Exploring the Effects of Teleworking on Travel Patterns: A Simulation-Based Study with MATSim

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SHORT SUMMARY

This study assesses the impact on travel patterns of teleworking in Quebec City, Canada, using the MATSim/Eqasim model. It compares scenarios where (a): teleworkers stay home without altering daily activities or (b): engage in new activities, like driving children to school or additional shopping and leisure trips. The analysis uses origin-destination surveys and demographic data to evaluate modal shares, travel distances, and congestion changes. In previous practice, teleworking activity is assigned to random agents to generate scenarios, which may not reflect real-life conditions. This study fills that gap by predicting individuals' probability of teleworking based on socio-demographics, built environment, and assigns teleworking activities to those who are more likely to telework. The analysis is based on an ensemble learning method, Extreme Gradient Boosting. Findings show that teleworking significantly reduces car usage and overall travel distances while increasing short walk trips, leading to more sustainable urban mobility and reducing congestion.

Keywords: Activity-based modeling, MATSim, Teleworking, XGBoost

1. INTRODUCTION

The rise of teleworking, accelerated by the COVID-19 pandemic, has profoundly transformed daily mobility patterns. Beginning in March 2020, widespread office closures made telecommuting necessary, significantly impacting travel demand. In Canada, including Quebec, the prevalence of teleworking has evolved markedly across the periods before, during, and after the pandemic. According to Wray (2024), the share of Canadians working most of their hours from home increased from 7% in May 2016 to 24% in July 2022, before declining slightly to 21% by July 2023.

The adoption of teleworking as a mode is influenced by a variety of socio-demographic variables. Some key factors include occupation type, income level, education level, age, gender, family composition, geographical location, commute distance, technology access, car ownership, and dwelling size (Rahman Fatmi et al., 2022). The impacts of teleworking on travel are multifaceted. Telework is often regarded as a valuable strategy for reducing peak travel demand and vehicle miles traveled (VMT) (Lachapelle et al., 2018). Telework holds significant potential for energy savings and the reduction of greenhouse gas (GHG) emissions. Researchers have conflicting views on telecommuting's impact on non-commute travel, with evidence suggesting that in the long term, teleworkers may live farther from work, increasing weekly travel due to longer commutes and additional non-work trips, known as the rebound effect (Caldarola & Sorrell, 2022). Teleworking also reshapes daily routines, including departure times, shopping habits, and leisure activities.

This study addresses two key gaps in teleworking research: (1) the limited integration of contextual actors in predicting teleworking behavior, which this research bridges by incorporating weather data, and (2) the lack of methods to preserve trip sequence integrity and spatial-temporal compatibility when modeling daily activity changes due to teleworking, addressed here with a novel approach. Using MATSim/Eqasim, the study analyzes teleworking's impact on travel patterns in Quebec City through two scenarios: (i) teleworkers staying home without altering activities and (ii) teleworkers engaging in additional secondary activities.

2. METHODOLOGY

This study employs MATSim/Eqasim for simulation and Extreme Gradient Boosting to design teleworking scenarios based on real-life conditions.

2.1. Simulation techniques

This study utilizes the Multi-Agent Transport Simulation (MATSim) model, enhanced with the Eqasim discrete choice module, to examine the rebound effects of teleworking. MATSim, an open-source agent-based transport simulation tool, optimizes daily activity-travel plans by maximizing individual utility based on travel time, congestion, schedules, and available modes (Horni et al., 2016). Its iterative process shapes collective system performance while accounting for agent-specific preferences, as shown in Figure 1, and identifies the best scenarios for the individual agents.

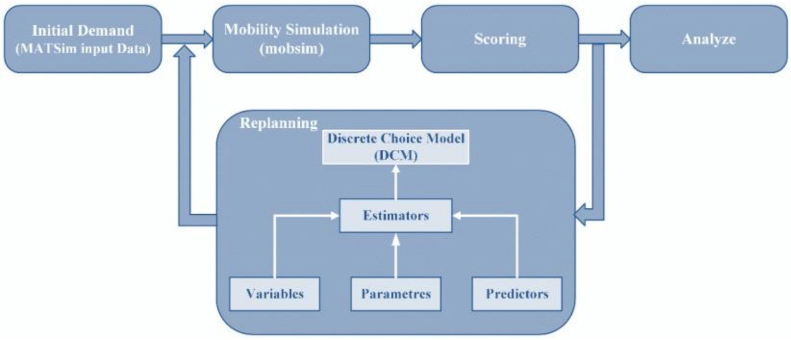


Figure 1: Structure of the simulation in MATSim/Eqasim, adapted from (Hörl & Balac, 2021; W Axhausen et al., 2016)

In MATSim, agents start with initial activity plans that specify locations, durations, modes, and routes. These plans are executed in a mobility simulation (mobsim) and evaluated using a utility function. Agents modify routes, schedules, or modes through multiple iterations to improve utility, a process known as replanning. Eqasim enriches this by integrating a discrete choice model (DCM) that evaluates mode changes using parameters from a multinomial logit model (Hörl & Balac, 2021).

