang Loop (Dans Energy pvt ltd (DEPL))	96	Sikkim	Private	543.15	1507.52	964.37	177.55	21.52	156.03	11.951
Rangit HEP (NHPC)	60	Sikkim	Central	163.49	492.26	328.77	201.094	62.28	138.814	17.655
Tuirial (NEEPCO)	60	Mizoram	Central	368.72	1381.71	1012.99	274.73	130.67	144.06	18.479
Himshakti SHP (Himshakti Projects Pvt. Ltd.)	5	H.P.	Private	34.1	35.96	1.86	5.45	7.53	-2.08	0.762

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Jongini SHP (Gandhari Hydro Power Pvt. Ltd.	16	H.P.	Private	119.18	135.36	16.18	13.58	4.79	8.79	1.132
Debal SHP (M/s Chamoli Hydro Power Private Limited.)	5	Chamoli Uttrakhand	Private	28.63	32.69	4.06	14.18		14.18	1.926
Brahmganga HEP (Harison Hydel Construction Pvt Ltd)	5	HP	Private	22.73	26.28	3.55	15.62		15.62	1.595
Sainj (H.P. Power Corpn. Ltd)	100	H.P.	State	676.29	784.56	108.27	16.01	12.65	3.36	1.185
Parbati-III(NHPC)	520	H.P.	Central	2304.56	2716	411.44	17.85	38.48	-20.63	0.997
Dah SHP	9	J&K	State	86.96	104.6	17.64	20.29	11.90	8.39	1.960
Uri-II (NHPC)	240	J&K	Central	1724.79	2081	356.21	20.65	42.18	-21.53	2.042
Maujhi Phase-II (Dharmshala Hydro Power Limited)	5	HP	Private	27.58	35.75	8.17	29.62			2.913

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Sumez SHP (Rangaraju Warehousing Pvt. Ltd.)	14	H.P.	Private	81.21	106.69	25.48	31.38	0.00	31.38	2.783
Nanti SHP (Surya kantha Hydro Energies Private Limited)	14	H.P.	Private	66.94	88.36	21.42	32.00	0	32.00	1.929
Chamera-III (NHPC)	231	H.P.	Central	1405.63	2048.11	642.48	45.71	20.15	25.56	4.253
Chutak (NHPC)	44	J&K	Central	621.26	913.25	291.99	47.00	20.15	26.85	10.149
Baglihar Stage-II	450	J&K	State	2113.09	3115.21	1002.12	47.42	27.34	20.08	2.492
Baglihar-II (JKPDC)	450	J&K	State	2113.09	3115.21	1002.12	47.42	93.26	-45.84	2.649
Neogal HEP (Om Hydropower Ltd.)	15	HP	Private	82.6	123.8	41.2	49.88	32.23	17.65	3.778
Himalayan Crest Power	3	HP	Private	15.04	22.61	7.57	50.33		50.33	4.109

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Rishiganaga SHP (Rishiganga Power Corporation Ltd.)	13.2	Uttrakhand	Private	85.4	128.84	43.44	50.87	9.75	41.12	5.033
Nimoo Bazgo(NHPC)	45	J&K	Central	611.01	936.1	325.09	53.21	32.23	20.98	9.938
Kishanganga (NHPC)	330	J&K	Central	3642.04	5783.17	2141.13	58.79	19.67	39.12	6.828
Kol Dam (NTPC)	800	H.P.	Central	4527.15	7220	2692.85	59.48	77.42	-17.94	4.005
Rampur (SJVNL)	412	H.P.	Central	2047.03	3337.91	1290.88	63.06	26.50	36.56	3.949
Chanju-I (M/s IA Energy)	36	H.P.	Private	295.09	482.39	187.3	63.47	12.65	50.82	5.694
Nathpa Jhakri HEP (SJVNL)	1500	H.P.	Central	4985.86	8187	3201.14	64.20	7.65	56.55	5.908
Budhil (GREENKO)	70	H.P.	Private	418.8	688.77	269.97	64.46	46.00	18.46	5.898
Kashang-I (H.P. Power Corpn. Ltd.)	65	H.P.	State	478.02	789.84	311.82	65.23	15.71	49.52	5.368

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Sew-II (NHPC)	120	J&K	Central	665.46	1108.83	443.37	66.63	32.37	34.26	7.565
Baglihar Stage-I	450	J&K	State	3495	5827	2332	66.72	28.67	38.05	11.641
Maneri Bhali Stage II Large Hydro Power	304	Uttrakhand	State	1249.18	2203.54	954.36	76.40	137.01	-60.61	3.139
Koteshwar HEP	400	Uttrakhand	Central	1301.56	2364.06	1062.5	81.63	79.62	2.01	4.062
Uri Stage I (NHPC)	480	J&K	Central	1720.7	3388	1667.3	96.896	22.11	74.786	13.798
Alaknanda HEP (GVK group)	330	Uttrakhand	Private	2069	4573	2504	121.02	15.26	105.76	9.565
Dulhasti HEP (NHPC)	390	J&K	Central	1262.97	5078.49	3815.52	302.11	32.05	270.06	23.208
Pulichintala (TSGENCO)	120	Telangana	State	380	563.49	183.49	48.29	54.59	-6.30	1.609
Kallada (KSEB)	15	Kerala	State	11.8	18.02	6.22	52.711	46.39	6.321	2.373
Peppara (KESB)	3	Kerala	State	3.92	6.81	2.89	73.724	81.14	-7.415	4.225
Nagarajuna Sagar TR (APGENCO)	50	Andhara Pradesh	State	464.63	958.67	494.04	106.33	89.57	16.76	10.815

Name	Installed Capacity (MW)	State	Owner	Initial Estimated Cost(cr.)	Actual Cost (cr.)	Cost Overrun (cr.)	Cost Overrun (%)	Inflation in% (b/w estimated completion & actual)	% Cost overrun discarding inflation	per MW overrun (as of 2019, inflation adjusted) (cr.)
Idukki Stage II (KSEB)	390	Kerala	State	31.68	68	36.32	114.646	90.94	23.706	1.013
Lower Jurala (TSGENCO)	240	Telangana	State	908.34	1969.14	1060.8	116.78	27.34	89.44	4.946
Idamalaya (KSEB)	75	Kerala	State	23.4	90.03	66.63	284.743	108.53	176.213	8.849
Lower Periyar (KESB)	180	Kerala	State	88.43	353.04	264.61	299.231	75.88	223.351	5.840
Bhawani Kattalai Barrage-III (TNEB)	30	Tamilnadu	State	99.75	442.73	342.98	343.84	85.48	258.36	15.727
Bhawani Kattalai Barrage-II	30	Tamilnadu	State	99.15	497.46	398.31	401.72	85.48	316.24	18.264
Darana SHP (DLI Power Pvt. Ltd.)	4.9	Maharastra	Private	33.39	35.59	2.2	6.59	9.47	-2.88	0.731

3.2 Comparison of Cost overrun

As given in Table 3.1, It can be seen that project cost overrun ranges from 5.45% to 401% whereas per MW cost overrun ranges from 1.73 cr. INR to 23.71cr. INR. The value of cost overrun without inflation is also calculated to get an idea about how much cost overrun is on the basis of poor planning or project extension only. It is obtained by deducting the cumulative value of inflation during the delay from the value of cost overrun. As it come out, for 6 projects the cost overrun is less than the inflation during the delay time period but in other cases the cost overrun without inflation ranges from 2% to 316%.

On the basis of details given in Table 3.1; analysis of comparison of cost overrun based on ownership has been charted out in table 3.2.

3.2.1 Based on percentage of projects

Ownership	Cost Overrun %					
	No. of projects	0-25%	25-50	51-100 %	101-200%	>200%
Central	19	2	2	9	3	3
Private	20	6	5	5	4	0
State	22	2	3	7	6	4

Table 3.2: No.of projects having cost overrun based on ownership

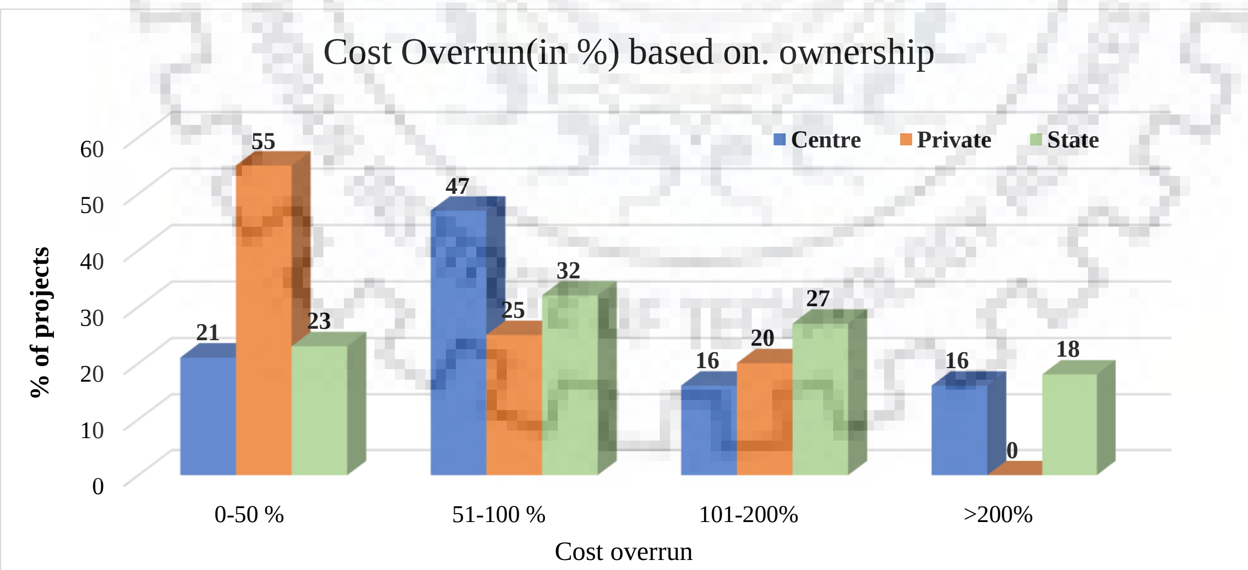


Fig 3.2: Cost overrun based on ownership

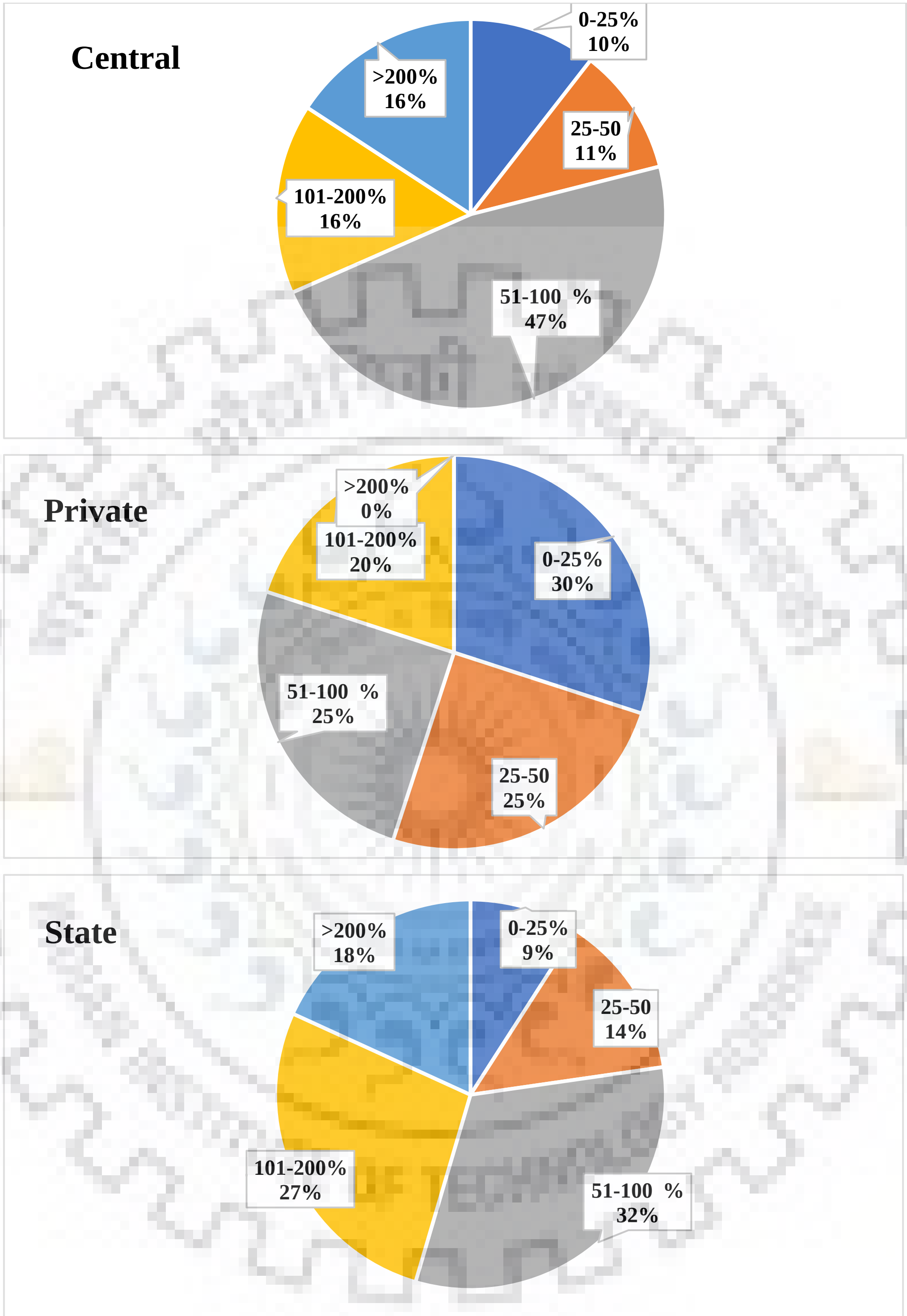


Fig 3.3 : Percentage of project with various cost overrun.

Table 3.2 gives the number of projects having various cost overrun out of mentioned projects but the absolute number of projects can't be used for comparison so, pie chart in Fig 3.3, shows percentage of projects having cost overrun for various owners. As it can be seen, private owned scheme has no project above 200% cost overrun and 55% projects have less than 50% overrun. For central govt projects, 16% projects have their completion price above thrice of the initial estimate after completion and just 21% projects have less than 50% cost overrun. In case of state owned projects, 18% have above 200% overrun and 23% projects have less than 50% cost overrun. It can be safely concluded that based on ownership, private projects are better than the other two. Whereas state government projects have more cost overrun as compared to other two.

