

Civil Engineering Insight Studio

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INTRODUCTION

1.1 Project Overview

This project, titled “**Civil Engineering Insight Studio**,” is developed as part of the **SmartBridge Virtual Internship Program**. The objective of this project is to address the challenge of manually describing structures based on images, which can be time-consuming and subjective.

Without automated tools, generating detailed descriptions of civil engineering structures, including types, materials, dimensions, construction methods, and notable features, requires significant human effort and expertise. To address this challenge, there is a need for an efficient and reliable tool that can automatically analyze images of civil engineering structures and generate insightful descriptions, enabling engineers to make informed decisions and communicate effectively about their projects.

1.2 Purpose

The main purpose of this project is to apply theoretical knowledge of artificial intelligence and large language models(LLM) to build a practical solution for a real-world problem. This project helps in understanding data processing, model integration, and system development using Python and related technologies.

The project also provides hands-on experience and improves problem-solving and technical skills.

IDEATION PHASE

1.3 Problem Statement

Civil engineers are responsible for the safety and longevity of critical infrastructure. Currently, assessing the structural integrity of bridges often involves **manual visual inspections**, which are labor-intensive, subjective, and can pose safety risks to the inspectors.

The goal is to develop the **Civil Engineering Insight Studio**, an AI-driven diagnostic tool. This tool must bridge the gap between raw visual data and actionable engineering intelligence by

Automating Component Identification: Using deep learning to distinguish between various structural members

Technical Characterization: Extracting material types, estimated dimensions, and construction methods from image metadata and visual cues

Risk Highlighting: Pinpointing anomalies, engineering challenges, or environmental stressors (e.g., corrosion, shear cracks) that require immediate human intervention

1.4 Empathy Map Canvas

The Empathy Map Canvas is used to understand the users, their problems, emotions, and expectations. This helps in designing a user-centric solution.

What the User Thinks

- Wants to understand complex civil engineering structures.
- Expects accurate risk reports in designing patterns.

What the User Feels

- Frustrated when unable to understand a structures

What the User Says

- “I cannot understand this construction models”
- “I need a quick and accurate LLM model to analyze the structures.”

What the User Does

- Uses online tools
- Tries manual ways to understand.

User Pain Points

- Takes a lot of time.
- And result is not accurate .

User Needs

- Use LLM models.
- Easy-to-use application

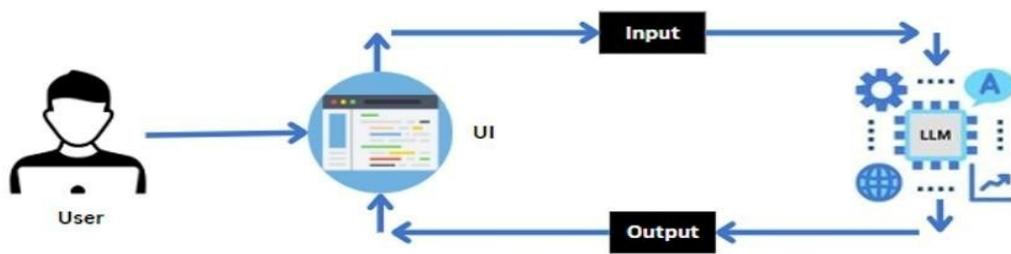
1.5 Brainstorming

During the brainstorming phase, different approaches were discussed to solve the civil engineering problem. These included different temple architectures and different construction sites images.

After evaluating all options, the AI-powered approach was selected because it provides better accuracy, scalability, and reduces a lot of human efforts by analyzing the structural components.

The Customer Journey Map explains the sequence of steps followed by the user while interacting with the system. It helps in understanding how the user experiences the application from start to end.

The journey begins when the user opens the application and enters an image to analyze the gemini model and quickly identifies the structures and the components used and gives the risk analysis report.



3.2 Solution Requirements

This section describes the functional and non-functional requirements of the proposed system.

Functional Requirements

- **Image Upload:** Must allow users to upload high-resolution images of bridge structures.
- **Component Labeling:** Must automatically identify and bound boxes around beams, columns, and trusses.
- **Material Detection:** Must classify whether a component is made of steel, concrete, or wood.
- **Dimension Estimation:** Must calculate approximate lengths and thicknesses of visible members.
- **Damage Detection:** Must highlight visual anomalies like cracks, rust, or spalling.
- **Report Generation:** Must produce a downloadable summary of all identified parts and their condition.