Eqasim's core components (Figure 1) include variables (individual and spatial attributes), parameters (customizable elements influencing choices), predictors (travel time estimations), and estimators (utility assessment). These independent variables are used to explain the model choice with a multinomial logit model to compute utility scores. After repeated iterations, the system stabilizes, reaching User Equilibrium (UE), where agents' plans approximate real-world behavior and offer insights into travel patterns under teleworking conditions.

2.2. Teleworking probability

To set up a realistic simulation the selected teleworkers in simulation scenarios should have similar attributes as potential teleworkers in real life. That is, considering a random population as teleworkers leads to misleading results since some of them may be unable or unlikely to telework, given their individual characteristics. To address this, this study uses advanced machine learning models to identify the key drivers of teleworking, subsequently, predicts the probability of teleworking for all workers, and finally, assigns individuals with the highest teleworking probabilities as teleworkers in the designed scenarios.

A probabilistic model, powered by Extreme Gradient Boosting (XGBoost), was employed to predict individuals' probability of teleworking based on socio-demographics, built environment, and contextual factors. XGBoost is a powerful ensemble learning method widely used to address regression and classification problems. This method is famous for parallel processing capabilities, quick execution, and remarkable accuracy in complex problems (Naseri, Aliakbari, et al., 2024) .Like other ensemble learning algorithms, XGBoost generates a given number of weak models (i.e., decision trees). Then, the predicted outcomes of weak models are merged to present the final predicted value.

XGBoost operates as an iterative method, refining the structure of decision trees through multiple iterations. To achieve this, it leverages an optimization algorithm that utilizes both first order and second-order gradients to enhance the tree structures. Additionally, the objective function in the optimization process includes a regularization term, which helps minimize the risk of overfitting(Naseri, Waygood, et al., 2024) XGBoost can predict the probability of an outcome (here teleworking) by making a weighted average over the predicted labels (teleworking or not) of decision trees.

In this model, the dependent variable was the individual decision (teleworking or not). Independent variables were selected through a filter-based feature selection approach, eliminating those with Variance Inflation Factors (VIF) exceeding 5 (Akinwande et al., 2015), to address multicollinearity. Given the imbalanced distribution of teleworkers (2.12%), the F1-score macro was used for tuning, with Optuna and k-fold cross-validation (k=5) for optimizing hyperparameters (Sun et al., 2022). Further, SHapley Additive exPlanation (SHAP; a game-theory-based method developed by (Lundberg & Lee, 2017) was synchronized with XGBoost to determine the strongest determinants of teleworking.

3. DATA

The MATSim simulation framework uses five primary XML files to represent road and public transit networks, population distribution, daily activities, and geographic locations. A synthetic population, derived from the 2016 Census and 2017 OD Survey, mirrors demographic and travel patterns in Quebec CMA, including 54,753 individuals and 182,263 trips focused on home-based activities. The PopGen (McNally et al., 2014) module constructs this population, with trip locations assigned using 2018 assessment roll data. Public transit networks are integrated using pt2matsim. Data predicting teleworkers is based on the OD survey and enriched with Google Maps API, Walk Score data, and climate data. The final dataset, with 16 variables such as income, age, gender, and environmental factors, calculates teleworking probabilities via XGBoost for the MATSim population.

4. SCENARIOS

This study examines two main scenarios: (i) teleworkers who remain at home and do not alter their daily activities **(Figure 2)**, and (ii) teleworkers who stay home but engage in additional secondary activities.

