FOSSEE Summer Fellowship Report

On

Backend and BOQ Formulation for OSDAG's Life Cycle Cost Assesment

Submitted by

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Chapter 1

Introduction

1.1 National Mission in Education through ICT

The National Mission on Education through ICT (NMEICT) is a scheme under the Department of Higher Education, Ministry of Education, Government of India. It aims to leverage the potential of ICT to enhance teaching and learning in Higher Education Institutions in an anytime-anywhere mode.

The mission aligns with the three cardinal principles of the Education Policy—**access, equity, and quality**—by:

- Providing connectivity and affordable access devices for learners and institutions.
- Generating high-quality e-content free of cost.

NMEICT seeks to bridge the digital divide by empowering learners and teachers in urban and rural areas, fostering inclusivity in the knowledge economy. Key focus areas include:

- Development of e-learning pedagogies and virtual laboratories.
- Online testing, certification, and mentorship through accessible platforms like EduSAT and DTH.
- Training and empowering teachers to adopt ICT-based teaching methods.

For further details, visit the official website: www.nmeict.ac.in.

1.1.1 ICT Initiatives of MoE

The Ministry of Education (MoE) has launched several ICT initiatives aimed at students, researchers, and institutions. The table below summarizes the key details:

No.	Resource	For Students/Researchers	For Institutions
Audio-Video e-content			
1	SWAYAM	Earn credit via online courses	Develop and host courses; accept credits
2	SWAYAMPRABHA	Access 24x7 TV programs	Enable SWAYAMPRABHA viewing facilities
Digital Content Access			
3	National Digital Library	Access e-content in multiple disciplines	List e-content; form NDL Clubs
4	e-PG Pathshala	Access free books and e-content	Host e-books
5	Shodhganga	Access Indian research theses	List institutional theses
6	e-ShodhSindhu	Access full-text e-resources	Access e-resources for institutions
Hands-on Learning			
7	e-Yantra	Hands-on embedded systems training	Create e-Yantra labs with IIT Bombay
8	FOSSEE	Volunteer for open-source software	Run labs with open-source software
9	Spoken Tutorial	Learn IT skills via tutorials	Provide self-learning IT content
10	Virtual Labs	Perform online experiments	Develop curriculum-based experiments
E-Governance			
11	SAMARTH ERP	Manage student lifecycle digitally	Enable institutional e-governance
Tracking and Research Tools			
12	VIDWAN	Register and access experts	Monitor faculty research outcomes
13	Shodh Shuddhi	Ensure plagiarism-free work	Improve research quality and reputation
14	Academic Bank of Credits	Store and transfer credits	Facilitate credit redemption

Table 1.1: Summary of ICT Initiatives by the Ministry of Education

1.2 FOSSEE Project

The FOSSEE (Free/Libre and Open Source Software for Education) project promotes the use of FLOSS tools in academia and research. It is part of the National Mission on Education through Information and Communication Technology (NMEICT), Ministry of Education (MoE), Government of India.

1.2.1 Projects and Activities

The FOSSEE Project supports the use of various FLOSS tools to enhance education and research. Key activities include:

- **Textbook Companion**: Porting solved examples from textbooks using FLOSS.
- **Lab Migration**: Facilitating the migration of proprietary labs to FLOSS alternatives.
- **Niche Software Activities**: Specialized activities to promote niche software tools.
- **Forums**: Providing a collaborative space for users.
- **Workshops and Conferences**: Organizing events to train and inform users.

1.2.2 Fellowships

FOSSEE offers various internship and fellowship opportunities for students:

- Winter Internship
- Summer Fellowship
- Semester-Long Internship

Students from any degree and academic stage can apply for these internships. Selection is based on the completion of screening tasks involving programming, scientific computing, or data collection that benefit the FLOSS community. These tasks are designed to be completed within a week.

For more details, visit the official FOSSEE website.

Figure 1.1: FOSSEE Projects and Activities

1.3 Osdag Software

Osdag (Open steel design and graphics) is a cross-platform, free/libre and open-source software designed for the detailing and design of steel structures based on the Indian Standard IS 800:2007. It allows users to design steel connections, members, and systems through an interactive graphical user interface (GUI) and provides 3D visualizations of designed components. The software enables easy export of CAD models to drafting tools for construction/fabrication drawings, with optimized designs following industry best practices [1, 2, 3]. Built on Python and several Python-based FLOSS tools (e.g., PyQt and PythonOCC), Osdag is licensed under the GNU Lesser General Public License (LGPL) Version 3.

1.3.1 Osdag GUI

The Osdag GUI is designed to be user-friendly and interactive. It consists of

- **Input Dock**: Collects and validates user inputs.
- **Output Dock**: Displays design results after validation.
- **CAD Window**: Displays the 3D CAD model, where users can pan, zoom, and rotate the design.
- **Message Log**: Shows errors, warnings, and suggestions based on design checks.

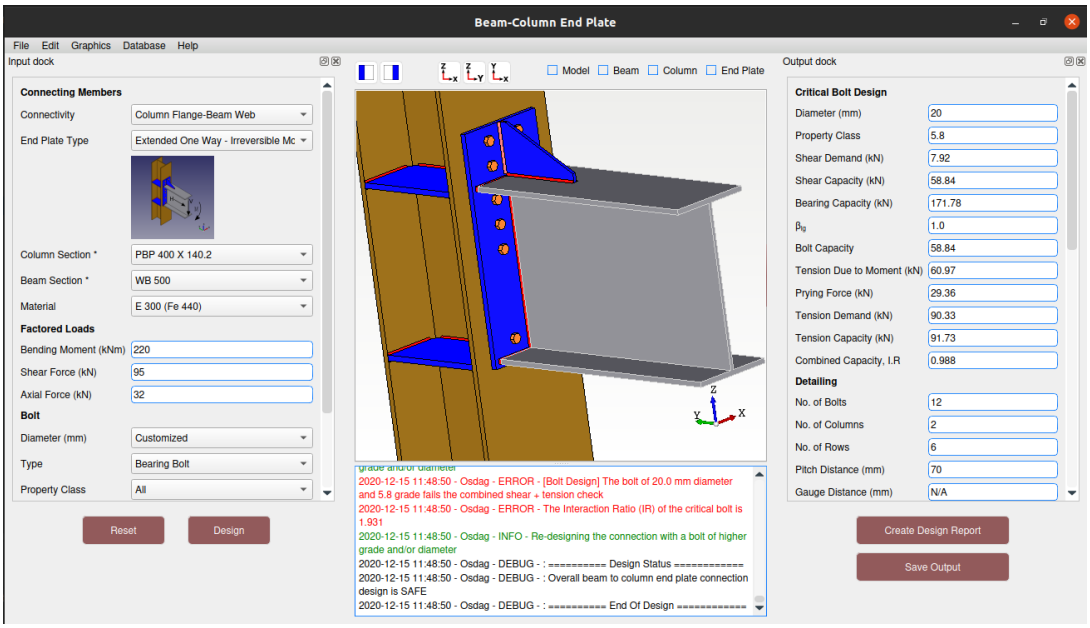


Figure 1.2: Osdag GUI

1.3.2 Features

- **CAD Model**: The 3D CAD model is color-coded and can be saved in multiple formats such as IGS, STL, and STEP.
- **Design Preferences**: Customizes the design process, with advanced users able to set preferences for bolts, welds, and detailing.
- **Design Report**: Creates a detailed report in PDF format, summarizing all checks, calculations, and design details, including any discrepancies.

For more details, visit the official Osdag website.

Chapter 2

Screening Task

2.1 Problem Statement

Develop a program to calculate shear force and bending moment for a beam experiencing a moving load. Applicants using the concept of influence line diagram will be given preference.

2.2 Tasks Done

A custom-developed desktop application was created to conduct structural analysis of a simply supported beam subjected to two moving point loads separated by a fixed distance. This tool aims to determine the beam's response under dynamic loading conditions by calculating critical parameters such as support reactions, shear forces, and bending moments as the load pair translates incrementally along the beam span. The problem formulation is rooted in classical mechanics, where the beam is assumed to be linear, elastic, and simply supported at both ends.

The user interface accepts input parameters including beam length (L), load magnitudes (W and W), and the inter-load spacing (x). Internally, the algorithm performs a discrete iteration over all feasible load positions, maintaining the fixed spacing between W and W, and at each step calculates reactions at supports A and B using static equilibrium. The shear force (SF) and bending moment (BM) are then computed across the beam length using segmented analytical expressions based on the relative position of the point of interest with respect to the applied loads.

Maximum values of RA, RB, SF, and BM, along with their corresponding positions, are extracted during this iterative sweep.

The analysis adheres to IS 800:2007 code provisions for structural steel design, ensuring conformity with standard engineering practices. The application also includes the ability to generate and display Shear Force Diagrams (SFD) and Bending Moment Diagrams (BMD) corresponding to selected load positions. These visual outputs assist in understanding the envelope behavior of internal forces under moving loads, which is crucial for evaluating fatigue, serviceability, and ultimate strength in members such as bridge girders or crane beams.

The entire application is developed in Python, with PyQt5 utilized to build a responsive and intuitive graphical user interface (GUI), and Matplotlib integrated for advanced plotting and visualization. The tool not only delivers detailed numerical results in real-time but also plots dynamic graphical outputs, allowing engineers to interactively study the influence of moving load positions on structural performance.

Chapter 3

Task 1: Cost Analysis of Composite Steel and Pre-Stressed Concrete Bridges Using Bill of Quantities (BOQ)

3.1 Problem Statement

To develop a detailed Bill of Quantities (BOQ) for the comparative cost analysis of a Composite Steel Bridge and a Pre-Stressed Concrete (PSC) Bridge of similar span and functional capacity. The objective is to quantify and evaluate the material, fabrication, erection, and lifecycle costs associated with both structural systems, thereby identifying the most cost-effective solution under given design, site, and loading conditions.

3.2 Tasks Done

To achieve the objectives of the study, a structured approach was followed encompassing detailed methodologies, systematic processes, and practical implementations, as outlined below.

3.2.1 Methodologies

The primary objective of this study was to develop and compare the Bill of Quantities (BOQ) and overall construction cost of two bridge types—Composite Steel I-Girder

Bridge and Pre-Stressed Concrete (PSC) Box Girder Bridge—for a 35-meter span under varying regional conditions. The study adopted a rate-based analytical approach, combining structural quantity estimation with region-specific government-approved unit rates.

The methodology involved:

- Comparative study of bridge types based on span, loading, and structural behavior.
- SOR-based costing, utilizing official and verified rate schedules for accuracy.
- Real-world case selection, focusing on urban (Mumbai) and rural (Bihar) contexts to highlight cost variations due to regional factors.

3.2.2 Processes

1. Data Collection - Government Schedules of Rates (SORs): A comprehensive review was conducted across multiple authoritative SORs, including:
    - USOR 2023 (Unified Schedule of Rates)
    - NH SOR
    - Maharashtra PT SOR 2021
    - Maharashtra SSR 2022–23
    - Bridge SOR 2023

    These sources provided unit rates for concrete, steel, prestressing, fabrication, transportation, labor, and other infrastructure-related works.

2. Technical Study of Bridge Components: Detailed understanding of the superstructure and substructure elements for both bridge types was carried out, referencing IRC guidelines and standard bridge design manuals. Each component was identified and classified for BOQ purposes.

3. Design Assumptions and Quantity Estimation:
    - A 35-meter span bridge was selected as a base model.
    - Quantity estimations were carried out for all structural components.

- Support and guidance were provided by internship mentor Er. Parth Karia Sir for quantity validation.

4. Data Compilation in Google Sheets: All unit rates extracted from the SORs were systematically tabulated and integrated with estimated quantities to compute the final BOQs. The Google Sheet enabled structured organization and automated cost computation for both bridge types.

5. Demolition Cost Estimation: Demolition costs were also calculated using SORs and relevant guidelines to assess the full life-cycle cost implications.

6. Cost Variation Assessment for Regional Application: The process was replicated for Bihar, considering locally applicable SORs and adjusting for transportation, labor, and material cost differences. This enabled comparative analysis between an urban infrastructure project (Mumbai) and a rural setting (Bihar).

3.2.3 Implementations

- A dynamic Google Sheet model was created to calculate BOQs for both bridge types. This included separate sheets for:
  - Construction Cost
  - Demolition Cost
- Case-specific cost analysis was completed for:
  - Composite Steel I-Girder Bridge
  - PSC Box Girder Bridge

  ...in both Mumbai and Bihar regions.
- The results can be used to:
  - Evaluate economic viability between steel and concrete bridge systems.
  - Demonstrate the cost impact of geography and material handling on bridge projects.

