Optimizing the expansion of carsharing network

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1. Introduction

In recent decades, the number of personal vehicles has increased, which presents a great challenge, especially in urban areas. Traffic congestion is one of these problems. To tackle this specific issue, the carsharing mode [1] was proposed allowing individuals to rent vehicles for short periods of time, often by the hour or minute, rather than owning cars. This service is typically provided by companies or cooperatives that maintain a fleet of vehicles distributed at various locations, usually in urban areas [2]. The challenge of optimizing carsharing station locations involves a combination of various factors such as population density, land use patterns, public transportation networks, socioeconomic characteristics, and travel behavior. Some methods, based on heuristic or rule-based approaches [3], may not accurately capture the usage of carsharing. In this paper, we propose an approach to expanding carsharing systems by optimizing new stations' locations. This approach uses the Multi-Agent Transport Simulation (MATSim) framework [4]. By introducing the accessibility metric for each carsharing station into an optimization process that includes MATSim, our goal is to identify optimal locations for new carsharing stations that maximize accessibility for users and improve the overall efficiency of the carsharing system.

2. Methodology

To expand an existing carsharing network, our methodology combines MATSim, which allows for detailed modeling of individual travel behavior and comprehensive analysis of transportation scenarios, functionalities, together with optimization algorithms. In the expansion process, the Montreal scenario is used as a baseline scenario. The expansion process has as an objective to detect the regions that have the need for another carsharing station. The method involved clustering algorithms and searching algorithms to detect these regions and to suggest the new carsahring station locations. Subsequently, these analysis are used to create new carsharing input files using the accessibility metric [5]. This modification creates another scenario that can be tested using MATSim simulation. The process is described in schema 1. To understand the information transmitted from one step to another, the following table 1 presents the detailed data.

Data	Explanations
MID	MATSim Input Data as described in the previous subsections
MSR_B	MATSim simulation results for the baseline scenario
R_i	Region i requiring the addition of a carsharing station
$SL_{i,j}$	Station location for each target region i during expansion iteration j
$M_{i,j}$	Members added during expansion iteration j related to each target region i
$MSR_{i,j}$	MATSim simulation results in expansion iteration j related to target region i
CR_j	Comparison results for the iteration j
SL_F	Final stations locations at the end of the expansion process

Table 1: Transmitted data from one step to another

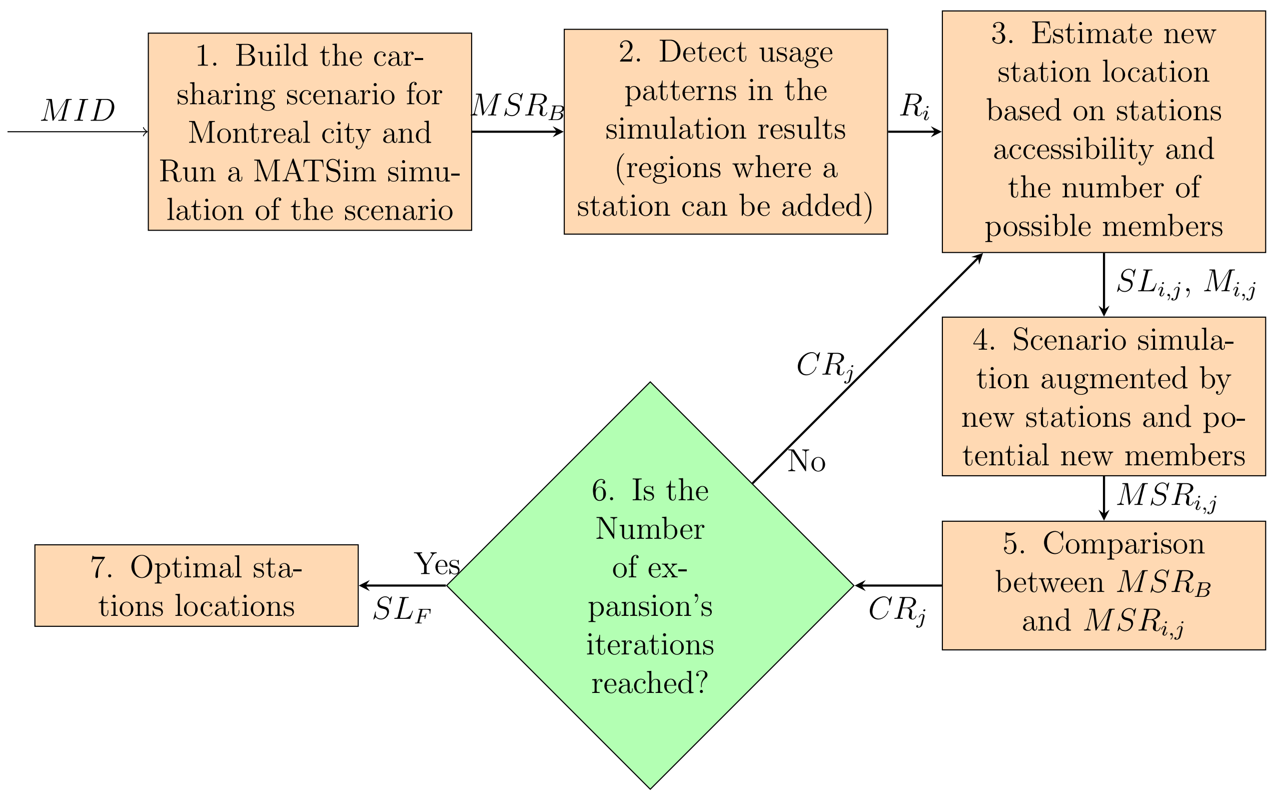


Figure 1: Expansion process for the carsharing system

Methodology's steps presented in figure 1 are explained as follows :