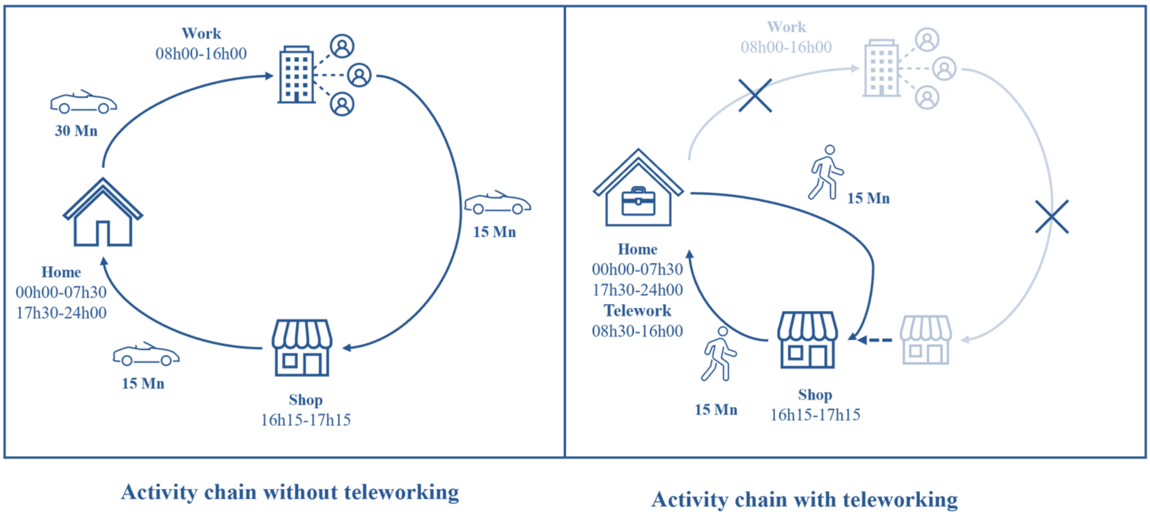


Figure 2: Activity shift and time-saving due to adoption of teleworking

The potential rebound effects of teleworking on traffic patterns are captured in second scenario, hypothesizing for example that teleworking parents may increase school transportation activities, and teleworkers may engage in additional secondary activities nearby. The left side of the **figure 2** illustrates a typical activity chain for an individual working on-site at an office. In contrast, if the individual works remotely from home, they do not need to commute, resulting in time savings both before and after work, as shown on the right side of the figure. This saved time can be used for additional activities, provided they are feasible in terms of typical activity performance, duration, and travel time, or employees may choose to stay at home instead. The study also explores three sub-scenarios with different levels of teleworking: 10%, 20%, and 40% of workers engaged in telecommuting, to evaluate their impacts on overall travel patterns and traffic congestion.

5. RESULTS AND DISCUSSION

Before analyzing these scenarios, a base scenario is run in MATSim, serving as a reference point for comparison. Validating the base scenario using real-world data, such as the origin-destination survey, is essential to ensure its accuracy as a representation of current conditions. Using parameters from previous work (Gharavi et al., 2024), the Eqasim modal choice module in MATSim simulates the reference scenario. The modal split in this simulation closely matches the origin-destination survey data, with a discrepancy of less than 2% **(Figure 3)**. This validation ensures the base scenario provides a reliable benchmark for evaluating future teleworking scenarios.

