DEVELOPMENT OF FULL-CHAIN TRANSPORTATION EMISSIONS, EXPOSURE, AND HEALTH MODELING PLATFORM

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16. Abstract

This project developed an automated modeling system to assess the impact of changes in the transportation system on on-road energy consumption, emissions, pollutant dispersion, and asthma cases attributable to traffic-related air pollution. The system employs well-established and, in many cases, regulatorily approved modeling components to ensure scientific rigor. Furthermore, the system uses cutting-edge technologies such as parallel computing to achieve rapid runtimes, reducing scenario analysis time from what traditionally would take months to less than 24 hours. Using the automated system, the project team demonstrated the impacts of various transportation strategies, such as micromobility, using El Paso, Texas, as a case study.

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Executive Summary

This project developed an automated modeling system to assess the impact of changes in the transportation system on on-road energy consumption, emissions, pollutant dispersion, and asthma cases attributable to traffic-related air pollution. The system employs well-established and, in many cases, regulatorily approved modeling components to ensure scientific rigor. Furthermore, the system uses cutting-edge technologies such as parallel computing to achieve rapid runtimes, reducing scenario analysis time from what traditionally would take months to less than 24 hours. Using the automated system, the project team demonstrated the impacts of various transportation strategies, such as micromobility, using El Paso, Texas, as a case study.

The method developed in the study consisted of a pipeline of proven tools for regional traffic operation, emissions, air quality, and public health assessment. The main contributions of the full-chain modeling pipeline are:

- The regional-level assessment of impacts.
- A full-chain pollutant dispersion assessment.
- The distribution of impacts at the community level.

Moreover, the mesoscopic traffic modeling added more realism to the platform by incorporating long-term traffic pattern changes after major infrastructure projects. The pipeline significantly reduced setup and computation time, allowing the analysis of several replicates of each scenario and establishing confidence intervals for the impact measures and the significance of differences between scenarios.

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Background and Introduction

CARTEEH QUICK FACTS

CARTEEH is a Tier 1 University Transportation Center, funded by the U.S. Department of Transportation's Office of the Secretary for Research and Technology.

Even though transportation planning professionals have long recognized the potential linkages between transportation and public health, it has been difficult to make transportation planning decisions to support public health objectives, such as those outlined in public health initiatives like Healthy People 2030,[1] due to a lack of decision-support tools. This gap is especially relevant in discussions related to environmental justice because traffic-related air pollution (TRAP) disproportionately affects the health outcomes of communities located near major transportation arteries. These communities tend to be disadvantaged in other ways as quantified by the U.S. Census. Advances in full-chain modeling are filling this critical gap. As such, this project developed the Platform to Assess Transportation, Health, and Sustainability (PATHS).

Methodology

PATHS is a cloud-based modeling platform for integrating and automating the deployment of transportation, energy, and emissions models. The pipeline accelerates analysis and provides sound evidence for optimized infrastructure decision-making to regulators and policy makers. The models integrated into PATHS range from land-use and travel patterns to emissions, air quality, and public health. Table 1 summarizes the key components, required inputs and outputs for each component, and outcome measures displayed on the interactive dashboard for evaluation purposes. These key components are required to be activated for a full-chain assessment of TRAP, starting from traffic assignment to emission modeling and concentration of particulate matter 2.5 microns or less in width ($PM_{2.5}$).

Table 1. PATHS Components and Data Flow

Component	Inputs	Model/Function	Outputs	Outcome Measures
Dynamic traffic assignment	• Travel demand • Transportation network	DynusT (Chiu et al., 2011)	Time-dependent vehicle trajectories	• Link-by-link vehicle miles traveled (VMT) • Link-by-link delay • Link-by-link speed
On-road emissions	• Vehicle trajectories • County fleet mix • Vehicle age distribution • Meteorology and fuel supply parameters	MOVES-Matrix (Liu et al., 2019)	Mass emissions by link and by vehicle type	• Link-by-link mass emissions for greenhouse gases (GHGs) and air pollutants • Link-by-link energy consumption
Particulate matter concentration	• Link-by-link $PM_{2.5}$ mass emissions • Transportation network • Meteorological and land use inputs (AERMET, AERMINUTE, and AERSURFACE)	AERMOD (Cimorelli et al., 2005)	$PM_{2.5}$ concentrations at discrete receptors	• $PM_{2.5}$ concentration averaged to census blocks

[1] https://health.gov/healthypeople.

