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Synthetic Sweden Mobility Model (SySMo): Optimal charging infrastructure for 100% EV adoption

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Project background: Synthetic Sweden

Electric vehicles (EVs) and shared autonomous electric vehicles (SEAVs) play vital roles in the sustainable transformation of future urban transport systems. To realize the potentials of these technologies, urban charging infrastructure needs careful design including the optimal design of charging stations. "Synthetic Sweden Mobility Model (SySMo) is an agent-based decision support framework for modeling and analysis of future urban transport scenarios, in particular, EVs and SEAVs and carry out pilot studies on the optimal location of charging infrastructure considering the interplay with the other components in the transport systems.

SySMo starts with generating heterogeneous agents' daily activity plans while preserving privacy and capacity for being modified for future scenarios. This paper deals with the MATSim part of the model in which the generated agents and their daily activity plans are fed into a baseline scenario for replanning until they converge on a set of reasonable activity plans. Next, we plan to develop an EV scenario which has the below contributions.

- The use of large synthetic population of the entire Sweden.
- The integration of real-world public transit (PT) data exploring the optimal combination of electrifying car trips and using PT.

We would like to know **how to optimize charging infrastructure and PT use given 100% EV adoption**? After doing some pilot studies on the major metropolitan areas of Sweden, we plan to scale up the scenario to entire Sweden (Figure 1).

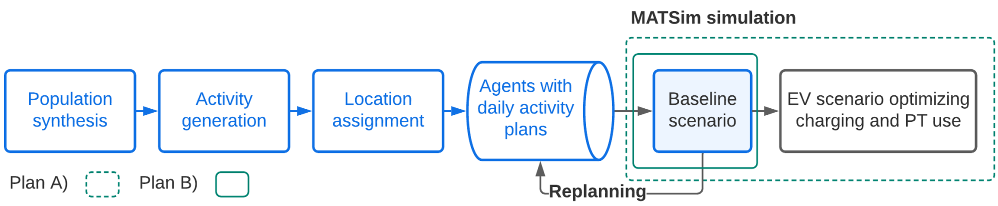

Figure 1: Synthetic Sweden Mobility Model (SySMo). Plan A) simulates the scenario within MATSim. Plan B) uses MATSim to get realistic travel times and traffic counts based on the synthetic agents' activity plans. The scenario is built externally with assumptions and simulations.

For the rest of this article, we present the preliminary results of a comparison between initial agents' plans and MATSim-simulated plans; such comparison is important to set the baseline for further queries and simulations. Following the comparison, we briefly describe a conceptual design of the EV scenario that we plan to implement including problem statement, technical solutions, and limitations.

Baseline scenario: 5% of synthetic population in Västra Götaland Region

The baseline scenario covers 5% of the synthetic population living in the Västra Götaland Region (VGR), i.e., 85,500 agents constituting a random sample of 1,710,000 residents in VGR. They have 366,443 daily activities and an average daily plan contains 4.3 activities falling in the four categories: home, work, school, and other. For moving between the locations of these activities, there are four assigned transport modes:

walk, bike, car, and public transit (PT). The road network covers the detailed roads within VGR and the main roads for the rest of Sweden. To make it easier for further exploration, the configuration follows the benchmark shipped together with MATSim 13.0 with minor modifications. The iteration number is 100 and the replanning strategy is a combination of BestScore (0.6), TimeAllocationMutator (0.3), and ReRoute (0.1).

The assigned travel times between activities in the input are preliminary therefore, we rely on MATSim's replanning module to give a more realistic estimation of travel times. As a consequence, we end up with 2.5% negative-duration activities involving 14.8% of the agents. There are 12.9% agents' plans that end up with a total duration of more than 24 hours. Moreover, 4.4% of the output plans have negative utility scores. The results suggest that some unrealistic agent plans are not completely eliminated after replanning, further measures are needed to fix these cases.

We compare the duration of the four activities between input and output (Figure 2a) as well as the share of en-route cars (Figure 2b). After replanning, neither activity duration nor share of cars en route changes dramatically. However, due to lower priority assigned to the activity Other, the number of long-duration Other activities decreases. The activity School has more long-duration activities, which is affected by its typical duration being 8 hours. The comparison between the input plans and the output ones suggests that some of the activity parameters may need to be adjusted to be more realistic, considering the particular statistical distributions of the input.

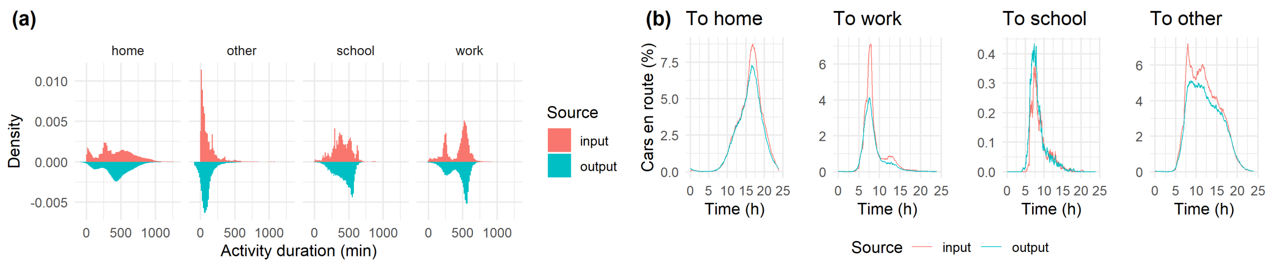

Figure 2: Input-output comparison. (a) Probability density of activity duration. (b) Share of cars en route.

Conceptual design of a scenario for electrification of passenger cars in VGR

As a start point, the EV scenario covers the same 5% of the synthetic population in VGR as the baseline scenario does. We assume a 100% electrification of the existing passenger cars owned by the agents considering increasing PT use. On top of the baseline scenario, First, we design a system (with existing PT infrastructure) that maximizes the benefits of combining PT with EVs. For instance, the trips with long travel times with PT are assigned with EVs. We consider how this combination affects the planning of optimal charging infrastructure that includes home/public charging. We explore charging strategies that cover the placement of different types of charging stations (varying e.g. the power level) in public charging as well as homes and workplaces. For instance, we would like to know how the electrification of passenger cars imposes demand on charging infrastructure, given many cities are implementing policies to reduce car use and encourage using PT, especially in the city core.

The EV scenario can be realised by invoking the EV extension and PT extension of MATSim. However, the current EV extension was developed for long-distance travel while the one feasible for urban driving is still under development. Therefore, we propose a viable solution. Instead of putting EV vehicles in the simulation loop, we make assumptions for the EV scenario considering electrifying the car trips or switching them to PT mode in the simulation output (Plan B). The involved assumptions are 1) no rerouting for charging the vehicle; 2) parking is the only occasion for charging; 3) the travel behaviour remains unchanged when a car is an EV.

The designed EV scenario has some limitations. First, it lacks a realistic consideration of energy flows between EVs and their driving environment (e.g., road slope) and charging stations. Second, the driving patterns remain unchanged when drivers switch from conventional cars to EVs. Third, it considers a typical weekday while long-distance trips may be under-represented by excluding overnight trips. Therefore, we will continue working on refining the design of the EV scenario. We will extend the simulation from one-day to multi-day.