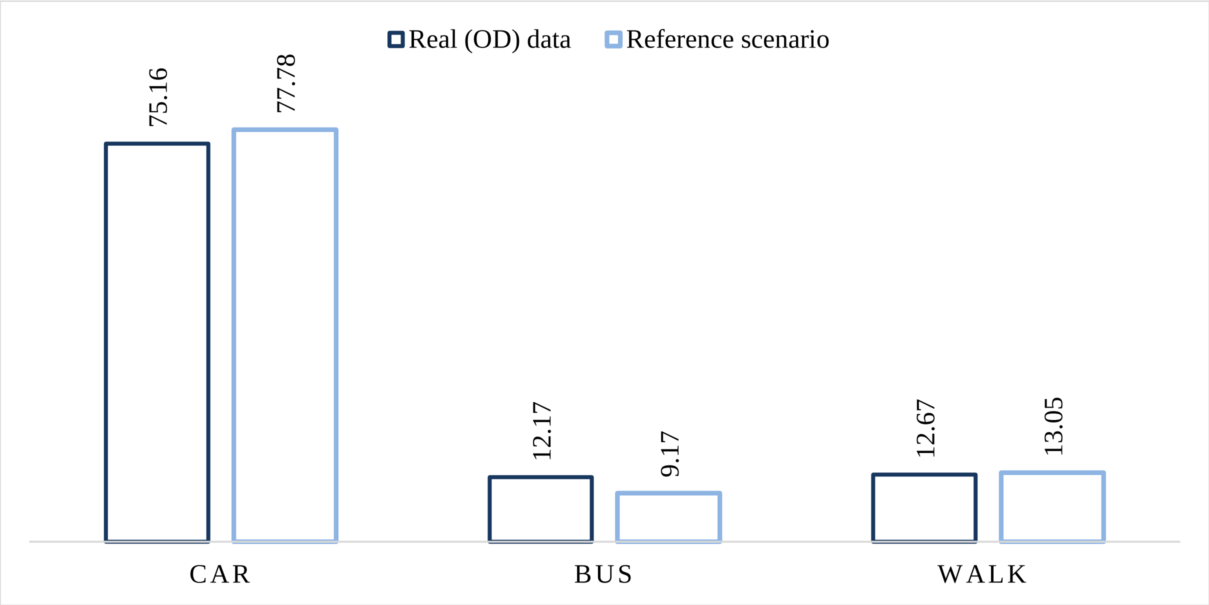


Figure 3: Comparison of travel modal shares between actual data (OD) and the reference scenario.

Applying the coefficient estimated in our previous works allows for a plausible representation of real-life choices. The results of **Figure 3** shows that the model is an accurate approximation of real-life condition.

After training the model using the OD survey (training data), the probability of teleworking for MATSim agents (testing data; individuals in the simulation) were predicted. Then, individuals were sorted based on probabilities, and those with the highest probabilities were considered to be teleworkers in each scenario. Consequently, the MATSim base scenario was changed to capture the scenarios' effect. Subsequently, the relative influence of variables on teleworking is illustrated in **Figure 4**.

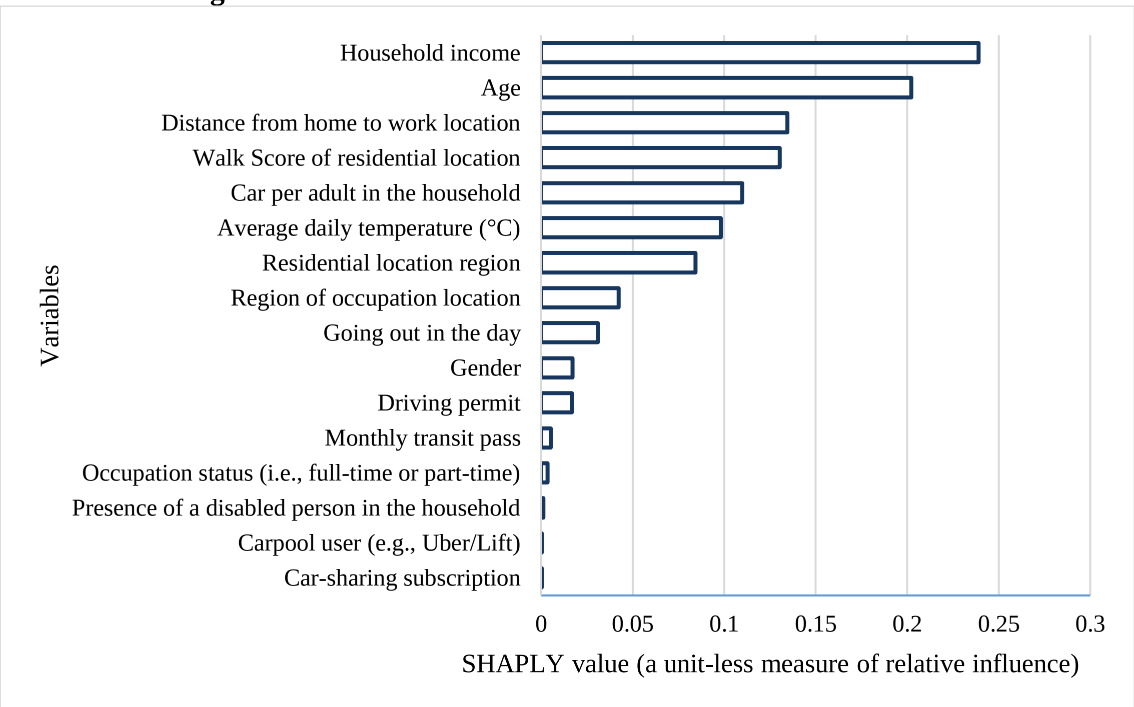
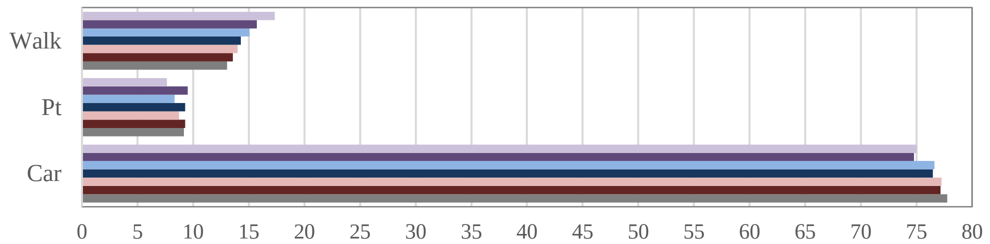