– The generated BOQ and cost comparison data can be used as a sample database to develop and code the Life Cycle Cost Assessment (LCCA) module in the OSDAG (Open-Source Design and Analysis of Girders), enabling integration of real-world economic factors into automated bridge design workflows.

3.3 Bill of Quantities

This section presents a set of structured tables developed to evaluate and compare the initial construction and demolition costs of two bridge types—Composite Steel I-Girder Bridge and Pre-Stressed Concrete (PSC) Bridge for a standardized span of 35 meters.

3.3.1 Description of the Tables

The tables are structured in a standard Bill of Quantities (BOQ) format and organized into clearly defined columns:

- Sr. No. – Serial number for each BOQ item.
- Reference / Item No. – Indicates the corresponding item number from the relevant Schedule of Rates (SOR).
- Description – Detailed description of the construction or demolition activity.
- Rate (excluding GST) – Unit rate for the item, based on the applicable government SOR.
- Quantity – Quantity of work or material required, based on the design of the 35 m span bridge.
- Unit – Measurement unit (e.g., Cum, Rmt, MT, Sqm).
- Amount (in INR) – Total cost for each item (Rate × Quantity).
- Assumptions / Remarks – Notes specifying design assumptions, clarifications, or rate conditions (e.g., span-specific modifiers, market rates, exclusions).

3.3.2 The BOQ's

BOQ – Steel Composite Bridge (35 m Span):

The following pages present the full Bill of Quantities (BOQ) for a 35-meter Steel Composite Bridge.

35 M Composite Steel I section Girder Bridge Initial Cost

Sr. No.	Refrence	Item no	Description	Rate (excluding GST)	Quantity	Unit	Amount (in INR)	Labour cost (excl.GST)	Assumptions / Remarks / References	
A	**Foundation**									
1	Bridge SOR 23	R3-CS-EW-1	Excavation for foundations, substructures, basements, tanks, sumps, walls, chambers, manholes, trenches, poles, pits & general building works in all types of soils, vegetable earth, soft murum, running sand, shingle, turf clay, loam, peat, ash, shale, slag, chalk, garbage, muddy / marshy / slushysoil, marine clay, reclaimed land etc. for depths / lifts upto 1.5 M measured from the ground level, including dressing / trimming the sides, leveling and ramming of bottoms, manual dewatering, removing rank vegetation, backfilling in layers not more than 200 mm thickness, watering, consolidating, compacting to achieve not less then 97 % Modified Proctor density conforming to relevant IS, stacking the selected material in measurable heaps for future use within owners space or disposing within an initial lead of 150 m as directed, loading, unloading, leveling excluding shoring, strutting etc. complete as directed by Engineer-in-Charge. Note: 1)The rate includes the handling / supporting the existing utilities such as cables, drains, pipes, water mains etc. 2) It also includes the royalty and other taxes applicable if any. For more details refer General Notes.	387.00	28.09	Cum	10870.83		Considered for 1m depth and 0.3m more than the length and widrh of the pile cap for ground preparation.	
2			Boring for Piles				0.00		Market Rate	
3	SSR_22-23	15.123	Providing and laying cast in situ / ready mix M35 RCC for 1000 mm diameter bored piles each of load capacity as per design and of specified diameter of as directed, placed through steel shell sunk to the required depth through all strata except rock, excluding provision of reinforcement including placing concrete by tremie arrangement, compaction of concrete and withdrawal of steel shell with fully automatic microprocessor based PLC with SCADA enabled with reversible drum type mixer / concrete batch mix plant (pan mixer) etc. complete. with fine aggregates of required specifications (VSI sand finely washed etc) i) Add 30% extra for depth 5 to 10 m ii) **Add 40% extra for depth 10 to 15 m** iii) Add 60% extra for depth 15 to 20 m iv) Add 100% extra for depth above 20 m	17875.20	48.00	Rmt	858009.60	2167.2	Concreting in Piles (for depth below 5 m rate is 12768)	
4	SSR_22-23	17.38	Providing and laying in situ / ready mix M-15 plain cement concrete of trap / granite / quartzite / gneiss metal for cast in situ piers, abutment, returns, wings etc. including provision of "V" shaped false joints to form suitable panels on the faces to approved design with compacting by vibrating and curing complete, including plywood / steel formwork centering (excluding dewatering by means of pump) and including bailing out water and curing finishing in CM 1:3 etc. complete. as directed by engineer in charge basic rate shall be increased for height above 5.00 m in following manners (a) Height up to 5 m. (With Concrete Mixer) With fine aggregates of required specifications (VSI sand finely washed etc) i) Height up to 5 m, normal rate. ii) Height 5 to 7.50 m, add 5 percent extra over basic rate. iii) Height 7.50 to 10 m, 7.50 percent extra. iv) Over 10 m Height, add 10 percent extra for every 2.50 m rise.	7519.00	28.09	Cum	211208.71	1929	150mm PCC below Pile Cap (same length and width as excavation)	
5	Bridge SOR 23	R3-BW-2-24-b	Providing and placing in position controlled cement concrete of M-35 grade for foundation work with minimum cement 400 kg./cum. and water cement ratio not exceeding 0.4 for RCC raft foundation slab with V notches Sloped / flat / strip footings, pile caps tie beams to required lines / levels including leveling, compacting by vibrators, curing including shuttering, centering as necessary and required etc. complete as specified and as directed but excluding reinforcement. With RMC and Concrete Pump	7632.00	31.88	Cum	243270.00		Concreting in Pile Cap	Alternative option with labour rates
6	Bridge SOR 23	R3-BW-2-107-a	Supplying, fitting and placing un-coated HYSD bar reinforcement (including lapping) in foundation complete as per drawing and technical specifications (Pile)	71289.00	5.23	MT	372841.47		Reinforcement in Pile	alternative option with labour rates
7	Bridge SOR 23	R3-BW-2-107-a	Supplying, fitting and placing un-coated HYSD bar reinforcement (including lapping) in foundation complete as per drawing and technical specifications (Pile Cap)	71289.00	1.68	MT	119765.52		Reinforcement in Pile Caps	alternative option with labour rates
B	**Substructure**									
8	SSR_22-23	17.55	Providing and laying in situ / ready mix controlled M-35 cement concrete of trap / granite / quartzite / gneiss metal for reinforced cement concrete caps over piers and abutments including necessary scaffolding, plywood / steel formwork, compacting by vibrating, finishing in CM 1:3 and curing etc. complete (Excluding reinforcement) With reversible drum type mixer / concrete batch mix plant (pan mixer) with fine aggregates of required specifications (VSI sand finely washed etc)	9574.00	6.79	Cum	65007.46	1964	Concrete in Pier	
9	SSR_22-23	17.55	Providing and laying in situ / ready mix controlled M-35 cement concrete of trap / granite / quartzite / gneiss metal for reinforced cement concrete caps over piers and abutments including necessary scaffolding, plywood / steel formwork, compacting by vibrating, finishing in CM 1:3 and curing etc. complete (Excluding reinforcement) With reversible drum type mixer / concrete batch mix plant (pan mixer) with fine aggregates of required specifications (VSI sand finely washed etc)	9574.00	27.54	Cum	263667.96	1964	Concrete in Pier Cap with Pedestal	
10	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	1.34	MT	95527.26		Reinforcement in Pier	alternative option
11	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	2.65	MT	188915.85		Reinforcement in Pier Cap and Pedestal	"
12	SSR_22-23	13.07	Supplying, fitting and fixing in position true to line and level elastomeric bearing including all accessories as per drawing and technical specifications and IRC:83 (Pt-II) section IX and clause 2005 of MoRTH specifications etc. complete.			Cum	0.00		Bearings (As per Market Rate)	
13	SSR_22-23	53.25	Supplying, drilling / cleaning hole and fixing of Torque Controlled Expansion Anchor HST3, of sizes ranging from M8 to M24. The Anchor should be third party tested, possess ETA approval and should be pre-assembled with a galvanized bolt as per EN ISO 4042:1999, ingenious expansion sleeve M10 and M16 (galvanized) and M8, M12, M20, M24 Stainless Steel (EN ISO 4042:1999), a nut of Strength Class 8 (EN ISO 20898-2:2012) and a galvanized washer (EN ISO 4042:1999). The anchors should be approved for use in Cracked Concrete. Anchor must be tested and approved as per Seismic C1 and C2 Category of TR045. ETA to have Fire Resistance values for up to 120 mins as per EOTA TR020 and FM Approval (use in Pipe Hangers). Anchor shall be fixed at right embedment depth as per embedment mark and activated using AT Tool Module to ensure adequate torque as per manufacturer's torque tolerance published in ETA and same shall be documented and submitted to Project Manager at the time of inspection. Design of Anchors should be done as per ETAG 001 Annex C and TR045 using PROFIS Software as per actual load data and site conditions as provided by structural consultant and the report to be submitted to the project manager and design engineer for approval. Scanning before drilling to be done with PS Scanning tool to avoid rebar hits. stud anchor HST3 SS M24x200 30	3326.00	40.00	Each	133040.00	13	Anchor Rods for Bearings	
C	**Superstructure**									
14	SSR_22-23	14.89	Providing and laying in situ M35 controlled cement concrete of trap / granite / quartzite / gneiss metal for RCC work in solid / deck slab etc. including ramming, vibrating, curing, formwork, centering and finishing in cement plaster excluding reinforcement etc. complete. (With fully automatic microprocessor based PLC with SCADA enabled concrete batch mix plant / pan mixer with natural sand) i) Height up to 5 m, normal rate. ii) Height 5 to 7.50 m, add 5 percent extra. iii) Height 7.50 to 10 m, 7.50 percent extra. iv) Over 10 m Height, add 10 percent extra for every 2.50 m rise.	11702.00	116.94	Cum	1368431.88	3,485.90	Deck Slab Concrete, Quantitiy has been increased by 10% because height is greater by 10 m	
15	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	4.66	MT	332206.74		Deck Slab Steel, Min 0.12% steel has been used	ALternative
16	Bridge SOR 23	R3-BW-2-38-a	Providing sacrificial shuttering for deckslab made up with galvanised Cold Rolled Cold Annealed (CRCA) steel of 310 MPA Grade with all Contractor's material, labour,erection fixing, welding etc. (Decking Sheet)	66368.00	4.08	MT	270781.44		Decking Sheet	alternavive

