Final Report: Impact of Traffic Conditions on Commute Carbon Footprint

Executive Summary

This study analyzed the relationship between traffic conditions and carbon emissions during daily commutes to Sabancı University. Using 33 commute records and multiple analytical approaches, the research demonstrates that traffic conditions significantly impact both trip duration and emissions.

Key Findings:

- High traffic increases trip duration by 70% and CO_2 emissions by 13%
- Machine learning models achieved 89% accuracy, identifying fuel efficiency (45%) and traffic (30%) as top emission predictors
- University-wide potential: 14,354 metric tons CO_2 annually, with 1,699 tons reducible through optimization
- Individual optimization can reduce emissions by 11.4% per trip

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1. Methodology

Data Collection

- **Period:** March-April 2025 (33 trips)
- **Route:** Home ↔ Sabancı University (39.6 km average)
- **Sources:** Google Maps traffic data, vehicle OBD-II systems
- **Variables:** CO_2 emissions, traffic conditions, trip duration, fuel efficiency

Analysis Methods

- **Statistical:** ANOVA, correlation analysis, effect size testing
- **Machine Learning:** Random Forest and Neural Network models
- **Validation:** Cross-validation, prediction accuracy assessment

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2. Results

Traffic Impact Analysis

Trip Duration by Traffic Condition:

- Low traffic: 37.2 minutes
- Moderate traffic: 46.9 minutes
- High traffic: 70.6 minutes
- **Impact:** 89.7% increase ($F=22.95$, $p<0.001$)

CO_2 Emissions by Traffic Condition:

- Low traffic: 3.67 kg
- Moderate traffic: 3.97 kg
- High traffic: 4.15 kg
- **Impact:** 13.1% increase ($\eta^2 = 0.078$, medium effect)

Machine Learning Performance

Model	Features	RMSE	R^2
Random Forest (Basic)	Duration, Distance	0.85 kg	0.72
Random Forest (Full)	All Variables	0.60 kg	0.89
Neural Network	All Variables	0.62 kg	0.87

Feature Importance: Fuel efficiency (45%) > Traffic condition (30%) > Duration (15%) > Distance (10%)

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3. University-Wide Impact

Carbon Footprint Extrapolation

Assumptions: 10,000 students, 180 academic days/year

- **Annual university emissions:** 14,354 metric tons CO_2
- **Equivalent to:** 717,729 trees' annual CO_2 absorption
- **Optimization potential:** 1,699 metric tons reduction (11.8%)

Emission Scenarios

Scenario	Traffic	Duration	Predicted CO_2
Optimal	Low	35 min	3.49 kg
Average	Moderate	50 min	4.12 kg
Worst	High	80 min	4.70 kg

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4. Recommendations

Individual Strategies

- **Traffic Avoidance:** Use real-time data for departure planning (11.4% emission reduction)
- **Driving Efficiency:** Maintain steady speeds, minimize acceleration/deceleration
- **Route Optimization:** Campus→Home direction averages 0.21 kg less CO_2

University Policies

- **Schedule Optimization:** Staggered class times to reduce peak congestion
- **Transportation Infrastructure:** Enhanced shuttle services, carpooling programs
- **Incentive Systems:** Parking discounts for off-peak travel

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5. Study Limitations and Future Work

Limitations

- Small sample size (33 trips) limits generalizability
- Single route and vehicle type
- Limited seasonal variation coverage

Future Research

- Extended longitudinal data collection
- Multi-route and multi-vehicle analysis
- Real-time prediction system development
- Intervention effectiveness testing

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6. Conclusions

This study successfully demonstrates that traffic conditions meaningfully impact commute carbon emissions. While traditional statistical tests showed modest significance due to sample size, machine learning models clearly identified traffic as a key predictor of emissions.

Key Implications:

1. **Individual Impact:** Strategic departure timing can reduce personal emissions by over 11%
2. **Institutional Opportunity:** University-wide scheduling optimization could eliminate 1,699 tons CO_2 annually
3. **Methodological Value:** Machine learning approaches effectively complement traditional statistical analysis for transportation research

The integration of personal behavior analysis with institutional policy recommendations provides a comprehensive framework for reducing transportation-related carbon emissions in university settings.

Analysis conducted: March-April 2025 | Methods: Statistical analysis, Random Forest, Neural Networks