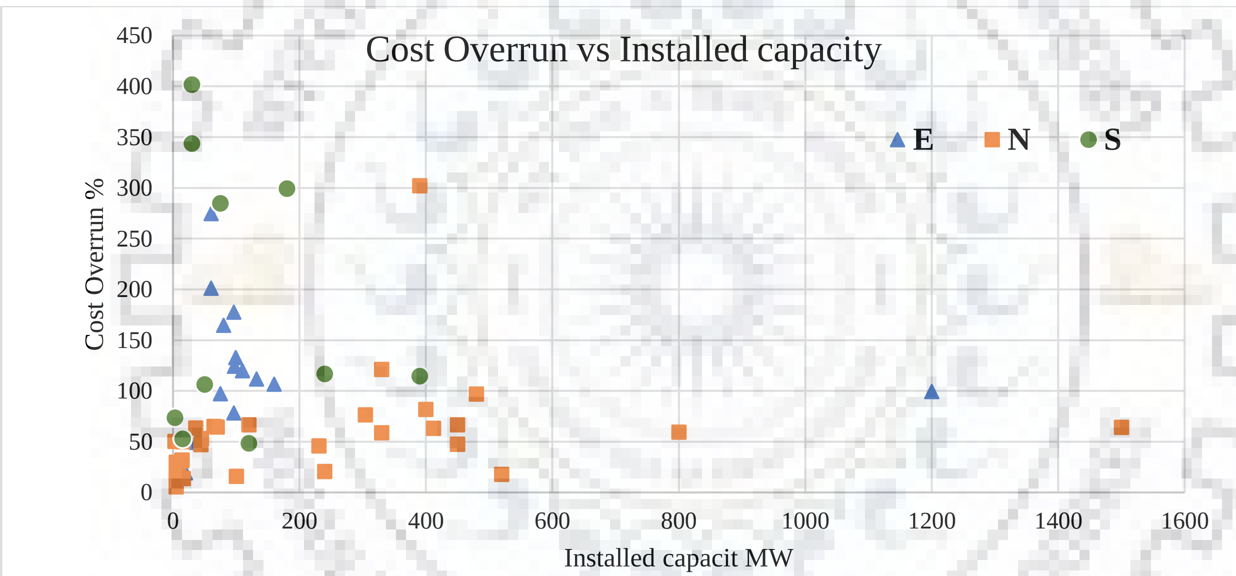


Fig 3.4: Comparison of cost overrun and installed capacity

Fig 3.4 shows that project located in NE and E zone tend to have more than 100% cost overrun whereas project in north India are a bit better in that sense as only 2 projects out of 19 have more than 100% cost overrun. Projects in south zone have mixed trends. Hence, it can be concluede that based on location project in NE and E zone tend to have more cost overrun as compared to other two.

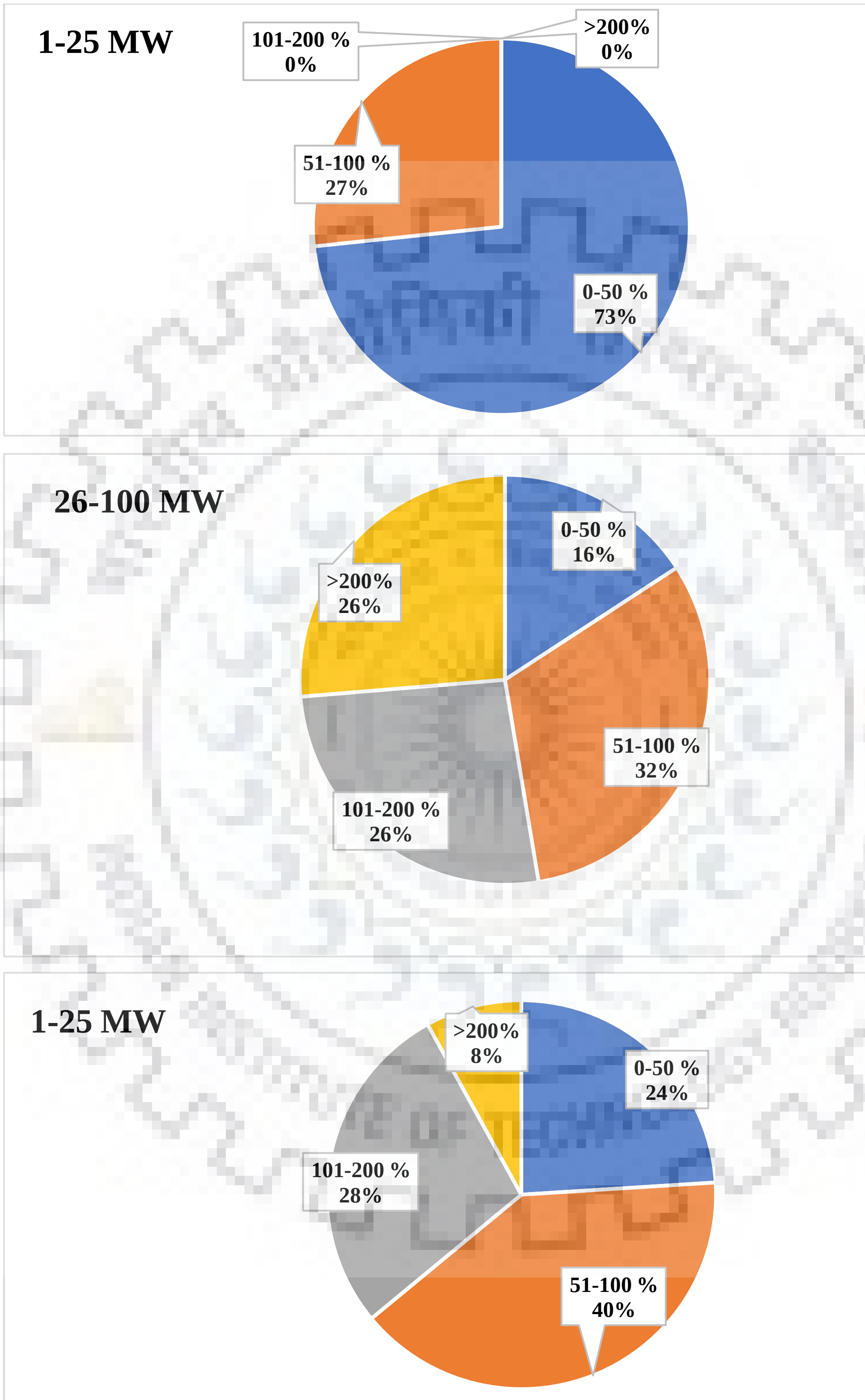


Fig 3.5: Percentage of projects having cost overrun

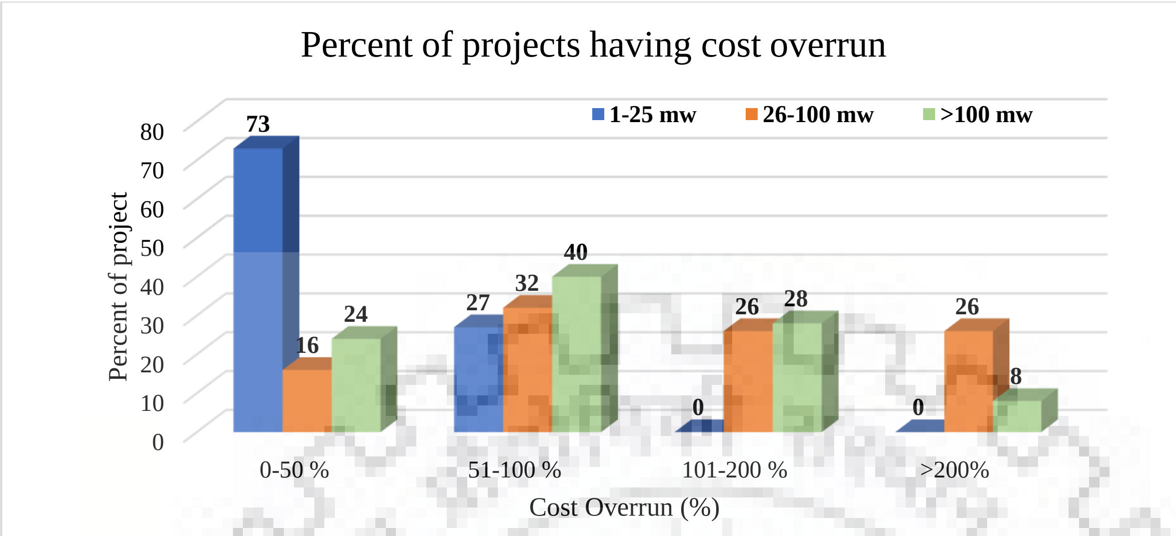


Fig 3.6: Percentage of projects having cost overrun based on installed capacity

As shown in Fig 3.5 and Fig 3.6, small hydro power projects (1-25 mw) have no projects in above 100% cost overrun (out of 17 project data available). Around 73% projects i.e. about 3 out of 4 SHP gets completed within 50% cost overrun. For Medium capacity projects (26-100 mw), they have 1 out of 4 projects with greater than 200% cost overrun. Whereas, large hydro projects (capacity >100 mw), they have 36% projects with above 200% cost overrun and around 40 with 51-100% cost overrun. Among the three types compared, it is clear that SHP have least cost overrun whereas only 1 out of 6 for medium capacity and 1 out of 4 for large capacity hydro projects tend to have less than 50% cost overrun.

3.2.2 Based on average cost overrun

Table 3.3 & Fig 3.7 : Average cost overrun based on ownership

Ownership	Average % Cost overrun
Centre	62.06
Private	79.97
State	57.90

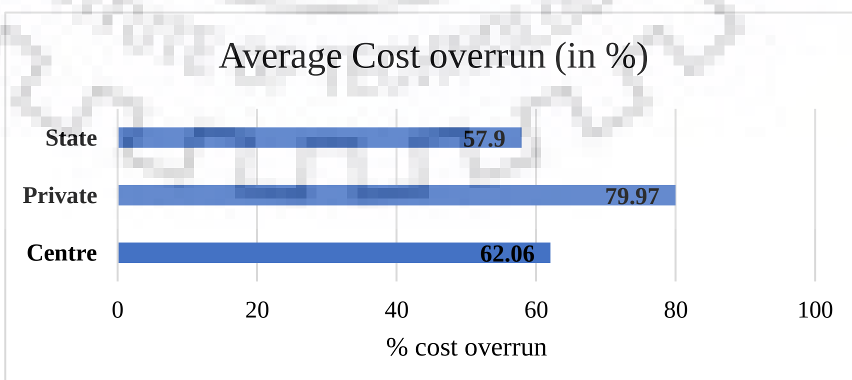


Table 3.4 & Fig 3.8: Average cost overrun based on project location

Project Location (zone)	Average % Cost overrun
NE &E	77.42
N	55.69
S	98.09

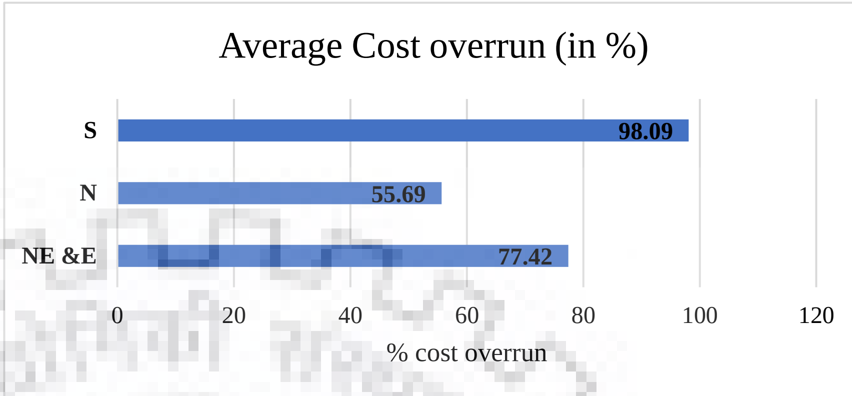
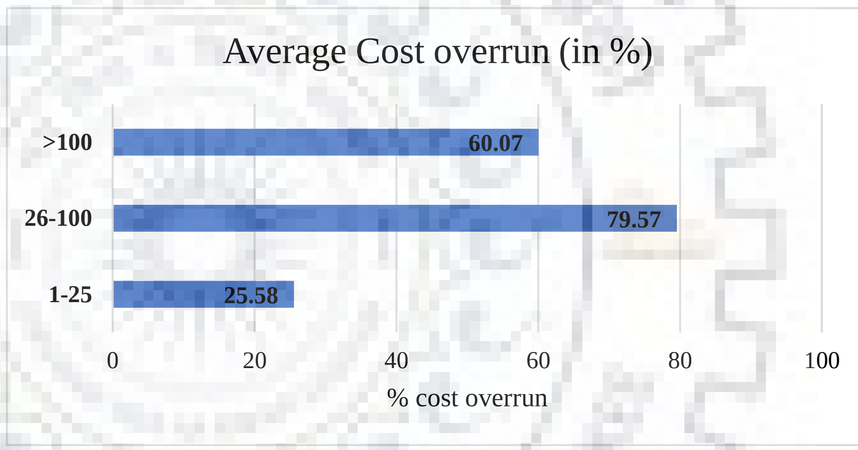


Table 3.5 & Fig 3.9: Average cost overrun based on installed capacity

Installed Capacity (MW)	Average Cost overrun (%)
1-25	25.58
26-100	79.57
>100	60.07



As far as average cost overrun is concerned with respect to type based on ownership, from Fig 3.7, It can be seen that, privately owned projects tend to have more average cost overrun and it is least for state government owned projects. As shown in Fig 3.8, based on location, south zone projects have almost 100% average cost overrun whereas, north zone projects have around 56% average cost overrun. Similarly, as shown in Fig 3.9, based on installed capacity, SHP have least average cost overrun of 25% whereas, medium and large capacity hydropower projects have around 80% and 60% average cost overrun respectively.

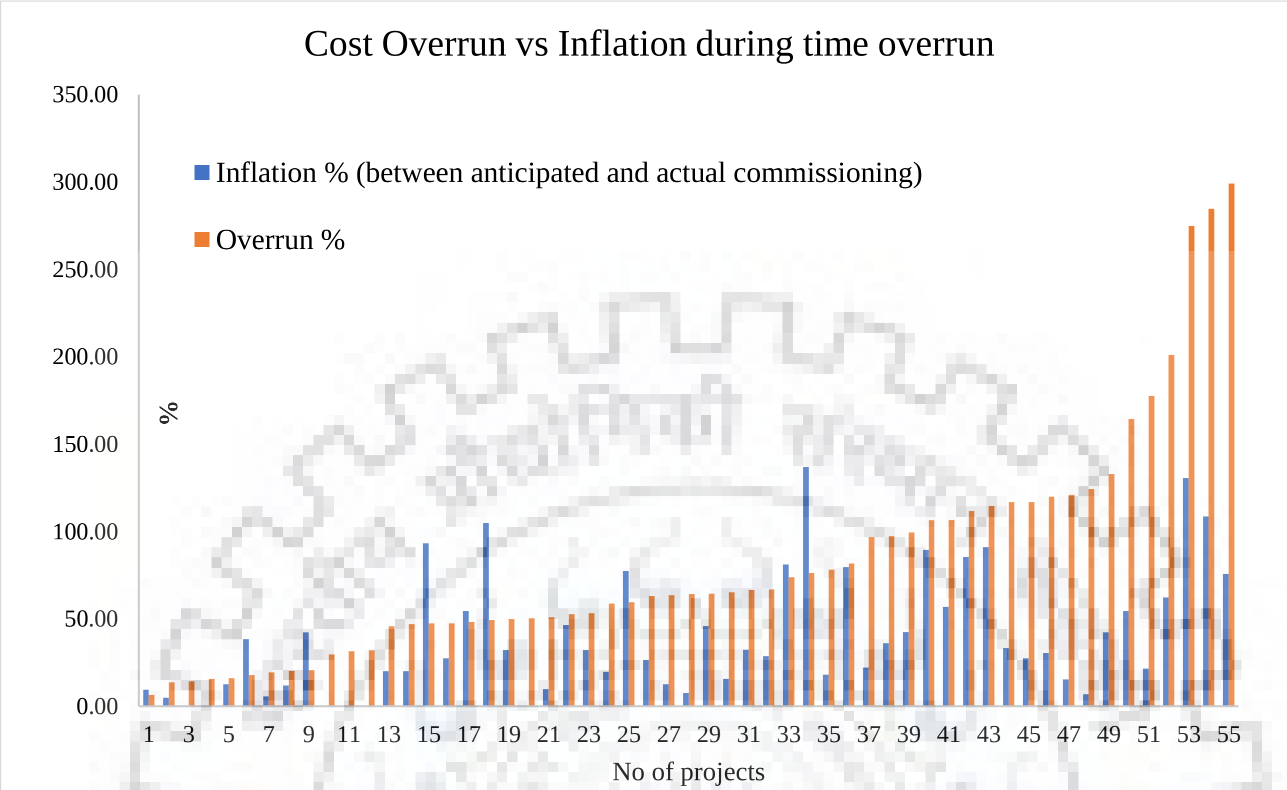


Fig 3.10: Comparison of Cost overrun vs inflation during the delay of the project

Generally, inflation plays a pivotal role for cost overrun in case of delayed project. Here it can be seen that, there are hardly 9 projects out of 56 which have nearly same value for both but in other cases it varies significantly at times cost overrun being thrice of inflation. This disparity between both are due to that fact that large extent of projects does suffer due to inadequate estimation or design or change in design later on as project progresses confirming the analysis pointed out by Naveenkumar.G.V, & Prabhu.V, 2016[17]. The plot of cost overrun vs inflation during delay in construction does not show a solid linear correlation but it does indicate the need of better estimation during DPR preparation.