Non-Functional Requirements

Accuracy: The system must achieve at least 90% precision in component identification.

Performance: Image analysis must be completed and displayed within 15 seconds of upload.

Scalability: The platform must support multiple simultaneous uploads from different field engineers.

Availability: The service must be accessible 24/7 for emergency structural inspections.

Security: Infrastructure data must be encrypted to protect sensitive public safety information.

3.3 Data Flow Diagram

The Data Flow Diagram (DFD) explains how data moves within the system during the analysis process.

The user inputs the image and the system cleans the image and removes noise and generates the risk analysis report.



3.4 Technology Stack

The following technologies are used in the development of this project:

- **Programming Language:** Python
- **Framework:** Streamlit (for building the web-based user interface)
- **Libraries:** Google Gen ai, Python-dotenv

- **Development Tools:** VS Code, Git, Github

PROJECT DESIGN

1.6 Problem–Solution Fit

The main problem identified in this project is the analysis of difficult structural patterns in the real world.

The proposed AI-powered LLM to identify the structures and complex designing patterns and building and sight architectures to generate the risk analysis report and minimum time consuming to complete the project.

1.7 Proposed Solution

The proposed solution is an AI-based application that enables users to analysis the sight structures. The working of the system is described below:

- **User Input:** Users provide descriptions and upload images of civil engineering structures.
- **Backend Processing:** Input data is analyzed by specialized algorithms.
- **Insight Generation:** Detailed descriptions and related information are autonomously generated.
- **Frontend Display:** Generated insights and information are presented on the user interface.