Figure 4: The relative influence of variables on the teleworking probability

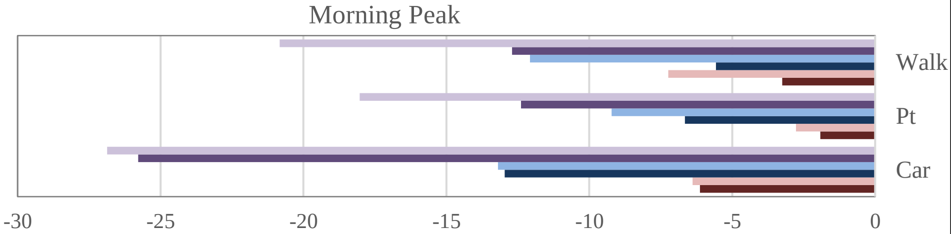
According to **Figure 4**, household income, age, distance to work location, walkability of the residential location, and car ownership are the strongest determinants of teleworking. High-income groups are generally more likely to telework, which can be related to their job characteristics (Walls et al., 2007). Also, there is a strong correlation between age and teleworking probability, and younger groups generally have more intention to telework and also a higher level of in-role performance (Hamouche & Parent-Lamarche, 2023) .Increasing the commuting distance increases the probability of teleworking (Helminen & Ristimäki, 2007) , and car owners are less likely to work from home. In the simulation, the impact of teleworking on travel patterns is significant and multi-faceted. Using these variables, we were able to expand the teleworking rates in our synthetic population based on probability factors of teleworking. We created different scenarios where 10%, 20%, and 40% of the labor force engage in teleworking in MATSim. **Figure 5** compares travel modal shares between the reference scenario and various teleworking scenarios in Quebec CMA.



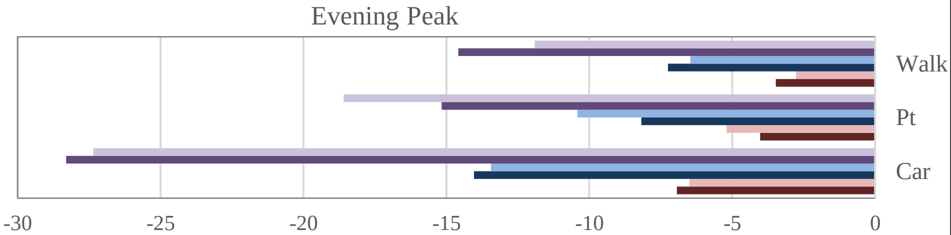
	Car	Pt	Walk
S2 (40% TW)	75.02	7.64	17.33
S1(40% TW)	74.78	9.50	15.73
S2(20% TW)	76.62	8.34	15.04
S1(20% TW)	76.46	9.27	14.27
S2(10% TW)	77.25	8.74	14.00
S1(10% TW)	77.17	9.27	13.56
Refrence Scenario	77.78	9.17	13.05

Figure 5: Comparison of travel modal shares between the reference scenario and teleworking scenarios among workers in Quebec CMA.

