**Innovative AI Solutions for Smart Construction**

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Date: [date of final presentation]

**Final Approval**

This is to certify that we have read the report submitted by ***Mir Allahyar Khan Talpur (36527), Syed Touqeer Hussain Shah (32161), Haider Ali (32404)*** for the partial fulfillment of the requirements for the degree of the Bachelors of Science in Computer Science (BSCS). It is our judgment that this report is of sufficient standard to warrant its acceptance by Riphah International University, Islamabad for the degree of Bachelors of Science in Computer Science (BSCS).

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**Declaration**

We hereby declare that this document “**Innovative AI Solutions for Smart Construction**” neither as a whole nor as a part has been copied out from any source. It is further declared that we have done this project with the accompanied report entirely on the basis of our personal efforts, under the proficient guidance of our teachers, especially our supervisor **Mubariz Rehman**. If any part of the system is proved to be copied out from any source or found to be reproduction of any project from anywhere else, we shall stand by the consequences.

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**Dedication**

Our project is dedicated to our parents, seniors, friends and our supervisor “Mubariz Rehman” whose unwavering support, guidance and inspiration have been instrumental to its success. We are deeply grateful for their love and encouragement throughout this journey. Their belief in us has fueled our determination to overcome challenges and achieve our goals. This achievement stands as a testament to their continuous care and mentorship and we dedicate every millstone to them.

**Acknowledgement**

First of all, we are obliged to Allah Almighty the Merciful, the Beneficent and the source of all Knowledge, for granting us the courage and knowledge to complete this Project.

We would like to express our sincere gratitude to our project supervisor “Mubariz Rehman” whose invaluable guidance, advice, and constant support have played a key role in the successful completion of this project. Without his expertise and encouragement this work would not have been possible.

We are also deeply thankful to our parents and family whose unwavering support and belief in us have been a constant source of strength. They have instilled in us the values of honesty, hard work and perseverance which have been instrumental in the completion of this project.

Our heartfelt thanks go to our teachers, classmates and friends for their encouragement and assistance throughout this journey. Their collective support has helped us stay motivated and focused making this achievement even more meaningful.

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**Abstract**

As technology continues to reshape industries, AI is opening up exciting possibilities in construction, making complex tasks easier and more accessible for everyone involved. Our project, **Innovative AI Solutions for Smart Construction**, introduces a user-friendly platform designed to simplify the construction process, especially for homeowners and contractors. With this platform, users can generate front elevation designs for their homes by simply entering details like plot size, making professional design accessible at their fingertips.

Beyond design, the platform also provides detailed cost estimates, factoring in current market rates with material and without material, so users have a clear understanding of their budget right from the start. Additionally, the platform fosters community by offering a chat feature where users, contractors, and service providers can interact, ask questions, and share insights. For added convenience, a bidding system allows contractors to submit project proposals, enabling users to make informed choices that suit both their vision and budget. This blend of AI-driven design, cost transparency, real-time interaction, and competitive bidding aims to transform residential construction into a more seamless, efficient, and personalized experience for everyone involved.

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# Abstract

A web-based platform called **Innovative AI Solutions for Smart Construction** is created with the goal of streamlining the home construction planning process. This application is developed with the **MERN** (*MongoDB, Express, React, Node.js*) **Stack**, uses generative AI to automatically generate front elevation designs so that users can easily visualize the front of their home. Additionally, the platform offers a **cost calculation tool** that provides customers with clear financial insights for their projects by estimating expected construction prices based on current labor and material market rates. For seamless communication, a **community chatbot** facilitates real-time interaction, allowing users, contractors and service providers to connect and collaborate effortlessly. Additionally, a **bidding featu**re enables user to submit competitive proposals, giving users the flexibility to choose the best fit for their project. With its unique combination of AI-driven design, budget clarity, interactive community support and a streamlined bidding process, this platform offers a complete solution that simplifies construction planning for house.