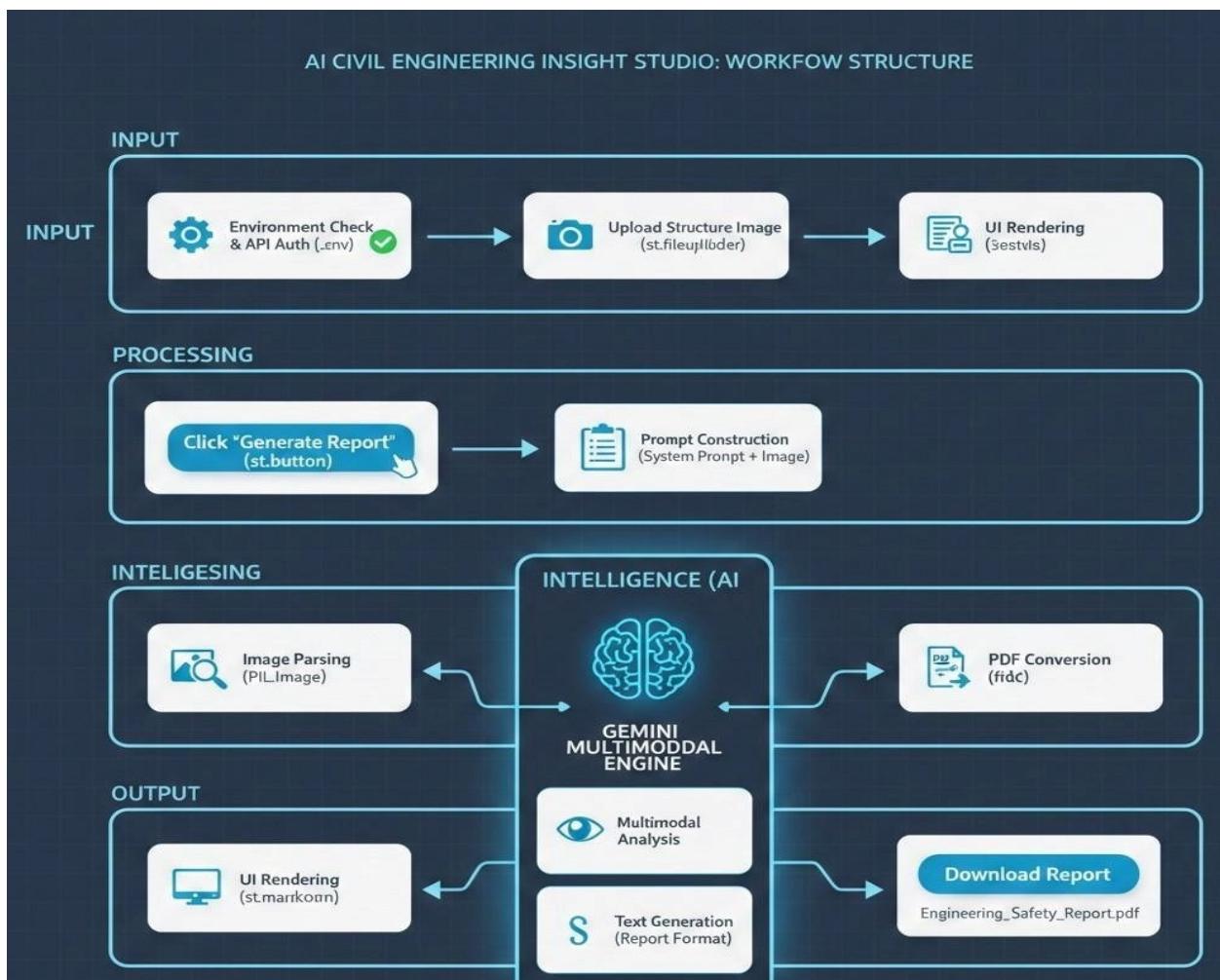
1.8 Solution Architecture

The solution architecture explains the overall structure of the system and how different components interact with each other.

The architecture consists of the following components:

- User Input: Users provide descriptions and upload images of civil engineering structures.
- Backend Processing: Input data is analyzed by specialized algorithms.
- Insight Generation: Detailed descriptions and related information are autonomously generated.
- Frontend Display: Generated insights and information are presented on the user interface.

These components work together in a sequential manner to ensure accurate and efficient analysis..



PROJECT PLANNING AND SCHEDULING

Project planning plays an important role in completing the project in a systematic and organized manner. The planning of the project was carried out in the following stages:

- **Requirement Analysis**

Understanding the problem, defining project objectives, and identifying user needs.

- **Design Phase**

Designing the system architecture and defining the interaction between different components.

- **Development Phase:**

Implementing the application using Streamlit and integrating Google Gemini Generative AI models.

- **Testing Phase:**

Testing the application for risk analysis report, response time, and user interaction.

- **Deployment Phase:**

Running the application locally using Streamlit and preparing it for further enhancements.

This phased approach helped in managing the project efficiently and reducing development errors.

5.2 Project Scheduling

The project schedule was planned to complete all activities within a total duration of **20 days**, as per the SmartBridge internship timeline. Each phase was carefully allocated time to ensure proper implementation, testing, and documentation of the project.

The scheduling of the Civil engineering insight studio project is shown below:

Phase	Activity	Duration
Phase 1	Requirement Analysis	3 Days
Phase 2	System Design	3 Days
Phase 3	Application Development	7 Days
Phase 4	Testing and Debugging	4 Days
Phase 5	Deployment and Documentation	3 Days

FUNCTIONAL AND PERFORMANCE TESTING

1.9 Functional Testing

Functional testing is performed to verify that all features of the Civil engineering insight studio application work according to the specified requirements.

The following functional tests were conducted:

- Verification of image functionality
- Validation of source and targeted patterns
- Checking correct integration with Google Gemini Generative AI
- Verification of resulted output display
- Validation of secure API key handling using environment variables

All functional requirements were tested successfully, and the system performed as expected.

1.10 Performance Testing

Performance testing is conducted to evaluate the response time and efficiency of the application.

