Texas A&M Transportation Institute

Performance Measures and Tools for Assessing CMAQ Project Effectiveness

MEMORANDUM

Prepared for the Texas Department of Transportation

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Texas A&M Transportation Institute

TECHNICAL MEMORANDUM

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INTRODUCTION

This report summarizes the activity on *"Performance Measures and Tools for Assessing CMAQ Project Effectiveness"* conducted as part of Subtask 2.1 (TWG Technical Issues Analysis) under the TTI-TxDOT Air Quality and Conformity Interagency Contract (IAC). This report presents the application of Transportation and Emissions Modeling Platform for Optimization (TEMPO), as an innovative and holistic means for Congestion Mitigation and Air Quality Improvement (CMAQ) project assessment to include public health impacts. The motivation for using TEMPO in the CMAQ context stems from the needs and opportunities in CMAQ benefits quantification as revealed from literature review and expert interviews. A case study of TEMPO application to rideshare and micromobility project scenarios in El Paso, TX further illustrates the use case.

BACKGROUND

The CMAQ program was first established in 1991 as part of the Intermodal Surface Transportation Efficiency Act (ISTEA)(Federal Highway Administration, 2020a) . At the time, the Clean Air Act Amendments of 1990 had resulted in new transportation conformity requirements for air quality nonattainment areas, and the CMAQ program was intended to help nonattainment areas advance projects and initiatives aimed at reducing congestion and improving air quality.

Subsequent surface transportation legislations have all reauthorized the CMAQ program. Currently, the CMAQ program under the FAST Act includes over $2 billion in funding annually for ozone, carbon monoxide (CO), and/or particulate matter (PM) nonattainment and maintenance areas across the United States. While the FAST Act amended the eligible activities to include diesel retrofits and other strategies to reduce PM2.5 emissions from on-road and non-road equipment (Federal Highway Administration, 2016), the program continues to provide mostly flexible funding for projects or programs that can effectively reduce air pollution, included in statewide and/or metropolitan transportation plans and transportation improvement programs.

CMAQ PROJECT SELECTION AND REPORTING

CMAQ funds are apportioned to each state by the Federal Highway Administration (FHWA). The nonattainment areas in the state then receive a share of the funds for their region and are generally responsible for identifying and prioritizing projects at the local level. In Texas, CMAQ funds are one of the funding categories in the Unified Transportation Program (UTP), and Metropolitan Planning Organizations (MPOs) in nonattainment areas are responsible for programming projects in this category (Texas Department of Transportation, n.d., a) (Texas Department of Transportation, n.d., b). The projects are then included in MPOs' Transportation Improvement Program (TIP), the Statewide Transportation Improvement Program (STIP), and in the UTP. There are a wide range of projects that have historically been implemented using CMAQ funds in Texas, including travel demand management strategies, transit improvements, shared ride services, traffic flow improvements and pedestrian and bicycle programs (TxDOT Internal Audit, 2005).

States are required to report on their CMAQ programs to FHWA annually through an online reporting system. The project details for each state in turn are compiled and made available as part of an annual CMAQ report, and through the CMAQ public access system (Federal Highway Administration, 2019). In addition to the detailed reporting of individual projects, many state DOTs and MPOs are also required to establish targets and report progress on three CMAQ performance measures as part of FHWA's Transportation Performance Management processes. These measures include two measures on traffic congestion (peak hour excessive delay and non-single occupancy vehicles), and one on on-road mobile source emissions.

CMAQ PROJECT SELECTION AND ASSESSMENT NEEDS

As noted previously, the CMAQ program provides fairly flexible funding, with projects that can be prioritized based on local needs. Therefore, project selection criteria vary, though common ones include emission benefits, congestion benefits and cost-effectiveness of emissions reductions. While DOTs and MPOs are asked to quantify and report emissions benefits for most CMAQ projects, there are no mandated requirements in terms of methods, tools, or models that are to be used. A 2014 report assessing the CMAQ program noted that the tools and methods used by DOTs and MPOs varied, with different levels of technical rigor (Battelle and Texas A&M Transportation Institute, 2014). With a view of providing assistance to states and regions, FHWA has developed a CMAQ emissions calculator toolkit as an additional optional resource to agencies. Similarly, FHWA has also conducted research to provide guidance on cost-effectiveness of CMAQ strategies (Federal Highway Administration, 2020b). However, state and local agencies are encouraged to and continue to use locally-specific methods, tools and data for CMAQ project assessments, such as the Texas Guide to Accepted Mobile Source Emissions Reduction Strategies (MOSERS) in Texas.

These established methods are focused on quantifying emissions and congestion benefits, usually for individual projects. However, there is an opportunity to also evaluate additional performance measures for CMAQ projects to better understand their effectiveness, at the individual project level, at the network level and at a programmatic level. This is especially important as there is an increasing emphasis on other outcomes of the CMAQ program, such as understanding of health impacts/benefits (Battelle and Texas A&M Transportation Institute, 2014).