# Introduction

The real estate construction industry has always faced challenges with using modern technology. This has led to inefficiencies, poor coordination and major delays in projects. Even though platforms like Houzz and Thumbtack help with specific tasks such as design and managing vendors, they don’t cover the entire construction process. This makes things harder for homeowners, contractors and others involved in building houses. As a result, there are many problems like inaccurate cost estimates, project delays and communication issues among various stakeholders.

To solve these problems, this project proposes a web-based platform that uses artificial intelligence (AI) to make the construction process smoother. The idea is to use AI for house design, estimating costs and improving communication between everyone involved. This platform will make the whole process more efficient, reduce the need for in-person meetings and speed up decision-making. The goal is to create a seamless, integrated solution that improves coordination, cuts down on delays and ensures more accurate cost estimates. This will lead to construction projects being completed in a more efficient and cost-effective way.

The proposed platform will use Deep learning, specifically a DCGAN (Deep Convolutional Generative Adversarial Network) model, to generate house designs based on user preferences. Users can input their plot dimension and the AI will create realistic front elevation designs for houses. It will also provide accurate cost estimates based on current market prices. In addition, the platform will include a community chat feature to allow homeowners, contractors and service providers to communicate easily and work together throughout the construction process. With a dataset of 500-600 images of house designs, the AI model will be able to create detailed and realistic house plans for standard plot sizes.

This chapter introduces the key issues in the real estate construction industry, explains why using AI is important for improving the construction process, and outlines the goals of the project. The next sections will go into more detail about the specific objectives and the scope of the project, offering a clear plan for developing and implementing the platform.

## Goals and Objectives

**Goals:**

* To provide an AI-powered platform that integrates design, cost estimation and vendor communication in the real estate construction industry.
* To streamline the house construction process by automating design generation and providing accurate cost estimates.
* To improve communication and collaboration between stakeholders, reducing the need for in-person meetings and accelerating project decision-making.

**Objectives:**

* To develop a system that uses Deep learning algorithms (DCGAN) to generate front elevation designs.
* To implement a cost estimation tool that calculates construction costs using current market rates and material costs.
* To facilitate collaboration between contractors, service provider and homeowners through an integrated community chat feature.
* To address the issues of poor coordination, inaccurate cost estimates and delays commonly experienced in the traditional construction process.

## Scope of the Project

The scope of this project includes the development of a web-based platform built on AI technologies, with the following key features:

* **AI-Based Design Generation**: The platform will allow users to generate customized front elevation designs of houses using Deep Learning algorithm (DCGAN).
* **Cost Estimation**: The system will provide accurate cost estimates for house construction based on current market rates, material costs and user-specific preferences.
* **Community Chat**: A feature that enables communication and collaboration among different stakeholders, including homeowners, contractors, service provider and other parties involved in the construction process.
* **Bidding System**: It allows users to submit their project proposal, which are then displayed to all contractors. This ensures contractor can review various projects, understand the requirements and make informed decisions based on their expertise, vision and budget alignment.
* **Contractor and service provider**: It allow user to find contractor and service provider.
* **Data Set**: The platform will use a dataset of 500-600 images of front house elevations, collected from various architectural sources, to train the AI model.

The project will focus on integrating the main elements Design, cost estimation, Bidding system, find contractor, find service provider and communication—into a single platform, with the goal of improving overall efficiency, reducing delays and minimizing errors in cost Calculation. The platform will be accessible online, providing an easy-to-use interface for homeowners and contractors to interact and collaborate efficiently. Future versions of the platform may expand to include additional features or support a wider range of architectural designs.

# Literature Review

## Introduction

The advent of artificial intelligence (AI) and deep learning has revolutionized various fields, including the construction and architecture domains, where traditional practices are increasingly augmented by computational methods. One significant breakthrough in AI is the development of Generative Adversarial Networks (GANs), first introduced by Goodfellow et al. in 2014. GANs employ a unique adversarial framework, consisting of two neural networks—the generator and the discriminator—that work together to produce synthetic data that closely mimics real-world datasets. Over the years, the capabilities of GANs have been extended to various applications, such as image synthesis, design generation, and data augmentation, driving innovations across diverse industries.