Several additional components of the pipeline—electrification estimation, advanced traveler information system, and life-cycle assessment—are triggered under specific scenarios. Each component of the pipeline is a well-established, mature model, and the connections between models are quality assured.

The mesoscopic dynamic traffic assignment (DTA) model analyzes the movement of individual vehicles (as in microscopic models) according to macroscopic traffic flow models without complicated vehicle interactions (Chiu et al., 2011). Thus, the mesoscopic DTA model significantly outperforms microscopic simulations in large-scale networks and over long time periods. On the other hand, MOVES-Matrix (Liu et al., 2019) enables the rapid vehicle emission assessment of the network. AERMOD (Cimorelli et al., 2005), the air dispersion model, is the U.S. Environmental Protection Agency's approved regulatory model for transportation-related air quality analysis and was also integrated into PATHS to simulate the dispersion of traffic-related $PM_{2.5}$ pollution. The health impact of the exposure to $PM_{2.5}$ pollution was then estimated using a previous study on transportation-related health problems (Khreis et al., 2018), where the fraction of childhood asthma cases directly attributable to TRAP was determined to vary exponentially with the average $PM_{2.5}$ concentration. With the reported parameters of the relationship between the concentration and the fraction of TRAP attributable asthma cases, the health impact of the daily average $PM_{2.5}$ pollution from mobile sources can be computed.

With rapid changes in transportation technology (e.g., electric vehicle adoption) and infrastructure (e.g., road construction), PATHS can be used as a tool for rapid environmental and public health assessment of transportation investments. PATHS was applied to multiple case studies during the study period for rapid scenario analysis.

The PATHS code repository provides detailed documentation and source code: https://github.com/meitiv-tti/paths. Figure 1 illustrates the workflow of PATHS.

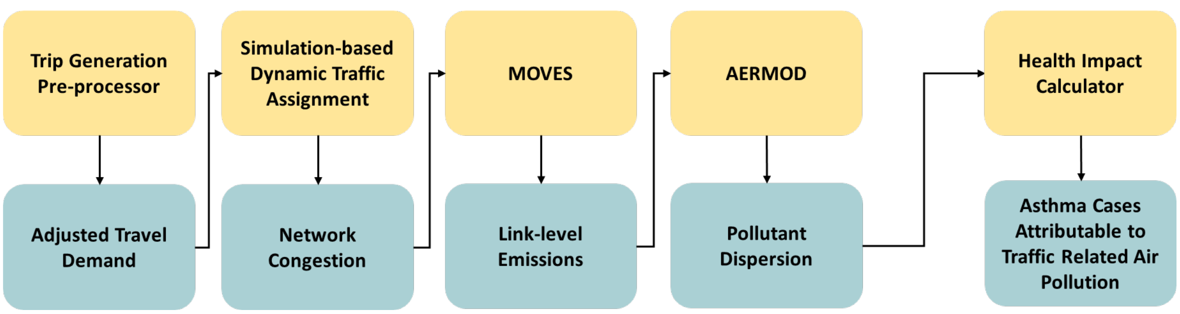


Figure 1. PATHS work flow.

Results

El Paso, Texas, Case Study on Micromobility

With the rapid population growth in urban areas, micromobility has become an attractive mode of transportation for short or first/last-mile trips in recent years. Micromobility, ranging from human-powered bikes to electric scooters—shared or personal, docked or dockless—offers a good solution and can be an efficient substitution for short vehicle trips. Although micromobility has faced practical challenges in real-world implementation, its growing popularity warrants a comprehensive assessment of its potential benefits to the triple bottom line of urban sustainability.

