Masters Thesis Information Showcase
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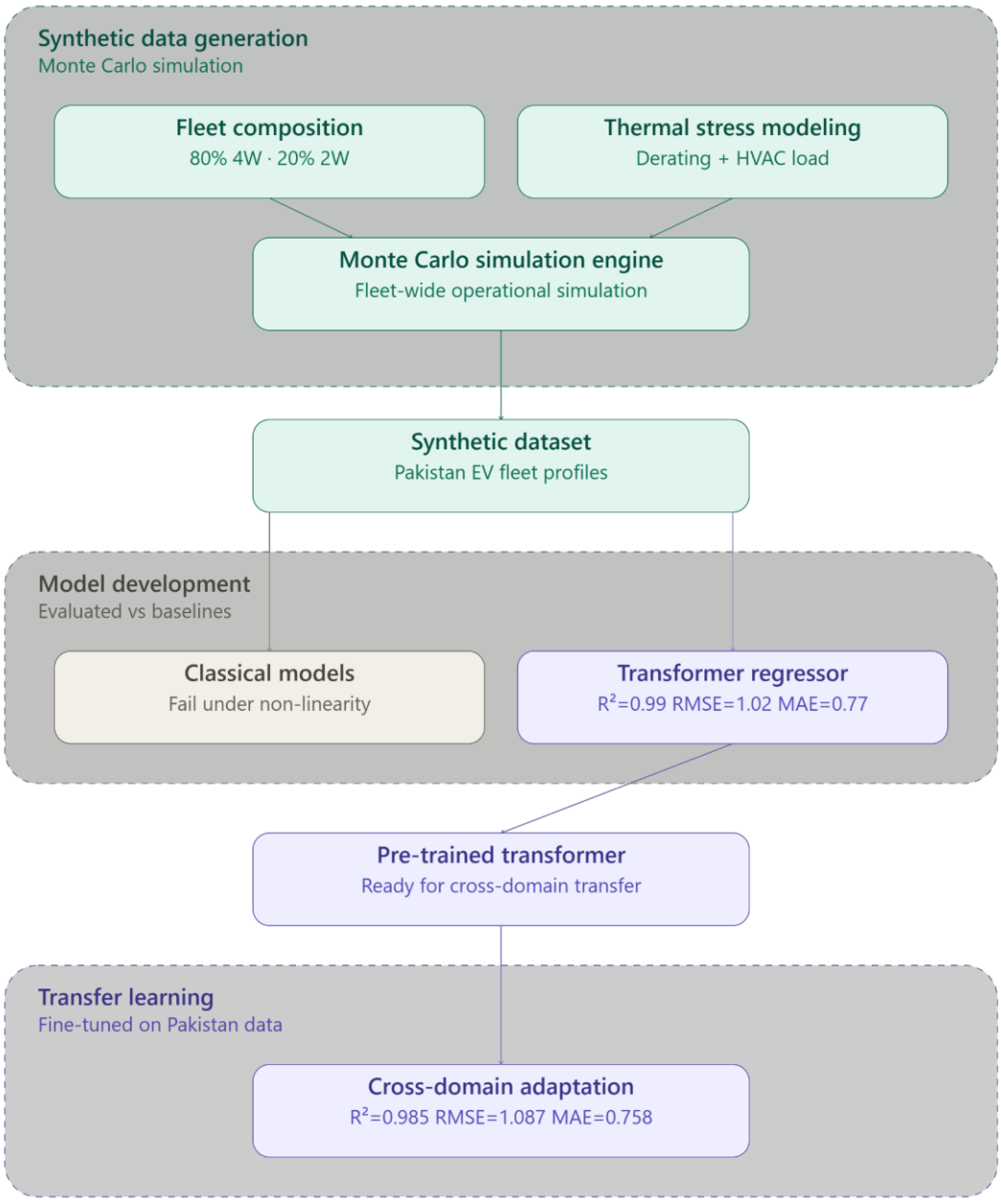
Department: Computer Science & Information Technology
Programme: Master of science
Specialization: Smart Grid