In architectural design, particularly in generating house elevations, GANs offer an unprecedented opportunity to enhance creative processes, enabling designers to explore numerous aesthetic possibilities while adhering to structural and spatial constraints. The challenge of manually designing front elevations is not only time-consuming but also constrained by the creativity and experience of individual designers. GANs address these challenges by automating the generation of diverse and innovative designs based on learned patterns, reducing human effort and increasing efficiency.

The motivation for this research lies in addressing the practical needs of architects and construction professionals by leveraging GANs to automate and optimize the design process for house front elevations. With the growing interest in generative models, the focus has shifted toward harnessing the potential of GANs for high-quality, realistic design outputs that cater to aesthetic preferences and functional requirements.

This literature review aims to explore the evolution, applications, and challenges of GANs in related fields, analyzing their potential to innovate front elevation design. Five significant research papers are reviewed in detail, each contributing unique insights into the implementation of GANs for generative modeling. This review sets the foundation for understanding the state-of-the-art technologies and identifying gaps that guide the scope of this research.

The subsequent sections will elaborate on the historical background, existing challenges, and technological advancements that have shaped the development of GANs, followed by a detailed analysis of related research, definitions, and a consolidated summary of findings to establish the groundwork for developing a GAN-based approach to generate house front elevations.

## Background and Problem Elaboration

The field of architectural design and construction has long relied on manual methods and rule-based systems to create building designs, including house front elevations. These traditional methods, while effective, are often labor-intensive, time-consuming, and limited by human creativity. As demands for personalized, aesthetically pleasing, and structurally sound designs increase, there is a need for innovative solutions that can automate the design process while maintaining high-quality outputs.

Generative Adversarial Networks (GANs) have emerged as a promising solution in the domain of generative modeling. Introduced by Goodfellow et al. in 2014, GANs utilize a dual-network structure—a generator that creates synthetic data and a discriminator that evaluates its authenticity. This adversarial training approach enables GANs to learn complex data distributions and produce high-quality outputs, making them ideal for applications such as image synthesis, data augmentation, and creative design generation.

Despite their potential, GANs face several challenges, particularly when applied to the construction and architectural sectors. Training GANs is computationally intensive and requires substantial data, which is often scarce in the construction domain. Additionally, issues such as training instability, mode collapse, and vanishing gradients can hinder their performance. For architectural applications, GANs must generate designs that are not only visually appealing but also adhere to structural and spatial constraints—a complex task requiring a balance between aesthetic and functional considerations.

In the context of generating house front elevations, traditional methods often struggle to address the diverse stylistic preferences of homeowners while maintaining practical feasibility. Designers must account for numerous variables, including cultural influences, environmental factors, and material constraints, making the manual design process both intricate and repetitive. Existing automated systems, such as rule-based or parametric design tools, lack the creative adaptability needed to produce novel and diverse designs.

The problem is further compounded by the lack of comprehensive datasets that capture the diversity of architectural styles and elements necessary for training robust generative models. This scarcity of data often leads to overfitting or limited generalization in GAN-based models, reducing their effectiveness in real-world applications. Additionally, integrating GAN-generated designs into existing workflows remains a challenge, as the outputs must meet industry standards for safety, durability, and sustainability.

This research seeks to address these challenges by leveraging GANs to automate the generation of house front elevations. By exploring advancements in GAN architectures and training methodologies, this study aims to develop a solution that combines creativity with practicality, enabling the generation of diverse and high-quality designs that cater to both aesthetic and structural requirements. The review of related works will provide insights into existing approaches, highlight their limitations, and identify opportunities for innovation in this field.

## Detailed Literature Review

The literature review aims to provide a comprehensive understanding of the advancements, applications, and challenges of Generative Adversarial Networks (GANs) in various domains, with a particular focus on their potential for generating house front elevations.