3.3 Comparison using per MW cost overrun

As various projects have been commissioned in various years so directly comparing their per MW cost overrun would not be a good idea as the inflation varies with the year. So, to make it comparable, first the inflation after the project had been installed is calculated upto 2019 and overrun is converted in 2019 price level. For each project. For comparison in per MW cost overrun, 2019 has been taken as base year to get rid of disparity due to inflation for projects installed during different years. For inflation data government published data has been used along with various reliable online sources available for inflation calculator.

Equation 3.1 has been used to adjust the inflation value according to 2019 to get the value of cost overrun and hence per MW cost overrun. For example : A 50mw project is commissioned in 2002 with 100 crore cost overrun. The inflation between 2002 and 2019 is 196.4% so in terms of 2019 price level, the cost overrun would be 296.4crore rupees. So, cost overrun per MW of the project will be equal to 296.4cr. divided by installed capacity which come out to be 5.93crore per mw.

Cost overrun per MW (at 2019 price level)

$$= \frac{(\textbf{\textit{Cost overrun in crore at the time of comissioning x}} \ (\textbf{\textit{inflation factor between comissioning and 2019}})}{\textbf{\textit{Installed capacity}} \ (\textbf{\textit{in MW}})}$$

(Eq. 3.1)

3.3.1 Per MW cost overrun at 2019 price level are (based on Ownership)

For centrally funded projects	INR 7.13cr
For private entity projects	INR 7.534Cr
For state owned projects	INR 4.942cr

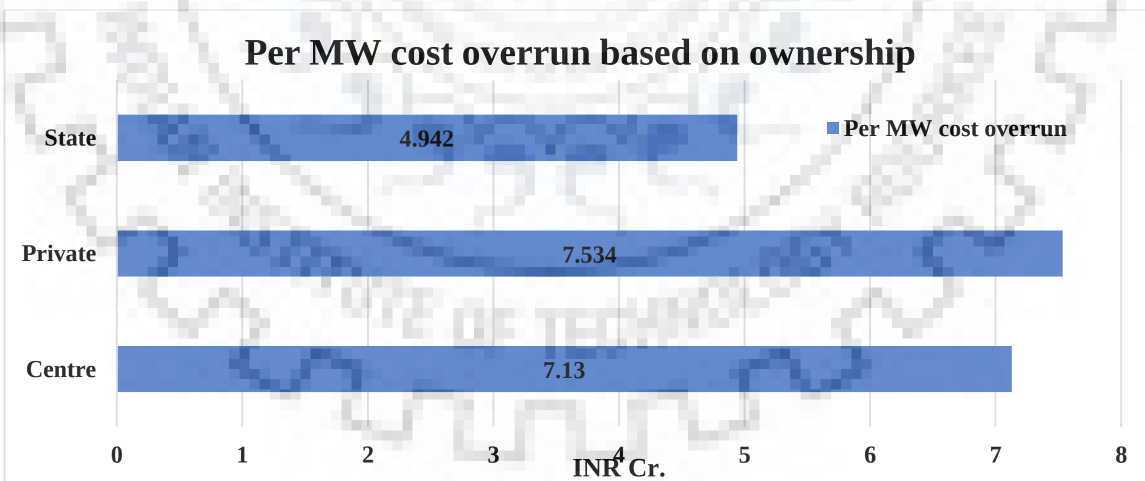


Fig 3.11: Per MW cost overrun at 2019 price level are (with respect to Ownership)

As shown inf Fig 3.11, projects funded by state govt have least value of per MW cost overrun with a value of 4.94 crore INR. Whereas the per MW cost overrun for central govt project and state government projects 7.13 and 7.53 Cr. INR which is as comparable to installation cost of per MW of large hydro power in India as reported in Benchmark cost for Hydropower Projects, AHEC.[4]

3.3.2 Per MW cost overrun at 2019 price level are (with respect to Installation zone)

For North Zone (North India Projects) : INR 6.36Cr

For South Zone (South India Projects) : INR 4.78Cr.

For north-east and eats Zone (north-east and eastern India Projects): INR 7.11Cr.

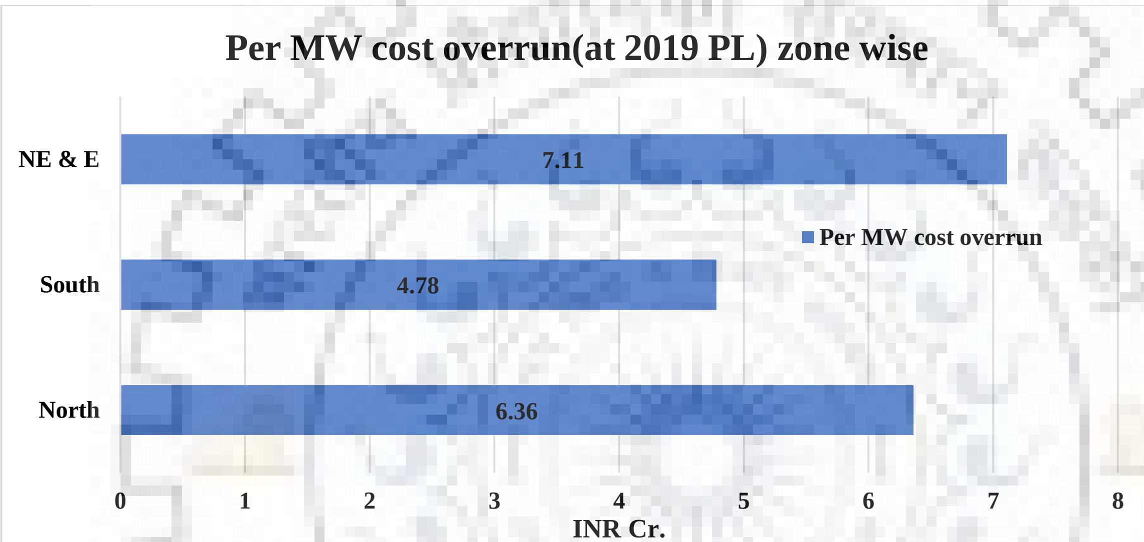


Fig 3.12: Per MW cost overrun at 2019 price level are (with respect to Installation zone)

3.3.3 Per MW cost overrun at 2019 price level are (with respect to Installed capacity)

For 0-25MW : INR 2.53Cr.

For 26-100MW : INR 9.04Cr.

For above 100MW : INR 6.02Cr.

As shown in Fig 3.12, Projects in south India have less value of per mw cost overrun of 4.78 cr. INR contrary to earlier trends of high cost overrun in term of percentage of projects and average cost overrun.

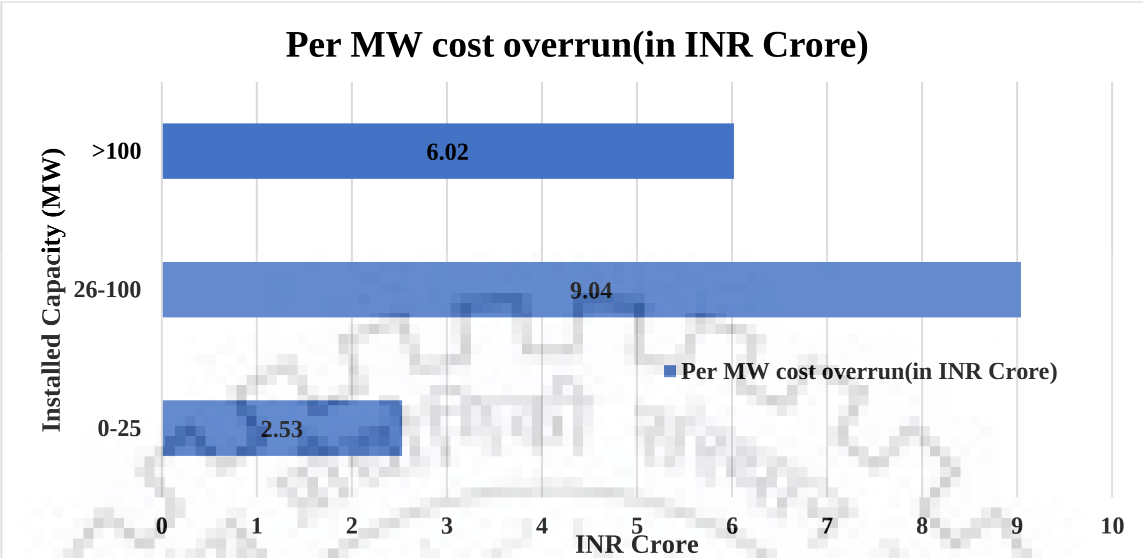


Fig 3.13: Per MW cost overrun at 2019 price level are (with respect to Installed capacity)

As shown in Fig 3.13, the per mw cost overrun for small hydro projects are the lowest at 2.53 crore INR but for medium capacity hydro projects it has the highest value of 9.04 crore INR which is even higher than installation cost of per mw in most of the cases.

After analysing the cost overrun, following results are concluded,

- Privately owned projects have least % of projects in higher cost overrun brackets as compared to others whereas, central government projects have most % of projects in higher cost overrun brackets and state owned projects somewhere lie in between.
- Projects in NE &E zone in India tend to have more cost overrun as compared to north and south zone projects.
- Per MW cost overrun for private owned projects is maximum at 7.53crore INR whereas state owned projects have least per MW cost overrun at 4.94 crore INR .
- Per MW cost overrun of NE&E zone projects is maximum at 7.11 crore INR whereas, least for south zone projects at 4.78 crore INR.
- Per MW cost overrun for small hydro (0-25MW) is the least at 2.53 crore INR whereas, for large hydropower it is 9.04 crore INR.

Table 3.6: Project data with Time overrun

Name	Installed Capacity (MW)	State	Owner	Cost Overrun (%)	Clearance/ Construction start/Approval	Initial Com. Time	Final Commissioning	Estimated time (in months)	Actual time (in Months)	Time Overrun (in Months)	% Time overrun
Peppara (KESB)	3	Kerala	State	73.724	1987	1990	Jun-96	36	108	72	200.00
Darana SHP (DLI Power Pvt. Ltd.)	4.9	Maharastra	Private	6.59	1-Sep-2008	31-Mar-10	Jan-11	18	28	10	55.56
Himshakti SHP (Himshakti Projects Pvt. Ltd.)	5	H.P.	Private	5.45	24-Mar-2008	1-Oct-09	May-10	18	25	7	38.89
Dah SHP	9	J&K	State	20.29	20-Oct-2012	20-Oct-16	Feb-19	48	75	27	56.25
Rishiganaga SHP (Rishiganga Power Corporation Ltd.)	13.2	Uttrakhand	Private	50.87	24-Dec-2008	1-Dec-11	Apr-12	35	40	5	14.29
Sumez SHP (Rangaraju Warehousing Pvt. Ltd.)	14	H.P.	Private	31.38	12-Apr-2010	12-May-13	Mar-12	37	23	-14	-37.84
Nanti SHP (Surya kantha Hydro Private Limited)	14	H.P.	Private	32.00	30-Jun-12	19-Nov-15	May-14	40	22	-18	-45.00
Neogal HEP (Om Hydropower Ltd.)	15	HP	Private	49.88	31-Mar-2006	26-Apr-10	May-13	48	85	37	77.08
Kallada (KSEB)	15	Kerala	State	52.711	1981	1989	Sep-94	96	156	60	62.50
Jongini SHP (Gandhari Hydro Power Pvt. Ltd.	16	H.P.	Private	13.58	30-May-2012	Nov-15	Mar-16	41	45	4	9.76

Name	Installed Capacity (MW)	State	Owner	Cost Overrun (%)	Clearance/ Construction start/Approval	Initial Com. Time	Final Commissioning	Estimated time (in months)	Actual time (in Months)	Time Overrun (in Months)	% Time overrun
Samal SHP (Orrisa Power Consortium Ltd.)	20	Odisha	Private	19.334	3-Jan-02	1-Jan-05	Feb-06	35	48	13	37.14
Bhawani Kattalai Barrage-III (TNEB)	30	Tamil Nadu	State	343.84	27-Mar-2002	2006-07	Sep-13	53	137	84	158.49
Bhawani Kattalai Barrage-II	30	Tamilnadu	State	401.72	6-Nov-1999	2006-07	Oct-13	87	166	79	90.80
Chanju-I (M/s IA Energy)	36	H.P.	Private	63.47	24-Apr-2010	2014-15	Jul-17	52	87	35	67.31
Kolab HEP (Meenakshi Power Ltd.)	37	Odisha	Private	49.40	1-Mar-2002	Mar-06	Feb-09	48	83	35	72.92
Chutak (NHPC)	44	J&K	Central	47.00	23-Apr-2004	2010-11	Nov-12	88	102	14	15.91
Nimoo Bazgo(NHPC)	45	J&K	Central	53.21	16-Mar-2004	Sep-10	Oct-13	77	114	37	48.05
Nagarajuna Sagar TR (APGENCO)	50	Andhara Pradesh	State	106.33	10-Jan-2005	Sep-08	Jan-17	43	144	101	234.88
Tuirial (NEEPCO)	60	Mizoram	Central	274.73	16-Jul-1998	16-Jul-06	Nov-17	96	232	136	141.67
Rangit HEP (NHPC)	60	Sikkim	Central	201.094	1-Sep-90	1-Sep-95	Feb-00	60	113	53	88.33
Kashang-I (H.P. Power Corpn. Ltd.)	65	H.P.	State	65.23	31-Jul-2008	2013-14	Oct-16	67	98	31	46.27
Budhil (GREENKO)	70	H.P.	Private	64.46	2-Jun-2005	2008-09	May-12	40	82	42	105.00

Name	Installed Capacity (MW)	State	Owner	Cost Overrun (%)	Clearance/ Construction start/Approval	Initial Com. Time	Final Commissioning	Estimated time (in months)	Actual time (in Months)	Time Overrun (in Months)	% Time overrun
Doyang HEP (NEEPCO)	75	Nagaland	Central	97.192	1-Jul-93	1-Jul-97	Jul-00	48	84	36	75.00
Idamalaya (KSEB)	75	Kerala	State	284.743	1970	1978	1987	96	204	108	112.50
New Umtru (MePGCl)	80	Meghalaya	State	164.58	13-Mar-2006	2011-12	Jan-18	71	141	70	98.59
Jorethang Loop (Dans Energy pvt ltd (DEPL))	96	Sikkim	Private	177.55	12-May-2008	2012-13	Sep-15	59	87	28	47.46
Dikchu (Sneha Kinetic Power Projects Pvt. Ltd.)	96	Sikkim	Private	78.24	21-Oct-2011	Mar-13	Apr-17	16	65	49	306.25
Tashiding (M/s Shiga Energy Pvt. Ltd.)	97	Sikkim	Private	124.37	28-Mar-2011	2015-16	Nov-17	53	79	26	49.06
Chujachen (Gati Infrastructure Ltd)	99	Sikkim	Private	132.75	30-Nov-2004	2009-10	Apr-13	51	100	49	96.08
Sainj (H.P. Power Corpn. Ltd)	100	H.P.	State	16.01	29-Dec-2010	2014-15	Sep-17	50	80	30	60.00
Pare (NEEPCO)	110	Arunachal Pradesh	Central	119.91	4-Dec-2008	2013-14	May-18	62	113	51	82.26
Sew-II (NHPC)	120	J&K	Central	66.63	9-Sep-2003	9-Sep-07	Jul-10	48	81	33	68.75
Pulichintala (TSGENCO)	120	Telangana	State	48.29	25-Apr-2007	2010-11	Nov-18	46	138	92	200.00