Advances in transportation modeling and data analytics also present an opportunity for systematic modeling and visualization of the impacts of CMAQ projects on different congestion and emissions-related measures, as well as on other emissions-related outcomes such as health impacts. This can support reporting of mandated CMAQ project benefits and performance measures, as well as in the evaluation of other measures for communication with stakeholders.

STUDY OVERVIEW

In this study, the TTI team investigated the current state of CMAQ projects, and project reporting and assessment processes, with an emphasis on Texas state-of-practice. Then, the study identified performance measures relevant to CMAQ projects, and quantification and modeling approaches that could be used to conduct more holistic assessments of project benefits. Finally, a case study analysis was conducted demonstrating how a wider range of transportation project impacts and benefits could be modeled for a more holistic picture of CMAQ project effectiveness. This study’s findings can be used to inform the Technical Working Group (TWG) about the current state of practice, key gaps in knowledge, and approaches to better understand the impacts and benefits of CMAQ projects.

THIS REPORT

Following this introductory section, this report includes a scan of current status of CMAQ reporting and assessment, a case study of a holistic CMAQ assessment approach, and a summary of discussion of findings.

CURRENT CMAQ REPORTING AND ASSESSMENT PRACTICES

NEED FOR CMAQ BENEFIT QUANTIFICATION

The need for improved CMAQ program benefits calculation methods stems from various layers of reporting requirements and assessment of stewardship of taxpayers' dollars. In addition to required reporting, there is also an increased emphasis on communicating the benefits of transportation investments to stakeholders, including environmental and health co-benefits that may occur from implementation of projects.

Annual Reports of CMAQ Project Obligation Data

All states report CMAQ project obligation data to FHWA. These reports do not require, but are highly encouraged to include quantitative estimates of emission benefits (Glaze, 2019). Although the reporting system is standardized, state DOTs and MPOs use different tools and methods to calculate the estimates to be reported. Data for all states is available through the FHWA CMAQ Public Access System: https://fhwaapps.fhwa.dot.gov/cmaq_pub/.

The CMAQ Public Access System (PAS) allows the public to query all projects since the inception of the CMAQ program in 1992. The attributes available to view in the system include project investment levels, project type, and emission reduction quantifications of VOC, CO, NO_x, PM_{10}, $PM_{2.5}$, and CO_2. Not all projects report quatititive emission reductions. Most projects only report a few of the emission types mentioned earlier.

Some projects do not include any quantitative estimates at all.

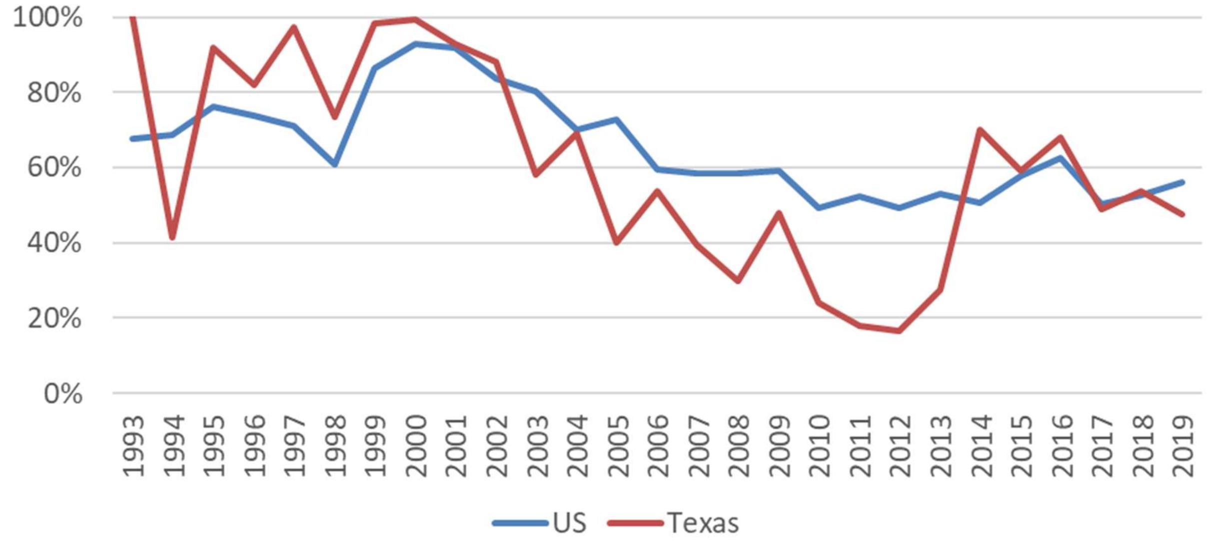


Figure 1 shows the trends of projects that reported any quantitative emission benefits since 1993, the first year Texas reported CMAQ projects. The trend lines indicate that the reporting from Texas has been on par with the rest of the country since 2015, the year FHWA updated the CMAQ PAS.

