HERITAGE INSTITUTE OF TECHNOLOGY
Department of Computer Science & Engineering (IoT)

FINAL YEAR PROJECT REPORT
AI-Driven Digital Twin for Smart Traffic Management using LLM-Orchestrated Simulation, Spatio-Temporal Forecasting and Multi-Agent Reinforcement Learning (Web + Mobile Platform)

Submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (B.Tech)

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CERTIFICATE

This is to certify that the project entitled **“AI-Driven Digital Twin for Smart Traffic Management using LLM-Orchestrated Simulation, Spatio-Temporal Forecasting and Multi-Agent Reinforcement Learning (Web + Mobile Platform)”** submitted by **Adarsh Kumar Singh, Shubham Kumar, Shubham Raj, Sudhanshu Shekhar, Priyanshu Kumar** of CSE (IoT), Heritage Institute of Technology, is a bonafide record of work carried out under our supervision and guidance for the fulfillment of the requirements for the award of B.Tech.

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ABSTRACT

Traffic congestion is a critical challenge in modern cities, leading to increased travel time, fuel consumption, emissions, and reduced productivity. Conventional traffic management systems mainly depend on fixed-time signal control and lack predictive and adaptive capabilities. To overcome these limitations, this project proposes an AI-driven, software-based digital twin platform for smart traffic management.

The proposed system builds a virtual digital twin of a city traffic network using simulation tools and datasets. A spatio-temporal deep learning model predicts near-future traffic conditions such as congestion levels, speed, and flow patterns. A Multi-Agent Reinforcement Learning (MARL) framework autonomously learns adaptive traffic signal control strategies to minimize queue length, waiting time, and average travel time. Additionally, an LLM-based decision assistant provides natural language interaction for traffic analytics, scenario simulation, and automated reporting.

The solution is deployed as a global-level Web + Mobile application, where the web dashboard supports planners/administrators and the mobile application supports general users with congestion views and route suggestions. The system performance is evaluated using accuracy metrics (MAE, RMSE) and traffic efficiency metrics (delay, throughput, queue length). Results indicate improved traffic signal efficiency compared to baseline fixed-time control.

CHAPTER 1: INTRODUCTION

Urban traffic congestion is increasing due to rapid urbanization and a growing number of vehicles. Traditional traffic systems use fixed control logic and manual monitoring, which are not sufficient for dynamic traffic conditions. This project introduces an AI-driven digital twin framework that enables simulation, forecasting, and optimization of traffic through web and mobile platforms.

CHAPTER 2: LITERATURE SURVEY

This chapter reviews existing work in traffic forecasting using spatio-temporal deep learning models, reinforcement learning based signal control, digital twins for smart cities, and the use of large language models for decision support. The review highlights a gap in fully integrated platforms combining these components.

CHAPTER 3: PROBLEM STATEMENT & OBJECTIVES

The project aims to design a software-only smart traffic management system capable of predicting congestion, optimizing traffic signals dynamically, supporting what-if scenario simulations, and providing decision support using an LLM assistant. The objectives include development of digital twin simulation, forecasting models, MARL signal optimization and full-stack deployment.

CHAPTER 4: PROPOSED SYSTEM DESIGN

The system consists of web and mobile user interfaces, backend microservices, AI modules (forecasting, MARL, LLM), and database storage. Functional requirements include scenario management, real-time visualization, predictive analytics, adaptive signal strategies and automated report generation.

CHAPTER 5: METHODOLOGY

Traffic data is generated using simulation and/or public datasets. Forecasting is performed using spatio-temporal deep learning. Signal control is optimized using multi-agent reinforcement learning with reward functions based on queue length and delay reduction. The LLM assistant orchestrates scenario execution and provides explanations.

CHAPTER 6: IMPLEMENTATION DETAILS

The web dashboard is developed using Next.js and Tailwind CSS, the mobile application uses Flutter/React Native, and backend services are implemented in FastAPI/Node.js. AI modules are built using PyTorch and RL frameworks. Databases include PostgreSQL and optional time-series storage.

CHAPTER 7: RESULTS & DISCUSSION

System evaluation compares fixed-time baseline control against MARL optimized control. Metrics include MAE/RMSE for forecasting accuracy, and traffic metrics such as average travel time, queue length and throughput. Results show improvements in congestion mitigation and planning capabilities.

CHAPTER 8: CONCLUSION & FUTURE SCOPE

The project demonstrates a scalable AI-driven traffic digital twin platform integrating simulation, forecasting, MARL optimization and LLM-based decision support. Future work includes multi-city scaling, integration of weather/event signals, public transport prioritization and federated learning.

REFERENCES

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