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.
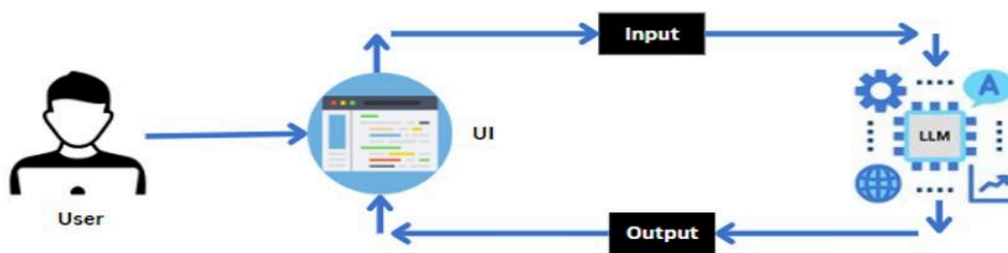
- Easy-to-use application

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 effects by analyzing the structural components.

REQUIREMENT ANALYSIS

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.

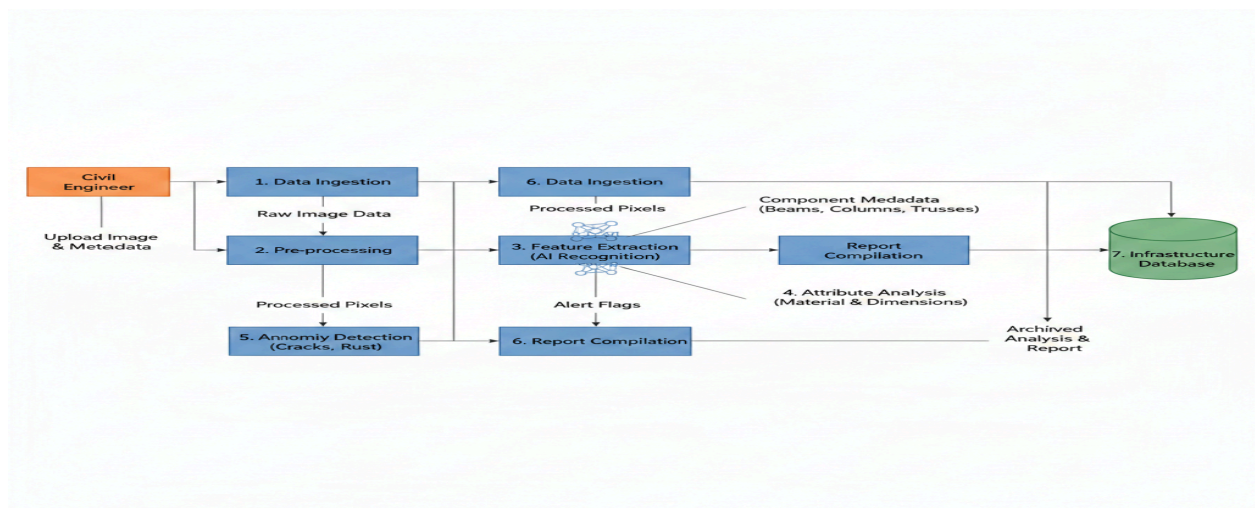**Scalability:** The platform must support multiple simultaneous uploads from different field engineers.