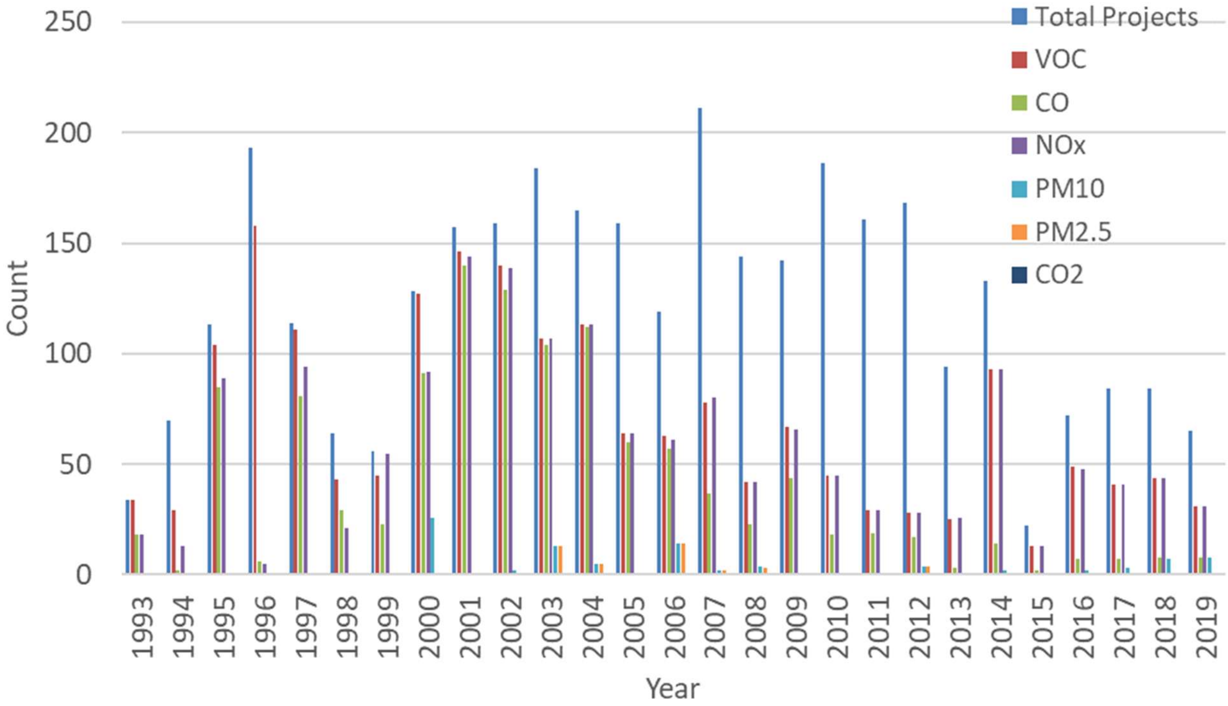


Figure 2 further presents the Texas project counts by the pollutant type reported. Among Texas projects, the most reported pollutants are VOC and NO_x, which is not surprising given the ozone nonattainment status of major MPOs in Texas. Over the years, CO has become less of a concern, so the number of projects reporting CO reductions have declined, too. Only a small portion of all projects report PM reduction estimates, indicating a lack of readily available methods or lack of applicability for these pollutants. No projects in Texas reported CO_2 reduction estimates. FHWA no longer requires reporting of CO_2.