The Civil engineering insight studio application was tested for:

- Risk analysis report
- Stability during multiple requests
- Smooth interaction between the web interface and AI model

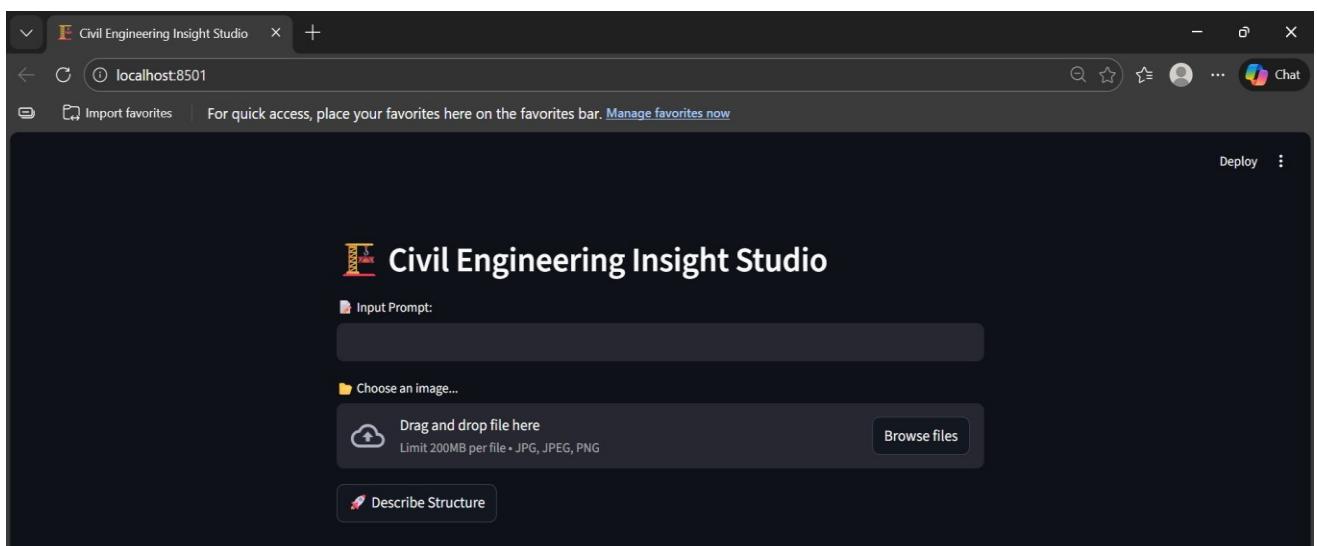
7.RESULT

The Civil engineering insight studio application was successfully developed and tested using Streamlit and Google Gemini Generative AI. The system provides accurate and best risk reports .

The application interface consists of:

- It contains the browse media button to input the image.
- It contains the download pdf button to download the report as pdf format.
- It has the gemini api integration.

7.1 output screenshots





Uploaded Image

Civil Engineering Insight Studio +

localhost:8501

Import favorites | For quick access, place your favorites here on the favorites bar. [Manage favorites now](#)

Deploy :

Civil Engineering Insight Studio

Input Prompt:

You are a civil engineering expert. Analyze the uploaded image and provide: 1. Type of structure 2. Mat

Choose an image...

Drag and drop file here
Limit 200MB per file • JPG, JPEG, PNG

roadbridge.jpeg 7.0KB

X

📌 Describe Structure

📌 Description of the Civil Engineering Structure:

As a civil engineering expert, I've analyzed the provided image of the bridge structure. Here's a detailed breakdown:

Civil Engineering Analysis of the Bridge Structure

1. Type of Structure: The structure is a **multi-span road bridge** designed to carry vehicular traffic over a significant water body, likely a fjord, estuary, or large river. Based on the visible structural elements:

- The **main span** over the deepest part of the water is a **steel deck truss bridge**. The primary load-bearing members form a truss system located *below* the bridge deck, allowing the roadway to sit directly on top of the truss. This configuration is common for achieving long spans while maintaining a relatively low vertical profile for the deck itself.
- The **approach spans** leading to the main truss section appear to be either **steel girder** or **reinforced concrete girder** bridges, supported by piers. These have a simpler, more uniform cross-section compared to the main truss.

- compared to the main cross.
- A defining characteristic is its **significant curvature**, making it a **curved bridge**. This adds considerable complexity to both design and construction.

In summary, it's a **hybrid multi-span, curved road bridge**, predominantly featuring a steel deck truss for its main crossing and likely girder construction for its approaches.