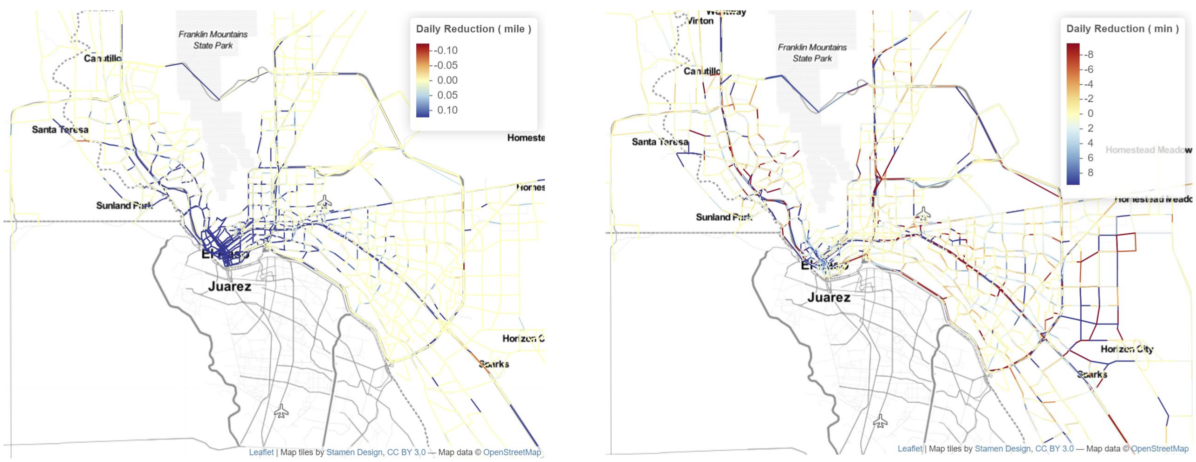
This study sheds light on the regional role of micromobility, considering all three aspects of sustainability. The project simulates the substitution of short car trips in dense urban core areas with micromobility options on a DTA platform such that local congestion relief can be examined in the regional context for El Paso, Texas. The regional traffic impacts are further translated into economic impacts measured in revenue and medical expenses, environmental impacts measured in greenhouse and air pollutant emissions, and societal impacts measured in public health outcomes attributable to traffic-related air pollution and related environmental justice implications.

This study conducted the analysis using PATHS. The levels of micromobility adoption were formulated based on two critical travel behavior variables:

- The average distance of a trip taken via a micromobility mode.
- The probability of a very short car trip being replaced by a micromobility trip.

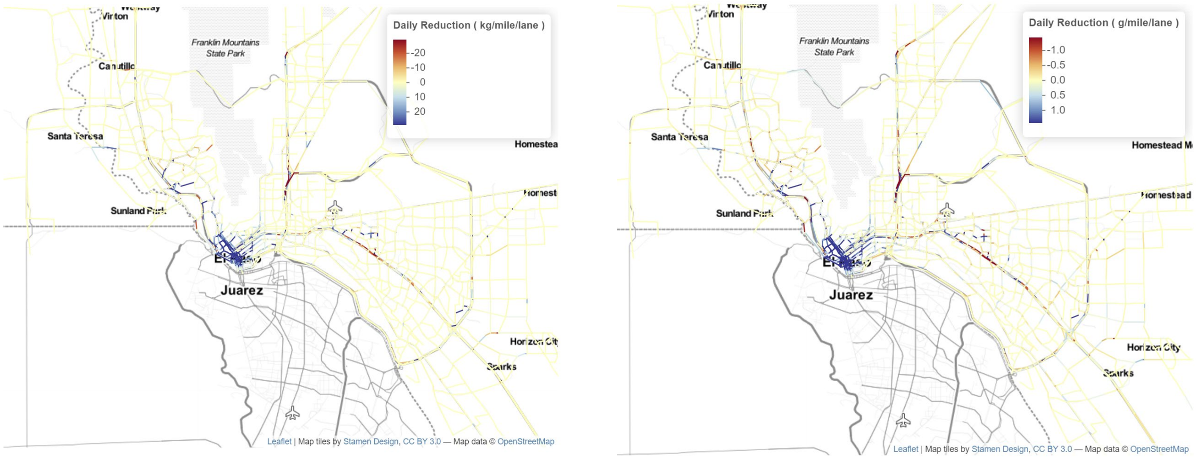
Car trips that originated and terminated in high-traffic zones (downtown and university campus) were removed from the roster of vehicle trips with probabilities that depended exponentially on the trip length.

Three scenarios (low, medium, and high adoption) were developed and compared to the base scenario, zero micromobility activity. The results show an average daily saving of 130 tons in GHG emissions (equivalent to 1.3 percent and statistically significant) and 14,187 gallons of gasoline for the highest adoption. The health impacts were analyzed and visualized at the census block level for any equity concerns and aggregated to the regional level to examine potential savings in medical care expenses. Figure 2, Figure 3, and Figure 4 showcase the visual outputs of the spatial distribution of the changes between the baseline and micromobility scenarios.