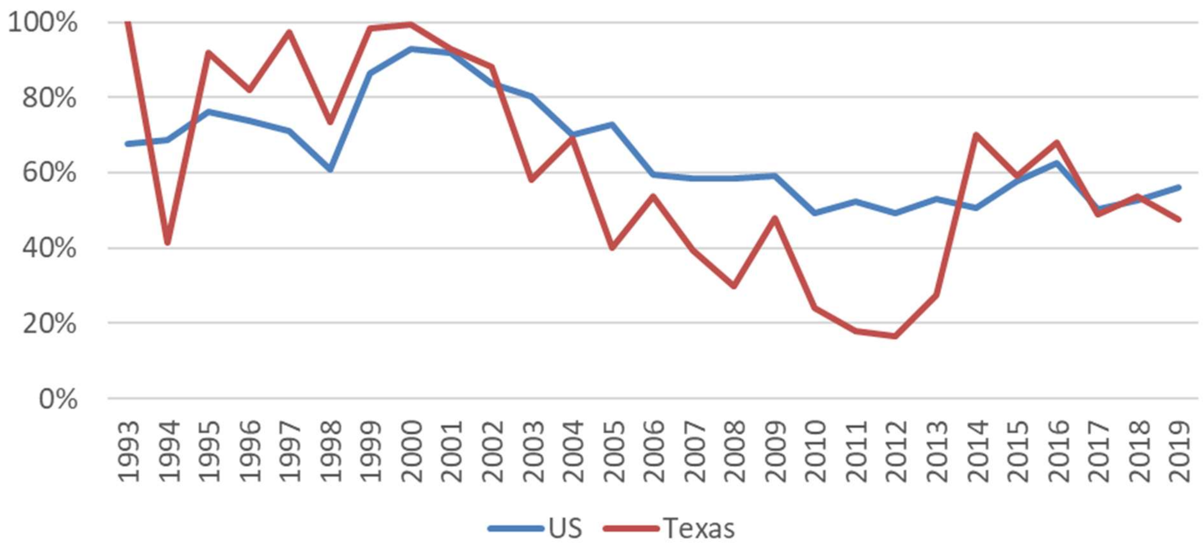


Figure 1 Percent of Projects Reporting Emission Reduction Estimates

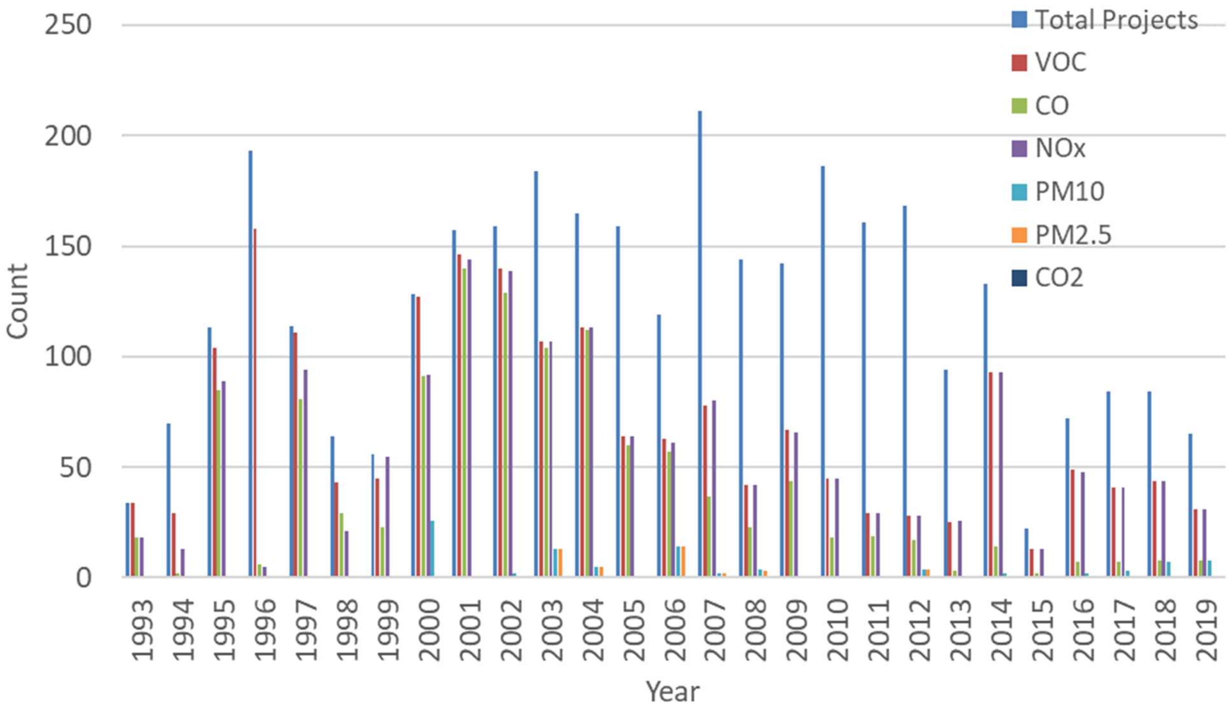


Figure 2 Count of Texas Projects Reporting Quantitative Reduction Estimates

Performance Measures

Since the enactment of MAP-21, and subsequently, the FAST Act, the CMAQ program has been subject to performance measures. MPOs and state DOTs are required to report CMAQ performance measures to the USDOT. The federally-required CMAQ measures focus on congestion reduction (Annual hours of peak hour excessive delay per capita and non-single occupancy vehicle travel measure) and emissions reduction (2- and 4-year total emission reductions for each applicable criteria pllutant and precursor) regionally or statewide (Federal Highway Administration, 2019b).

