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Development and application of TeEMs (Telecommuting Expectation Models): Predicting post-pandemic Telecommuting Choice and Frequency using Machine learning models

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DEVELOPMENT AND APPLICATION OF TeEMs (TELECOMMUTING EXPECTATION MODELS): PREDICTING POST-PANDEMIC TELECOMMUTING CHOICE AND FREQUENCY USING MACHINE LEARNING MODELS

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ABSTRACT

- This project develops Telecommuting Expectation Models (TeEMs) for predicting the post pandemic Telecommuting Choice and Frequencies using Machine Learning Models. These models could aid Metropolitan Planning Organizations (MPOs) nationwide to forecast telecommuting, so that it can be incorporated into Travel Demand Models (TDM) to predict future congestion and need for additional transportation facilities. The data utilized to develop the models was derived from responses to the national survey "COVID-19 and the Future Survey."
- The TeEMs Choice Model was demonstrated by a case study in the Dallas Fort Worth Metroplex using the 2017 National Household Travel Survey (NHTS) data
- Transportation Impact Scenario Analysis found Scenario 1 with a 15% reduction in HBWT and 9.3% rebound trips, resulted in reduction of 6 million VMT/day (2.65%). Scenario 2, to 5 had 20% trip reduction and various rebounds ranging from 10.9 to 13.4%. On average, a reduction of 8.3 million VMT per day (3.6%) was observed in these scenarios. In scenario 6, 35% telecommute adoption, with 20.5% rebound trips, decreased VMT by 15.9 million per day (6.9%). The Vehicle Hour Travelled (VHT) also showed a trend similar to VMT. The findings suggest that telecommuting has the potential to reduce VMT and VHT. The demonstration of TeEMs Choice Model for DFW suggests that telecommuters have more than doubled post-pandemic, and with the growing population influx to the Metroplex, promoting telecommuting could serve as a valuable strategy to alleviate congestion.

BACKGROUND

- Telecommuting is prevalent in today's workforce.
- Hybrid work model expected to grow from 42% in 2021 to 81% in 2024 (AT&T study, 2022)
- Conventional working practices and commuting behavior evolved.
- Telecommuting alters the homebased work trips made, especially during the peak hour.
- This prompts a reevaluation of travel behavior of worker and updating travel demand models (TDM) to optimize transportation planning.
- Existing models cannot be readily adopted by the Metropolitan Planning Organizations (MPOs) into TDM as they use pre pandemic data or are difficult to integrate with existing models.

OBJECTIVES

- Develop supervised machine learning models based on the socio-demographic and trip related factors available nationally to predict Post Pandemic Telecommute adoption
  - A binary classification model to predict the telecommute status of a worker
  - A multi-class classification model to predict frequency of telecommute.
- Choice model classifies the workers as telecommuters or commuters while, Frequency model classify telecommuters to 5 categories based on frequency of telecommute.
- Demonstrate TeEMs for the Dallas-Fort Worth metroplex, which is 4th largest metropolitan area in US, utilizing 2017 NHTS dataset.
- Conduct Transportation Impact Scenario Analysis for DFW region, to study the potential change in VMT & VHT when people adopt telecommuting.

METHODS

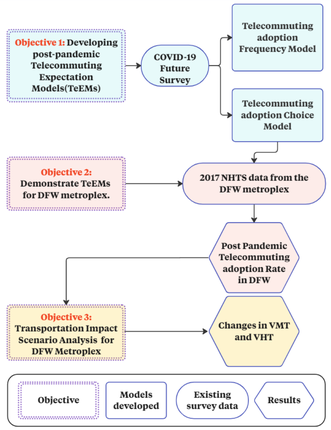

Figure 1. Research methodology overview

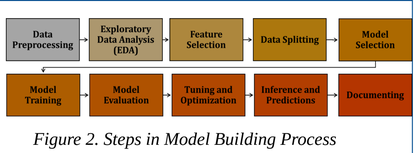

Figure 2. Steps in Model Building Process

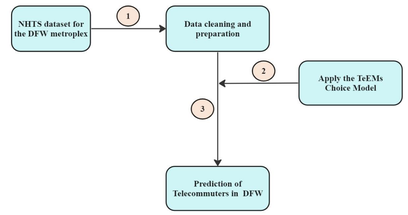

Figure 3. Steps in the case study to demonstrate TeEMs Choice Model

MODEL DEVELOPMENT

➢ **Choice Model**

Table 1:Confusion matrix of selected algorithms

Algorithms	TP	FP	FN	TN
Ada Boost	77	32	**20**	88
Gradient Boost	85	24	33	75
SVM	69	40	38	70
Logistic Reg.	74	35	36	72