2. Materials Used:

- **Superstructure (Main Span Truss):** Clearly constructed from **structural steel**. The individual members (chords, diagonals, verticals) are visible and appear to be fabricated steel sections (e.g., built-up I-sections or box sections), connected using bolted or welded joints.
- **Superstructure (Approach Spans):** Likely **reinforced concrete** (pre-stressed or post-tensioned girders) or **structural steel** girders, supporting a concrete deck slab. Given the overall aesthetic and the main span, steel girders are a strong possibility for continuity.
- **Bridge Deck:** Consists of an underlying **reinforced concrete slab**, which provides the structural base for the roadway, topped with an **asphalt concrete pavement** for the driving surface.
- **Substructure (Piers):** All visible piers supporting both the main truss and the approach spans are constructed from **reinforced concrete**. They vary in size, with the main truss piers being substantially larger and more robust.
- **Foundations:** Not directly visible, but given the water crossing and the scale of the structure, deep foundations such as **reinforced concrete piles** or **caissons** would be essential, anchored into competent bedrock or suitable bearing strata.

3. Dimensions (if possible): Without any scale reference objects, precise dimensions are impossible to ascertain. However, we can make informed estimations:

- **Total Length:** The bridge spans a wide water body with significant approaches. The total length could easily be in the range of **300 to 600 meters (1,000 to 2,000 feet)**.
- **Main Span Length:** The longest span of the steel truss appears to be substantial, perhaps in the range of **100 to 180 meters (330 to 600 feet)**.
- **Width:** The bridge deck accommodates a two-lane roadway (one lane in each direction) with narrow shoulders. A typical two-lane highway width (including shoulders and barriers) would be approximately **10 to 13 meters (33 to 43 feet)**.
- **Vertical Clearance (from water):** There appears to be significant navigational clearance beneath the main truss span, possibly in the range of **20 to 30 meters (65 to 100 feet)**, depending on the requirements of the waterway.
- **Truss Depth:** The structural depth of the main steel truss itself looks to be around **15 to 25 meters (50 to 80 feet)** to provide the necessary rigidity for the span.
- **Curvature Radius:** The bridge exhibits a pronounced curve, making it a prominent feature. The radius of curvature would be considerable, but significantly less than for a straight bridge, introducing complex geometric challenges.

- **Steel Truss Erection:** The steel truss members would have been **pre-fabricated** in sections off-site and then transported to the site. Erection could involve several methods:
 - **Cantilever construction:** Sections are lifted by large **cranes** (either land-based, if accessible, or barge-mounted) and progressively connected from each pier, with temporary falsework or stay cables potentially used for support during connection.
 - **Barge-mounted heavy lift:** Larger pre-assembled truss segments could have been floated into position and lifted by heavy-lift cranes or strand jacks.
 - Given the curvature, precise geometric control and surveying would have been paramount during steel erection to ensure proper alignment and fit-up of members.
- **Approach Spans:** Depending on the material:
 - **Precast girders:** Transported to site and lifted into place by cranes.
 - **Cast-in-place concrete girders:** Constructed using extensive temporary falsework and formwork.
 - **Steel girders:** Fabricated, transported, and lifted by cranes, then typically connected with field welds or high-strength bolts.
- **Deck Construction:** A **cast-in-place concrete deck slab** would be constructed on top of the supporting girders and truss, using formwork. This would then be cured, and finally, the **asphalt concrete pavement** laid.

5. Notable Features or Engineering Challenges:

- **Significant Curvature:** This is the most outstanding feature. Designing and constructing a curved truss bridge is immensely more complex than a straight one. It introduces:
 - **Torsional stresses:** Due to eccentric loading and geometric effects, the bridge experiences significant twisting forces.
 - **Complex member forces:** Axial, shear, and bending forces in truss members are distributed differently and are more intricate to analyze.
 - **Geometric control:** Fabrication and erection require extremely precise measurements and alignment to achieve the desired curved profile without introducing locked-in stresses or fit-up issues.
 - **Dynamic behavior:** Vibration characteristics can be more complex for curved structures.
- **Hybrid Structure:** Integrating different structural systems (steel truss and girder approaches) requires careful design of transition zones to ensure smooth load transfer and structural continuity.
- **Marine Environment Construction:**
 - **Deep Foundations:** Constructing robust foundations in water, especially potentially deep or challenging geological conditions, requires specialized equipment and expertise to manage water intrusion, scour, and seismic risks.
 - **Logistics:** Transporting large components and construction equipment over water and managing work within environmental regulations.
 - **Weather Dependency:** Marine operations are highly sensitive to wind, waves, and currents.