Specific to Texas and TxDOT, the following CMAQ performance measures are applicable (Federal Highway Administration, 2017):

- Traffic congestion measures: required for Houston and Dallas-Fort Worth-Arlington urbanized areas
- On-road mobile source emissions performance measures required for:
    - 24-hour PM10
    - Ozone (2008)

  - CO

The traffic congestion measures and the emissions performance measures draw from very different data sources. The reporting of traffic congestion measures primarily relies on measured data, such as the highway performance data for peak hour excessive delay and the American Community Survey (ACS) for percent of non-single occupancy vehicle (SOV) travel (Federal Highway Administration, 2020c). The emissions performance measures reporting must use the reported reductions from the CMAQ PAS (Federal Highway Administration, 2018). According to FHWA guidance, the measure is simply computed as the summation of emission reductions from all projects reported to the CMAQ PAS. This requirement provides a strong incentive for TxDOT and its partner agencies to increase the proportion of projects with quantitative emission reduction estimates.

Program Outcomes Assessment

In addition to reporting requirements, the CMAQ program is assessed periodically for its effectiveness as a public spending program. A recent assement study was conducted per MAP-21 requirements (Battelle and TTI, 2014). The study assessed projects impacts on emissions, air quality and human health. The emphasis on air quality and human health in the study solicitation signaled the public and lawmakers' desire to understand the program's outcomes in these areas. However, the study admitted severe limitations on the ability to quantify human health impact due to limited data and tools, and wide variability in how projects' emissions benefits are assessed.

MAP-21 also directed US DOT to develop cost-effectiveness tables for CMAQ projects (Volpe, 2020). Projects were evaluated in dollars per ton of emissions reduced and rated as having strong, weak, or mixed cost-effectiveness. The report also analyzed congestion impacts quantified as vehicle-hours of idling. The report also pointed out that cost-effectiveness should be considered along with other benefits such as fuel consumption reduction in project prioritization.

EXISTING TOOLS

Several tools and methods exist to meet the need for CMAQ benefit quantification. Notable CMAQ calculation tools include:

- The Atlanta Regional Commission's (ARC's) CMAQ Calculator: https://atlantaregional.org/natural-resources/air-quality/air-quality/

- FHWA's CMAQ Toolkit: https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/
- Texas Guide to Accepted Mobile Source Emission Reduction Strategies (MOSERS): https://txaqportal.org/mosers_strategies

These tools exist to a large extent in Excel format. The spreadsheet format is intuitive to most users, but has some limitations with complex calculations and the ability to easily integrate with traffic and travel demand data inputs. To further assess the state of the practice in CMAQ benefits quantification, the TTI team interviewed selected experts who played or are playing key roles in developing CMAQ-related tools at FHWA, ARC, and TTI. The experts raised the following issues as areas of improvement in CMAQ quantification methods:

- Difficulty to assess the statistical significance of emission reduction. CMAQ projects only need to show some reduction in emissions, no matter how small. The fact that some CMAQ projects receive funding with negligible amount of emissions seems to be a source of frustration among practitioners. A rigorous method that could indicate the statistical significance of the estimated reductions would be desirable.
- Current CMAQ tools do not allow for the assessment of a portfolio of projects, for example to conduct a programmatic assessment of benefits across a transportation network.
- There are limited tools and methods available to assess new mobility options, especially for strategies that are regional in nature, such as implementation of micro-mobility systems, ridesharing, area-wide incident management strategies, etc.

GAPS AND OPPORTUNITIES FOR IMPROVEMENT

The scan of current needs for CMAQ benefit quantification tools and existing tools reveals multiple gaps and opportunities for improvement. These include:

- **Additional performance measures**: Currently, emissions reductions (tons/kgs) is the most common metric for CMAQ projects, following federal guidance (Federal Highway Administration, 2018). However, if we take a more holistic view on *outcomes*, CMAQ projects' effectiveness can also be looked at in terms of cost effectiveness, exposure and health impacts. This more holistic view on performance measures can support a broader range of reporting and communication needs for transportation agencies.

- **Consistent framework to support regional assessments:** There is a need for tools and methods to sum up benefits of all projects in a region or state, especially to model and compute them in an integrated manner. The need to consistently sum up project benefits goes beyond the federal guidance on adding up emission reductions in a state or region to report performance measures. A common framework would allow the examination of compounding effects across projects. For example, a rideshare project might be enhanced by a coordinating bike facility project that allows for more flexibility in commuting choice. As such, the actual emissions reduction of the two projects may be greater than the simple summation of the projects' respective reductions.

CASE STUDY OF HOLISTIC CMAQ ASSESSMENT

MOTIVATION

Based on the findings from the current state of practice, CMAQ benefit quantification can benefit from tools that:

- Can provide regional estimates for projects of regional scale with a consistent methodology
- Can indicate the significance of the estimated reductions
- Can evaluate new project types such as innovative mobility options, and
- Can evaluate a broader range of performance measures beyond emissions and congestion benefits.