1	**Title of the Thesis** A Data-Driven Framework for Intelligent Electric Vehicle Charging Management in Pakistan
2	**Abstract** Integrating electrified vehicles poses a large challenge to load management in the limited distribution grid of Pakistan. Whereas the overall aim of the smartening of the grid is intelligent charging management such as load shifting, an essential prerequisite for achieving this is load forecasting, which is severely hampered due to the absence of telemetry data from operational EVs in the region. In order to provide this missing data, a framework that utilizes data generation by means of transfer learning is offered in this study. Firstly, a Monte Carlo engine was developed for the generation of a synthesized dataset suited to the conditions in Pakistan, generating 50,000 charging records in one year. Parameters were randomized using arrival/departure time, daily distance traveled and initial SoC. For localization purposes, environment constraints typical for cities such as Lahore and Karachi (temperatures above 45°C in summer) were implemented via physics equations for battery derating and HVAC parasitic loads under varying conditions. The distribution was set up as 80% four-wheelers and 20% two-wheelers for the sake of exploring the demographic of early adopters. The target variable was load consumption in kW. When evaluating the task using baseline algorithms (Linear Regression, K-Nearest Neighbors, Support Vector Regression, XGBoost and Long Short-Term Memory) it became apparent that there were difficulties with modeling the non-linear and high-variance spikes in loading caused by extreme weather variables. An Enhanced Transformer Regressor was designed to solve this problem, featuring temporal aware attention mechanisms. Chronological train/test splits (80/20) were used to avoid temporal data leakage. The proposed architecture proved to be highly capable of predicting the synthetic target data (R^2 = 0.9896, RMSE = 1.0231 kW, MAE = 0.7660 kW). In order to validate the transfer ability of the algorithm across domains, a model pre-trained on a publicly available source-domain dataset and then fine-tuned on the Pakistan-specific synthetic dataset was tested. High levels of accuracy were retained (R^2 = 0.9850, RMSE = 1.0874 kW, MAE = 0.7578 kW). Finally, through providing accurate demand forecasts localized to the Pakistani conditions, this framework provides the basis for future implementation of scheduling and control functionality.

3	**Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities"** **Introduction to the Urban Context:** Sustainable Development Goal 11 (SDG-11) envisions cities that are inclusive, safe, resilient, and sustainable. In the context of Pakistan, rapid urbanization and infrastructure deficits present significant barriers to this goal. Major metropolitan centers face deteriorating air quality and overburdened utility networks. The transition to electric mobility is a vital strategy for emissions reduction; however, without accurate demand forecasting, unmanaged EV charging threatens to exacerbate existing grid vulnerabilities, leading to localized transformer overloads and voltage instability. This study supports SDG-11 by providing the predictive data foundation necessary to integrate EVs into fragile urban ecosystems safely. **Enhancing Urban Grid Resilience** A core component of SDG-11 is building resilient urban infrastructure. Currently, utility operators in Pakistan lack the telemetry data required to model how EVs will impact local feeders, particularly under extreme thermal conditions. The framework developed in this thesis addresses this by utilizing Monte Carlo simulations to synthesize load profiles that account for temperature-dependent HVAC usage and battery derating. By accurately predicting the hourly charging demand, the Enhanced Transformer model enables grid operators to anticipate peak load events. While this study focuses on predictive modeling, this forecasting capability is the mandatory first step for downstream grid-control functions, such as dynamic pricing and load shifting, which prevent outages and maintain the reliability of essential urban services. **Supporting Efficient Energy Utilization and Planning** Accurate load prediction directly facilitates more efficient urban energy use. By understanding the diurnal patterns of EV charging demand, municipal planners can theoretically align charging windows with the availability of renewable energy generation, such as solar peaks during midday hours. Furthermore, the localized synthetic data allows urban planners to make evidence-based decisions regarding the spatial distribution of charging infrastructure. Rather than relying on generic models built for cooler climates, planners can utilize this region-specific framework to identify which neighborhoods require infrastructure upgrades before deploying charging stations. **Fostering Equitable Infrastructure Development** Intelligent load forecasting contributes to the economic sustainability of urban regions. Unmanaged charging spikes often necessitate capital-intensive upgrades to physical grid infrastructure (e.g., transformers and substations). By utilizing predictive AI to identify when and where charging loads will peak, utilities can optimize existing capacity, thereby deferring expensive hardware upgrades. This financial efficiency supports SDG-11 by ensuring that the modernization of urban transport does not disproportionately increase utility costs for residents. It helps ensure that grid stability is maintained equitably across both high-income and low-income neighborhoods sharing the same distribution networks. **Conclusion** The realization of sustainable cities requires evidence-based integration of emerging technologies. By bridging the gap in operational telemetry data and demonstrating robust, localized load prediction, this framework provides a necessary tool for urban energy management in Pakistan. It establishes the technical prerequisites for future smart-charging infrastructure, directly supporting the targets of SDG-11 by promoting infrastructural resilience, resource efficiency, and sustainable urban transport planning in the Global South.

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6	**Graphical Abstract**