step 1 Generate MATSim simulation results for the Montreal base case scenario.

step 2 Detect usage patterns in simulation results of step 1 in the form of geographic areas. This analysis is conducted with two clustering with KNN and HDBSCAN [6].

step 3 Choose station locations (centroids for the first iteration, then TABU algorithm [7] is used to select another location using the accessibility measure as defined in [5]).

step 4 Run MATSim simulation with new files for the extended carsharing network.

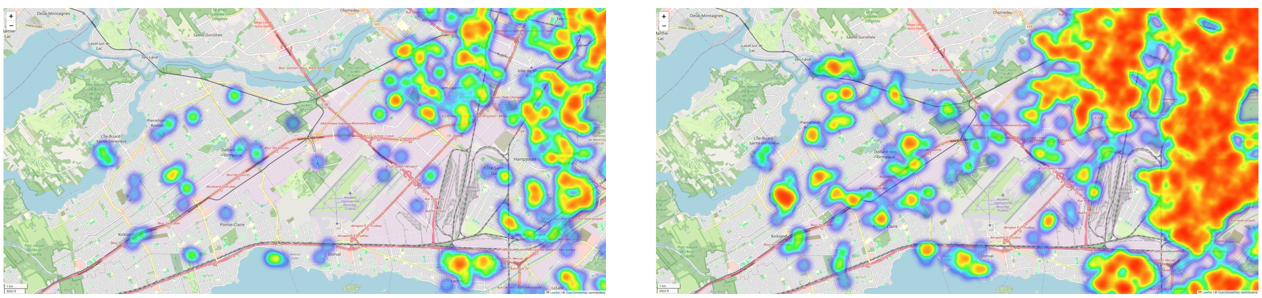
step 5 Compare the simulation results of step 4 with the baseline scenario results.

step 6 Test the number of budgeted iterations.

step 7 Save the locations group as optimal locations for carsharing network expansion.

3. Results

This section explains the last iteration results which is the output of the expansion process, comparing it with the baseline scenario and a scenario where new stations are selected randomly from in the targeted regions. The heat maps, shown in the figure 2, present the difference between the initial carsharing output scenario and the output of the last iteration in the expansion process. The numbers of the carsharing reservations increased in the regions where new carsharing stations are added as it can be seen in the figure 2b in comparison with the reservations in the same region in the baseline scenario in the same geographical regions in Montreal island as presented in the figure 2a.



(a) Reservations in baseline scenario in Montreal west

(b) Reservations in the last iteration in Montreal west

Figure 2: Heat maps for the baseline scenario and the last expansion iteration scenario

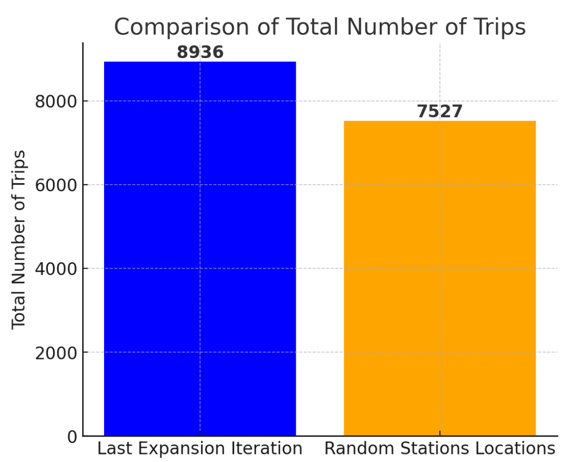


Figure 3: Number of trips comparison between the expansion results and a random carsharing stations' locations choice

Thus, our approach ensures that the selection process aligns with specific geographic and strategic considerations relevant to the study. This is demonstrated in the figure 3 which compares the total number of trips performed using carsharing in the last expansion iteration and the simulation where the stations locations are chosen randomly in the target areas. The figure shows that the total number in the last expansion iteration is higher than the random stations locations. With these values, the increase is $\approx 18.7\%$ of carsharing trips.

4. Conclusion

The study demonstrates the potential of combining MATSim simulations with optimization techniques to enhance the planning and expansion of carsharing systems' networks. By adding accessibility metrics to an iterative optimization process, the methodology identifies strategic station locations that match user demand and improve system efficiency. The case study conducted on Montreal island carsharing system highlights key results and insights into optimizing such a system in urban areas.

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