As such, this report presents the application of a tool that can satisfy these requirements with a case study on El Paso, Texas. El Paso is a major Texas nonattainment area, and a relevant case because the El Paso MPO has received CMAQ funding since the year 2000, when the PAS started to record MPO information, according to the CMAQ PAS records from 2000 to 2019 (Figure 3).

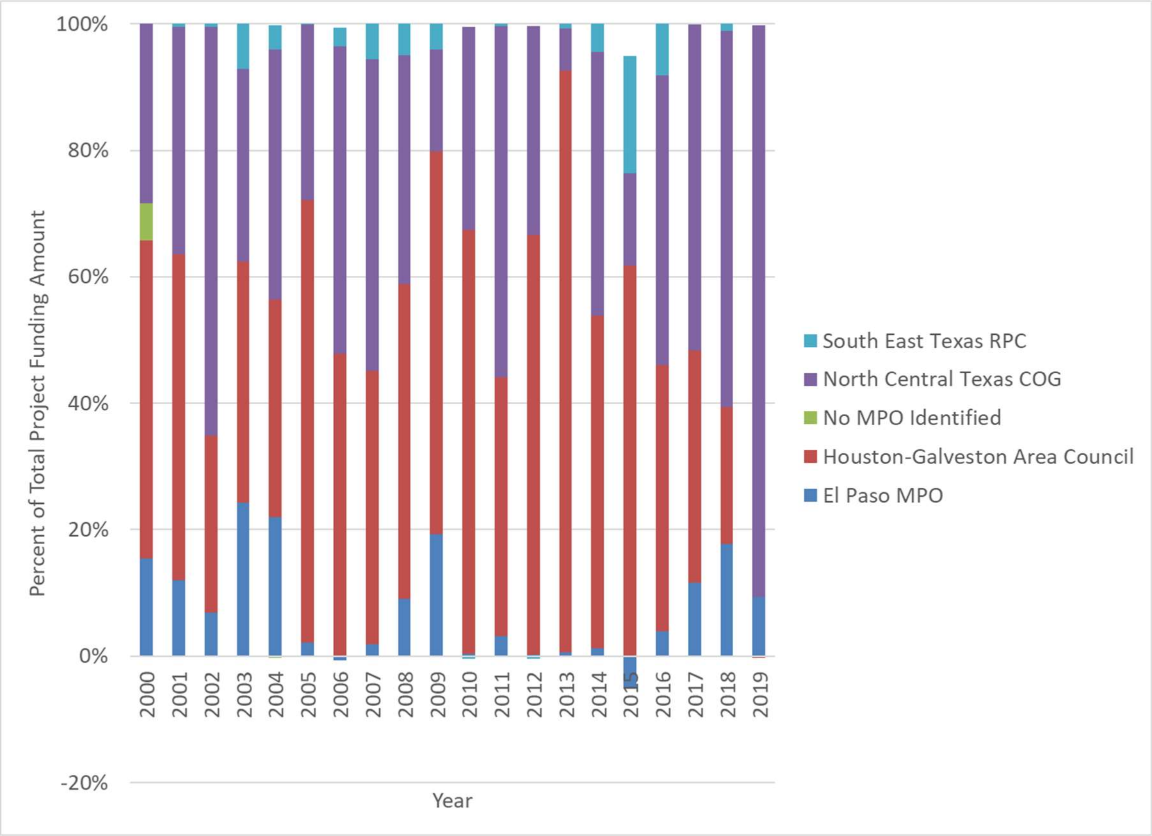


Figure 3 CMAQ Funding Amount by MPO in Texas

The case study focuses on two potential project types: micro-mobility and rideshare. With the rapid population growth in urban areas, micro-mobility has become an attractive mode of transportation for short or first/last mile trips in recent years. Micro-mobility, 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. Recently, cities have initiated programs and policies to promote micro-mobility and transform urban travel behavior, and it has faced practical challenges in real-world implementation (Shaheen, and Cohen, 2019) (Zarif, Pankratz, and Kelman, 2019). Micro-mobility has yet to be officially recognized as an eligible CMAQ project type, but interviews with experts have revealed that there is growing interest in such recognition.

Carpooling and vanpooling projects have long been eligible project types under CMAQ funding. Recent growth in rideshare associated with the advancement of smartphone technologies and start-ups capitalizing on the shared economy warrants a fresh look at rideshare's effectiveness in congestion mitigation and air quality improvement. There are existing tools that estimate the emission reductions of rideshare projects, such as the FHWA CMAQ Toolkit. However, the new wave of rideshare options differ from traditional carpooling or vanpooling projects in that the new rideshare options are driven by mobile technologies rather than subscription to a government program. As such, new rideshare options are more regional in nature rather than confined to certain commuting corridors. The level of vehicle emission reductions depends on the adoption level of the programs and requires a holistic evaluation of the traffic patterns of the entire region.

