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# SITEM: A FRAMEWORK FOR INTEGRATED TRANSPORT AND ENERGY SYSTEMS MODELLING FOR CITY-WIDE ELECTRIFICATION SCENARIO PLANNING

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## ABSTRACT

Electrification of the transport sector is a key initiative for cities combating climate change. However, transitioning from combustion engine vehicles that can refuel at petrol stations to battery-electric vehicles (EVs) that need to be connected to the distribution grid to charge, presents significant challenges in planning for new infrastructure planning and behaviour patterns. We developed SITEM, an advanced modelling framework that combines behavioural modelling, geospatial optimisation, agent-based simulation of multi-modal city-wide transport and a high-fidelity digital twin of the distribution grid. The framework is designed to address infrastructural planning challenges faced by local planning agencies such as finding optimal solutions for placement of chargers and quantifying the impact of electrification on the grid. We showcase some key technical achievements of the modelling framework which include simulation-based validation of the quality of different charger placement schemes, and the determination of the efficacy of smart charging in shared public residential chargers in helping to reduce peak energy demand.

## 1 BACKGROUND AND INTRODUCTION

To adequately address challenges faced in planning for infrastructural requirements of vehicle electrification in a metropolitan city such as Singapore, a bottom-up modelling approach would be necessary in order to effectively model the key interactions and trade-offs between the transport system and power system. This is because patterns of charging demand are heavily influenced by individual driver decisions and behaviour, and aggregate or reductionist models would not provide sufficient fidelity to accurately predict spatio-temporal fluctuations and peak energy demand at specific locations, which is a necessary output to size up infrastructural needs. Moreover, an exploration of complex trade-offs between transport and energy outcomes was an important concern to be addressed. For example, how to model the impact of driving demand patterns and charging needs on peak demand at individual grid nodes, and in the other direction, how a limited energy supply or charger provisioning would affect availability of charging energy and therefore quality of service experienced by drivers. Such problems could only be fully explored through an integrated behavioural, transport and power system modelling framework.

## 2 COMPONENTS OF SITEM'S MODELLING AND SIMULATION FRAMEWORK

In the following subsections, we describe the four components that constitute the modelling framework codenamed SITEM (Singapore Integrated Transport and Energy Model), developed to perform advanced scenario-based analysis of vehicle electrification in metropolitan cities such as Singapore.

## 2.1 Behavioural Modelling

An agent-based microscopic modelling approach for transport demand requires us to determine the individual rules and assumptions for simulating drivers' charging and movement behaviour. To alleviate the issue of a lack of representative data for drivers' charging decisions, the team conducted a comprehensive literature review and adapted empirical findings from overseas cities with infrastructure similar to Singapore. Universal factors affecting charging decisions (such as state of charge, parking time, fleet or private owned vehicles) were identified, and estimations of the quantities of these parameters for the local context were appropriately made.

## 2.2 Charger Placement and Optimisation

Algorithms were developed that utilised a combination of granular mobility data, geospatial data and input planning parameters (for eg, number of chargers, charger power ratings) in order to solve for the optimal solution for the distribution of EV chargers in a metropolitan city. The developed optimisation procedure utilises a set of user-defined cost/utility functions and geospatial constraints to arrive at the solution. Further advanced features of this module include ideal mix of slow and fast chargers based on the type of candidate locations (residential, workplace or commercial) and the expected number of vehicles they would be expected to serve.

## 2.3 Mobility & Charging Simulation

To determine the charging demand arising from the EVs modelled in our scenarios, our framework uses CityMoS (Zehe, Nair, Knoll, and Eckhoff 2017), a high performance simulation platform that allows for microscopic agent-based modelling of multiple transport vehicles embedded with individual charging and driving decisions. CityMoS was designed with specific features to model EVs, incorporating realistic features of vehicle energy utilisation, traffic dynamics, congestion and lane changing as well as realistic queuing and occupancy at chargers. Lastly, CityMoS was designed with suitable interfaces that enable seamless coupling and integration with tools for power system simulation and optimisation.

## 2.4 Electrical Grid Simulation

To determine the level of impact of future EV charging on Singapore's grid infrastructure, we built a digital twin of Singapore's grid network using MESMO (Troitzsch, Kleinschmidt, Schelo, and Ahmed 2021),a software library for modelling, simulation, and optimisation of grid networks. By utilising base load data obtained from transformers in the distribution network, combined with charging demand from CityMoS, the simulation outputs the expected utilisation of the network components for each scenario and provides recommendations for locations where grid upgrades would be necessary.

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# REFERENCES

Troitzsch, S. and V. Kleinschmidt and T. Schelo and A. Ahmed 2021. "MESMO – Multi-Energy System Modeling and Optimization". https://zenodo.org/record/4892760. accessed: 2022-10-06.

Zehe, D., S. Nair, A. Knoll, and D. Eckhoff. 2017. "Towards CityMoS: A Coupled City-Scale Mobility Simulation Framework". In *Proceedings of the 5th GI/ITG KuVS Fachgespräch Inter-Vehicle Communication (FG-IVC 2017)*, 1–5. Erlangen, Germany: FAU Erlangen-Nuremberg.