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.
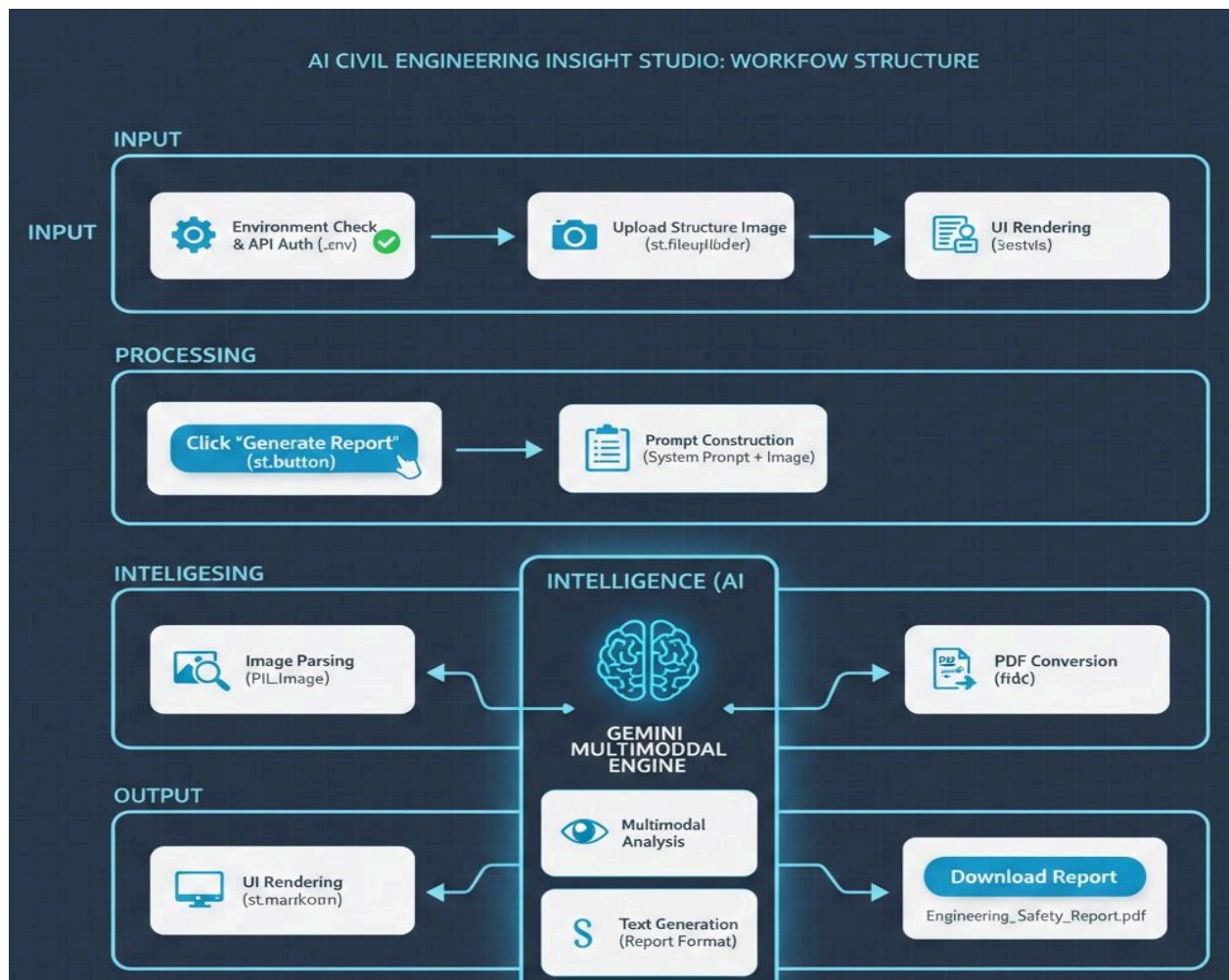- **Frontend Display:** Generated insights and information are presented on the user interface.

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 Analysi**s

  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 theCivil 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 Site Photo

Generate Engineering Report

📊 **Engineering & Safety Report**

OFFICIAL SITE INSPECTION REPORT

ATTENTION: Site Supervisor / Project Manager **PREPARED BY:** Senior Structural and Safety Engineer

1. RISK ASSESSMENT SCORE: HIGH

While the site appears organized, the inherent nature of high-rise reinforced concrete construction carries a high risk profile. The combination of active overhead concrete work, a high density of temporary shoring, and numerous unprotected or semi-protected perimeters necessitates constant vigilance and strict adherence to safety protocols.

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2. STRUCTURAL TYPE & MATERIALS

- **Structural System:** Reinforced Concrete Frame (Cast-in-place columns and flat-plate slabs).
- **Primary Materials:** High-strength reinforced concrete (columns and slabs).
- **Secondary Materials (Infill):** Cold-formed steel (CFS) metal stud framing used for exterior curtain wall backing and interior partitions on lower levels.
- **Temporary Materials:** Steel adjustable shoring/reshoring posts (the orange vertical members) and modular aluminum/steel formwork systems.

3. CONSTRUCTION PHASE

- **Phase:** Vertical Superstructure / Shell & Core.

framing. The middle levels are in the curing phase, and the upper-most level is currently in the formwork/reinforcement stage, preparing for a subsequent concrete pour.

4. ⚠️ SAFETY ALERT FLAGS

- **Perimeter Fall Hazards:** While some temporary orange mesh and metal railings are visible on the middle floors, the topmost active levels appear to have minimal edge protection beyond the formwork itself. Standardized guardrail systems must be extended to the highest point of activity immediately.
- **Falling Object Risk:** There is a significant amount of loose material (metal studs, formwork components) stored near open edges. Without debris netting installed on the building exterior, the "Drop Zone" below remains a critical hazard area.
- **Shoring Stability:** The extremely high density of reshoring on the middle levels indicates that those slabs are currently carrying the "live" weight of the wet concrete and construction equipment from the floors above. Any

5. ENGINEERING INSIGHT

- **Load Distribution (Reshoring Strategy):** This image perfectly illustrates the "Reshoring" process. Because a newly poured concrete slab takes weeks to reach full design strength, it cannot support its own weight *plus* the weight of the floor being poured above it. The orange poles (reshores) are designed to transfer these massive temporary construction loads down through multiple levels of cured concrete until the load is eventually absorbed by the foundation.
- **Transfer of Forces:** The massive cylindrical columns at the base level are designed to handle the cumulative vertical dead load of the entire structure. The transition from these heavy columns to the lighter metal stud framing on the exterior shows a clear distinction between the

Disclaimer: This report is based solely on a visual analysis of the provided image and does not constitute a full, legal, or on-site safety inspection. All local OSHA/HSE regulations must be followed.

⬇️ Download Report as PDF

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/Civil Engineering Insight Studio

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 : civil engineering insight studio