Name	Installed Capacity (MW)	State	Owner	Cost Overrun (%)	Clearance/ Construction start/Approval	Initial Com. Time	Final Commissioning	Estimated time (in months)	Actual time (in Months)	Time Overrun (in Months)	% Time overrun
Teesta Low Dam-III (NHPC)	132	WB	Central	111.73	28-Nov-2002	Dec-06	Jan-13	48	121	73	152.08
Teesta Low Dam-IV(NHPC)	160	W.B.	Central	106.63	30-Nov-2005	2009-10	Mar-16	39	123	84	215.38
Lower Periyar (KESB)	180	Kerala	State	299.231	1983	1991	Nov-97	96	168	72	75.00
Chamera-III (NHPC)	231	H.P.	Central	45.71	1-Sep-2005	2010-11	Jun-12	60	81	21	35.00
Uri-II (NHPC)	240	J&K	Central	20.65	11-Feb-2004	2009-10	Sep-13	93	114	21	22.58
Lower Jurala (TSGENCO)	240	Telangana	State	116.78	4-Dec-2008	Dec-11	Oct-15	35	81	46	131.43
Maneri Bhali Stage II Large Hydro Power (UJVNL)	304	Uttrakhand	State	76.40	25-Jun-02	31-Mar-07	Mar-19	57	200	143	250.88
Kishanganga (NHPC)	330	J&K	Central	58.79	14-Jan-2009	Jun-14	May-18	64	112	48	75.00
Alaknanda HEP (GVK group)	330	Uttrakhand	Private	121.02	1-Aug-2007	31-Mar-12	Oct-14	55	86	31	56.36
Dulhasti HEP (NHPC)	390	J&K	Central	302.11	12-Jul-1989	Mar-01	Mar-07	139	211	72	51.80
Idukki Stage II (KSEB)	390	Kerala	State	114.646	1970	1978	1986	96	192	96	100.00
Koteshwar HEP	400	Uttrakhand	Central	81.63	10-Apr-2000	1-Mar-05	Apr-12	58	143	85	146.55
Rampur (SJVNL)	412	H.P.	Central	63.06	25-Jan-2007	2011-12	Mar-14	49	85	36	73.47

Name	Installed Capacity (MW)	State	Owner	Cost Overrun (%)	Clearance/ Construction start/Approval	Initial Com. Time	Final Commissioning	Estimated time (in months)	Actual time (in Months)	Time Overrun (in Months)	% Time overrun
Baglihar-II (JKPDC)	450	J&K	State	47.42	1-Jul-2002	Jul-07	Sep-15	60	158	98	163.33
Baglihar Stage-II	450	J&K	State	47.42	1-Apr-1999	1-Oct-12	May-16	162	205	43	26.54
Baglihar Stage-I	450	J&K	State	66.72	9-Apr-1999	31-Dec-04	Oct-08	68	114	46	67.65
Uri Stage I (NHPC)	480	J&K	Central	96.896	22-Nov-89	Dec-95	Apr-97	72	88	16	22.22
Parbati-III(NHPC)	520	H.P.	Central	17.85	9-Nov-2005	Nov-10	Mar-14	59	99	40	67.80
Kol Dam (NTPC)	800	H.P.	Central	59.48	1-Oct-2002	Mar-09	Mar-15	77	149	72	93.51
Teesta-III (Teesta Urja Ltd.)	1200	Sikkim	State	99.49	12-May-2006	2011-12	Feb-17	63	129	66	104.76
Nathpa Jhakri HEP (SJVNL)	1500	H.P.	Central	64.20	1-Jun-1993	Mar-02	May-04	105	131	26	24.76

3.4 Comparison using time overrun

By analysing the Table 3.7, it can be seen that there are two projects which were completed before the scheduled time otherwise the time overrun ranges from 9% to upto 300% in case of Dikchu (96MW) HEP. At the same time there were two projects out of 61 that completed before the estimated time. As far as time overrun in months are concerned it ranges from as less as 5 months to 143 months.

3.4.1 Based on percentage of project

Ownership	Time Overrun %					
	No. of projects	0-25%	25-50	51-100 %	101-200%	>200%
Central	19	4	2	9	3	1
Private	16	4	4	6	1	1
State	22	0	2	8	9	3

Table 3.7: Time overrun data with respect to ownership

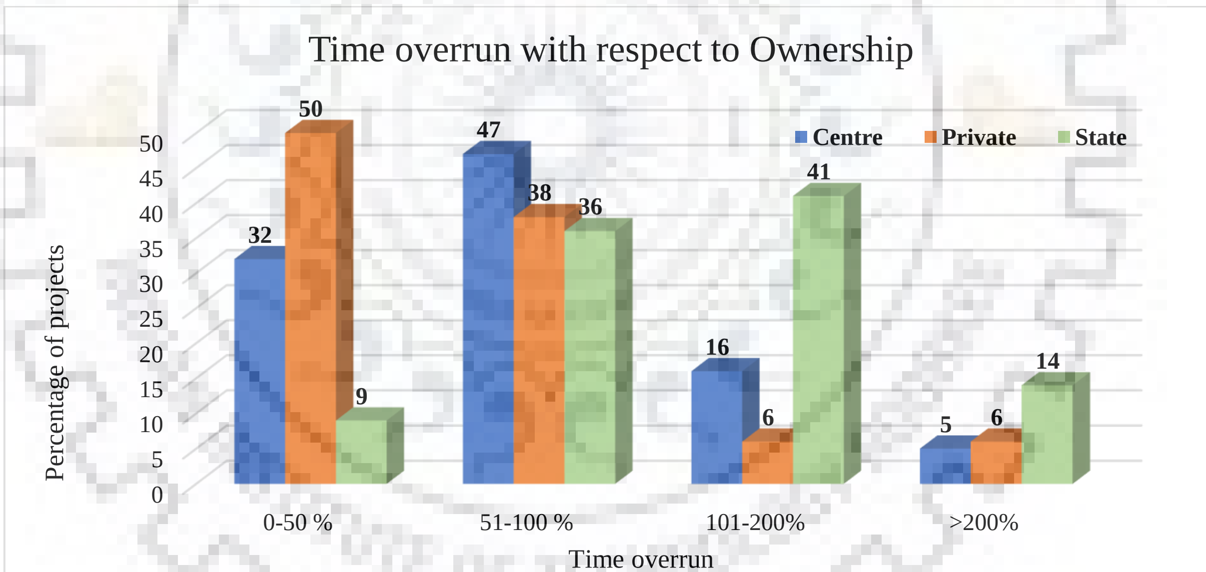


Fig 3.14: Time overrun with respect to ownership

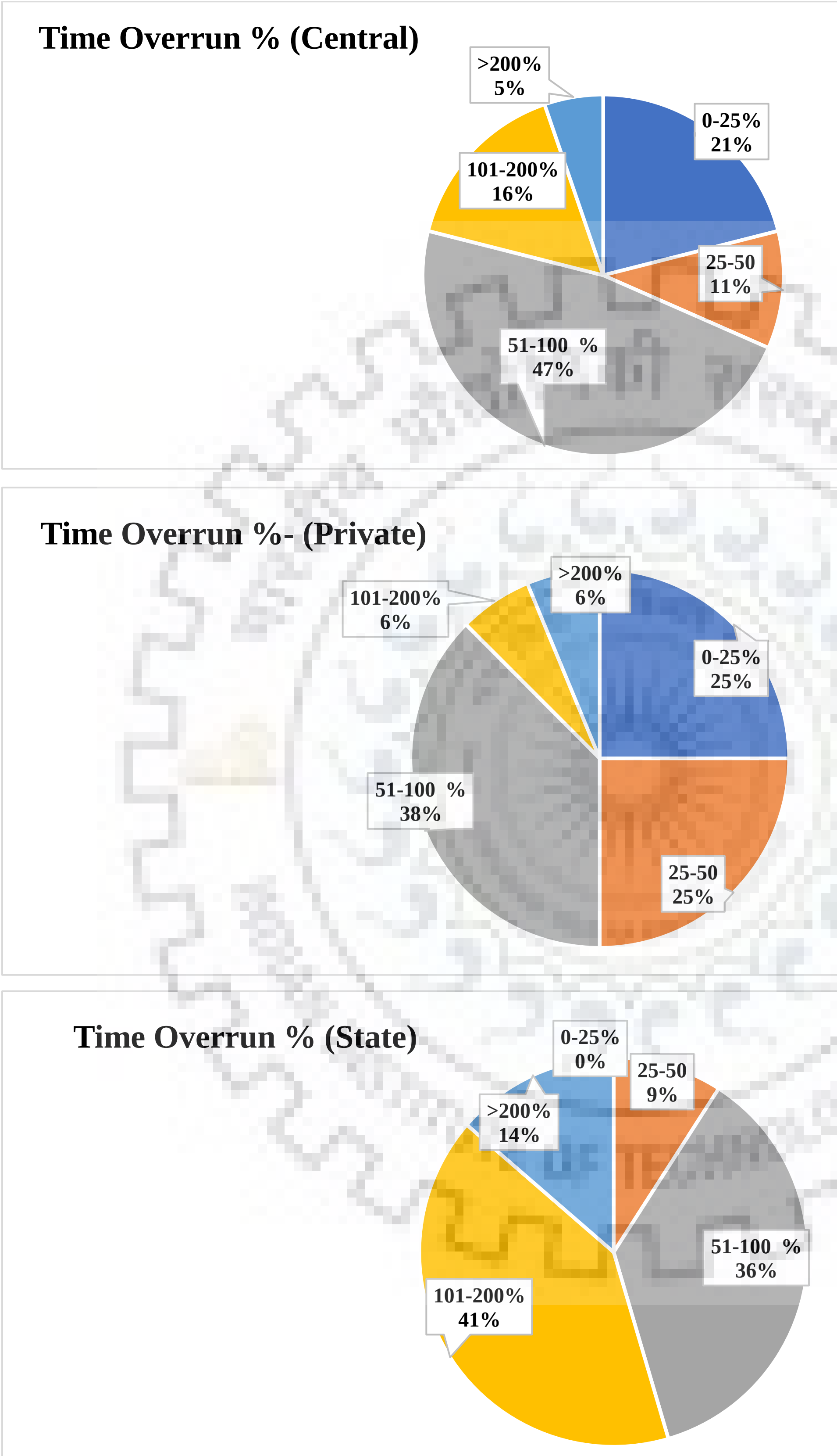


Fig 3.15: Comparison of time overrun with respect to ownership

It can't be directly compared the number of projects in various overrun categories as total number of projects are different for each so, pie chart in fig 14 gives the number of % of projects in various categories of time overrun. In case of central govt projects 31% have less than 50% time delays and 63% have delays in between 50-200%. In case of state owned projects just 9% projects have less than 50% overrun and 77% projects have overrun between 50-200%. Privately owned projects tend to have less than 50% delays in 1 out of 2 projects. These values of % of projects for various owners are summarized in fig 13. Like the cost overrun trend, here too privately funded projects are better at keeping the project in time than other two. It can be safely said that, privately owned projects show more accountability in terms of project implementation.

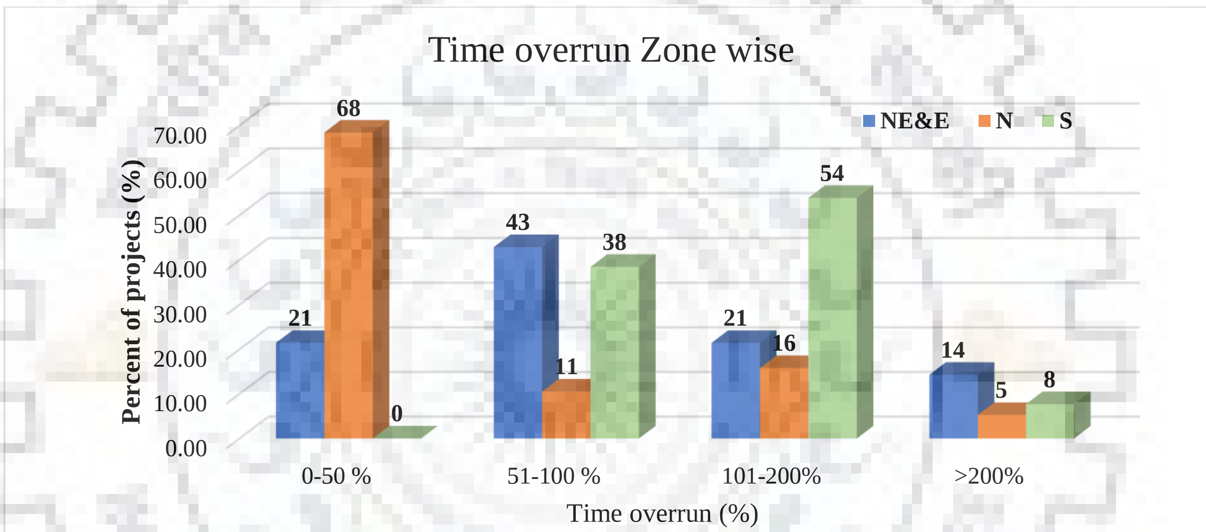


Fig 3.16: Time overrun with respect to project location

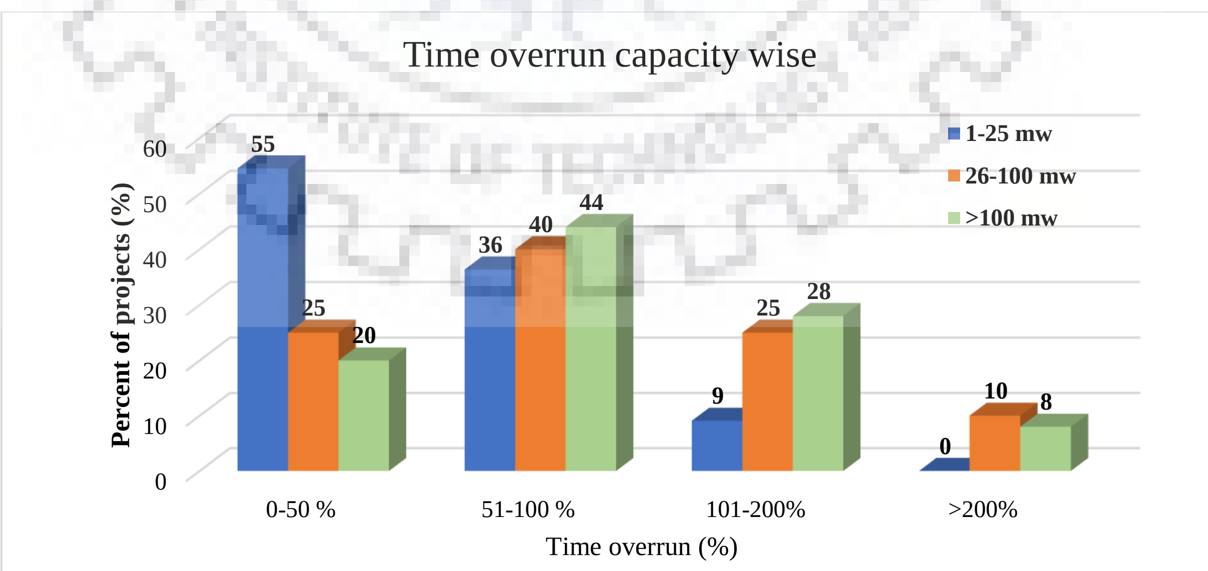


Fig 3.17 Time overrun with respect to installed capacity

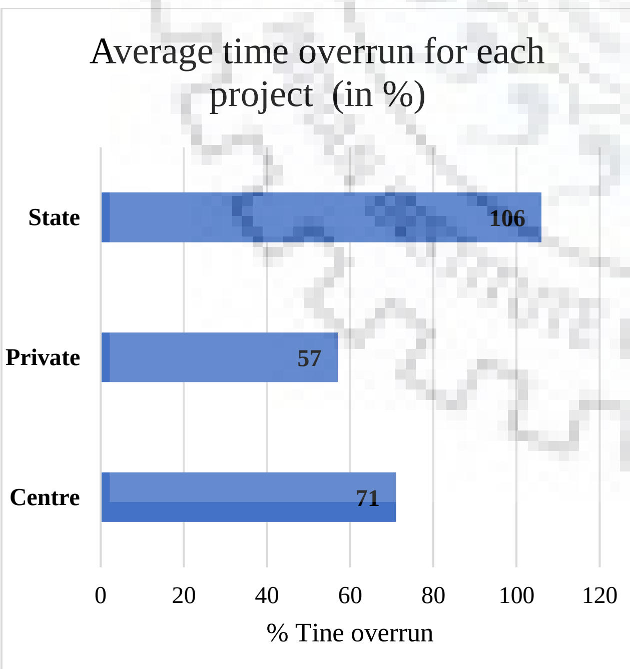
As shown in Fig 3.16 , north zone projects have least percentage of projects with high time overrun and around 70% of them lie in 0-50% category. For projects installed in south zone, they have more tendency to have higher time overrun.