METHODOLOGY

Overall Approach

This study conducts the analysis using the Transportation and Emissions Modeling Platform for Optimization (TEMPO) developed by TTI to conduct analyses for several ongoing projects (https://tempo-dashboard.io/home). TEMPO is a cloud-based platform for automating a suite of models. A dynamic traffic assignment (DTA) model simulates vehicle activity to estimate the vehicle mile traveled and speed for each link in the system. MOVES-Matrix (Xu et al., 2016), a multi-dimensional emission rate database generated from US Environmental Protection Agency's (EPA) MOtor Vehicle Emission Simulator (MOVES) (US EPA, 2015), is used to quantify the greenhouse gas emissions and air pollutants for each link, including CO_2, $PM_{2.5}$, PM_{10}, NO_X, and VOC. The resultant pollutant emissions are converted to concentrations using the EPA's AERMOD (Cimorelli et al., 2005) (US EPA, 2019) system, and the attributable health impact is computed as the percentage of asthma cases attributable to traffic related air pollution (TRAP) (Alotaibi et al., 2019). Figure 4 illustrates the flow of TEMPO.

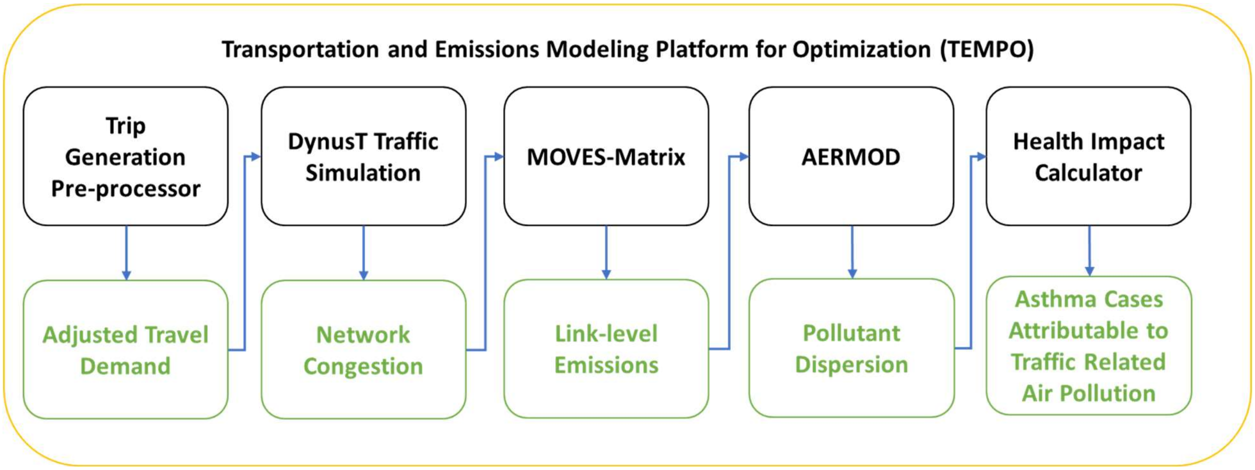


Figure 4 TEMPO's Analysis Pipeline

Micro-mobility

The levels of micro-mobility adoption were formulated based on two critical travel behavior variables: 1) the average distance of a trip taken via a micro-mobility mode, 2) the probability of a very short car trip being replaced by a micro-mobility 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 micro-mobility activity.

To mathematically formulate the scenarios, the trip generation pre-processor for micro-mobility scenarios are characterized by two parameters: P_{max} in [0:1) and L > 0 in miles. For every eligible trip of length L_i we compute P = P_{max} *exp(-L_i/L) and remove this trip with probability P. For example, if P_{max} = 0.2 and L = 1 mile, the trip that is 0.5 miles long is removed with probability P = 0.121. This is accomplished by generating a random number uniformly distributed in [0:1) and removing the trip if this random number is smaller than P. In an intuitive sense, P_{max} is the probability that a very short car trip is replaced by a walking/biking/scooter mode. L is the mean distance of all car trips that were replaced by a micro-mobility mode.

Table 1 summarizes the parameters defining the three micro-mobility scenarios. These parameters are chosen based on a study on Portland, OR (Portland Bureau of Transportation, 2018).

Table 1 Micro-mobility Scenario Definitions

Scenario	P_{max}	L	Trips Removed
Low Adoption	0.2	1	1,743
Medium Adoption	0.25	1.25	2,772
High Adoption	0.3	1.5	3,845

Rideshare

The levels of rideshare adoption were formulated based on two critical travel behavior variables: 1) the maximum difference in departure time or the largest time interval a person may accept to leave earlier. 2) the probability of being matched or the percentage a person may be willing to ride-share. Using these two variables for the same zone origin-destination demands, the new ride-sharing demand matrix was generated for the emission estimation.