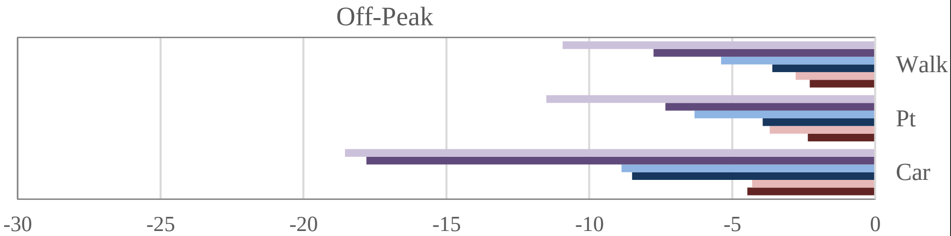
The results show a notable shift in modal shares due to teleworking. In the reference scenario, car usage is at 77.78%. With 40% teleworking, car usage drops to approximately 3%, while walking increases around 2.7%. There is also a slight shift to public transport, but it is negligible. However, in Scenario 2, where teleworkers engage in additional activities, car usage slightly increases by around 0.5% compared to the scenario without additional activities. To clearly and deeply present how much distance is traveled in this mode after teleworking scenarios, **Figure 6** illustrates the percentage change in Passenger Kilometers Traveled (PKT) for each mode during the morning peak, evening peak, and off-peak hours compared to the reference scenario.



	Car	Pt	Walk
S2 (40% TW)	-26.87	-18.03	-20.84
S1(40% TW)	-25.79	-12.39	-12.70
S2(20% TW)	-13.19	-9.22	-12.07
S1(20% TW)	-12.96	-6.65	-5.57
S2(10% TW)	-6.39	-2.77	-7.24
S1(10% TW)	-6.13	-1.92	-3.25



	Car	Pt	Walk
S2 (40% TW)	-27.35	-18.59	-11.90
S1(40% TW)	-28.31	-15.17	-14.58
S2(20% TW)	-13.44	-10.42	-6.47
S1(20% TW)	-14.03	-8.18	-7.25
S2(10% TW)	-6.50	-5.21	-2.78
S1(10% TW)	-6.93	-4.03	-3.48



	Car	Pt	Walk
S2 (40% TW)	-18.55	-11.50	-10.93
S1(40% TW)	-17.80	-7.33	-7.76
S2(20% TW)	-8.87	-6.32	-5.39
S1(20% TW)	-8.50	-3.93	-3.60
S2(10% TW)	-4.30	-3.69	-2.79
S1(10% TW)	-4.48	-2.35	-2.28

Figure 6: Percentage Change in Passenger Kilometers Traveled (PKT) for Each Mode During Morning Peak, Evening Peak, and Off-Peak Hours Compared to Reference Scenario

Figure 6 shows a substantial reduction in car usage, with up to a 26.87% decrease in PKT observed in the scenario with 40% teleworking, highlighting teleworking's potential to decrease car travel distances and alleviate traffic congestion. In the S1 scenario, 10% teleworking results in a 6.13% decrease in car usage, which nearly doubles to around 12% at 20% teleworking. When teleworking reaches 40%, car usage significantly drops by 26.87%. This trend indicates a clear relationship between increased teleworking policies and reduced car usage.

To better investigate this rebound effect in traffic volume, **Figure 7** shows the absolute traffic volume in the reference scenario in Quebec, highlighting three major highways: Laurentienne Highway, Highway 40, and Pierre Laporte Bridge. The analysis in Figure 7 examines the changes in traffic volume on these highways under different teleworking scenarios.