17	Bridge SOR 23	R3-BW-2-38-a	Providing, detailing, fabricating and fixing at desired location using hot rolled sections and M S Plates of high grade steel as per specifications and approved fabrication drawings (which are to be prepared by Contractor and got approved from Engineer), transporting to site and erecting / launching structural steel members / girders for all heights & at all levels including provision of necessary erection / launching accessories and machinery for erection / launching, bolts, fixing bolts, nuts, washers, cleats, stiffeners, gussets, base plate and all necessary fixtures and operations like preheating as per specifications, straightening, bending, cutting, drilling, grinding, machining if specified, welding, grinding and removing the welding burr and preparing surface for painting with sand blasting, metalizing and painting of loose fabricated components and girders with sprayed aluminium followed by protective coating of painting outside running line complete with contractor's own paint, other material, labour, scaffolding, consumable. Note: The protective coating of paint shall be as follows: (i) First coat of Etch primer to IS:5666. (ii) One coat of Zinc Chromate primer to IS:104 and two coats of aluminium paint to IS:2339. Total thickness will be not less than 200 micron. Guarantee period will be 5 years including touching up with spray painting after erection etc. complete as directed by Engineer In Charge. E-350 Grade Steel	198920.00	130.00	MT	25859600.00	160000	Increasing Structural Steel Quantity by a (25) % to account for the weight of splice connections, shear connectors, bolts, nuts etc.	Labour rate as per MR
D	**Miscellaneous**									
18	SSR_22-23	23.03	Providing structural steel work in single stanchions composed of R. S.J. Channel etc. withcaps, bases, mild steel plated, angle brackets, cleats, gusset plates, anchor bolts etc. as per detailed designs and drawings or as directed including cutting, fabrication, hoisting, erecting fixing in position, making riveted/ bolted/ welded connection and onecoat of anticorrosivepaint andover it two. coatsofoil painting approved quality and shade etc. complete.	98009.00	1.40	MT	137212.60	14265	Steel Railing	
19	SSR_22-23	7.37	Providing Reinforced cement concrete crash barrier at the edges of the road, approaches to bridge structures and medians, constructed with R.C.C. M30 Grade concrete with HYSD reinforcement conforming to IRC:21 and dowel bars 25 mm dia, 450 mm long at expansion joints filled with pre-moulded asphalt filler board, keyed to the structure on which it is built and installed as per design given in the enclosure to MOST circular No. RW/NH-33022/1/94-DOIII dated 24June 1994 as per dimensions in the approved drawing and at locations directed by the Engineer, all as specified etc. complete.Spec: MORT and H 2013 Cl 811 Page No 360	4234.00	70.00	Rmt	296380.00	119	Crash Barrier	
20	SSR_22-23	14.68	Providing and laying of a strip seal expansion joint catering to maximum horizontal movement up to70mm to be installed by themanufacturer /supplier to their authorized representative ensuring compliance to the manufacturer s instruction for installation as per approved drawings and standard specifications etc. complete.	13295.00	13.50	Rmt	179482.50	82	Expansion Joint	
21	Bridge SOR 23	R3-BW-5-1-j	Providing and fixing in position Drainage Spouts including trough of 260 x 260. size fabricatede using mild steel plates, flats, MS grating, etc. and 100mm dia GI pipe 1 m long as per detailed drawings etc. complete as specified and directed.	2224.00	7.00	Each	15568.00		Drainage Sprouts, Provided for every 5 m	alternative
22	Bridge SOR 23	R3-BW-5-4-a	Providing and fixing in position PVC pipe 150 mm dia. in any position including all fittings and accessories, making joints / connections water tight with solvent cement, scaffolding if necessary and making good the damages if any etc. complete as specified and directed.	955.00	12.80	Rmt	12224.00		PVC Pipes for Drainage	alternative
23	Bridge SOR 23	R3-BW-5-3-c	Providing and applying epoxy base paint to RCC piers, columns, beams, girders, diaphragms, slabs, parapets etc. including cleaning the surfaces thoroughly so as to remove deposited salts, oil, grease, tar, moisture etc. from the surface, preparing the surface, applying putty consisting of epoxy base paint and steolite powder, to render the concrete surfaces smooth by covering small irregularities and applying one coat of epoxy paint including scaffolding etc. complete as specified and directed.(2 coats epoxy + primer)	512.00	73.24	Sqm	37498.88		Epoxy on Pier and Pier Caps	alternative
24	SSR_22-23	35.11	Providing and applying two coats (exterior quality) of flat oil paint of approved colour and shade to the plastered surface in buildings and workshops including scaffolding if necessary, cleaning the surface and preparing surface etc. complete. (excluding primer coat)	88.00	73.24	Sqm	6445.12	44	Paint on Pier and Pier Cap	alternative
25	SSR_22-23	35.06	Providing and applying 2 coats of alluminium paint of approved maket onew structural steel work in buildings and workshops including scaffolding if necessary, cleaning and preparing the surface (excluding primer coat) etc. complete.	128.00	1155.00	Sqm	147840.00	47	Two Coat of Alluminium Paint on Structural Steel Members	alternative
26	SSR_22-23	48.06	Providing and Laying factory made coloured chamfered edge Cement concrete grass paver blocks of required strength,thickness & size/shape, made by table vibratory method using PU mould, laid in required colour & pattern over 50 mm thick compacted bed of fine fine aggregate (natural sand/crushed sand VSI grade finely washed etc.), compacting and proper embedding / laying of inter locking paver blocks into the fine aggregate (natural sand /crushed sand VSI grade finely washed etc.) bedding layer through vibratory compaction by using plate vibrator, filling the joints with fine aggregate (natural sand /crushed sand VSI grade finely washed etc.) and cutting of paver blocks as per required size and pattern, finishing and sweeping extra fine aggregate (natural sand/crushed sand VSI grade finely washed etc.) and complete as per manufacturer spsecifications & direction of Engineer-in-Charge. 60 mm thick CC paver block of M-35 grade concrete with approved colour and design & pattern.	1171.00	53.20	Sqm	62297.20	99	Paver Blocks for Footpath	Brick work rate
27	SSR_22-23	50.06	Providing and applying two coats of protective membrane over the cured concrete surface like R.C.C. footings, columns, plinth beams etc. which will be submerged under soil so as to protect the same. Apply two pack coal tar epoxy system of Sun epoxy Coal tar of approved make & approved by Engineer incharge, having solid content ranges from 80 100%,Tack free time 4-6 hrs. Re coat after 16-24 hrs. Mix Part A and Part B of Sun epoxy Coal tar of approved make & approved by Engineer incharge in 1:1 ratio with slow speed stirrer and apply the same ona clean R.C.C.surface by brush. Allow to set for 8-10 hours and apply these cond coat.The rate to include for application at all levels to various RCC elements to the satisfaction of the EIC etc. complete.	247.00	50.50	Sqm	12473.50	120	Waterproofing for Pile Cap	alternative
28	SSR_22-23	51.114	Providing and laying Hyperplas standard or equivalent polymeric multiple monolithic five layer water proofing flexible, pliable and high tensile strength membrane (3 Kilogram / One Square Metre) & consist of centre core of 90 micron thick High Molecular High density Polyethylene film (HMHDPE) which is protected on both the side with polymeric mix. Applying the membrane by thermofusing to roof & parapet after applying thin film of hot blown bitumen 85 / 25 or 90 /15 grade @ 1.2 Kilogram / One Square Metre maximum as per surface condition or Hyperplasprimer @ 250 gms / One Square Metre as per site condition on the surface to be treated with 10 cm overlapping including finishing etc. complete and covering guarantee of 7 years on stamp paper of Rs. 100/-and as directed by Engineer-in-charge. (Prior permission of S.E.in writing is necessary be fore inclusion of this item in estimate).	678.00	472.50	Sqm	320355.00	115	Waterproofing Below WC on Deck Slab	alternative
29	Bridge SOR 23	R3-BW-5-2-c	Providing and laying bitumen mastic layer 20 mm thick over bridge deck excluding tack coat etc. complete as specified and directed. (with bitumen 10/20 penetration not less than 10.5% and lime stone dust not, less than 40%)	986.00	472.50	Sqm	465885.00		Asphalt Road	around 25% cost
30	SSR_22-23	7.37	Providing Reinforced cement concrete crash barrier at the edges of the road, approaches to bridge structures and medians, constructed with R.C.C. M30 Grade concrete with HYSD reinforcement conforming to IRC:21 and dowel bars 25 mm dia, 450 mm long at expansion joints filled with pre-moulded asphalt filler board, keyed to the structure on which it is built and installed as per design given in the enclosure to MOST circular No. RW/NH-33022/1/94-DOIII dated 24 June 1994 as per dimensions in the approved drawing and at locations directed by the Engineer, all as specified etc. complete.Spec: MORT and H 2013 Cl 811 Page No 360	4234.00	35.00	Rmt	148190.00	119	Median/divider (assuming 0.5)	alternative, labour cost is 108

31	Bridge SOR 23	R3-BW-5-7-i,j	Providing and applying hot applied thermoplastic road marking material with glass beads extremely high skid resistance 2.5 mm thick without primer coat (Tack coat) on Asphalt road surface. All labour, materials, with special aggregates as specified in B.S. part - I & II 1989 and carrying out the marking on any road in center line and other marking continuous or intermittent 10 cm or 15 cm width also pedestrians crossing strips as well as spraying further quantity of glass beads of type II uniformly into a mono layer on to the hot paint line in quick succession of the paint spraying operation @ 250 gms per sqm. area as directed and as per BS / MOST specifications in white / yellow colour.	1011.00	8.00	Sqm	8088.00		Yellow and White Paint on Road for directions	
			.		150.72	Cum				
			Total quantity of RCC barriers		22.18					
			Total RCC Qantity for Demolition of any grade		183.15	Cum			Piles and Crash Barrier Excluded	
			Total PCC for Demolition under M 20 Grade		28.09	Cum				
			Total Quantity of Steel sections		130.00	MT				
			Total Amount of Reinforcement		11.23	Mt			Included reinforcement in Pile, Pile caps, Pier, Pier caps and Deck slab	
			Total Cost of Construction				32243084.52	322.4308452		

BOQ – Demolition Cost for PSC Bridge (35 m Span)

The following pages present the full Bill of Quantities (BOQ) for demolition of a 35-meter span Steel Composite Bridge.

35 M_PSC I section Bridge								
Sr. No.	**Reference**	**Item no**	**Description**	**Rate (excluding GST)**	**Quantity**	**Unit**	**Amount (in INR)**	**Assumptions / Remarks / References**
A								
1	Demoltion and Reconstruction of Bridges	R3-SWD-36	Cutting down completely RCC slab, walls, beams, columns, arches, piles, pile caps of any thickness and or size of any height/depth by any means below or above ground level including cutting down steel reinforcement, removing and stacking them properly as direc fed etc.complete, asspecified & as directed by Engineer-in-Charge.	2491.00	482.00	Cum	1200662.00	Includes Pile caps, Pier, Pier Caps, PSC Girders, Cross Diaphragms, Deckslab and Crash barriers. No mention of height
2	Mah PT_SOR 21		Scraping, cleaning and straightening reinforcement bars obtained from demolition of RCC work and stacking at site within a lead of 100 Mtrs. complete as directed.	510.00		qntl.	0.00	Includes all reinforcement (Ex Piles)
3	Mah PT_SOR 23		Dismantling steel work in built-up sections in frame work and trusses of span upto 10 Mtrs. and height of 5 Mtrs. in R.S.Joists, angles, 'T's, flats & channels including all gusset plates, bolts, nuts, cutting rivets and weldings including dismembering and handing over all serviceable materials at sectional office or at MbPT store yard as directed complete. Extra over rate for Item No. 16 for dismantling trusses, rafters, purlins etc. of steel for every per Mtr. additional span of 1 Mtr. beyond 10 Mtrs add 55/- per m	386.00	14.00	qntl.	5404.00	The base cost for spans up to 10 meters is ₹386. For each additional meter beyond 10 meters, an extra charge of ₹55 per meter shall apply.
4	NH_SOR	2.5 A	Dismantling of flexible pavements and disposal of dismantled materials up to a lead of 1000 meters, stacking serviceable and unserviceable materials separately and as per relevant clauses of section-200. (Bituminous Course)	741.00	9.45	Cum	7002.45	Dismantling and disposal of flexible pavement
5	Mah PT_XIV_26		Dismantling PVC pipes of any dia. with it's fittings and clamps including stacking the serviceable and unserviceable material separately within a lead of 100 Mtrs. complete as directed.	40.00	12.80	Rmt	512.00	Dismantaling and stacking of PVC Pipes
6	USOR_23	R3-CS-DD-5-b	Demolishing stone rubble masonry manually/ by mechanical means including stacking of serviceable material and disposal of unserviceable material within 50 metres lead as per direction of Engineer-in-charge In cement mortar	8.08	1797.00	Cum	14519.76	Dismantaling and stacking of servicable Paver Blocks

BOQ – PSC Bridge (35 m Span):

The following pages present the full Bill of Quantities (BOQ) for a 35-meter span Pre-Stressed Concrete (PSC) Bridge.