### Definitions

1. **Generative Adversarial Networks (GANs):** Introduced by Goodfellow et al. (2014), GANs consist of a generator that produces synthetic data and a discriminator that evaluates its authenticity. The adversarial process between these networks enables GANs to learn data distributions and generate realistic outputs.
2. **Conditional GANs (cGANs):** A GAN variant where the generator is conditioned on auxiliary information (e.g., labels or images), allowing controlled data generation for specific applications such as labeled house elevations.
3. **Deep Convolutional GANs (DCGANs):** A GAN architecture leveraging convolutional layers to generate high-resolution images. It improves the stability of GAN training and is widely used for image synthesis tasks.
4. **Least Squares GANs (LSGANs):** A GAN variant that replaces the traditional cross-entropy loss with a least-squares loss to address vanishing gradients and enhance training stability, producing higher-quality outputs.
5. **U-Net Architecture:** Originally designed for biomedical segmentation, U-Net has been adapted for GAN frameworks due to its ability to capture both contextual and localization features. It is particularly effective in tasks requiring high spatial resolution.
6. **Mode Collapse:** A common issue in GANs where the generator produces limited diversity, failing to capture the full range of the target data distribution.
7. **f-Divergence:** A statistical measure related to GANs, including the Pearson χ² divergence minimized in LSGANs, influencing the model's ability to generate realistic outputs.

### Related Research Work 1

Goodfellow et al. (2014) [1] introduced Generative Adversarial Networks (GANs), marking a transformative advancement in generative modeling. The framework involves two neural networks, a generator and a discriminator, competing in a zero-sum game to improve each other's performance. GANs can learn complex data distributions, enabling the creation of synthetic data that closely resembles real-world datasets. However, the initial GAN model faced challenges like training instability and mode collapse, necessitating further architectural improvements. This foundational work established the groundwork for subsequent GAN variants and applications, including image synthesis and design generation.

**GAN Architecture to generate the new images.**



Figure 1 : Gan Architecture

### Related Research Work 2

Radford et al. (2015) [2] proposed Deep Convolutional GANs (DCGANs), an architectural enhancement of GANs that replaced fully connected layers with convolutional layers. This modification improved the stability and quality of GAN outputs, enabling the generation of high-resolution synthetic images. DCGANs demonstrated their effectiveness in unsupervised representation learning, making them highly suitable for visual domains such as architectural design. By leveraging convolutional features, DCGANs set a benchmark for applying GANs in tasks requiring high-quality and detailed visual outputs, such as generating house elevations.

### Related Research Work 3

Mao et al. (2017) [3] introduced Least Squares GANs (LSGANs) to address the vanishing gradient problem associated with traditional GANs. By adopting a least-squares loss function for the discriminator, LSGANs achieved greater training stability and generated higher-quality outputs. Experimental evaluations demonstrated LSGANs’ effectiveness in image generation tasks, making them suitable for structured data applications, such as architectural designs. The improvement in stability and output quality addressed some of the critical limitations of earlier GAN models, paving the way for their adoption in domains requiring precise and reliable generative modeling.

### Related Research Work 4

Ronneberger et al. (2015) [4] developed the U-Net architecture, primarily for biomedical image segmentation. Featuring a contracting path to capture context and an expanding path for precise localization, U-Net excelled in tasks requiring spatial accuracy and detail preservation. Its ability to produce segmented outputs from limited training data made it adaptable for architectural applications, including elevation design. U-Net's integration with GANs enables the generation of designs that are both aesthetically and structurally consistent, highlighting its potential in automating house front elevation generation.

### Related Research Work 5

Zhu et al. (2017) [5] introduced CycleGAN, a GAN variant for image-to-image translation tasks without the need for paired training data. CycleGAN utilizes a cycle-consistency loss to ensure that translations preserve the essential features of the input images. This architecture is particularly useful for converting architectural sketches or floor plans into realistic house elevations. By eliminating the dependency on paired datasets, CycleGAN broadens the applicability of GANs in design automation, enabling creative exploration of diverse styles and layouts for house front elevations.