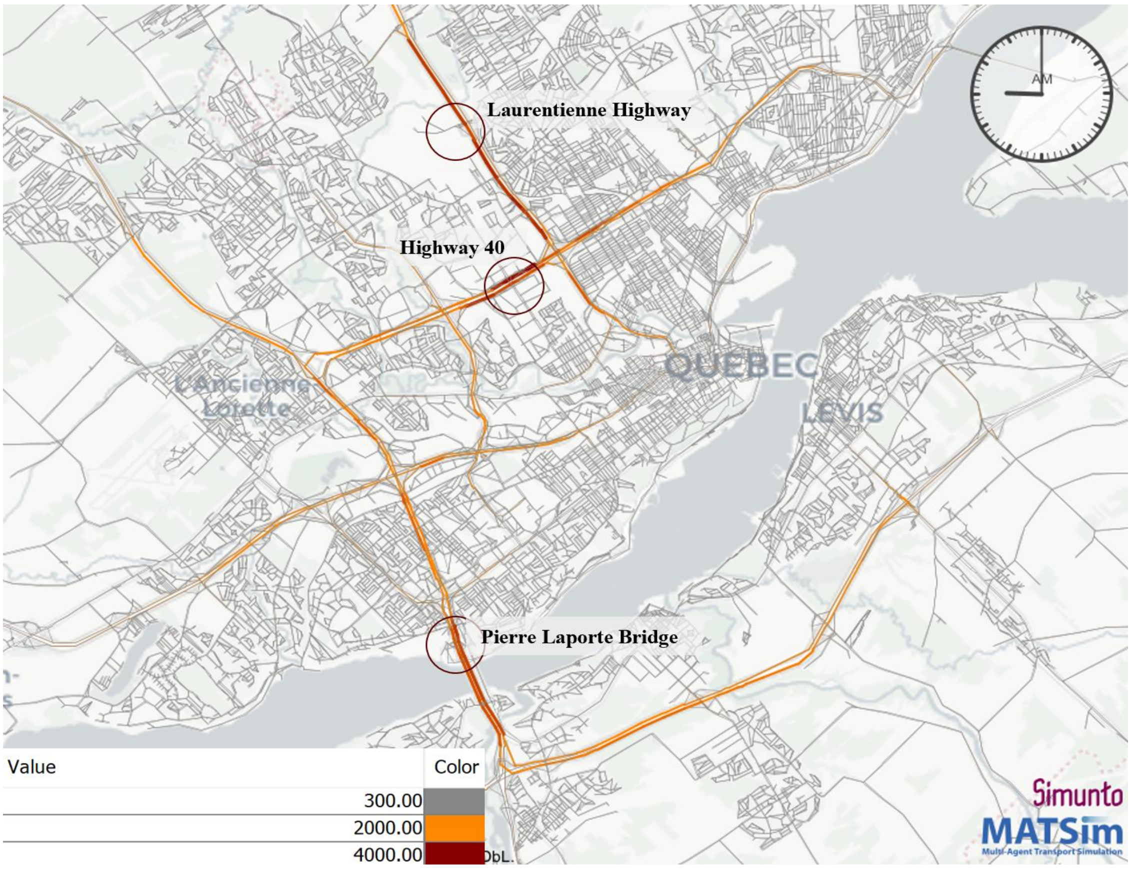
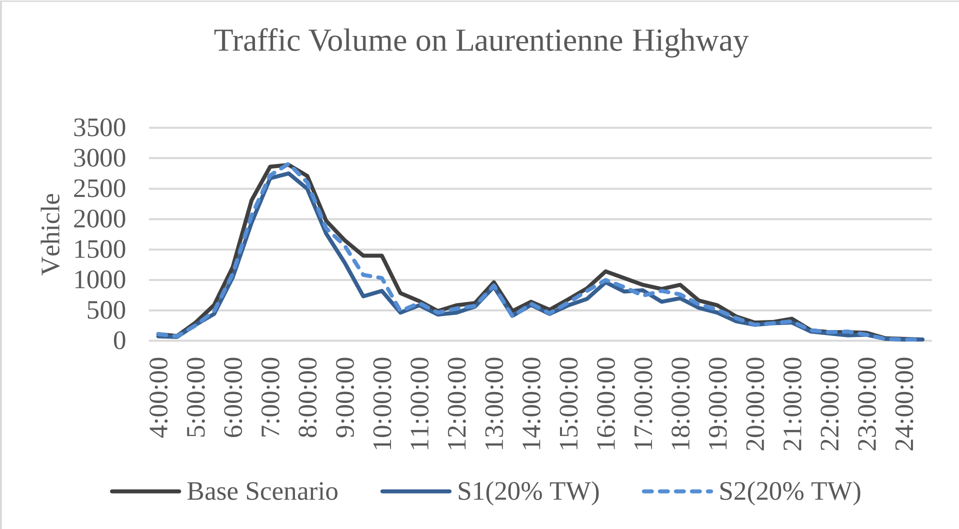
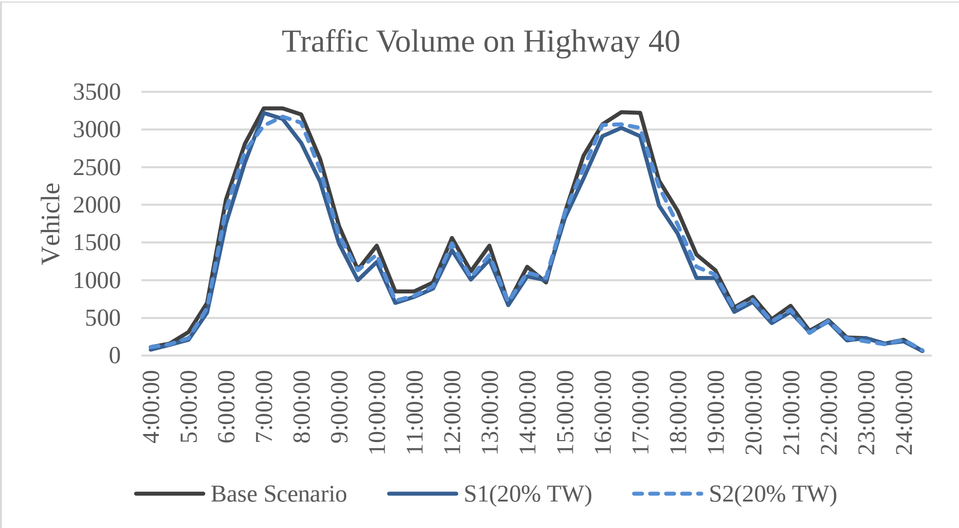