In Fig 3.17 , it is shown that small hydro projects, less than 10% of projects have above 100% time overrun. One out of two projects of shp have less than 50% of time overrun. Whereas, medium capacity and large capacity hydro projects have more or less equal probability of having time overrun and around 40% projects tend to have more than double the actual completion time than expected.

3.4.2 Based on average time overrun

Owner	Installed Capacity (MW)	Weighted average Time overrun per MW (in months)	Average time overrun for each project (in %)
Centre	6109	0.16	71
Private	963	0.39	57
State	4531	0.35	106

Table 3.8 : Average time overrun with respect to Owner



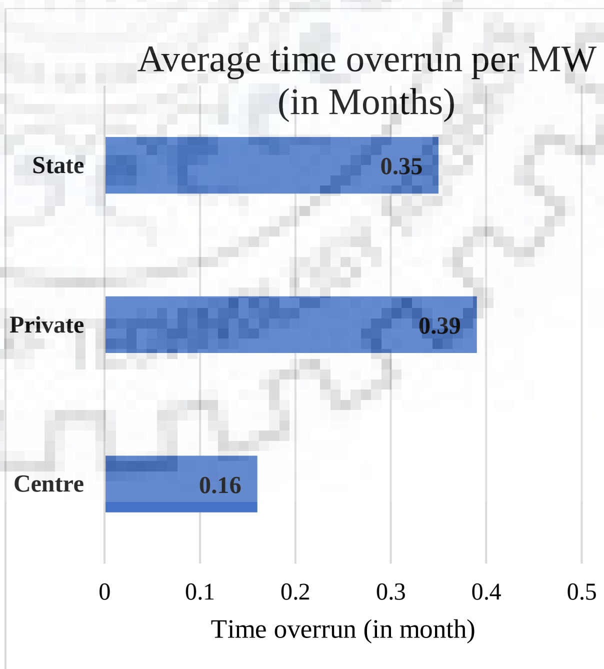


Fig 3.18 : Average time overrun with respect to Owner

As shown in Fig 3.18 , average time overrun for projects based on owner are 106, 57 and 71% for state, private and central government respectively. Average time overrun for state government owned projects are about double of that of privately owned projects. Similarly, average time overrun per mw of installed capacity are 0.35, 0.39 and 0.16 months for state, private and central government respectively. Here, privately owned projects tend to have highest value of per mw time overrun whereas central government owned project has the least value.

Region	Installed Capacity (MW)	Weighted average Time overrun per MW (in months)	Average time overrun for each project (in %)
NE & E	2322	0.33	103
North	7853.2	0.14	57
South	1377.9	0.64	118

Table 3.9: Average time overrun with respect to region

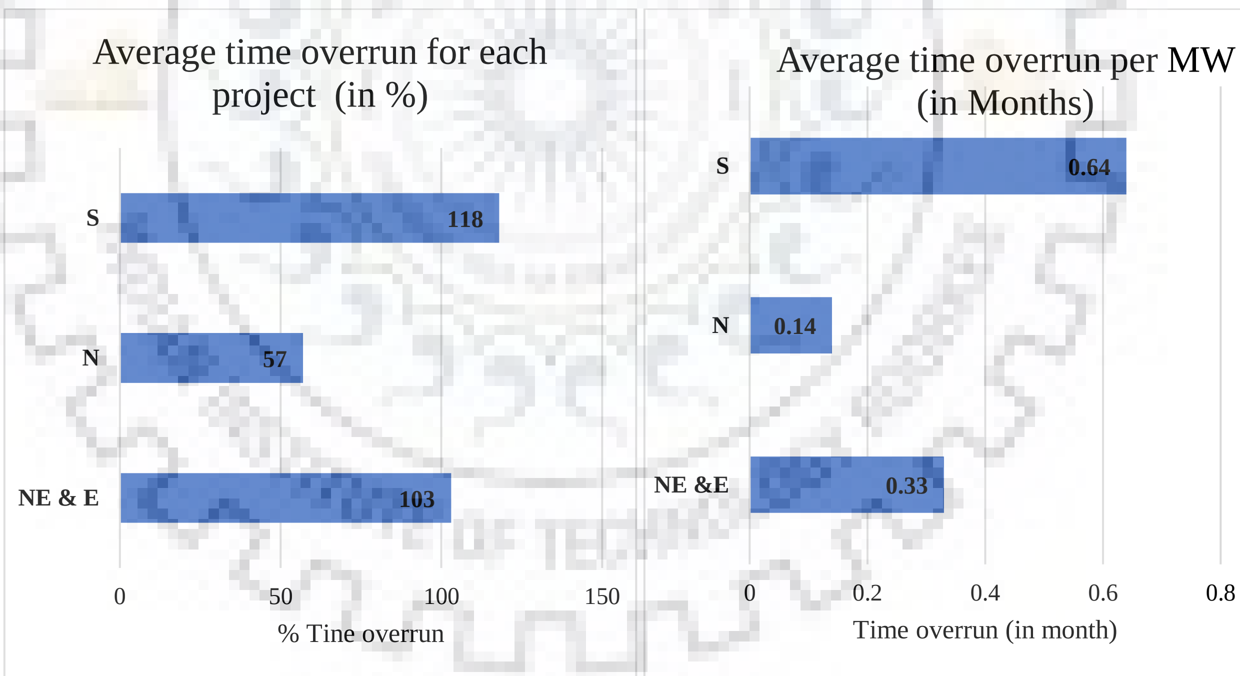


Fig 3.19: Average time overrun per project and per MW(zone wise)

As seen from fig 3.19, projects installed in NE &E one has average time overrun of 103%, projects in south zone has 118% average time overrun which is more than double of average time overrun in north zone projects with value 57%. Similar trend can be for per MW time overrun as south zone projects have 0.64 month average time overrun per MW. Projects in NE & E zone have 0.33 month average overrun per MW whereas, projects in north zone have 0.14 month average time overrun per MW which is less than half of projects in NE&E zone.

Installed capacity range(MW)	Aggregate Installed capacity (MW)	Per MW Weighted average time overrun (in months)	Average time overrun per project (in %)
0-25	129	1.57	45
26-100	1245	0.84	90
>100	10179	0.14	84

Table 3.10: Time overrun comparison installed capacity wise

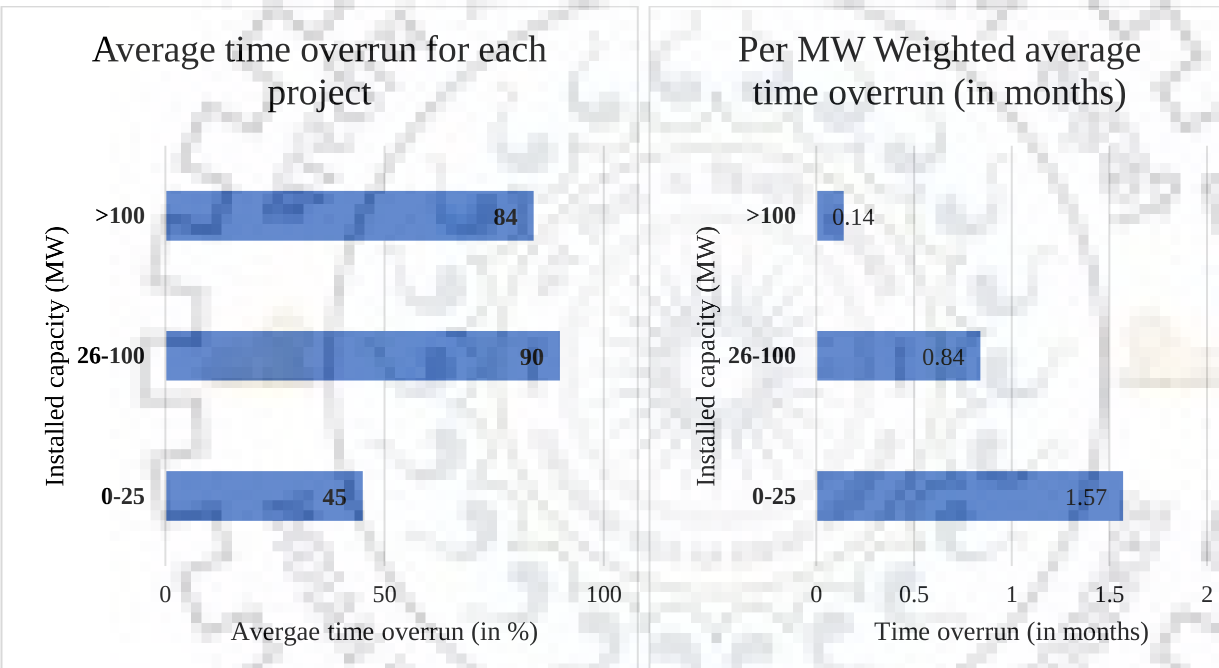


Fig 3.20 Average time overrun per project and per MW(capacity wise)

As shown in fig 3.20, Small hydropower has least time overrun per project 45% but has the highest average per MW time overrun of 1.57 months. At the same time, for projects above 100MW, average time overrun is 84% and per MW overrun is of 0.14 month. For Medium capacity hydropower, average time overrun is 90% i.e. average time taken for these kinds of project is almost double of what is anticipated at the start of project. Per MW time overrun for 26-100 mw hydro power is .84, about half of the small capacity hydro power.

Hence, it can be sais that, in terms of ownership, privately owned projects have least chance of time overrun and central government projects has highest. In terms of region, south zone projects have maximum % time overrun as well as average per MW time overrun whereas north has both these parameters as least. In terms of installed capacity, SHP has least % time overrun but the highest per mw time overrun.

Scatter plots of time overrun and installed capacity for different region doesn't yield any pattern, its random in nature.

3.5 Comparison using Capital Time waste factor

Morris (1990)[45] Kannan& Pillai(2002) [18] used this method to analyse the cost and time overrun of hydro power projects in Kerla. In this method, problem of overruns can be analysed by considering the combined effect of both time and cost overrun, a measure which is called 'capital time waste factor'. It is calculated (as shown in Eq. 3.3) by taking difference between the actual capital x time (CaTa) and the originally planned capital x time (CoTo) measures as a percentage of the latter (where Ca and Co are the actual (or latest) and originally planned estimates of capital cost and Ta and To are the corresponding period of commissioning).

Capital x Time waste factor (%)

$$= \frac{\textit{Actual Capital}\,(\mathbf{Ca})\,\mathbf{x\ Actual\ Time\ taken}(\mathbf{Ta}) - \textit{Original cost est.}(\mathbf{Co})\mathbf{xOriginal\ time\ est.}(\mathbf{To})}{\textit{Original cost est.}(\mathbf{Co})\ \mathbf{x\ Original\ time\ est.}(\mathbf{To})}\ \boldsymbol{x}\ \mathbf{100}$$

(Eq. 3.3)

For example, if a project has 500% capital x time waste factor then it stands for it has consumed 5 times extra resources than it was estimated or in other words in different circumstance, using this much resources, it could have built 5 more such projects.

Table 3.11 gives the value of capital waste factor calculated using anticipated and actual cost and time schedule of the given projects. It can be seen that capital waste factor ranges from 24% for Jogini SHP to upto 1050% for Bhawani Kattalai (30MW).

Table 3.11: Data for capital time waste factor

Name	Installed Capacity (MW)	State	Ca*Ta (Crore month)	Co*To (Crore month)	Diff. (Ca*Ta - Co*To)	Capital* Time Waste Factor (%)
Peppara (KESB)	3	Kerala	735.48	141.12	594.36	421.17
Darana SHP (DLI Power Pvt. Ltd.)	4.9	Maharastra	996.52	601.02	395.50	65.80
Himshakti SHP (Himshakti Projects Pvt. Ltd.)	5	H.P.	899.00	613.80	285.20	46.46
Dah SHP	9	J&K	7845.00	4174.08	3670.92	87.95
Rishiganaga SHP (Rishiganga Power Corporation Ltd.)	13.2	Uttrakhand	5153.60	2989.00	2164.60	72.42
Sumez SHP (Rangaraju Warehousing Pvt. Ltd.)	14	H.P.	2453.87	3004.77	-550.90	-18.33
Nanti SHP (Surya kantha Hydro Energies Private Limited)	14	H.P.	1943.92	2677.60	-733.68	-27.40
Neogal HEP (Om Hydropower Ltd.)	15	HP	10523.00	3964.80	6558.20	165.41
Kallada (KSEB)	15	Kerala	2811.12	1132.80	1678.32	148.16
Jongini SHP (Gandhari Hydro Power Pvt. Ltd.	16	H.P.	6091.20	4886.38	1204.82	24.66
Samal SHP (Orrisa Power Consortium Ltd.)	20	Odisha	5590.56	3416.00	2174.56	63.66
Bhawani Kattalai Barrage-III (TNEB)	30	Tamil Nadu	60654.01	5286.75	55367.26	1047.28
Bhawani Kattalai Barrage-II	30	Tamilnadu	82578.36	8626.05	73952.31	857.31