## Literature Review Summary Table

The columns in the table depend upon your problem and should be specific to your project.

Table 1: Literature Review

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | Reference | Inventor | Year | Input | Output | Description |
| 1. | [1] | Ian Goodfellow et al. | 2014 | Random noise vector | Synthetic data resembling real data | Introduced the concept of GANs, forming the basis for generative modeling. |
| 2 | [2] | Alec Radford et al. | 2015 | Random noise vector | High-resolution synthetic images | Enhanced GAN training stability and quality using convolutional layers. |
| 3 | [3] | Xudong Mao et al. | 2017 | Random noise vector | High-quality and stable synthetic images | Addressed vanishing gradient issue with least squares loss for improved outputs. |
| 4 | [4] | Olaf Ronneberger et al. | 2015 | Biomedical images | Segmented images | Used for biomedical segmentation; adaptable to architectural tasks. |
| 5 | [5] | Jun-Yan Zhu et al. | 2017 | Unpaired image datasets | Image-to-image translations | Enabled image-to-image translations without paired datasets. |

## Research Gap

1. Generative Adversarial Networks (GANs)

**Gap:** The original GAN framework by Goodfellow et al. (2014) introduced the concept of adversarial training but faced critical challenges, including training instability, mode collapse, and vanishing gradients. These issues hinder the scalability and reliability of GANs for complex, high-resolution applications such as house elevation generation.

1. Deep Convolutional GANs (DCGANs)

**Gap:** While DCGANs (Radford et al., 2015) improved training stability and quality through convolutional layers, they still struggled with issues like limited diversity in generated outputs (mode collapse) and difficulties in integrating architectural constraints. The lack of mechanisms to incorporate structural guidelines or design standards into the generation process limits their applicability in architecture.

1. Least Squares GANs (LSGANs)

**Gap:** LSGANs (Mao et al., 2017) addressed vanishing gradients with a least-squares loss function, improving output stability and quality. However, the framework lacks exploration in generating outputs that adhere to real-world constraints, such as structural feasibility, material limitations, and aesthetic consistency for architectural designs like house elevations.

1. U-Net Architecture

**Gap:** Although U-Net (Ronneberger et al., 2015) excelled in biomedical image segmentation and demonstrated potential for tasks requiring high spatial accuracy, its integration into GAN frameworks for architectural design remains underexplored. Additionally, U-Net's adaptation to handle complex and diverse styles in house elevations, while maintaining structural integrity, is an area that requires further research.

1. CycleGAN

**Gap:** CycleGAN (Zhu et al., 2017) introduced the ability to perform unpaired image-to-image translations, which is promising for converting sketches into realistic elevations. However, it lacks mechanisms to incorporate architectural constraints or user-defined preferences, limiting its practicality in real-world design workflows. Moreover, the focus on unstructured data prevents it from fully addressing the precision needed for architectural outputs.

## Problem Statement

The construction industry suffers from delays, poor coordination and inaccurate cost estimations due to fragmented design, communication and budgeting processes.

Homeowners struggle to get specific designs understanding accurate cost estimates and coordinate with different stakeholders which leads them to delays, miscommunication, and unexpected expenses. The present options frequently force users to switch between different tools since they don’t take a single approach that covers all these features. In addition to increasing inefficiencies this fragmented approach reduces accessibility for both contractors and homeowners. The present situation of issues requires the creation of a single platform that makes construction project management easier while giving all stakeholders accurate and effective tools.

# 

# Requirements and Design

In this chapter, we have developed the functional requirements for the main actors of our platform, i.e., Users, Contractors, Service Providers, and Admin. These requirements are specifically designed for the Innovative AI Solutions for Smart Construction platform, which aims to streamline the construction process by integrating design, cost estimation, and collaboration into a single web-based solution.