PSC_cost

Sr. No.	Refrence	Item no	Description	Rate (excluding GST)	Quantity	Unit	Amount (in INR)	Labour Cost (excl.GST)	Assumptions / Remarks / References
A	**Foundation**								
1	Bridge SOR 23	R3-CS-EW-1	Excavation for foundations, substructures, basements, tanks, sumps, walls, chambers, manholes, trenches, poles, pits & general building works in all types of soils, vegetable earth, soft murum, running sand, shingle, turf clay, loam, peat, ash, shale, slag, chalk, garbage, muddy / marshy / slushysoil, marine clay, reclaimed land etc. for depths / lifts upto 1.5 M measured from the ground level, including dressing / trimming the sides, leveling and ramming of bottoms, manual dewatering, removing rank vegetation, backfilling in layers not more than 200 mm thickness, watering, consolidating, compacting to achieve not less then 97 % Modified Proctor density conforming to relevant IS, stacking the selected material in measurable heaps for future use within owners space or disposing within an initial lead of 150 m as directed, loading, unloading, leveling excluding shoring, strutting etc. complete as directed by Engineer-in-Charge. Note: 1)The rate includes the handling / supporting the existing utilities such as cables, drains, pipes, water mains etc. 2) It also includes the royalty and other taxes applicable if any. For more details refer General Notes.	387.00	39.70	Cum	15363.90		Considered for 1m depth and 0.3m more than the length and widrh of the pile cap for ground preparation.
2			Boring for Piles				0.00		Market Rate
3	SSR_22-23	15.126	Providing and laying cast in situ/ready mix M35 RCC for 1200 mm diameter bored piles eachof load capacityas per designandof specified diameter of as directed, placed through steel shell sunk to the required depth throughall strata except rock, excluding provision of reinforcement including placing concrete by tremie arrangement, compaction of concrete and with drawal of steel shell with fully automatic micro processor based PLC with SCADA enabled with reversible drumty pemixer/ concrete batch mix plant (pan mixer) etc. complete.with fine agreegates of required specifications (VSI sand finely washed etc) i) Add 30% extra for depth 5 to 10 m ii) Add 40% extra for depth 10 to 15 m iii) Add 60% extra for depth 15 to 20 m iv) Add 100% extra for depth above 20 m	24753.40	48.00	Rmt	1188163.20	3073	Concreting in Piles (for depth below 5 m cost is 17681)
4	SSR_22-23	17.38	Providing and laying in situ / ready mix M-15 plain cement concrete of trap / granite / quartzite / gneiss metal for cast in situ piers, abutment, returns, wings etc. including provision of "V" shaped false joints to form suitable panels on the faces to approved design with compacting by vibrating and curing complete, including plywood / steel formwork centering (excluding dewatering by means of pump) and including bailing out water and curing finishing in CM 1:3 etc. complete. as directed by engineer in charge basic rate shall be increased for height above 5.00 m in following manners (a) Height up to 5 m. (With Concrete Mixer) With fine aggregates of required specifications (VSI sand finely washed etc) i) Height up to 5 m, normal rate. ii) Height 5 to 7.50 m, add 5 percent extra over basic rate. iii) Height 7.50 to 10 m, 7.50 percent extra. iv) Over 10 m Height, add 10 percent extra for every 2.50 m rise.	7519.00	39.70	Cum	298504.30	1929	150mm PCC below Pile Cap (same length and width as excavation)
5	Bridge SOR 23	R3-BW-2-24-b	Providing and placing in position controlled cement concrete of M-35 grade for foundation work with minimum cement 400 kg./cum. and water cement ratio not exceeding 0.4 for RCC raft foundation slab with V notches Sloped / flat / strip footings, pile caps tie beams to required lines / levels including leveling, compacting by vibrators, curing including shuttering, centering as necessary and required etc. complete as specified and as directed but excluding reinforcement. With RMC and Concrete Pump	7181.00	54.90	Cum	394236.90		Concreting in Pile Cap
6	Bridge SOR 23	R3-BW-2-107-a	Supplying, fitting and placing un-coated HYSD bar reinforcement (including lapping) in foundation complete as per drawing and technical specifications (Pile)	71289.00	7.00	MT	499023.00		Reinforcement in Pile
7	Bridge SOR 23	R3-BW-2-107-a	Supplying, fitting and placing un-coated HYSD bar reinforcement (including lapping) in foundation complete as per drawing and technical specifications (Pile Cap)	71289.00	2.37	MT	168954.93		Reinforcement in Pile Caps
B	**Substructure**								
8	SSR_22-23	17.55	Providing and laying in situ / ready mix controlled M-35 cement concrete of trap / granite / quartzite / gneiss metal for reinforced cement concrete caps over piers and abutments including necessary scaffolding, plywood / steel formwork, compacting by vibrating, finishing in CM 1:3 and curing etc. complete (Excluding reinforcement) With reversible drum type mixer / concrete batch mix plant (pan mixer) with fine aggregates of required specifications (VSI sand finely washed etc)	9574.00	8.59	Cum	82240.66	1964	Concrete in Pier
9	SSR_22-23	17.55	Providing and laying in situ / ready mix controlled M-35 cement concrete of trap / granite / quartzite / gneiss metal for reinforced cement concrete caps over piers and abutments including necessary scaffolding, plywood / steel formwork, compacting by vibrating, finishing in CM 1:3 and curing etc. complete (Excluding reinforcement) With reversible drum type mixer / concrete batch mix plant (pan mixer) with fine aggregates of required specifications (VSI sand finely washed etc)	9574.00	34.63	Cum	331547.62	1964	Concrete in Pier Cap with Pedestal
10	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	1.80	MT	128320.20		Reinforcement in Pier
11	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	3.56	MT	253788.84		Reinforcement in Pier Cap and Pedestal
12	SSR_22-23	13.07	Supplying, fitting and fixing in position true to line and level elastomeric bearing including all accessories as per drawing and technical specifications and IRC:83 (Pt-II) section IX and clause 2005 of MoRTH specifications etc. complete.			Cum	0.00		Bearings (As per Market Rate)
13	SSR_22-23	53.25	Supplying, drilling / cleaning hole and fixing of Torque Controlled Expansion Anchor HST3, of sizes ranging from M8 to M24. The Anchor should be third party tested, possess ETA approval and should be pre-assembled with a galvanized bolt as per EN ISO 4042:1999, ingenious expansion sleeve M10 and M16 (galvanized) and M8, M12, M20, M24 Stainless Steel (EN ISO 4042:1999), a nut of Strength Class 8 (EN ISO 20898-2:2012) and a galvanized washer (EN ISO 4042:1999). The anchors should be approved for use in Cracked Concrete. Anchor must be tested and approved as per Seismic C1 and C2 Category of TR045. ETA to have Fire Resistance values for up to 120 mins as per EOTA TR020 and FM Approval (use in Pipe Hangers). Anchor shall be fixed at right embedment depth as per embedment mark and activated using AT Tool Module to ensure adequate torque as per manufacturer's torque tolerance published in ETA and same shall be documented and submitted to Project Manager at the time of inspection. Design of Anchors should be done as per ETAG 001 Annex C and TR045 using PROFIS Software as per actual load data and site conditions as provided by structural consultant and the report to be submitted to the project manager and design engineer for approval. Scanning before drilling to be done with PS Scanning tool to avoid rebar hits. stud anchor HST3 SS M24x200 30	3326.00	40.00	Each	133040.00	13	Anchor Rods for Bearings
C	**Superstructure**								
14	SSR_22-23	14.89	Providing and laying in situ M35 controlled cement concrete of trap / granite / quartzite / gneiss metal for RCC work in solid / deck slab etc. including ramming, vibrating, curing, formwork, centering and finishing in cement plaster excluding reinforcement etc. complete. (With fully automatic microprocessor based PLC with SCADA enabled concrete batch mix plant / pan mixer with natural sand) i) Height up to 5 m, normal rate. ii) Height 5 to 7.50 m, add 5 percent extra. iii) Height 7.50 to 10 m, 7.50 percent extra. iv) Over 10 m Height, add 10 percent extra for every 2.50 m rise.	11702.00	116.94	Cum	1368431.88	3485.9	Deck Slab Concrete, Quantitiy has been increased by 10% because height is greater by 10 m
15	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00	4.66	MT	332206.74		Deck Slab Steel, Min 0.12% steel has been used

16	Bridge SOR 23	R3-BW-4-42-c	Providing and placing in position controlled cement concrete of M-40 grade using minimum cement content as 400Kg/cum and max water cement ratio of 0.40 for Prestressed Concrete Girders as per detailed drawings and designs having form finish surfaces including formwork on casting bed and temporary supports as necessary and required, compacting by vibrators, levelling, curing and finishing etc.complete as specified and directed including launching the girders in position using plant and equipment and providing erecting and removing the temporary staging as necessary and required etc. complete as specified and directed excluding reinforcement and placing in position.(using concrete mixer),PSC Grade M-40 Using concrete mixer.For T-beam & slab Height above 10m	11434.00	244.76	Cum	2798585.84		For concrete in precast girders (height above 10 m)
17	Bridge SOR 23	R3-BW-4-35-c	Providing and placing in position controlled cement concrete of M-40 grade using minimum cement content as 400Kg/cum and max water cement ratio of 0.40 for cast-in situ portions after launching girders of RCC Deck Slab, cross diaphragms to required lines and levels including levelling, compacting by vibrators, curing including formwork, temporary supports as necessary and required etc. complete as specified and directed but excluding reinforcement. RCC M 40 Grade Using RMC and Concrete PumpFor T-beam & slab	9625.00	16.46	Cum	158427.50		
18	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00		MT			Reinforcement for Prestreesed Girders
19	Bridge SOR 23	R3-BW-2-38-a	Providing and cutting bending, hooking, laying in position and tying HYSD bars for reinforcement (including lapping) as per detailed drawings for R.C.C.work.	71289.00		MT			Reinforcement for Diaphragms
D	**Miscellaneous**								
20	SSR_22-23	23.03	Providing structural steel work in single stanchions composed of R. S.J. Channel etc. withcaps, bases, mild steel plated, angle brackets, cleats, gusset plates, anchor bolts etc. as per detailed designs and drawings or as directed including cutting, fabrication, hoisting, erecting fixing in position, making riveted/ bolted/ welded connection and onecoat of anticorrosivepaint andover it two. coatsofoil painting approved quality and shade etc. complete.	98009.00	1.40	MT	137212.60	14265	Steel Railing
21	SSR_22-23	7.37	Providing Reinforced cement concrete crash barrier at the edges of the road, approaches to bridge structures and medians, constructed with R.C.C. M30 Grade concrete with HYSD reinforcement conforming to IRC:21 and dowel bars 25 mm dia, 450 mm long at expansion joints filled with pre-moulded asphalt filler board, keyed to the structure on which it is built and installed as per design given in the enclosure to MOST circular No. RW/NH-33022/1/94-DOIII dated 24June 1994 as per dimensions in the approved drawing and at locations directed by the Engineer, all as specified etc. complete.Spec: MORT and H 2013 Cl 811 Page No 360	4234.00	70.00	Rmt	296380.00	119	Crash Barrier
22	SSR_22-23	14.68	Providing and laying of a strip seal expansion joint catering to maximum horizontal movement up to70mm to be installed by themanufacturer /supplier to their authorized representative ensuring compliance to the manufacturer s instruction for installation as per approved drawings and standard specifications etc. complete.	13295.00	13.50	Rmt	179482.50	82	Expansion Joint
23	Bridge SOR 23	R3-BW-5-1-j	Providing and fixing in position Drainage Spouts including trough of 260 x 260. size fabricatede using mild steel plates, flats, MS grating, etc. and 100mm dia GI pipe 1 m long as per detailed drawings etc. complete as specified and directed.	2224.00	7.00	Each	15568.00		Drainage Sprouts, Provided for every 5 m
24	Bridge SOR 23	R3-BW-5-4-a	Providing and fixing in position PVC pipe 150 mm dia. in any position including all fittings and accessories, making joints / connections water tight with solvent cement, scaffolding if necessary and making good the damages if any etc. complete as specified and directed.	955.00	12.80	Rmt	12224.00		PVC Pipes for Drainage
25	Bridge SOR 23	R3-BW-5-3-c	Providing and applying epoxy base paint to RCC piers, columns, beams, girders, diaphragms, slabs, parapets etc. including cleaning the surfaces thoroughly so as to remove deposited salts, oil, grease, tar, moisture etc. from the surface, preparing the surface, applying putty consisting of epoxy base paint and steolite powder, to render the concrete surfaces smooth by covering small irregularities and applying one coat of epoxy paint including scaffolding etc. complete as specified and directed.(2 coats epoxy + primer)	512.00	914.70	Sqm	468326.40		Epoxy on Pier, Pier Caps and Girders
26	SSR_22-23	35.11	Providing and applying two coats (exterior quality) of flat oil paint of approved colour and shade to the plastered surface in buildings and workshops including scaffolding if necessary, cleaning the surface and preparing surface etc. complete. (excluding primer coat)	88.00	914.70	Sqm	80493.60	44	Paint on Pier, Pier Cap & Girders
27	SSR_22-23	48.06	Providing and Laying factory made coloured chamfered edge Cement concrete grass paver blocks of required strength,thickness & size/shape, made by table vibratory method using PU mould, laid in required colour & pattern over 50 mm thick compacted bed of fine fine aggregate (natural sand/crushed sand VSI grade finely washed etc.), compacting and proper embedding / laying of inter locking paver blocks into the fine aggregate (natural sand /crushed sand VSI grade finely washed etc.) bedding layer through vibratory compaction by using plate vibrator, filling the joints with fine aggregate (natural sand /crushed sand VSI grade finely washed etc.) and cutting of paver blocks as per required size and pattern, finishing and sweeping extra fine aggregate (natural sand/crushed sand VSI grade finely washed etc.) and complete as per manufacturer spsecifications & direction of Engineer-in-Charge. 60 mm thick CC paver block of M-35 grade concrete with approved colour and design & pattern.	1171.00	53.20	Sqm	62297.20	99	Paver Blocks for Footpath
28	SSR_22-23	50.06	Providing and applying two coats of protective membrane over the cured concrete surface like R.C.C. footings, columns, plinth beams etc. which will be submerged under soil so as to protect the same. Apply two pack coal tar epoxy system of Sun epoxy Coal tar of approved make & approved by Engineer incharge, having solid content ranges from 80 100%,Tack free time 4-6 hrs. Re coat after 16-24 hrs. Mix Part A and Part B of Sun epoxy Coal tar of approved make & approved by Engineer incharge in 1:1 ratio with slow speed stirrer and apply the same ona clean R.C.C.surface by brush. Allow to set for 8-10 hours and apply these cond coat.The rate to include for application at all levels to various RCC elements to the satisfaction of the EIC etc. complete.	247.00	72.60	Sqm	17932.20	120	Waterproofing for Pile Cap
29	SSR_22-23	51.114	Providing and laying Hyperplas standard or equivalent polymeric multiple monolithic five layer water proofing flexible, pliable and high tensile strength membrane (3 Kilogram / One Square Metre) & consist of centre core of 90 micron thick High Molecular High density Polyethylene film (HMHDPE) which is protected on both the side with polymeric mix. Applying the membrane by thermofusing to roof & parapet after applying thin film of hot blown bitumen 85 / 25 or 90 /15 grade @ 1.2 Kilogram / One Square Metre maximum as per surface condition or Hyperplasprimer @ 250 gms / One Square Metre as per site condition on the surface to be treated with 10 cm overlapping including finishing etc. complete and covering guarantee of 7 years on stamp paper of Rs. 100/-and as directed by Engineer-in-charge. (Prior permission of S.E.in writing is necessary be fore inclusion of this item in estimate).	678.00	472.50	Sqm	320355.00	115	Waterproofing Below WC on Deck Slab
30	Bridge SOR 23	R3-BW-5-2-c	Providing and laying bitumen mastic layer 20 mm thick over bridge deck excluding tack coat etc. complete as specified and directed. (with bitumen 10/20 penetration not less than 10.5% and lime stone dust not, less than 40%)	986.00	472.50	Sqm	465885.00		Asphalt Rpad
31	SSR_22-23	7.37	Providing Reinforced cement concrete crash barrier at the edges of the road, approaches to bridge structures and medians, constructed with R.C.C. M30 Grade concrete with HYSD reinforcement conforming to IRC:21 and dowel bars 25 mm dia, 450 mm long at expansion joints filled with pre-moulded asphalt filler board, keyed to the structure on which it is built and installed as per design given in the enclosure to MOST circular No. RW/NH-33022/1/94-DOIII dated 24 June 1994 as per dimensions in the approved drawing and at locations directed by the Engineer, all as specified etc. complete.Spec: MORT and H 2013 Cl 811 Page No 360	4234.00	35.00	Rmt	148190.00	119	Median/divider (assuming 0.5)
32	Bridge SOR 23	R3-BW-5-7-i,j	Providing and applying hot applied thermoplastic road marking material with glass beads extremely high skid resistance 2.5 mm thick without primer coat (Tack coat) on Asphalt road surface. All labour, materials, with special aggregates as specified in B.S. part - I & II 1989 and carrying out the marking on any road in center line and other marking continuous or intermittent 10 cm or 15 cm width also pedestrians crossing strips as well as spraying further quantity of glass beads of type II uniformly into a mono layer on to the hot paint line in quick succession of the paint spraying operation @ 250 gms per sqm. area as directed and as per BS / MOST specifications in white / yellow colour.	1011.00	8.00	Sqm	8088.00		Yellow and White Paint on Road for directions