VMT: blue indicates reduction | Delay: blue indicates reduction

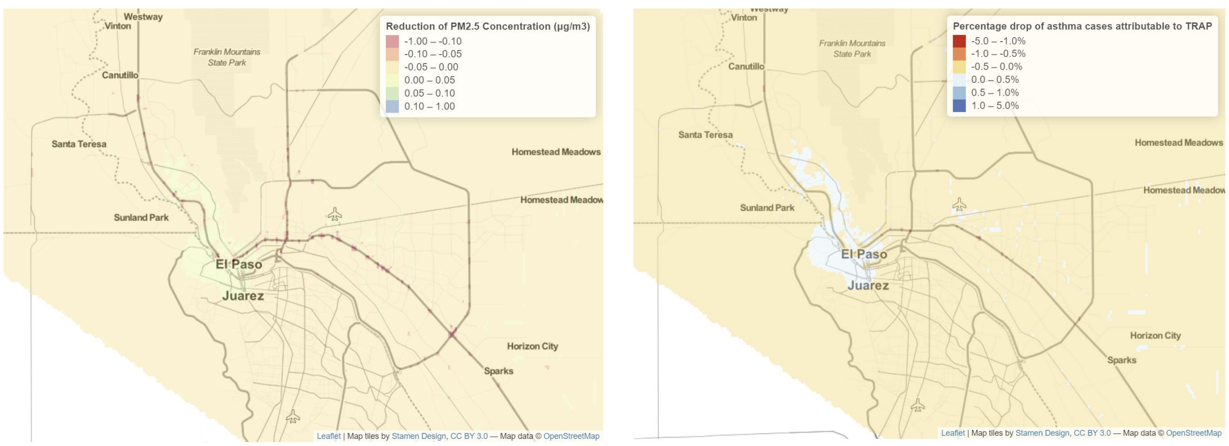
Figure 2. Multi-metric visual outputs of PATHS for traffic.



GHG: blue indicates reduction

PM$_{2.5}$: blue indicates reduction

Figure 3. Multi-metric visual outputs of PATHS for emissions.



PM$_{2.5}$ dispersion: green indicates reduction

Asthma cases: blue indicates reduction

Figure 4. Multi-metric visual outputs of PATHS for pollutant dispersion and health.

This case study demonstrated the ability of PATHS to simultaneously model multiple impacts at both the regional and local levels. Environmental impacts were measured in greenhouse and air pollutant emissions, and societal impacts were measured in public health outcomes attributable to traffic-related air pollution. In the case of micromobility modeled in El Paso, no significant improvement was observed in regional congestion and emission. Localized emission, pollutant concentration, and respiratory disease benefits were observed. The results indicate that micromobility is effective at the local level. Growing shared-micromobility services does not necessarily improve regional congestion and emissions. However, emission benefits and health impacts can be observed where micromobility is implemented. One caveat is that this set of results observed for El Paso does not necessarily translate to other regions. Current land use in El Paso does not allow for regional implementation of micromobility. Micromobility may have other emission and health implications in other regions.

Case Studies Using PATHS Funded under Other Sources

In addition to the previous case study funded under this effort, PATHS has been applied to multiple other case studies, including:

- El Paso, Texas, case study on post-COVID-19 traffic impacts:
  - Xu, X., Decherd, J., Meitiv, A., Xu, Y., Ramani, T., and Zietsman, J. *Emissions and Air Quality Impacts of the COVID-19 Pandemic.* Report funded by the Texas Department of Transportation. https://txaqportal.org/reports#/.
  - Xu, X., Decherd, J., Meitiv, A., and Xu, Y. (2021). Implications of Potential Post-COVID Travel Pattern on Transportation and Air Quality in Texas. Poster presentation at the 2021 Transportation Research Board Annual Meeting (virtual), January 29, 2021.
- Austin, Texas, case study on managed lanes:
  - Ettelman, B., Tsai, W., Xu, A., Meitiv, A., Sharifi, F., Ramani, T., and Zietsman, J. *TWG Technical Issues Analysis: Emissions, Air Quality and Health in Transportation Planning*. Report funded by the Texas Department of Transportation. https://txaqportal.org/reports#/.
- Houston, Texas, case study on truck electrification:
  - Xu, Y., and Meitiv, A. (2021). *Tailpipe Emission Benefits of Medium- and Heavy-Duty Truck Electrification in Houston, TX.* Report funded by the Energy Foundation. http://carteehdata.org/library/document/tailpipe-emission-benefit-7ea6.