The platform is user-friendly, easy to navigate, and provides a convenient and efficient way for all stakeholders to connect, interact, and manage their construction projects. It incorporates AI-driven features to generate house elevation designs, cost estimation tools for budgeting, and communication systems for collaboration.

We have created detailed use cases for each functional requirement and illustrated them with diagrams such as use case diagrams and system architecture. These artifacts ensure clarity and provide a foundation for the development and implementation of the platform.

## Requirements

### Functional Requirements

* **User**

|  |  |
| --- | --- |
| **Requirement No.** | **Requirement Description** |
| FR-1.1 | Users can register by providing their name, email, and password. |
| FR-1.2 | Users can log in to the system using their credentials. |
| FR-1.3 | Users can view available Contractors and Service Providers with filters. |
| FR-1.4 | Users can search for Contractors or Service Providers using a search bar. |
| FR-1.5 | Users can filter results by location, rating, and expertise. |
| FR-1.6 | Users can sort results based on predefined criteria (e.g., highest rated). |
| FR-1.7 | Users can view detailed profiles of Contractors and Service Providers. |
| FR-1.8 | Users can send service requests to selected Contractors or Service Providers. |
| FR-1.9 | Users can manage their profile by updating personal information. |
| FR-1.10 | Users can view the history of interactions and service requests. |

* **Contractor**

|  |  |
| --- | --- |
| **Requirement No.** | **Requirement Description** |
| FR-2.1 | Contractors can register by providing their name, email, and password. |
| FR-2.2 | Contractors must create a profile during the first login with details like expertise. |
| FR-2.3 | Contractors can log in using their credentials. |
| FR-2.4 | Contractors can list the services they provide, specifying expertise areas. |
| FR-2.5 | Contractors can view and respond to service requests sent by Users. |
| FR-2.6 | Contractors can manage their schedule and mark availability for new requests. |
| FR-2.7 | Contractors can edit and update their profile anytime. |
| FR-2.8 | Contractors can view feedback and ratings from Users. |

* **Service Provider**

|  |  |
| --- | --- |
| **Requirement No.** | **Requirement Description** |
| FR-3.1 | Service Providers can register by providing their name, email, and password. |
| FR-3.2 | Service Providers must create a profile during the first login, including services offered. |
| FR-3.3 | Service Providers can log in using their credentials. |
| FR-3.4 | Service Providers can list services and tools they provide, specifying pricing. |
| FR-3.5 | Service Providers can view requests sent by Users and respond accordingly. |
| FR-3.6 | Service Providers can edit and update their profile anytime. |
| FR-3.7 | Service Providers can view feedback and ratings provided by Users. |

* **Admin**

|  |  |
| --- | --- |
| **Requirement No.** | **Requirement Description** |
| FR-4.1 | Admin can access a dashboard to monitor and manage system activities. |
| FR-4.2 | Admin can view and manage User accounts. |
| FR-4.3 | Admin can deactivate or delete User accounts if necessary. |
| FR-4.4 | Admin can view and manage Contractor profiles and their services. |
| FR-4.5 | Admin can approve or reject new Contractors or their services. |
| FR-4.6 | Admin can view and manage Service Provider profiles and services/tools. |
| FR-4.7 | Admin can approve or reject new Service Provider registrations or service listings. |
| FR-4.8 | Admin can monitor feedback and ratings to ensure no offensive content is published. |
| FR-4.9 | Admin can remove inappropriate feedback or ban abusive users. |
| FR-4.10 | Admin can generate reports on platform activity (e.g., active Users, feedback trends). |
| FR-4.11 | Admin can resolve disputes between Users, Contractors, and Service Providers. |
| FR-4.12 | Admin can manage platform-wide settings like service categories and pricing policies. |

### Non-Functional Requirements

### Hardware and Software Requirements

* **Hardware Requirements**
* **Software Requirements**

## Proposed Methodology

## System Architecture

## Use Cases

**Fully-Dressed Use Cases Diagram**

# Implementation and Test Cases

## Implementation

## References

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Figure 3: references