			Quantity In Crash Bariers		22.18	Cum		10363270.01	103.6327001	
			Quantitiy in RCC Strucutures		482.00	Cum				

BOQ – Demolition Cost for PSC Bridge (35 m Span):

The following pages present the full Bill of Quantities (BOQ) for the demolition of a 35-meter span Pre-Stressed Concrete (PSC) Bridge.

35 M_PSC I section Bridge								
Sr. No.	**Reference**	**Item no**	**Description**	**Rate (excluding GST)**	**Quantity**	**Unit**	**Amount (in INR)**	**Assumptions / Remarks / References**
A								
1	Demoltion and Reconstruction of Bridges	R3-SWD-36	Cutting down completely RCC slab, walls, beams, columns, arches, piles, pile caps of any thickness and or size of any height/depth by any means below or above ground level including cutting down steel reinforcement, removing and stacking them properly as direc fed etc.complete, asspecified & as directed by Engineer-in-Charge.	2491.00	482.00	Cum	1200662.00	Includes Pile caps, Pier, Pier Caps, PSC Girders, Cross Diaphragms, Deckslab and Crash barriers. No mention of height
2	Mah PT_SOR 21		Scraping, cleaning and straightening reinforcement bars obtained from demolition of RCC work and stacking at site within a lead of 100 Mtrs. complete as directed.	510.00		qntl.	0.00	Includes all reinforcement (Ex Piles)
3	Mah PT_SOR 23		Dismantling steel work in built-up sections in frame work and trusses of span upto 10 Mtrs. and height of 5 Mtrs. in R.S.Joists, angles, 'T's, flats & channels including all gusset plates, bolts, nuts, cutting rivets and weldings including dismembering and handing over all serviceable materials at sectional office or at MbPT store yard as directed complete. Extra over rate for Item No. 16 for dismantling trusses, rafters, purlins etc. of steel for every per Mtr. additional span of 1 Mtr. beyond 10 Mtrs add 55/- per m	386.00	14.00	qntl.	5404.00	The base cost for spans up to 10 meters is ₹386. For each additional meter beyond 10 meters, an extra charge of ₹55 per meter shall apply.
4	NH_SOR	2.5 A	Dismantling of flexible pavements and disposal of dismantled materials up to a lead of 1000 meters, stacking serviceable and unserviceable materials separately and as per relevant clauses of section-200. (Bituminous Course)	741.00	9.45	Cum	7002.45	Dismantling and disposal of flexible pavement
5	Mah PT_XIV_26		Dismantling PVC pipes of any dia. with it's fittings and clamps including stacking the serviceable and unserviceable material separately within a lead of 100 Mtrs. complete as directed.	40.00	12.80	Rmt	512.00	Dismantaling and stacking of PVC Pipes
6	USOR_23	R3-CS-DD-5-b	Demolishing stone rubble masonry manually/ by mechanical means including stacking of serviceable material and disposal of unserviceable material within 50 metres lead as per direction of Engineer-in-charge In cement mortar	8.08	1797.00	Cum	14519.76	Dismantaling and stacking of servicable Paver Blocks

BOQ – Steel Composite Bridge (35 m Span, Bihar Region):

The following pages present the full Bill of Quantities (BOQ) for a 35-meter span Steel Composite Bridge located in Bihar, based on regional Schedule of Rates and construction conditions.

35 M Composite Steel I section Girder Bridge Initial Cost										
Sr. No.	**Refrence**	**Item no**	**Description**	**Rate (excluding GST)**	**Quantity**	**Unit**	**Amount (in INR)**	**Assumptions / Remarks / References**		
A	**Foundation**									
1	SOR_22_Vol 2	15.01_IV_B	Carrying out excavation in hard rock to achieve a specified slope of the rock face by controlled use of explosives and blasting accessories in properly aligned and spaced drill holes, collection of the excavated rock by a dozer, loading in tipper by a front end loader and disposing of the material with all lifts and lead upto 1000m, all as specified in clause No. 303. Marshy Soils with Machinery use	252.00	28.57	Cum	7199.64	Excavation for Pile cap (Considered for 1m depth and 0.3m more than the length and width of the pile cap for ground preparation).		6 M pile cap
2			Boring for Piles				0.00	Market Rate		
3	SOR_22_Vol 2	12.24	Bored cast-in-situ M35 grade R.C.C. Pile excluding Reinforcement complete as per Drawing and Technical Specifications and removal of excavated earth with all lifts and lead upto 1000 m.	10715.80	175.00	Rmt	1875265.00	M35 Bored Pile	No mention fo depth	35 m pile depth, 5 Piles
4	SOR_22_Vol 2	12.41 Case I	Providing and laying of PCC M15 levelling course 100 mm thick below the pile cap, PCC Grade M15 using batching plant & Concrete pump	3913.20	28.57	Cum	111800.12	150mm PCC below Pile Cap (same length and width as excavation)		
5	SOR_22_Vol 2	12.40 Case I	RCC Grade M35 using batching plant & Concrete pump for Pile Cap	5449.52	25.92	Cum	141251.56	Concreting in Pile Cap	Including all charges	
6	SOR_22_Vol 2	12.42 1600	Supplying,Fitting and Placing un-coated HYSD bar Reinforcement in Foundation complete as per Drawing and Technical Specifications.	78579.94	16.69	MT	1311499.20	Reinforcement in Pile		
7	SOR_22_Vol 2	12.42 1600	Supplying,Fitting and Placing un-coated HYSD bar Reinforcement in Foundation complete as per Drawing and Technical Specifications.	78579.94	2.37	MT	186234.46	Reinforcement in Pile Caps		
B	**Substructure**									
8	SOR_22_Vol 2	13.05 H (p)	Plain/Reinforced cement concrete in sub-strucutre complete as per drawing and Technical specifications, Height upto 5 m RCC Grade M35 using batching plant, transit mixer & concrete pump	5910.60	9.23	Cum	54554.84	Concrete in Pier	For 1 pier	4 Piers, 6m height, R = 0.7
9	SOR_22_Vol 2	17.55	"Plain/Reinforced cement concrete in sub-strucutre complete as per drawing and Technical specifications, Height 5m to 10m RCC Grade M35 using batching plant, transit mixer & concrete pump"	6039.50	23.50	Cum	141928.25	Concrete in Pier Cap with Pedestal	Height 5 m to 10 m	W=1.6 m, D=1.
10	SOR_22_Vol 2	13.06 Section 1600 & 2200	Supplying, fitting and placing HYSD bar reinforcement in sub structure complete as per drawing and technical specifications	78776.30	1.61	MT	126829.84	Reinforcement in Pier	Includes labour too	
11	SOR_22_Vol 2	13.06 Section 1600 & 2200	Supplying, fitting and placing HYSD bar reinforcement in sub structure complete as per drawing and technical specifications	78776.30	1.93	MT	152038.26	Reinforcement in Pier Cap and Pedestal	Includes labour too	
12	SOR_22_Vol 2	13.16 2000 & 2200	Supplying , fitting and fixing in position true to line and level elastomeric bearing conforming to IRC:83 (Part-II) section IX and clause 2005 of Mort&H specification complete including all accessories as per drwaing and technical specifications	0.86		cc	0.00	Bearings (As per Market Rate)	19200 cc used in sor for single one	
13					40.00	Each	0.00	Anchor Rods for Bearings		
C	**Superstructure**									
14	SOR_22_Vol 2	14.01 D (r)	Furnishing and Placing Reinforced/ Prestressed cement concrete in super-structure as per drawing and Technical Specification RCC/PSC Grade M35 Using Batching Plant, Transit Mixer and Concrete Pump For T-beam & slab, 23-33 per cent of (a+b+c) Height above 10m	7093.20	247.30	Cum	1754148.36	Deck Slab Concrete	Rate for Above 10 m height of construction	
15	SOR_22_Vol 2	14.02	Supplying, fitting and placing HYSD bar reinforcement in super structure complete as per drawing and technical specifications	78972.50	4.66	MT	368011.85	Deck Slab Steel, Min 0.12% steel has been used		0.12% * 1000 * Depth
16					4.08	MT	0.00	Decking Sheet		
17					88.19	MT	0.00	I Steel Section Girder	Increasing Structural Steel Quantity by a (25) % to account for the weight of splice connections, shear connectors, bolts, nuts etc.	
D	**Miscellaneous**									
18	SOR_22_Vol 2	14.08	Providing, fittingandfixingmildsteel railingcompleteasper drawing and Technical Specification	3811.00	70.00	Rmt	266770.00	Steel Railing		
19	SOR_22_Vol 2	14.15 B	Provision of an Reinforced cement concrete crash barrier at the bridge decks& approaches to bridge structures constructed with Rein forced Cement Concrete With HYSD reinforcement confirming MoRT&H Specification and as per details given IRC-5 including dowel bars ,expansion joints filled with pre-moulded asphalt filler board etc.. and approved drawing and at locations directed by the Engineer ,all as specified . Crash Barriers for Bridge (Height 1100 mm) as per detais given IRC-5 (fig.-2) (Area -0.298 sqm. For 1 meter length)	4271.50	70.00	Rmt	299005.00	Crash Barrier		
20	SOR_22_Vol 2	14.21	Providing and laying of a strip seal expansion joint catering to maximum horizontal movement upto 70 mm, complete as per approved drawings and standard specifications to be installed by the manufacturer/supplier or their authorised representative ensuring compliance to the manufacturer's instructions for installation.	12304.60	13.50	Rmt	166112.10	Strip Seal Expansion Joint		
21	SOR_22_Vol 2	14.09 2705	Drainage Spouts complete as per drawing and Technical specification	5705.40	7.00	Each	39937.80	Drainage Sprouts, Provided for every 5 m	Includes labour cost too	
22	SOR_22_Vol 2	M304	Polyvinyl Chloride Pipe (PVC)-135 mm	130.00	12.80	Rmt	1664.00	PVC Pipes for Drainage	No mention of labour	
23	SOR_22_Vol 2	13.19	Protection to sub strucutre by using coal tar epoxy Providing and applying two coats of two components, high build, 100% solid content, low VOC, polycyclin aromatic hydrocarbon based, Pot life= 2hrs @ 72 deg. F, Tack free- 4-6 hrs, DFT per coat 80-120 microns (dry) coal tar epoxy coating with coal tar		73.24	Sqm	0.00	Epoxy on Pier and Pier Caps		
24	SSR_22-23	14.16	Providing and applying 2 coats of water based cement paint to unplastered concrete surface after cleaning the surface of dirt, dust, oil, grease, efflorescence and applying paint @ of 1 litre for 2 sqm.	109.40	73.24	Sqm	8012.46	Paint on Pier and Pier Cap		
25					1155.00	Sqm	0.00	Two Coat of Alluminium Paint on Structural Steel Members		
26	SSR_22-23	M-324	Paver Block (Excluding GST) M -35 Grade and 60 mm thickness (a) White	516.79	53.20	Sqm	27493.23	Paver Blocks for Footpath	Excl. Labour rate	
27					50.50	Sqm	0.00	Waterproofing for Pile Cap		
28					472.50	Sqm	0.00	Waterproofing Below WC on Deck Slab		
29					472.50	Sqm	0.00	Asphalt Road (20 mm)	Only 12 mm available	
30						Rmt	0.00	Median/divider (assuming 0.5)	alternative, labour cost is 108	
31					8.00	Sqm	0.00	Yellow and White Paint on Road for directions		
			Total quantity of Piles		150.72	Cum				
			Total quantity of RCC barriers		22.18					
			Total RCC Qantity for Demolition of any grade		305.95	Cum		Piles and Crash Barrier Excluded		
			Total PCC for Demolition under M 20 Grade		28.57	Cum				
			Total Quantity of Steel sections		88.19	MT				
			Total Amount of Reinforcement		22.96	Mt		Included reinforcement in Pile, Pile caps, Pier, Pier caps and Deck slab		