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 - **Weather Dependency:** Marine operations are highly sensitive to wind, waves, and currents.
- **Long Span Aesthetics:** The bridge beautifully integrates with the natural landscape, showcasing how complex engineering can also be aesthetically pleasing, especially with the sweeping curve.
- **Load Analysis:** For a curved bridge, advanced structural analysis techniques (e.g., 3D finite element analysis) would be critical to accurately model stress distribution under various loading conditions, including vehicle live loads, wind, seismic forces, and thermal expansion/contraction.
- **Material Fatigue:** For a steel truss bridge, particularly one subjected to dynamic vehicle loads and potential wind-induced vibrations, fatigue analysis is a critical design consideration to ensure long-term durability.

This bridge represents a significant civil engineering achievement, combining functionality, structural integrity, and a distinctive aesthetic in a challenging environment.

8. ADVANTAGES & DISADVANTAGES:

Advantages

Faster Inspections: Turns days of manual work into seconds of automated analysis.

Enhanced Safety: Keeps engineers off dangerous high-climbing gear by using photos.

Total Consistency: Eliminates human bias by using the same "digital eye" for every bridge. **Early Warnings:** Spots tiny cracks or rust before they become expensive disasters.

Disadvantages

Quality Dependent: If the photo is blurry or dark, the AI can't see the problems.

False Alarms: The system might mistake a shadow or bird dropping for a real crack.

Surface Level: It can only analyze what it sees, missing internal structural rot.

High Startup Cost: Building a smart enough AI requires a lot of data and money.

9. CONCLUSION

The **Civil Engineering Insight Studio** successfully demonstrates that AI can transform raw visual data into critical safety intelligence. By automating the identification of structural components and flagging high-risk areas—as seen in the "High" Risk Assessment Score of the inspection report—this project proves that we can make infrastructure monitoring **faster, safer, and more consistent** than traditional manual methods. Ultimately, this tool serves as a vital second set of eyes for engineers, ensuring that even complex high-rise constructions are held to the highest safety standards through continuous, data-driven vigilance.

10. FUTURE SCOPE

- **Drone Integration:** Automating data collection by syncing the AI with autonomous drones to reach inaccessible bridge under-pinnings.
- **Digital Twins:** Creating 3D virtual models of bridges that update in real-time as new photos are uploaded to track aging over decades.
- **Predictive Maintenance:** Using historical data to "predict" exactly when a beam will fail before any visible cracks even appear.
- **Satellite Monitoring:** Scaling the system to use high-resolution satellite imagery for monitoring thousands of bridges across entire countries simultaneously.
- **Sensor Fusion:** Combining visual AI with "Internet of Things" (IoT) vibration sensors to hear structural stress that the eye cannot see.

APPENDIX

The complete source code of the project **Civil Engineering Insight Studio** is maintained using GitHub for version control. The repository contains all application files, configuration files, and documentation required to understand and run the project.

🔗 GitHub Repository Link:

<https://github.com/Navya2906/CivilEngineering-Insight-Studio/tree/main>

Repository Contents:

- app.py – Main Streamlit application file
- requirements.txt – List of required dependencies
- README.md – Project description and usage instructions
- .env file – contains the api key

Using GitHub helped in maintaining proper version control and following professional software development practices.

11.2 Security Implementation

The Civil Engineering Insight Studio project uses **Google Gemini Generative AI API keys** to perform image analysis. Security was given high priority during development.

The following secure practices were implemented:

- API keys are stored securely using environment variables
- A .env file is used to store the Google API key
- The .env file is excluded from GitHub using .gitignore
- API keys are never hardcoded in the source code

These practices ensure secure handling of sensitive credentials and prevent unauthorized access or key leakage.

video link :

https://drive.google.com/file/d/142Rb25vib1EcMj_jgZ4PgaJ--UC14TWPv/view?usp=drive_link