Name	Installed Capacity (MW)	State	Ca*Ta (Crore month)	Co*To (Crore month)	Diff. (Ca*Ta - Co*To)	Capital* Time Waste Factor (%)
Chanju-I (M/s IA Energy)	36	H.P.	41967.93	15344.68	26623.25	173.50
Kolab HEP (Meenakshi Power Ltd.)	37	Odisha	19963.99	7728.00	12235.99	158.33
Chutak (NHPC)	44	J&K	93151.50	54670.88	38480.62	70.39
Nimoo Bazgo(NHPC)	45	J&K	106715.40	47047.77	59667.63	126.82
Nagarajuna Sagar TR (APGENCO)	50	Andhara Pradesh	138048.48	19979.09	118069.39	590.96
Tuirial (NEEPCO)	60	Mizoram	320556.72	35397.12	285159.60	805.60
Rangit HEP (NHPC)	60	Sikkim	55625.38	9809.40	45815.98	467.06
Kashang-I (H.P. Power Corpn. Ltd.)	65	H.P.	77404.32	32027.34	45376.98	141.68
Budhil (GREENKO)	70	H.P.	56479.14	16752.00	39727.14	237.15
Doyang HEP (NEEPCO)	75	Nagaland	63730.8	18468.00	45262.80	245.09
Idamalaya (KSEB)	75	Kerala	18366.12	2246.40	16119.72	717.58
New Umtru (MePGCl)	80	Meghalaya	84459.00	16074.40	68384.60	425.43
Jorethang Loop (Dans Energy pvt ltd (DEPL))	96	Sikkim	131154.24	32045.85	99108.39	309.27
Dikchu (Sneha Kinetic Power Projects Pvt. Ltd.)	96	Sikkim	74100.00	10233.12	63866.88	624.12

Name	Installed Capacity (MW)	State	Ca*Ta (Crore month)	Co*To (Crore month)	Diff. (Ca*Ta - Co*To)	Capital* Time Waste Factor (%)
Tashiding (M/s Shiga Energy Pvt. Ltd.)	97	Sikkim	82589.76	24695.35	57894.41	234.43
Chujachen (Gati Infrastructure Ltd)	99	Sikkim	104450.00	22886.76	81563.24	356.38
Sainj (H.P. Power Corpn. Ltd)	100	H.P.	62764.80	33814.50	28950.30	85.62
Pare (NEEPCO)	110	Arunachal Pradesh	142636.51	35587.38	107049.13	300.81
Sew-II (NHPC)	120	J&K	89815.23	31942.08	57873.15	181.18
Pulichintala (TSGENCO)	120	Telangana	77761.62	17480.00	60281.62	344.86
Teesta Low Dam-III (NHPC)	132	WB	196988.00	36908.16	160079.84	433.72
Teesta Low Dam-IV(NHPC)	160	W.B.	269748.84	41393.82	228355.02	551.66
Lower Periyar (KESB)	180	Kerala	59310.72	8489.28	50821.44	598.65
Chamera-III (NHPC)	231	H.P.	165896.91	84337.80	81559.11	96.71
Uri-II (NHPC)	240	J&K	237234.00	160405.47	76828.53	47.90
Lower Jurala (TSGENCO)	240	Telangana	183130.02	34516.92	148613.10	430.55
Maneri Bhali Stage II Large Hydro Power (UJVNL)	304	Uttrakhand	440708.00	71203.26	369504.74	518.94
Kishanganga (NHPC)	330	J&K	647715.04	233090.56	414624.48	177.88

Name	Installed Capacity (MW)	State	Ca*Ta (Crore month)	Co*To (Crore month)	Diff. (Ca*Ta - Co*To)	Capital* Time Waste Factor (%)
Alaknanda HEP (GVK group)	330	Uttrakhand	393278.00	113795.00	279483.00	245.60
Dulhasti HEP (NHPC)	390	J&K	1071561.39	175552.83	896008.56	510.39
Idukki Stage II (KSEB)	390	Kerala	13056	3041.28	10014.72	329.29
Koteshwar HEP	400	Uttrakhand	338060.58	75490.48	262570.10	347.82
Rampur (SJVNL)	412	H.P.	283722.35	100304.47	183417.88	182.86
Baglihar-II (JKPDC)	450	J&K	492203.18	126785.40	365417.78	288.22
Baglihar Stage-II	450	J&K	638618.05	342320.58	296297.47	86.56
Baglihar Stage-I	450	J&K	664278.00	237660.00	426618.00	179.51
Uri Stage I (NHPC)	480	J&K	298144	123890.40	174253.60	140.65
Parbati-III(NHPC)	520	H.P.	268884.00	135969.04	132914.96	97.75
Kol Dam (NTPC)	800	H.P.	1075780.00	348590.55	727189.45	208.61
Teesta-III (Teesta Urja Ltd.)	1200	Sikkim	1468278.00	359449.65	1108828.35	308.48
Nathpa Jhakri HEP (SJVNL)	1500	H.P.	1072497.00	523515.30	548981.70	104.86

3.5.1 Based on ownership

On summarizing the Table 3.11: ,

Ownership	% Capital x Time waste Factor				
	No. of projects	**1-100%**	**101-200 %**	**201-500%**	**>500%**
Central	19	4	3	9	3
Private	16	2	4	6	4
State	20	8	5	4	3

Table 3.12: Capital time waste factor based on ownership

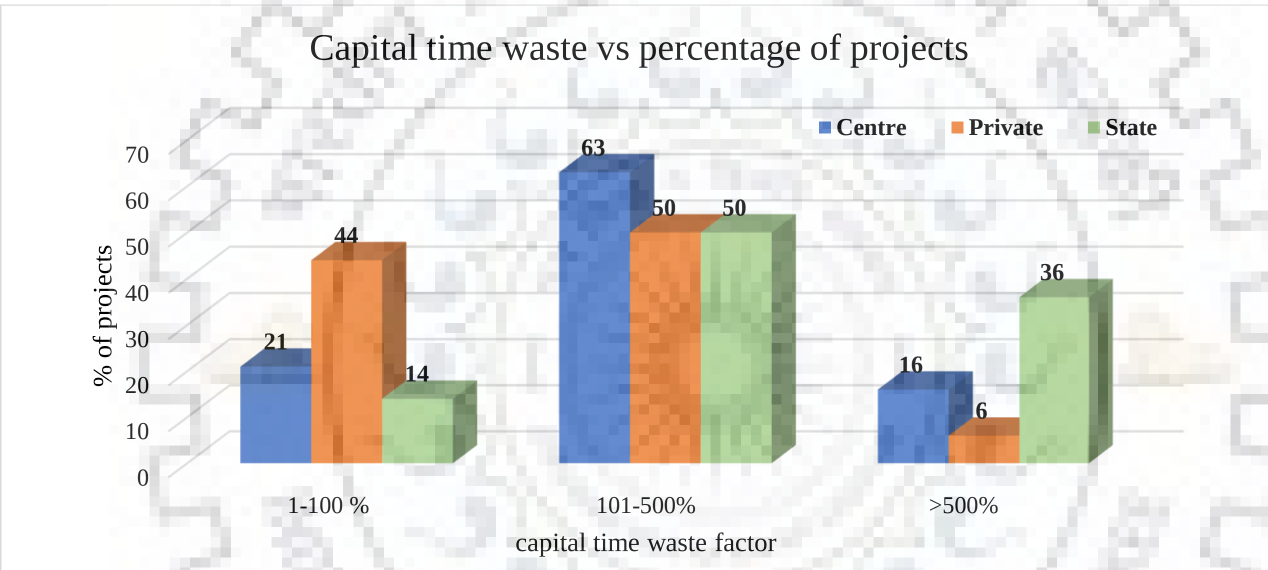
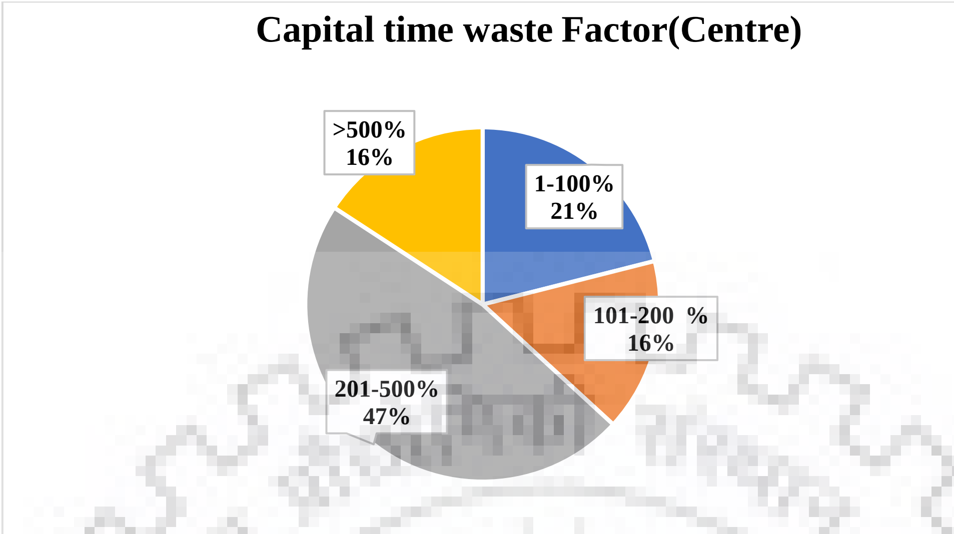
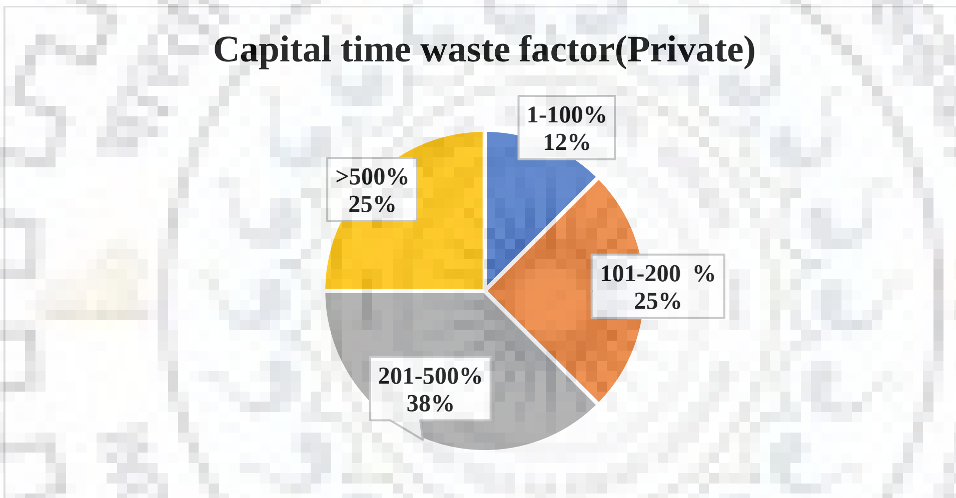


Fig 3.21 : Capital time waste factor with respect to ownership

To understand the meaning of the value of capital time waste factor, let’s say a project having 100% cost overrun and 100% time overrun will have 300% of capital time waste factor or project with 50% time overrun and 50% cost overrun will have 125% capital time waste factor i.e. after having 50% cost overrun and 50% time overrun, project has utilised 205 times resources it was intended to for completion.





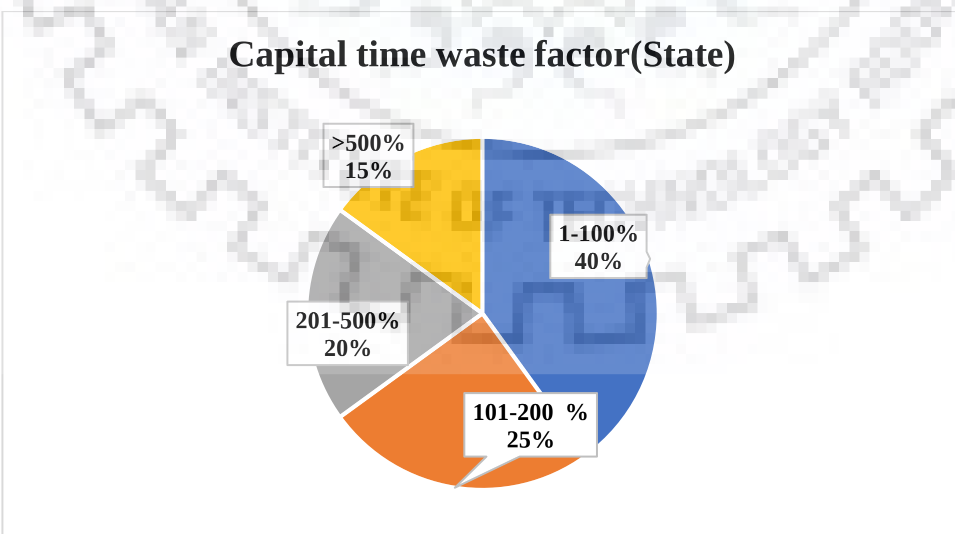


Fig 3.22: Capital time waste factor based on ownership

Fig 3.21 demonstrates the value of capital time waste factor for each criterion individually. For central government projects, 52% of projects will have less than 200% capital waste factor and around 16% will have above 500% . Privately owned projects tend to have less than 200% cost overrun for 63% of projects and just 6% chance of above 500% capital time waste factor. For state government owned projects, 1 out of 3 tend to have above 500% capital waste factor and just 14% of projects have less than 100% capital time waste factor. Hence, clearly it can be assumed that here too, privately owned projects show better resource management while execution whereas stage owned projects lag the most in resource management.

3.5.2 Based on location

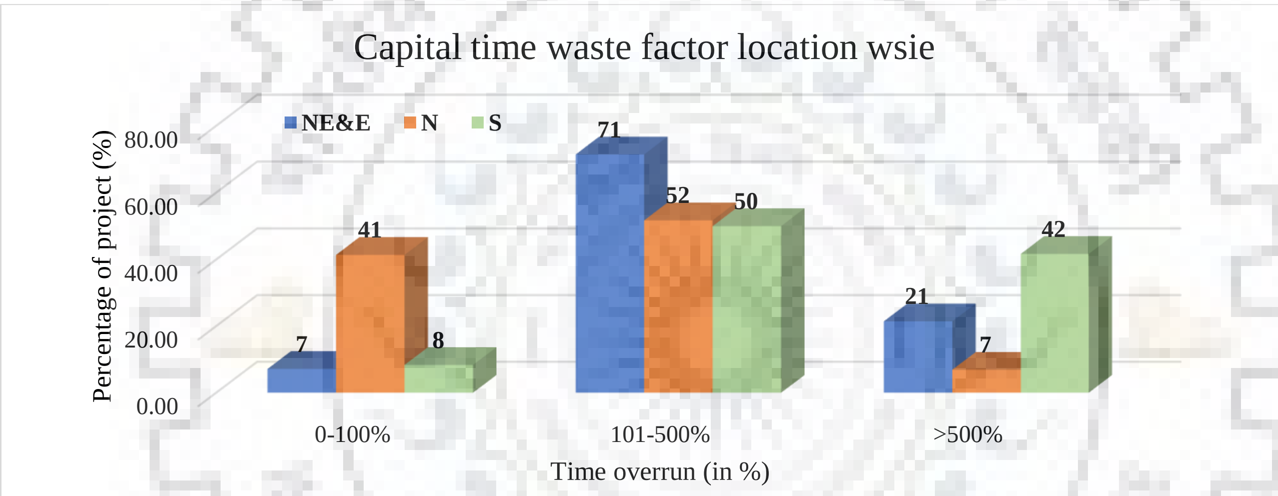


Fig 3.23 : Capital time waste factor with respect to location

3.5.2 Based on installed capacity

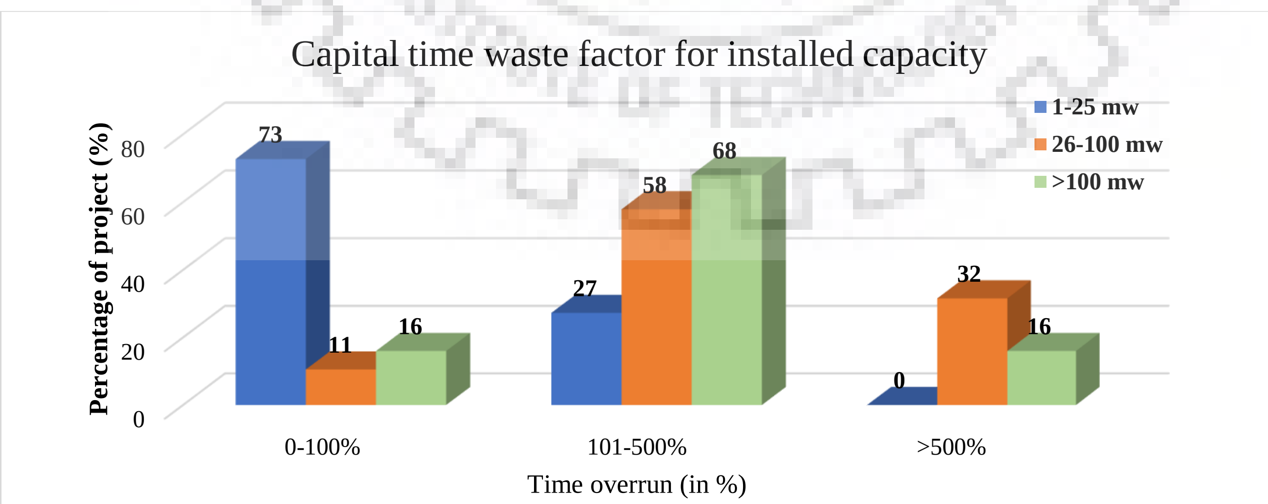


Fig 3.24 : Capital time waste factor with respect to installed capacity

As shown in Fig 3.23, south zone projects have maximum probability of having capital time waste factor but north zone projects tend to have least of it. Similarly, as in Fig 3.24, chances for capital time waste factor for medium capacity project is highest whereas least for small hydro power. Hence, it can be concluded that small hydro power projects have better resource utilization than medium or large hydropower. Similarly, projects located in south India tend to have worse resource utilization.