3.3.3 Explanation of the BOQ's

The structure of the BOQ tables begins with a heading that provides context about the bridge type and purpose of the estimate. Each entry in the table corresponds to a specific construction or demolition activity, with associated quantities derived from design assumptions. These quantities are paired with standardized units and matched to item codes from official government Schedule of Rates (SORs). The applicable rates are then used to compute the total cost for each line item. The tables are designed to account for regional variations, such as those between urban and rural contexts, by using localized SOR data. This systematic arrangement ensures clarity, traceability, and ease of comparison across different bridge types and locations.

Chapter 4

Task 2: Backend Calculations for LCCA

4.1 Problem Statement

A modular backend system is required to compute life cycle costs for infrastructure projects by integrating economic and environmental components such as construction, emissions, maintenance, inspection, repair, demolition, recycling, and reconstruction. The system must apply present worth factors, use user-defined inputs, and retrieve operational costs from a structured SQLite database to enable comprehensive cost aggregation over a defined analysis period.

4.2 Tasks Done

A Python-based backend module was developed to automate Life Cycle Cost Assessment (LCCA) for infrastructure projects. The system computes costs across various life cycle stages, including construction, carbon emissions, road user delays, maintenance, inspection, repair, demolition, recycling, and reconstruction. Each cost component is implemented as a class using object-oriented design and incorporates discounting through present worth factors. Additionally, a structured SQLite database `IRC_Road_Costs.db` was created to store and retrieve vehicle operation costs based on parameters such as vehicle type, lane category, road roughness, and reduction factors (RF), as per IRC guidelines. A supporting module, `material_types_consts.py`, was also developed to define material types, grades, units, and road user constants used throughout the application.

4.3 Python Code

A Python module was developed for automating Life Cycle Cost Assessment (LCCA) of infrastructure assets. The script performs cost computations for components such as initial construction, carbon emissions, time delays, road user impacts, periodic maintenance, inspection, repair, demolition, recycling, and reconstruction. It uses an object-oriented structure with abstract base classes to represent cost categories and applies discounting techniques using present worth factors. The tool takes user-defined parameters and retrieves operational cost data from an SQLite database based on real-world inputs like traffic volume and road roughness. This enables comprehensive, long-term cost estimation in line with standard LCCA methodologies, supporting informed decision-making.

4.3.1 4.3.1 Description of the Script

The script is structured as follows:

- **Input Parameters**: The user provides input data such as material quantities and rates, steel and concrete properties, vehicle types and traffic volume, construction time, discount rate, design life, and carbon emission factors. Road user data is dynamically fetched from an SQLite database.
- **Cost Calculations**: The program calculates costs across various life cycle stages, including initial construction, carbon emissions, time-related delays, road user impacts, periodic maintenance, inspection, repair, demolition, recycling, and reconstruction. Each cost component is modeled as a subclass of an abstract base class using object-oriented programming. Present worth factors are applied for future cost discounting.
- **Output**: The script outputs a detailed cost breakdown for each component in INR, enabling long-term economic and environmental assessment of the project.

4.3.2 Python Code

The Python script shown below performs cost calculations for various stages in the infrastructure life cycle. Each cost component is modularized and integrated using object-

oriented design.

Listing 4.1: Life Cycle Cost Assessment in OsBridgeLCCA

```
#--------------------begin code-------------

from core.cost_component import *
from core.cost_component import UserInputs

# Input parameters
inputs = UserInputs()
materials = inputs.user_materials
design_life = inputs.design_life
discount_rate = inputs.discount_rate
construction_time = inputs.construction_time
carbon_cost = inputs.carbon_cost

# Initial construction cost
total_initial_cost = 0
for item in materials:
    comp = InitialConstructionCost(item["quantity"], item["rate"])
    total_initial_cost += comp.calculate_cost()

# Carbon emission cost (concrete + steel)
total_concrete_kg = 214 * 2549.25  # Concrete density conversion
total_steel_kg = (27.99 + 5.69) * 1000
carbon_emission_cost = (
    total_concrete_kg * inputs.concrete_emission_factor +
    total_steel_kg * inputs.steel_emission_factor
) * carbon_cost

# Time cost
time_cost = TimeCost(total_initial_cost, inputs.interest_rate,
                     construction_time, inputs.investment_ratio).
                        calculate_cost()

# Road user cost (using SQLite DB data)
road_user_cost = 0
# SQLite logic omitted for brevity     included in full script

```

```
36 # Maintenance cost
37 maintenance = PeriodicMaintenanceCost(inputs.maintenance_cost_rate,
38                                        total_initial_cost,
39                                        discount_rate,
40                                        inputs.maintenance_period,
41                                        design_life).calculate_cost()
42
43 # Output results
44 print("Initial Construction Cost:", total_initial_cost)
45 print("Initial Carbon Emission Cost:", carbon_emission_cost)
46 print("Time Cost:", time_cost)
47 print("Maintenance Cost:", maintenance)
48
49 #-------------------- end code ---------------
```

4.3.3 Explanation of the Code

- **Line 1-2**: Imports the required classes and data structures from the `cost_component.py` module.
- **Line 4-8**: Initializes user-defined input parameters, including material data, design life, discount rate, and emission cost.
- **Line 10-13**: Iterates through all construction materials and calculates the total initial construction cost using quantity and rate.
- **Line 15-18**: Calculates the total carbon emission cost from concrete and steel by applying emission factors and carbon pricing.
- **Line 20-22**: Computes the time-related cost using interest rate, construction time, and investment ratio.
- **Line 24-25**: Placeholder for calculating road user cost using vehicle data and values from an SQLite database.
- **Line 27-30**: Calculates periodic maintenance cost by applying present worth factors based on discount rate, maintenance period, and design life.

- **Line 32-35**: Prints the computed cost outputs, providing a summary of life cycle cost components.