Conclusions and Recommendations

PATHS can rapidly assess the impact of policy and/or infrastructure projects on the TRAP-related burden of disease and therefore can help policy makers consider environmental justice issues in crafting policies aimed at improving health equity. Transportation and public health officials can also use these results to design targeted investment strategies to mitigate negative impacts in disadvantaged communities given an existing transportation project. The key advantages of PATHS include its ability to:

- Measure multiple metrics:
  - Mobility—VMT, speed, and delay.
  - Fuel consumption and GHG emissions.
  - Air pollutants and percentage of asthma cases.
- Communicate multi-faceted impacts:
  - Communities and environmental justice.
  - Health.
  - Disruptive technologies—automated, shared, electric, and micro-mobility.

Outputs, Outcomes, and Impacts

The project has produced an open-source code repository for wide dissemination. The outcomes and impacts of this project are timely because the continuous monitoring capability of air quality for communities is increasing the public's awareness of air quality measurement. This project is propelling a paradigm shift in transportation planning and modeling. The full-chain model allows stakeholders from many different fields to communicate, coordinate, and collaborate. The project was showcased in conjunction with the Healthy People 2030 launch by the U.S. Department of Health and Human Services to help practitioners understand transportation as a social determinant of health. The conversations the project outputs have sparked will help usher in an era of unprecedented cross-department collaboration.

Research Outputs, Outcomes, and Impacts

Peer reviewed journal articles include:

- Sharifi, F., Meitiv, A., Shelton, J., Xu, X., Burris, M., Vallamsundar, S., and Xu, Y. (2021). Regional Traffic Operation and Vehicle Emission Impact Assessment of Lane Management Policies. *Research in Transportation Economics,* 101067.

Presentations at conferences and technical meetings include:

- Sharifi, F., Shelton, J., Meitiv, A., Xu, X., and Xu, Y. (2020). Regional Vehicle Emission Impacts of RideSharing Adaptation. ASCE International Conference on Transportation and Development, Seattle, WA, May 26–29, 2020.
- Sharifi, F., Xu, X., Meitiv, A., Shelton, J., and Xu, Y. (2020). Regional Emission and Health Impact Assessment of Implementation of Micromobility: An El Paso, TX, Case Study. Sustainability and Emerging Transportation Technology (SETT) Virtual Forum, November 5, 2020.
- Meitiv, A., Xu, X., Sharifi, F., Shelton, J., Zietsman, J., and Xu, Y. (2020). Full-Chain Transportation and Health Modeling Platform: An Interactive Way to Explore. American Public Health Association's 2020 Annual Meeting and Expo, San Francisco, CA, October 24–28, 2020.

Technology Transfer Outputs, Outcomes, and Impacts

Code developed includes:

- Open-source code repository: https://github.com/meitiv-tti/paths.

Education and Workforce Development Outputs, Outcomes, and Impacts

Students involved in the project include:

- Farinoush Sharifi, Ph.D. student.
- Vipul Tiwari, master's degree student.
- Inshuya Muthukumar, master's degree student.

References

Chiu, Y. C., Bottom, J., Mahut, M., Paz, A., Balakrishna, R., Waller, S., & Hicks, J. (2011). Dynamic traffic assignment: A primer (transportation research circular e-c153).

Cimorelli, A. J., Perry, S. G., Venkatram, A., Weil, J. C., Paine, R. J., Wilson, R. B., ... & Brode, R. W. (2005). AERMOD: A dispersion model for industrial source applications. Part I: General model formulation and boundary layer characterization. *Journal of Applied Meteorology and Climatology*, *44*(5), 682-693. Khreis, H., de Hoogh, K., and Nieuwenhuijsen, M. J. (2018). Full-Chain Health Impact Assessment of Traffic-Related Air Pollution and Childhood Asthma. *Environment International*, 114, 365–375.

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