3.6 Summary of comparison analysis

Basis of comparison	Ownership		
Percentage of projects (cost Overrun)	Private < Centre < State		
Average cost overrun(%)	State	Centre	Private
	58	62	80
Per mw cost overrun (cr. INR)	State	Centre	Private
	4.9	7.13	7.5
Percentage of projects (Time Overrun)	Private < Centre < State		
Average time overrun (%)	Private	Centre	State
	57	71	106
Per mw average time overrun (in month)	Centre	State	Private
	0.16	0.35	0.39
Percent of projects (Capital waste factor (%)	Private < Centre < < State		

Table 3.13 : Comparison summery with respect to ownership

Based on ownership, as given in Table 3.13; the sequence for cost overrun, time overrun and capital time waste factor as percentage of total project remains same with privately owned projects with least value and state owned projects with the highest value. Privately owned projects have highest values for per mw cost overrun and per mw time overrun as 7.5 cr. INR and 0.39 months respectively.

Basis of comparison	Location		
Percentage of projects (cost Overrun)	North < South < East & North-east		
Average cost overrun(%)	North	East & North-east	South
	57.7	77..5	98
Per mw cost overrun (cr. INR)	South	North	East & North-east
	7.11	6.36	4.78
Percentage of projects (Time Overrun)	North < East & North-east < South		
Average time overrun (%)	North	East & North-east	South
	57	103	118
Per mw average time overrun (in month)	North	East & North-east	South
	0.14	0.33	0.64
Percent of projects (Capital waste factor (%)	North < East & North-east < South		

Table 3.14 : Comparison summery with respect to Location

Based on project location, as given in Table 3.14 ; the sequence for cost overrun, time overrun and capital time waste factor as percentage of total project remains almost same with north zone projects having least value among all the parameters. East and north-east zone as well as south zone projects have above 100% average time overrun.

Basis of comparison	Installed capacity		
Percentage of projects (cost Overrun)	Small < Large < Medium		
Average cost overrun(%)	Small	Large	Medium
	25.6	60	80.5
Per mw cost overrun (cr. INR)	Small	Large	Medium
	2.53	6.02	9.04
Percentage of projects (Time Overrun)	Small < Medium =Large		
Average time overrun (%)	Small	Large	Medium
	45	84	90
Per mw average time overrun (in month)	Large	Medium	Small
	0.14	0.84	1.57
Percent of projects (Capital waste factor (%)	Small < Large < Medium		

Table 3.15 : Comparison summery with respect to installed capacity

Based on project installed capacity, as given in Table 3.15; the sequence for cost overrun, time overrun and capital time waste factor as percentage of total project remains almost same with small hydro schemes having least value. Whereas, the medium capacity hydro projects tend to have highest value in almost each criteria of comparison.

3.6 Regression for time overrun and cost overrun

We know that sometimes delay in project completion does cause cost overrun due to increase in cost of labour as well as materials. Moreover, Dinesh K.R, 2016 [12] identified conflicts between various stakeholder due to inadequate pricing and modification in project design as prominent cause of time delay. Project work remain stalled many months due to these factors leading to revised cost estimated after work resumes. Hariharan S. and Sawant P.H., 2012[24] also found that there is a strong correlation between time and cost overrun though they are driven by factors independent of each other.

Plot of cost overrun vs time overrun Fig 3.25 shows that both doesn't always show the same kind of trend. There are also projects where even if project got completed early but there was cost overrun. Upto some extent it can be said that whenever time overrun is high project tend to have higher cost overrun compared to others. Whereas, the plot of cost overrun vs multiplication of time overrun and inflation (Fig 3.26) yields much better comparable trend than cost overrun vs time overrun (Fig:3.25). Moreover, when the same thing is tried with linear combination of time overrun and inflation there is no recognizable trend. Hence, it can be safely assumed that cost overrun can be expressed as non-linear regression of time overrun and inflation in multiplication.

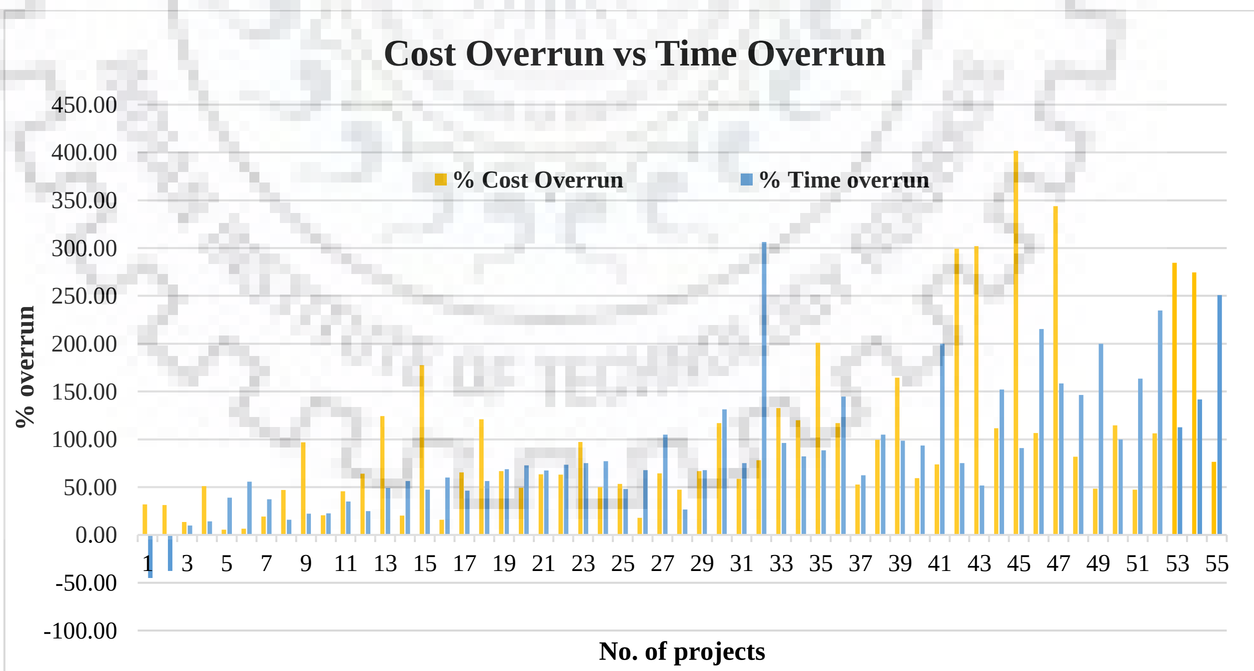


Fig 3.25: Plot of cost overrun vs time overrun

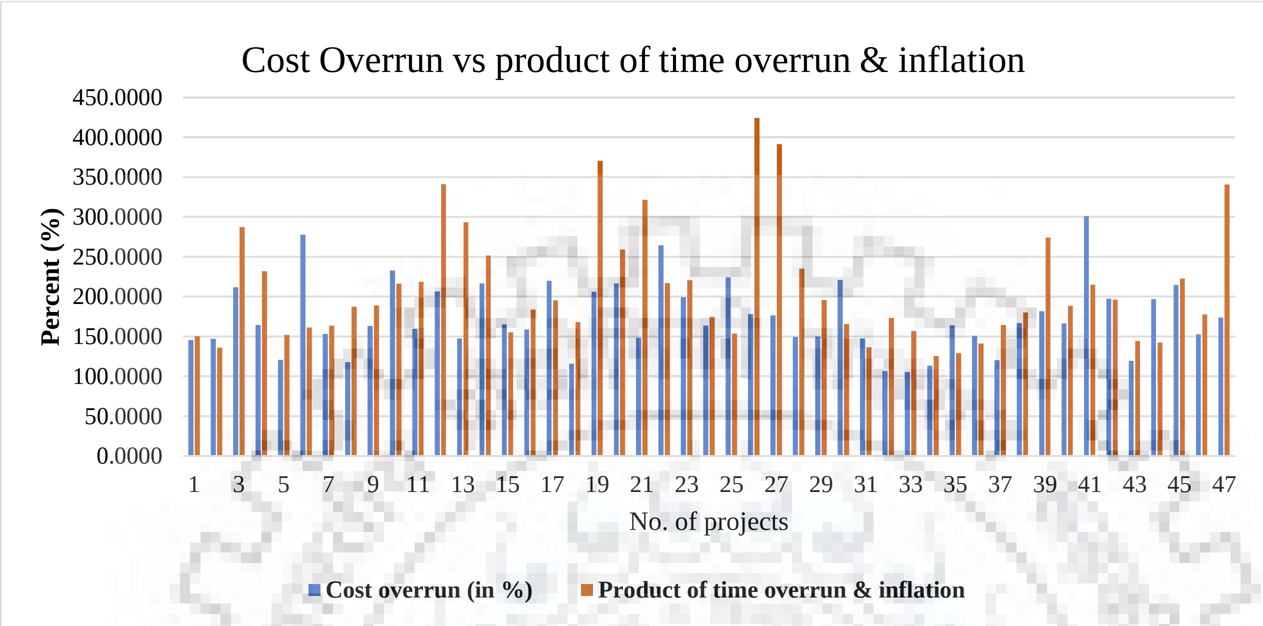


Fig 3.26: Plot of cost overrun vs product of time overrun and inflation

While developing the relationship between cost and time overrun, the study done by Ameh & Osegbo, 2011 [22], for developing the relationship between cost overrun vs time overrun and productivity for various construction activities was referred. In this direction first step was to find the factors that can affect the cost overrun using logical deduction as well as plotting the graph between probable factors and cost overrun. Following factors were considered initially, supposed to be affecting cost overrun.

- Time overruns
- Average inflation
- Project installation region
- Ownership

An analysis of scatter between the above four factors individually with the cost overrun data gives reasonable trend between only two factors namely time overrun and cost overrun. Other two probable factors don't yield any significant trend. Moreover, logically it makes sense that time overrun and inflation will directly affect the cost hence cost overrun. Non-linear regression is used to get the relationship between these.

The relation that was used for the analysis is

$$\textbf{Cost overrun (C)} = \mathbf{a} * \mathbf{T}^{\mathbf{b}} * \mathbf{i}^{\mathbf{c}} \qquad \text{(Eq 3.4)}$$

Where

Cost overrun(C) is in terms of fraction as no. of times of initial estimated cost of the project;

T is no. of times actual completion time is of estimated completion time of the project.

i is the average inflation factor (price of unit cost object supposed to increase every year on an average for the time overrun duration).

a, b & c are regression coefficient.

The coefficients of the relation mentioned above are determined with the help of least square non-linear regression analysis technique. The residual square function is minimized using GRG (generalized reduced gradient) non-linear method[27]. The residual square function Z is defined as

$$\mathbf{Z} = \sum \left[\textbf{actual cost overrun} - (\textbf{expected cost overrun } \mathbf{C}(\mathbf{T}, \mathbf{i})\right]^{2} \qquad \text{(Eq 3.5)}$$

Where

$$\mathbf{C}(\mathbf{T}, \mathbf{i}) = \mathbf{a} * \mathbf{T}^{\mathbf{b}} * \mathbf{i}^{\mathbf{c}} \qquad \text{(Eq. 3.6)}$$

Adding the error square for each of the projects considered. Three extreme project data were removed before analyzing considering them redundant.

On the basis of data available**,** following values for the coefficients are obtained

a	**b**	**c**	**Z (residual square)**
1.52	0.23	0.35	0.345

Table 3.16: Values of regression coefficient

As the value of residual square is very less hence it can be assumed that obtained coefficient can be taken as possible solution of the non-linear regression. Moreover, the residual scatter is also plotted to look out for any pattern in it or one sided value. As shown in Fig 3.27, residual points are evenly distributed on both sides of the x-axis as well as without any pattern hence this can be accepted as a solution.

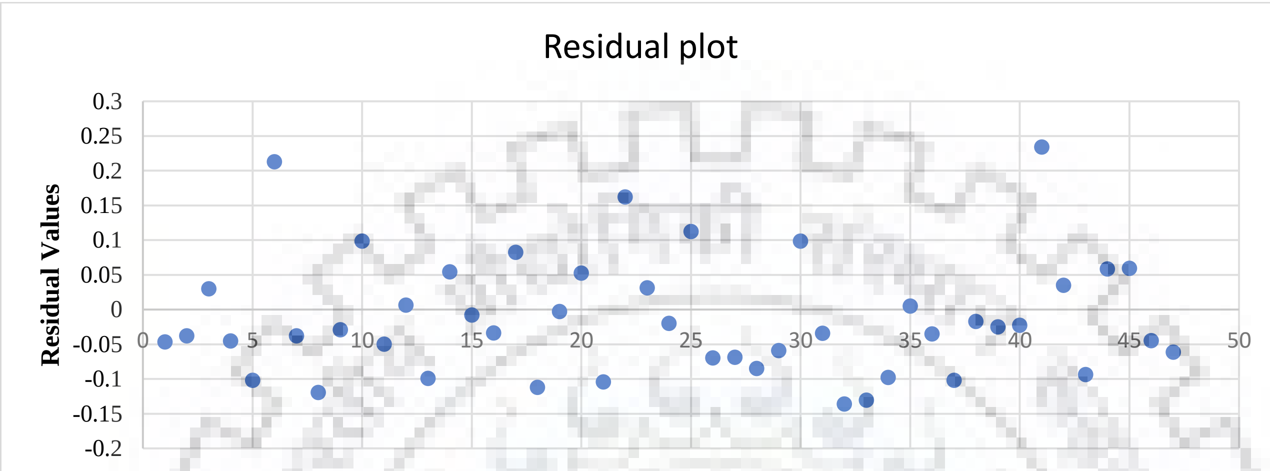


Fig 3.27: Showing residual plot of non-liner regression

Hence, the relationship obtained is

$$\textbf{Cost overrun (C)} = \mathbf{1.52 * T^{0.23} * i^{0.35}} \qquad \text{(Eq 3.7)}$$

Value of cost overrun C, obtained ne this relation will be in terms of fraction. For example, if a project is expected to have 50% overrun then the value of C will be 1.5. Similarly, for project having/expected of having 75% time overrun then value of T should be kept as 1.75.