4.3.4 Full code

```
from abc import ABC, abstractmethod
import os
import sqlite3
from typing import Optional, List, Dict, Any
from dataclasses import dataclass, field

class CostComponent(ABC):
    """Abstract Base Class for different cost components in Life
       Cycle Cost Analysis."""

    def __init__(self, amount, category, is_initial, is_recurring
       , present_worth_factor):
        """
        Initialize a generic cost component.

        :param amount: Cost amount in INR
        :param category: Economic, Environmental, or Social
        :param is_initial: True if an initial cost, False if
           future cost
        :param is_recurring: True if recurring, False if one-time
        :param present_worth_factor: Discounting factor for
           future costs (present_worth_factor)
        """
        self.amount = amount
        self.category = category
        self.is_initial = is_initial
        self.is_recurring = is_recurring
        self.present_worth_factor = present_worth_factor

    @abstractmethod
```

```
    def calculate_cost(self):
        """Abstract method to be implemented by subclasses for
           cost calculation."""
        pass


class InitialConstructionCost(CostComponent):
    """Covers material, labor, and equipment costs for bridge
       construction."""

    def __init__(self, quantity, rate):
        super().__init__(amount=quantity * rate, category="
           Economic", is_initial=True, is_recurring=False,
           present_worth_factor=1.00)

        self.quantity = quantity
        self.rate = rate

    def calculate_cost(self):
        return self.quantity * self.rate * self.
           present_worth_factor


class InitialCarbonEmissionCost(CostComponent):
    """Calculates initial carbon emissions from material
       production and transport."""

    def __init__(self, material_quantity, carbon_emission_factor,
        carbon_cost):
        amount = (material_quantity * carbon_emission_factor) *
           carbon_cost
        super().__init__(amount=amount, category="Environmental",
            is_initial=True, is_recurring=False,
           present_worth_factor=1.00)
```

```
        self.material_quantity = material_quantity
        self.carbon_emission_factor = carbon_emission_factor
        self.carbon_cost = carbon_cost

    def calculate_cost(self):
        return (self.material_quantity * self.
            carbon_emission_factor) * self.carbon_cost * self.
            present_worth_factor



class TimeCost(CostComponent):
    """Calculates economic losses due to construction delays."""

    def __init__(self, construction_cost, interest_rate, time,
        investment_ratio):
        cost = construction_cost * interest_rate * time *
            investment_ratio
        super().__init__(amount=cost, category="Economic",
            is_initial=True, is_recurring=False,
            present_worth_factor=1.00)
        self.construction_cost = construction_cost
        self.interest_rate = interest_rate
        self.time = time
        self.investment_ratio = investment_ratio

    def calculate_cost(self):
        return self.construction_cost * self.interest_rate * self
            .time * self.investment_ratio * self.
            present_worth_factor



class RoadUserCost(CostComponent):
```

```
    """Evaluates economic impact on road users due to delays and
       detours."""

    def __init__(self, vehicles_affected, vehicle_operation_cost,
        construction_time):
        cost = vehicles_affected * vehicle_operation_cost *
           construction_time
        super().__init__(amount=cost, category="Economic",
           is_initial=True, is_recurring=False,
           present_worth_factor=1.00)
        self.vehicles_affected = vehicles_affected
        self.vehicle_operation_cost = vehicle_operation_cost
        self.construction_time = construction_time

    def calculate_cost(self):
        return self.vehicles_affected * self.
           vehicle_operation_cost * self.construction_time * self
           .present_worth_factor


class AdditionalCarbonEmissionCost(CostComponent):
    """Accounts for increased emissions from detoured traffic
       during bridge work."""

    def __init__(self, vehicles_affected, reroute_distance,
       co2_emission_per_km, carbon_cost):
        cost = vehicles_affected * reroute_distance *
           co2_emission_per_km * carbon_cost
        super().__init__(amount=cost, category="Environmental",
           is_initial=True, is_recurring=False,
           present_worth_factor=1.00)
        self.vehicles_affected = vehicles_affected
        self.reroute_distance = reroute_distance
        self.co2_emission_per_km = co2_emission_per_km
```

```
        self.carbon_cost = carbon_cost

    def calculate_cost(self):
        return self.vehicles_affected * self.reroute_distance *
           self.co2_emission_per_km * self.carbon_cost * self.
           present_worth_factor


class PeriodicMaintenanceCost(CostComponent):
    """Includes expenses for routine maintenance activities."""

    def __init__(self, maintenance_cost_rate, construction_cost,
       discount_rate=0, period=1, design_life=1):
        pwf = sum(1 / ((1 + discount_rate) ** (i * period)) for i
            in range(1, int(design_life / period)))
        cost = maintenance_cost_rate * construction_cost * pwf
        super().__init__(amount=cost, category="Economic",
           is_initial=False, is_recurring=True,
           present_worth_factor=pwf)
        self.maintenance_cost_rate = maintenance_cost_rate
        self.construction_cost = construction_cost
        self.discount_rate = discount_rate
        self.period = period
        self.design_life = design_life

    def calculate_cost(self):
        return self.maintenance_cost_rate * self.
           construction_cost * self.present_worth_factor


class PeriodicMaintenanceCarbonCost(CostComponent):
    """Calculates emissions from maintenance activities."""
```

```
    def __init__(self, material_quantity, carbon_emission_factor,
        carbon_cost, discount_rate, period, design_life):
        pwf = sum(1 / ((1 + discount_rate) ** (i * period)) for i
            in range(1, int(design_life / period)))
        cost = material_quantity * carbon_emission_factor *
            carbon_cost * pwf
        super().__init__(amount=cost, category="Environmental",
            is_initial=False, is_recurring=True,
            present_worth_factor=pwf)
        self.material_quantity = material_quantity
        self.carbon_emission_factor = carbon_emission_factor
        self.carbon_cost = carbon_cost

    def calculate_cost(self):
        return self.material_quantity * self.
            carbon_emission_factor * self.carbon_cost * self.
            present_worth_factor


class RoutineInspectionCost(CostComponent):
    """Annual cost of inspections for structural integrity."""

    def __init__(self, inspection_cost_rate, construction_cost,
        discount_rate=0, design_life=1, period=1):
        pwf = ((1 + discount_rate) ** (design_life - 1)) / (
            discount_rate * (1 + discount_rate) ** design_life)
        cost = inspection_cost_rate * construction_cost * pwf
        super().__init__(amount=cost, category="Economic",
            is_initial=False, is_recurring=True,
            present_worth_factor=pwf)
        self.inspection_cost_rate = inspection_cost_rate
        self.construction_cost = construction_cost
        self.period = period
        self.discount_rate = discount_rate
```

```
        self.design_life = design_life

    def calculate_cost(self):
        return self.inspection_cost_rate * self.construction_cost
            * self.present_worth_factor


class RepairAndRehabilitationCost(CostComponent):
    """Covers major structural repairs and retrofitting."""

    def __init__(self, repair_cost_rate, construction_cost=0,
       discount_rate=0, period=1, design_life=1):
        pwf = 1 / ((1 + discount_rate) ** (period))
        cost = repair_cost_rate * construction_cost * pwf
        super().__init__(amount=cost, category="Economic",
           is_initial=False, is_recurring=True,
           present_worth_factor=pwf)

    def calculate_cost(self):
        return self.amount


class DemolitionCost(CostComponent):
    """Costs incurred at the end of bridge life for demolition
       and disposal."""

    def __init__(self, demolition_rate, construction_cost=0,
       discount_rate=0, design_life=1):
        pwf = 1 / ((1 + discount_rate) ** design_life)
        cost = demolition_rate * construction_cost * pwf
        super().__init__(amount=cost, category="Economic",
           is_initial=False, is_recurring=False,
           present_worth_factor=pwf)
        self.demolition_rate = demolition_rate
```

```
        self.construction_cost = construction_cost
        self.discount_rate = discount_rate
        self.design_life = design_life

    def calculate_cost(self):
        return self.amount


class RecyclingCost(CostComponent):
    """Accounts for material salvage and repurposing costs."""

    def __init__(self, scrap_value, quantity=0, scrap_rate=1.0,
       discount_rate=0, design_life=1):
        pwf = 1 / ((1 + discount_rate) ** design_life)
        cost = scrap_value * quantity * scrap_rate * pwf
        super().__init__(amount=cost, category="Economic",
           is_initial=False, is_recurring=False,
           present_worth_factor=pwf)
        self.scrap_value = scrap_value
        self.quantity = quantity
        self.scrap_rate = scrap_rate
        self.discount_rate = discount_rate
        self.design_life = design_life

    def calculate_cost(self):
        return self.amount


class ReconstructionCost(CostComponent):
    """Accounts for partial or complete reconstruction of the
       bridge due to structural failures or obsolescence."""

    def __init__(self, demolition_cost, reconstruction_cost,
       reconstruction_carbon_cost, reconstruction_time_cost,
```

```
        reconstruction_roaduser_cost,
        reconstruction_rerouting_carbon_cost, design_life,
        discount_rate):
         pwf = 1 / ((1 + discount_rate) ** design_life)
         cost = (demolition_cost + reconstruction_cost +
            reconstruction_carbon_cost + reconstruction_time_cost
            + reconstruction_roaduser_cost +
            reconstruction_rerouting_carbon_cost) * pwf
         super().__init__(amount=cost, category="Economic",
            is_initial=False, is_recurring=False,
            present_worth_factor=pwf)

    def calculate_cost(self):
        return self.amount




@dataclass
class UserInputs:
    user_materials: List[Dict[str, Any]] = field(default_factory=
        lambda: [
         {"material": "concrete", "grade": "M40", "unit": "cum", "
            quantity": 214, "rate": 11994},
         {"material": "steel", "grade": "E 250(Fe 410W)A", "unit":
             "MT", "quantity": 27.99, "rate": 91565},
         {"material": "steel", "grade": "E 300(Fe 440)", "unit": "
            MT", "quantity": 5.69, "rate": 185100},
    ])
    road_user_inputs: Dict[str, Any] = field(default_factory=
        lambda: {
         "Lane_Type": "Single Lane Roads",
         "Roughness": 2000,
```

```
        "RF": 5,
        "reroute_distance": 1,
        "Vehicles": [
            {"Vehicle_Type": "Small Cars", "Count": 1000},
            {"Vehicle_Type": "Big Cars", "Count": 2000},
            {"Vehicle_Type": "Two Wheelers", "Count": 4000},
        ]
    })
    user_input_steel_quantity: float = 0.0
    user_input_steel_unit: str = "MT"
    analysis_period: float = 50.0
    design_life: float = 50.0
    discount_rate: float = 0.0425
    construction_time: float = 0.75
    reroute_distance: float = 1.0
    interest_rate: float = 0.1
    investment_ratio: float = 0.5
    concrete_emission_factor: float = 0.084
    concrete_co2_emission_factor: float = 0.487032864540167
    steel_emission_factor: float = 2.6
    co2_emission_per_km: float = 0.1213
    carbon_cost: float = 6.3936
    maintenance_cost_rate: float = 0.0055
    maintenance_period: float = 5.0
    inspection_rate: float = 0.01
    inspection_period: float = 1.0
    repair_cost_rate: float = 0.10
    repair_period: float = 30.0
    demolition_rate: float = 0.10
    scrap_value: float = 50000.0
    scrap_rate: float = 0.98
```

```
#COST CALULATIONS



if __name__ == "__main__":

    # === USER INPUTS (all overridable parameters grouped) ===
    inputs = UserInputs()
    user_materials = inputs.user_materials
    road_user_inputs = inputs.road_user_inputs
    user_input_steel_quantity = inputs.user_input_steel_quantity
    user_input_steel_unit = inputs.user_input_steel_unit
    analysis_period = inputs.analysis_period
    design_life = inputs.design_life
    discount_rate = inputs.discount_rate
    construction_time = inputs.construction_time
    reroute_distance = inputs.reroute_distance
    interest_rate = inputs.interest_rate
    investment_ratio = inputs.investment_ratio
    concrete_emission_factor = inputs.concrete_emission_factor
    concrete_co2_emission_factor = inputs.
       concrete_co2_emission_factor
    steel_emission_factor = inputs.steel_emission_factor
    co2_emission_per_km = inputs.co2_emission_per_km
    carbon_cost = inputs.carbon_cost
    maintenance_cost_rate = inputs.maintenance_cost_rate
    maintenance_period = inputs.maintenance_period
    inspection_rate = inputs.inspection_rate
    inspection_period = inputs.inspection_period
    repair_cost_rate = inputs.repair_cost_rate
    repair_period = inputs.repair_period
    demolition_rate = inputs.demolition_rate
    scrap_value = inputs.scrap_value
    scrap_rate = inputs.scrap_rate
```

```
# 1. Initial Construction Cost Calculation
total_initial_construction_cost = 0
for item in user_materials:
    component = InitialConstructionCost(
        quantity=item["quantity"],
        rate=item["rate"]
    )
    total_initial_construction_cost += component.
       calculate_cost()
print("Total Initial Construction Cost:",
   total_initial_construction_cost)  # INR

# 2. Initial Carbon Emission Cost Calculation (Concrete +
   Steel)
total_concrete_kg = 0
for item in user_materials:
    if item["material"] == "concrete":
        qty = item["quantity"]
        unit = item["unit"].lower()
        if unit == "cum":
            qty = qty * 2549.25  # density: kg/cum
        total_concrete_kg += qty
total_steel_kg = 0
for item in user_materials:
    if item["material"] == "steel":
        qty = item["quantity"]
        unit = item["unit"].upper()
        if unit == "MT":
            qty = qty * 1000  # 1 MT = 1000 kg
        total_steel_kg += qty
total_carbon_emission_cost = (
    (total_concrete_kg * concrete_emission_factor) + (
       total_steel_kg * steel_emission_factor)
```

```
    ) * carbon_cost
    print("Total Initial Carbon Emission Cost:",
        total_carbon_emission_cost)  # INR

    # 3. Time Cost Calculation
    time_cost_component = TimeCost(
        construction_cost=total_initial_construction_cost,
        interest_rate=interest_rate,
        time=construction_time,
        investment_ratio=investment_ratio
    )
    print("Time Cost:", time_cost_component.calculate_cost())  #
        INR

    # 4. Road User Cost Calculation

    total_vehicles_affected = sum(v["Count"] for v in
        road_user_inputs["Vehicles"])

    # Use a relative path for the database
    db_path = os.path.join(os.path.dirname(__file__), '..', 'data
        ', 'databases', 'IRC_Road_Costs.db')
    db_path = os.path.abspath(db_path)

    total_road_user_cost = 0
    # construction_time and reroute_distance are now shared
        variables
    with sqlite3.connect(db_path) as conn:
        cursor = conn.cursor()
        cursor.execute("SELECT name FROM sqlite_master WHERE type
            ='table';")
        table_name = cursor.fetchone()[0]
        for vehicle in road_user_inputs["Vehicles"]:
            vehicle_type = vehicle["Vehicle_Type"]
```

```
            count = vehicle["Count"]
            lane_type = road_user_inputs["Lane_Type"]
            roughness = road_user_inputs["Roughness"]
            rf = road_user_inputs["RF"]
            cursor.execute(f'''
                SELECT Grand_Cost FROM {table_name} WHERE
                    Vehicle_Type = ? AND Lane_Type = ? AND
                        Roughness = ? AND RF = ?
            ''', (vehicle_type, lane_type, roughness, rf))
            result = cursor.fetchone()
            if result:
                grand_cost = result[0]
                ct = construction_time * reroute_distance
                road_user_cost_component = RoadUserCost(
                    vehicles_affected=count,
                    vehicle_operation_cost=grand_cost,
                    construction_time=ct
                )
                total_road_user_cost += road_user_cost_component.
                    calculate_cost()
            else:
                print(f"No Grand_Cost found for {vehicle_type}, {
                    lane_type}, {roughness}, {rf}")
    print("Total Road User Cost:", total_road_user_cost)  # INR


    # 5. Additional Carbon Emission Cost Calculation
    vehicles_affected = sum(v["Count"] for v in road_user_inputs[
        "Vehicles"])
    additional_carbon_inputs = {
        "vehicles_affected": vehicles_affected,
        "reroute_distance": reroute_distance,
    }
```

```
    additional_carbon_emission_component =
        AdditionalCarbonEmissionCost(
         vehicles_affected=additional_carbon_inputs["
            vehicles_affected"],
         reroute_distance=additional_carbon_inputs["
            reroute_distance"],
         co2_emission_per_km=co2_emission_per_km,
         carbon_cost=carbon_cost
    )
    print("Additional Carbon Emission Cost:",
        additional_carbon_emission_component.calculate_cost())  #
        INR

    # 6. Periodic Maintenance Cost Calculation
    period = maintenance_period
    periodic_maintenance_component = PeriodicMaintenanceCost(
         maintenance_cost_rate=maintenance_cost_rate,
         construction_cost=total_initial_construction_cost,
         discount_rate=discount_rate,
         period=period,
         design_life=design_life
    )
    print("Periodic Maintenance Cost:",
        periodic_maintenance_component.calculate_cost())  # INR

    # 7. Periodic Maintenance Carbon Emission Cost Calculation (
        Concrete only)
    maintenance_concrete_kg = 0
    for item in user_materials:
         if item["material"].lower() == "concrete":
             qty = item["quantity"]
             unit = item["unit"].lower()
             if unit == "cum":
                 qty = qty * 2549.25  # density: kg/cum
```

```
            # If already in kg, use as is
            maintenance_concrete_kg += qty
    maintenance_concrete_emission_factor =
        concrete_co2_emission_factor
    maintenance_carbon_cost = carbon_cost
    maintenance_discount_rate = discount_rate
    maintenance_period = period
    maintenance_design_life = design_life
    periodic_maintenance_concrete_carbon_component =
        PeriodicMaintenanceCarbonCost(
         material_quantity=maintenance_concrete_kg,
         carbon_emission_factor=
            maintenance_concrete_emission_factor,
         carbon_cost=maintenance_carbon_cost,
         discount_rate=maintenance_discount_rate,
         period=maintenance_period,
         design_life=maintenance_design_life
    )
    print("Periodic Maintenance Carbon Emission Cost (Concrete
        only):", periodic_maintenance_concrete_carbon_component.
        calculate_cost())  # INR

    # 8. Annual Routine Inspection Cost Calculation
    inspection_discount_rate = discount_rate
    inspection_design_life = design_life
    inspection_component = RoutineInspectionCost(
         inspection_cost_rate=inspection_rate,  # Use
            inspection_rate as inspection cost rate
         construction_cost=total_initial_construction_cost,  #
            Always use total_initial_construction_cost
         discount_rate=inspection_discount_rate,
         design_life=inspection_design_life,
         period=inspection_period  # always annual
    )
```

```
total_routine_inspection_cost = inspection_component.
    calculate_cost()
print("Total Routine Inspection Cost:",
    total_routine_inspection_cost)  # INR

# 9. Repair and Rehabilitation Cost Calculation
repair_period = repair_period
repair_component = RepairAndRehabilitationCost(
    repair_cost_rate=repair_cost_rate,
    construction_cost=total_initial_construction_cost,
    discount_rate=discount_rate,
    period=repair_period,
    design_life=design_life
)
print("Repair and Rehabilitation Cost:", repair_component.
    calculate_cost())  # INR

# 10. Demolition and Disposal Cost Calculation
demolition_discount_rate = discount_rate
demolition_design_life = design_life
demolition_component = DemolitionCost(
    demolition_rate=demolition_rate,
    construction_cost=total_initial_construction_cost,
    discount_rate=demolition_discount_rate,
    design_life=demolition_design_life
)
print("Demolition and Disposal Cost:", demolition_component.
    calculate_cost())  # INR

# 11. Recycling Cost Calculation
recycling_design_life = design_life
user_input_steel_quantity = 0  # eg (user input, 15 MT or
    15000 kg)
```

```
user_input_steel_unit = "MT"    # eg (user input, can be 'MT'
    or 'kg')
if user_input_steel_unit.lower() == "kg":
    user_input_steel_quantity_mt = user_input_steel_quantity
        / 1000
else:
    user_input_steel_quantity_mt = user_input_steel_quantity
recycling_component = RecyclingCost(
    scrap_value=scrap_value,
    quantity=user_input_steel_quantity_mt,
    scrap_rate=scrap_rate,
    discount_rate=discount_rate,
    design_life=recycling_design_life
)
print("Recycling Cost (user-input steel only):",
    recycling_component.calculate_cost())  # INR

# 12. Reconstruction Cost Calculation
demolition_cost = demolition_component.calculate_cost()
reconstruction_cost = total_initial_construction_cost
reconstruction_carbon_cost = total_carbon_emission_cost
reconstruction_time_cost = time_cost_component.calculate_cost
    ()
reconstruction_roaduser_cost = road_user_cost_component.
    calculate_cost()
reconstruction_rerouting_carbon_cost =
    additional_carbon_emission_component.calculate_cost()
reconstruction_design_life = design_life
reconstruction_result = 0
if analysis_period > design_life:
    reconstruction_component = ReconstructionCost(
        demolition_cost=demolition_cost,
        reconstruction_cost=reconstruction_cost,
```

```
            reconstruction_carbon_cost=reconstruction_carbon_cost
                ,
            reconstruction_time_cost=reconstruction_time_cost,
            reconstruction_roaduser_cost=
                reconstruction_roaduser_cost,
            reconstruction_rerouting_carbon_cost=
                reconstruction_rerouting_carbon_cost,
            design_life=reconstruction_design_life,
            discount_rate=discount_rate
        )
        reconstruction_result = reconstruction_component.
            calculate_cost()
    else:
        reconstruction_result = 0
    print("Reconstruction Cost:", reconstruction_result)  # INR




    # --- To be connected to UI ---
    results = {
        "Total Initial Construction Cost":
            total_initial_construction_cost,
        "Total Initial Carbon Emission Cost":
            total_carbon_emission_cost,
        "Time Cost": time_cost_component.calculate_cost(),
        "Total Road User Cost": total_road_user_cost,
        "Additional Carbon Emission Cost":
            additional_carbon_emission_component.calculate_cost(),
        "Periodic Maintenance Cost":
            periodic_maintenance_component.calculate_cost(),
        "Periodic Maintenance Carbon Emission Cost":
            periodic_maintenance_concrete_carbon_component.
```

```
            calculate_cost(),
        "Total Routine Inspection Cost":
            total_routine_inspection_cost,
        "Repair and Rehabilitation Cost": repair_component.
            calculate_cost(),
        "Demolition and Disposal Cost": demolition_component.
            calculate_cost(),
        "Recycling Cost": recycling_component.calculate_cost(),
        "Reconstruction Cost": reconstruction_result
    }
```