Figure 7a: Absolute Traffic Map in Quebec City in Reference Scenario





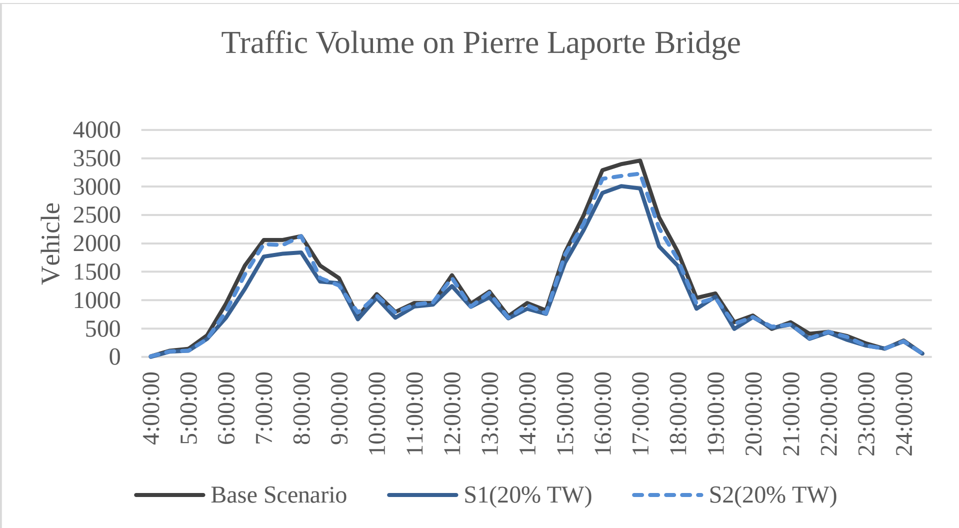


Figure 7b: Absolute Traffic Volume Changes on Major Highways in Quebec City Across Different Teleworking Scenarios

The traffic volume map and graph on major highways reveal that teleworking decreases traffic volumes during peak hours, if it is assumed that no activities are added to the chains as compared to the baseline scenario (Scenario 1). However, Scenario 2, which includes additional secondary activities by teleworkers, results in an increase in traffic volume compared to the basic teleworking scenario. This suggests that while teleworking can mitigate congestion during peak times, the introduction of new secondary activities may lead to increased traffic volumes at other times, potentially offsetting some of the congestion reduction benefits.

6. CONCLUSIONS

This study investigates the impact of teleworking on travel patterns among labor force in Quebec City region using the MATSim/Eqasim model, focusing on scenarios where teleworkers staying home without changing daily activities and those engaging in additional activities. The findings show that increased teleworking reduces car usage, benefiting urban mobility and sustainability. However, new activities by teleworkers can lead to a rebound effect, slightly increasing traffic volumes during non-peak hours.

The results highlight the positive impacts of teleworking, such as reduced car usage but also reveal its complex effects on travel patterns. Key determinants of teleworking include income, age, distance, walk score, and car per adult ratio, significantly influencing an individual's likelihood to telework and their travel behavior. Teleworking helps redistribute traffic from peak to off-peak hours, reducing congestion during critical times. There is a positive correlation between higher teleworking rates and significant reductions in car travel distances. For instance, a 10% increase in teleworking results in a 6.13% decrease in car usage, while a 20% increase leads to a 12% reduction.

Future research should focus on improving teleworking participation estimates, incorporating detailed job classifications, and enhancing the modeling of daily activities. Overall, teleworking is a promising strategy to enhance urban mobility and sustainability, but further research is needed to optimize its benefits and address potential rebound effects.

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