And **i** is the average inflation factor (price of unit cost object supposed to increase every year on an average for the time overrun duration). For example, during a time overrun of 3 year of project total inflation comes out to be 21% so, on an average yearly inflation would be 7% for the duration of time overrun hence value of **i** will be 1.07.

The value of actual and expected cost overrun using this relation has been given in Table 3.17.

Table 3.17 : Value for actual and expected cost overrun.

Name	Installed Capacity (MW)	State	Actual Cost Overrun in %	Cost overrun (in fraction)	Expected Cost overrun	Expected Cost overrun in%
Chamera-III (NHPC)	231	H.P.	45.71	1.457	1.503	50.344
Chutak (NHPC)	44	J&K	47.00	1.470	1.507	50.788
Teesta Low Dam-III (NHPC)	132	WB	111.73	2.117	2.087	108.712
Budhil (GREENKO)	70	H.P.	64.46	1.644	1.689	68.961
Uri-II (NHPC)	240	J&K	20.65	1.206	1.308	30.815
Jorethang Loop (Dans Energy pvt ltd (DEPL))	96	Sikkim	177.55	2.775	2.562	156.266
Nimoo Bazgo(NHPC)	45	J&K	53.21	1.532	1.569	56.955
Parbati-III(NHPC)	520	H.P.	17.85	1.178	1.298	29.805
Rampur (SJVNL)	412	H.P.	63.06	1.630	1.659	65.939
Chujachen (Gati Infrastructure Ltd)	99	Sikkim	132.75	2.327	2.228	122.886
Kol Dam (NTPC)	800	H.P.	59.48	1.594	1.644	64.454
Teesta Low Dam-IV(NHPC)	160	W.B.	106.63	2.066	2.059	105.957
Baglihar-II (JKPDC)	450	J&K	47.42	1.474	1.573	57.346
Lower Jurala (TSGENCO)	240	Telangana	116.78	2.167	2.113	111.346
Kashang-I (H.P. Power Corpn. Ltd.)	65	H.P.	65.23	1.652	1.659	65.999
Kishanganga (NHPC)	330	J&K	58.79	1.587	1.621	62.140

Name	Installed Capacity (MW)	State	Actual Cost Overrun in %	Cost overrun (in fraction)	Expected Cost overrun	Expected Cost overrun in%
Pare (NEEPCO)	110	Arunachal Pradesh	119.91	2.199	2.116	111.637
Sainj (H.P. Power Corpn. Ltd)	100	H.P.	16.01	1.160	1.272	27.213
Nagarajuna Sagar TR (APGENCO)	50	Andhara Pradesh	106.33	2.063	2.066	106.62
Pulichintala (TSGENCO)	120	Telangana	48.29	1.482	1.586	58.686
New Umtru (MePGCl)	80	Meghalaya	164.58	2.645	2.483	148.339
Teesta-III (Teesta Urja Ltd.)	1200	Sikkim	99.49	1.994	1.963	96.337
Chanju-I (M/s IA Energy)	36	H.P.	63.47	1.634	1.654	65.456
Tashiding (M/s Shiga Energy Pvt. Ltd.)	97	Sikkim	124.37	2.243	2.131	113.125

Name	Installed Capacity (MW)	State	Actual Cost Overrun in %	Cost overrun (in fraction)	Expected Cost overrun	Expected Cost overrun in%
Dikchu (Sneha Kinetic Power Projects Pvt. Ltd.)	96	Sikkim	78.24	1.782	1.851	85.175
Maneri Bhali Stage II Large Hydro Power	304	Uttrakhand	76.40	1.764	1.832	83.239
Kolab HEP (Meenakshi Power Ltd.)	37	Odisha	49.40	1.494	1.578	57.856
Neogal HEP (Om Hydropower Ltd.)	15	HP	49.88	1.498	1.557	55.747
Alaknanda HEP (GVK group)	330	Uttrakhand	121.02	2.210	2.111	111.139
Baglihar Stage-II	450	J&K	47.42	1.474	1.508	50.806
Darana SHP (DLI Power Pvt. Ltd.)	4.9	Maharastra	6.59	1.065	1.201	20.158

Name	Installed Capacity (MW)	State	Actual Cost Overrun in %	Cost overrun (in fraction)	Expected Cost overrun	Expected Cost overrun in%
Himshakti SHP (Himshakti Projects Pvt. Ltd.)	5	H.P.	5.45	1.054	1.185	18.513
Jongini SHP (Gandhari Hydro Power Pvt. Ltd.	16	H.P.	13.58	1.135	1.233	23.347
Nathpa Jhakri HEP (SJVNL)	1500	H.P.	64.20	1.642	1.636	63.680
Rishiganaga SHP (Rishiganga Power Corporation Ltd.)	13.2	Uttrakhand	50.87	1.508	1.543	54.369
Dah SHP	9	J&K	20.29	1.202	1.304	30.472
Baglihar Stage-I	450	J&K	66.72	1.667	1.684	68.436
Koteshwar HEP	400	Uttrakhand	81.63	1.816	1.840	84.096
Sew-II (NHPC)	120	J&K	66.63	1.666	1.688	68.895
Rangit HEP (NHPC)	60	Sikkim	201.094	3.010	2.776	177.650
Doyang HEP (NEEPCO)	75	Nagaland	97.192	1.971	1.936	93.674

Name	Installed Capacity (MW)	State	Actual Cost Overrun in %	Cost overrun (in fraction)	Expected Cost overrun	Expected Cost overrun in%
Samal SHP (Orrisa Power Consortium Ltd.)	20	Odisha	19.334	1.193	1.286	28.678
Uri Stage I (NHPC)	480	J&K	96.896	1.969	1.910	91.046
Idukki Stage II (KSEB)	390	Kerala	114.646	2.146	2.086	108.690
Kallada (KSEB)	15	Kerala	52.711	1.527	1.571	57.177
Peppara (KESB)	3	Kerala	73.724	1.737	1.798	79.858

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Cost and Time overrun are the most regular problems in hydroelectric projects across India. Project are stalled at various stages due to various reasons which not only contribute to overrun but loss in revenue too which could have been generated in case of timely completion of projects. As per the data obtained, comparison has been done between central vs state vs privately owned hydroelectric projects as well as between various region in India and also based on installed capacity. Comparison are made for cost overrun, time overrun, per MW cost overrun in terms of 2019 price level and capital time waste factor. Non-linear regression analysis has been done to find the dependency of cost overrun with time overrun and inflation. Following conclusions are derived based on the comparative and regression analysis.

- Privately owned projects tend to perform better across cost overrun, time overrun as well as capital waste factor in terms of percentage of project
- State government owned projects have least value of average cost overrun of 58% as well as least per mw cost overrun of 4.9 crore INR. Apart from these two criteria, it has the worst track record for percentage of projects with high time overrun, cost overrun and capital waste factor. Average time overrun for state government projects tend to have more than 100% time overrun.
- With respect to project location, project in north India tend to perform better for parameters like percentage of project having cost overrun, time overrun as well as capital waste factor. North zone also has the least value of average time overrun of 57% and average cost overrun of 55.7%.
- Projects in south India have the highest values for average time overrun and average cost overrun of 118% and 98% respectively.
- NE&E has highest percentage of projects with high cost overrun as well as high value of per MW cost overrun at 7.11 crore INR. Hence proper study, focus and better implementation is the need of the hour for NE &E zone projects.
- With respect to installed capacity, SHP (1-25 mw) performed better across all the criteria with least percentage of projects with time and cost overrun of high value, just 25.6% of average cost overrun and 45% of average time overrun with least value of 2.53 crore INR per mw cost overrun.

- Medium capacity hydropower project (26-100 mw) MW has highest per MW cost overrun as has the highest value for percentage of project with high time and cost overrun. Average time and cost overrun being 90% and 80.5% respectively. It has the highest per mw cost overrun of 9.04 crore INR even greater than the average installation cost of per mw.
- The high difference between cost overrun and inflation points to inadequacy of planning as well as poor implementation of the projects resulting in claims and disputes.
- The coefficient obtained using regression indicate that time overrun and inflation together directly impact and have positive relationship with the cost overrun.
- The obtained relationship can be used to better estimate the cost during DPR preparation based on assumed or expected time overrun and inflation.

RECOMMENDATIONS

Further this study can be done to get a better result with large data including all zones using the methodology used. Moreover, efforts can also be made to analyse the reasons of overrun with respect to both kinds of overrun and finding the contribution of each along with deriving a model to predict the overrun pertaining to a particular reason.

REFERENCES

1. Hydropower Photos from https://in.pinterest.com/hydropower/?lp=true accessed on October 2018
2. CEA report on 'All India installed capacity (in mw) of power stations' Jan 2018, http://www.cea.nic.in/
3. IS: 4877-1968 'Guide for preparation of estimate for river valley projects'
4. 'Benchmark costs For Small and Large Hydro Projects' a report by AHEC IITR
5. PowerPoint presentation on 'Different types of SHP' by Prof Arun Kumar, AHEC IITR
6. Report on 'Regional Workshop on Small Scale Hydropower' by ECOWAS Regional Centre for Renewable Energy and Energy Efficiency
7. Flyvbjerg, B., Bruzelius, N., Rothengatter, W., 2003. "Megaprojects and Risk: An Anatomy of Ambition." Cambridge University Press, New York
8. Benjamin, S., Nugent, D., & GilbeRT, A., (2014). "Construction Cost Overruns and Electricity Infrastructure: An Unavoidable Risk?". The Electricity Journal. 27. 10.101/j.tej.2014.03.015.
9. Sambu, N., & Irdus, A, "Case study and Survey on Time and Cost overrun of Multiple D&B Projects" *2011 National Postgraduate Conference*. doi:10.110/ natpc.2011.613
10. Aibinu, A.A., & Odeyinka, H.A., 'Construction Delays and Their Causative Factors in Nigeria', Journal of Construction Engineering and Management, Vol. 132, Issue 7 (July 2006)
11. Chan, W.M., & Kumaraswamy, M.M., 'A comparative study of causes of time overruns in Hong Kong construction projects' International Journal of Project Management, Volume 15, Issue 1, February 1997, https://doi.org/10.101/S0263-7863(96)00039-7
12. Dinesh Kumar R "Causes and Effects of Delays in Indian Construction Projects" , International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 04 | Apr-2016, p-ISSN: 2395-0072
13. Report of the world commission on dams, 'Dams and development - a new framework for decision-making', 2000, Earthscan in association with World Commission on Dams, 404 pp. (hardback), ISBN: ISBN:1853837970. *Environmental Management and Health*, *12*(4), 444-445. doi:10.110/emh.2001.12.4.444.2
14. The Report on Hydropower Project Cost Overrun' by Bhutan Electricity Authority, www.bea.gov.bt accessed on Sept 2018

15. Shibani,A., Kumar, A., 'Avoiding Cost Overruns in Construction Projects in India' Management Studies, August 2015, Vol. 3, No. 7-8, 192-202, doi: 10.172/2328-2185/2015.070.003

16. Owolabi et.al., 'Causes and effect of delay on project construction delivery time', International Journal of Education and Research Vol. 2 No. 4 April 2014

17. Naveenkumar.G.V, & Prabhu.V, "Factors Influencing Time and Cost Overruns in Construction Projects", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 4, April 2016, ISSN (Print) : 2347-6710

18. Pillai, N.V., & Kannan, K.P., " Time and Cost Overruns of the Power Projects in Kerala" Working Paper No. 320, Centre for Development Studies, October 2001

19. Singh, Ram(2009), —'Delays and Cost Overruns in Infrastructure Projects: An Enquiry into Extents, Causes and Remedies'August 2009 ISSN: 2231-5381

20. Report on 'Study on project schedule and cost overruns' , by Ministry of Statistics & Programme Implementation (MoSPI) GoI accessed on Sept 2018

21. Ansar, A, Flyvbjerg B, Budzier, A, & Lunn, D, "Should we build more large dams? The actual costs of hydropower megaproject development," Energy Policy, Volume 69, 2014, SSN 0301-4215

22. Ameh, Oko & Emmanuel Osegbo, Emeka. (2011). Study of relationship between time overrun and productivity on construction sites. International Journal of Construction Supply Chain Management. 1. 56-67. 10.144/ijcscm101011-56-67.

23. Ludovique et al., (2016) "cost overruns and delays on energy megaprojects: when bigger is worse" 2016 of Universidade Federal do Rio de Janeiro accessed from https://6elaee.aladee.org/webtree/submit/download.php?subId=146&final=yes

24. **Hariharan S. and Sawant P.H., 2012 "**Analysis of Relationship between Time and Cost Overruns in some Infrastructure Projects**"** NICMAR-Journal of Construction Management, Vol. XXVII, No. 2&3, April-June & July-Sept. 2012

25. Inflation data accessed from govt sources https://data.gov.in/catalog/capita-emoluments-central-public-sector-enterprises-employees-relation-increase-average-all on April 2019

26. Inflation calculator https://calculatorstack.com/inflation-calculator-india.php accessed on May 2019

27. GRG non-linear method https://www.engineerexcel.com/excel-solver-solving-method-choose/ accessed on May 2019

28. Power purchase documents, tariff orders and petitions on Himachal SERC(accessed in May 2019) http://portal.hpseb.in/irj/go/km/docs/internet/New_Website/Pages/PowerPurchaseAgreement.html

29. CEA quarterly reports http://www.cea.nic.in/reports/ accessed in April 2019

30. Government data repository data.gov.in accessed in April 2019

31. Information about Alaknand Hydro projects (accessed in May 2019) : https://www.power-technology.com/projects/alaknanda-hydroelectric-project-uttarakhand/

32. Data for various NEEPCO projects " http://neepco.co.in/projects/hydro-projects/" accessed in April 2019

33. Information about various HEP http://www.eai.in/ accessed in April 2019

34. Napth Jakhri project detail : http://sjvn.nic.in/project-details.htm?7 (accessed in April 2019)

35. Holistic Information Portal on Renewable Energy by All About Renewables, India. (n.d.). Retrieved from http://allaboutrenewables.com/ipp-small-hydro-search

36. Napth Jhakri report from World bank: http://projects.worldbank.org/P009869/nathpa-jhakri-power-project?lang=en&tab=financial (accessed on March 2019)

37. Information about NHPC projects: http://www.nhpcindia.com/project.htm?CatId=1

38. NHPC tariff orders: http://www.nhpcindia.com/tariff-petitions.htm

39. Information about Jorethang Loop 96MW: Dans Group. (n.d.). Retrieved from http://dansenergy.com/jorethang-project-brief.html

40. Chanju 36mw DPR for cost and schedule data: (accessed on 16 May 2019) http://agisac.gov.in/hpcampa/CD%20INDI%20CAT%20Plan/Chanju-1%20Hydro%20Electric%20Project.pdf

41. Upper and middle kolab: 37MW http://www.meenakshigroup.com/lower-kolab.html accessed on April 2019

42. Information about Sainj HEP 100MW retrieved from (on April 2019) http://nromoef.gov.in/Environment_Reports/Reports/2013/NEW/6-79-2007.pdf

43. Sovacool, B. K., Gilbert, A., & Nugent, D. (2014). An international comparative assessment of construction cost overruns for electricity infrastructure. *Energy Research & Social Science*, *3*, 152-160. doi:10.101/j.erss.2014.07.016

44. RENA (2018). "Electricity Storage and Renewables: Costs and Markets to 2030", page 30. *International Renewable Energy Agency*, Abu Dhabi.

45. Morris, Sebastian, Cost and Time Overruns in Public Sector Projects. Economic and Political Weekly, Vol. 25, No. 47, pp.M154-M168, November 24, 1990.