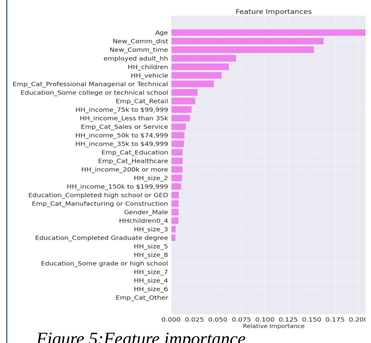

Figure 5:Feature importance

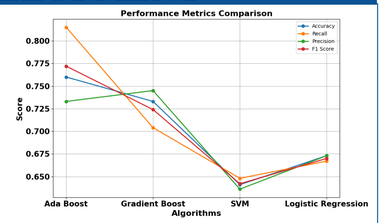

Figure 4:Comparison of Performance metrics

Table 2: Influence of Attributes

Factor	Range/Category	Telecommuting Influence
Gender	Female vs. Male	Lower among females
Age	35-55 years	Higher adoption
Industry Sector	Manufacturing, Construction, Retail	Lower adoption
Education Level	Bachelor's / Master's	Higher adoption
Household Income	Above $75,000	Higher adoption
Parental Status	With children 0-4yrs	Higher adoption
Household Employment	Two employed adults	Higher adoption
Commute Time	Over 40 minutes	Higher adoption
Commute Distance	Over 40 miles	Higher adoption

- The Choice model had balanced dataset and AdaBoost model obtained the highest values for every criterion except precision, followed by Gradient Boost model.
- Age, Commute distance and Time were most important attributes.

RESULTS

➢ **Frequency Model**

- Frequency model data was highly imbalanced, and faced challenges in classifying minority class accurately, even with oversampling techniques like SMOTE.
- Addition of more organizational attributes significantly improved model performance.

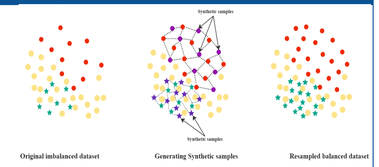

Figure 6: Handling imbalanced dataset using SMOTE

➢ **Demonstration of TeEMs Choice Model for Dallas Fort Worth Metroplex.**

- The result predicts that ~ 67 % of the employed adults in the survey are telecommuters, which is also 34% of the total sample population.
- 20.5% increase in telecommuters in DFW.

➢ **Transportation Impact Scenario Analysis for the DFW Region**

- All scenarios showed significant reduction in Vehicle Travelled and Vehicle Hour Travelled.

Table 3: Percentage reduction in VMT and VHT for scenarios

Scenario No.	% reduction in HBWT	Rebound rate	Net reduction I n HBWT	% Reduction in VMT	% Reduction in VHT
1	15	62%	5.66	2.65	5.65
2	20	56%	8.84	3.77	7.79
3	20	65%	6.97	3.47	7.33
4	20	67%	6.55	3.47	7.22
5	20	54%	9.11	3.79	7.85
6	35	59%	14.50	6.92	13.41

➢ **Limitations**

- The scope of the study is limited to employees and excludes self-employed individuals.
- Employer related and attitudinal factors are not considered in the model due to lack of such data on a national scale.
- Current Frequency Model does not fully encapsulate 2 or 3 day telecommute which is now prevalent, compared to post-pandemic period.

CONCLUSIONS AND FUTURE WORK

- The AdaBoost model outperformed other TeEMs Choice models in terms of classification accuracy, precision, recall, and F1-score.
- Frequency model faced challenges in classifying the minority class accurately suggesting the underlying patterns in the minority class are complex to capture, or the socio demographic attributes may not effectively discriminate between classes. The addition of more organizational attributes yielded significant improvements in model performance.
- The findings suggest that telecommuting has the potential to reduce VMT and VHT
- Future work includes Emission study for the metroplex using MOVES (MOtor Vehicle Emission Simulator)
- Conducting National survey including attitudinal and organizational factors to enhance models.
- Track telecommuting trends evolution and update models.

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