4.4 Documentation

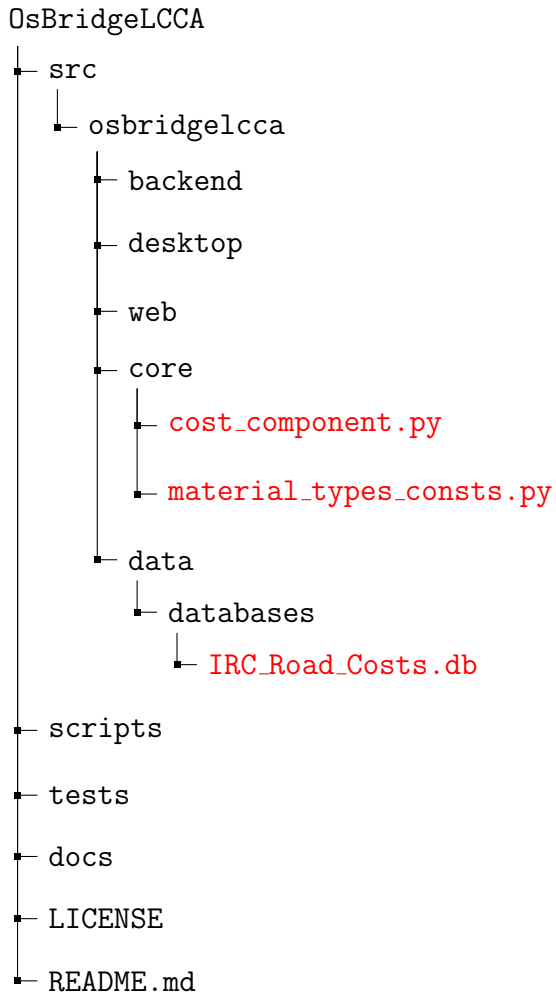
As part of the development process, detailed documentation was created for the Life Cycle Cost Assessment (LCCA) backend module in the OsBridgeLCCA project. The contribution includes:

- Comprehensive documentation of the backend script `cost_component.py`, including the class hierarchy and cost calculation logic.
- Explanation of input parameters such as material data, emission factors, construction time, discount rate, and traffic volume.
- Guide on executing the Python module, interpreting output costs, and integrating it with frontend interfaces.
- Developed and documented `material_types_consts.py`, which defines structured templates for material types, grades, units, and road user parameters such as vehicle types, lane categories, road roughness, and RF values used across the cost calculation logic and UI integrations.
- Development and documentation of the `IRC_Road_Costs.db` SQLite database, which stores cost values based on vehicle type, lane type, road roughness, and reduction factors (RF), as per IRC guidelines.

- Integration instructions for fetching cost data dynamically from the database during analysis.

The documentation is designed to support both developers and users, and is structured in a format aligned with the Osdag Developer/User Manual standards.

4.4.1 Directory Structure



Program Start Calls

The main entry point for the cost calculation module is `cost_component.py`. To execute the program, navigate to the project root and run the following command:

```
$ python src/osbridgelcca/core/cost_component.py
```

Chapter 5

Conclusions

5.1 Tasks Accomplished

The summer fellowship involved a combination of cost engineering analysis and back-end software development, contributing significantly to the integration of practical BOQ workflows and automated Life Cycle Cost Assessment (LCCA) systems. The major tasks completed are as follows:

- Conducted a comparative cost analysis of a 35-meter span Composite Steel I-Girder Bridge and a Pre-Stressed Concrete (PSC) Box Girder Bridge using detailed Bill of Quantities (BOQ) methodology.
- Reviewed and extracted unit rates from government-authorized Schedules of Rates (SORs), including USOR 2023, NH SOR, Maharashtra PT SOR 2021, and Bihar regional SORs.
- Created detailed BOQs for construction and demolition using Google Sheet, enabling real-time cost computation.
- Performed a comparative cost analysis between a Pre-Stressed Concrete (PSC) Box Girder Bridge and a Composite Steel I-Girder Bridge for a 35-meter span to highlight structural and locational cost variability.
- Developed a Python-based backend module for automating LCCA across various components: construction, carbon emissions, road user costs, maintenance, inspection, repair, demolition, recycling, and reconstruction.

- Authored `cost_component.py`, applying object-oriented principles to model cost components with present worth factor calculations.
- Created the `IRC_Road_Costs.db` SQLite database to support real-time road user cost estimation based on IRC specifications.
- Developed the `material_types_consts.py` module for structured definition of materials, grades, units, and traffic parameters.
- Documented the structure, logic, and implementation of all scripts and tools developed, aligning with professional open-source and academic standards.

5.2 Skills Developed

The summer fellowship provided valuable technical and analytical learning, fostering skills in both engineering and software development domains:

- **BOQ and Cost Analysis**: Gained hands-on experience in preparing Bill of Quantities using standard SORs, along with lifecycle cost integration.
- **Python Programming & OOP**: Enhanced proficiency in modular Python programming, class-based structures, and reusable logic design.
- **LCCA Implementation**: Developed a working understanding of Life Cycle Cost Assessment, with environmental and time-based cost modeling.
- **Data Structuring and Integration**: Built and queried a structured SQLite database for dynamic data retrieval based on traffic and road parameters.
- **Material and Rate Definition**: Engineered data templates for managing material types, grades, and units across BOQ and LCCA systems.
- **Documentation & Reporting**: Created technical documentation and BOQ tables formatted for clarity, traceability, and integration into platforms like Osdag.
- **Analytical Thinking & Regional Sensitivity**: Applied engineering judgment to study regional cost variability, transportation effects, and project feasibility across geographies.

Bibliography

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[2] FOSSEE Project. FOSSEE News - January 2018, vol 1 issue 3. Accessed: 2024-12-05.

[3] FOSSEE Project. Osdag website. Accessed: 2024-12-05.