To formalize the underpinning logic that defines rideshare adoption levels, we pre-process trip generation as illustrated in Figure 5. When two trips have 1) the same origin and destination nodes and 2) start times within τ of each other, we remove the later trip with probability P_{max}. Varying τ and P_{max}, we consider five rideshare scenarios as shown in Table 2.

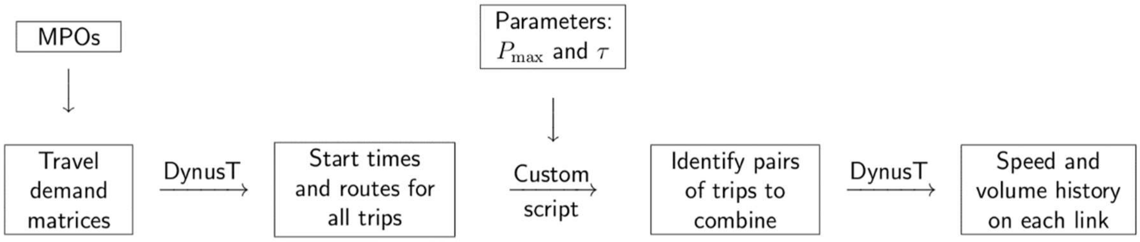


Figure 5 Work Flow for Rideshare Scenario Analyses

Table 2 Rideshare Scenario Definitions

Scenario	τ, min	$P_{\max}$	Total trips	Removed #	Removed %
Baseline			2,493,235		
Low	5	0.05	2,470,914	22,321	0.90
Medium 1	10	0.05	2,453,040	40,195	1.61
Medium 2	5	0.10	2,452,582	40,653	1.63
Medium high	10	0.10	2,422,140	71,095	2.85
High	15	0.15	2,361,742	131,493	5.27

In summary, the case study presents eight scenarios in total – three micro-mobility scenarios and five rideshare scenarios. Table 3 summarizes the scenario descriptions.

Table 3 Scenario Descriptions

Scenario	Description
Micro-mobility: Low Adoption	Car trips up to 1 mile in length that originate in the downtown and university areas are removed with a probability up to 20%
Micro-mobility: Medium Adoption	Car trips up to 1.25 miles in length that originate in the downtown and university areas are removed with a probability up to 25%
Micro-mobility: High Adoption	Car trips up to 1.5 mile in length that originate in the downtown and university areas are removed with a probability up to 30%
Ride-share: Low Adoption	Car trips with the same origin and destination and the start time within 5 minutes are combined with probability 5%
Ride-share: Medium Adoption 1	Car trips with the same origin and destination and the start time within 10 minutes are combined with probability 5%
Ride-share: Medium Adoption 2	Car trips with the same origin and destination and the start time within 5 minutes are combined with probability 10%
Ride-share: Medium High Adoption	Car trips with the same origin and destination and the start time within 10 minutes are combined with probability 10%
Ride-share: High Adoption	Car trips with the same origin and destination and the start time within 15 minutes are combined with probability 15%

RESULTS

This section showcases the results from TEMPO from two main aspects: 1) the region-wide aggregate emission and congestion reduction results and 2) the spatial distribution of emission reductions and the resulting impacts in pollutant dispersion and asthma cases.

Significance of Project Effectiveness

One frequent criticism of CMAQ projects is that the projects only need to show some emission reduction, however small the reduction may be. A key advantage of TEMPO is its ability of rapid scenario runs, which in turn allows for multiple simulation runs to establish the range of likely outcomes. In this case study, each scenario is run five times. The results are compared using a t-test to assess the significance levels of the changes of scenarios compared to the baseline. Table 4 presents the results for the three micro-mobility scenarios. Table 5 presents the results for the five rideshare scenarios. Each scenario is evaluated according to seven metrics, i.e. performance measures: vehicle miles traveled (VMT) and total delay for traffic, energy consumption and CO_2e for fuel consumption, and PM_{10}, $PM_{2.5}$, and NO_x for criteria pollutants. The modeling platform is able to produce results for all criteria pollutants, air toxics, and signal delay, but only seven metrics are provided owing to space constraints.

Table 4 Micro-mobility Scenarios Compared to Baseline

Scenario	Metric	Total Reduction	Percent Change	P-value*
Micro-mobility: Low Adoption	PM_{10} (kg/day)	0.38	0.06%	0.64
	$PM_{2.5}$ (kg/day)	0.34	0.06%	0.64
	NOx (kg/day)	8.77	0.05%	0.60
	Energy Consumption (MMBTU)	322,809	0.25%	0.45
	CO_{2e} (kg/day)	24,501	0.25%	0.45
	Total Delay (min/day)	-13,886	-0.12%	0.85
	VMT	2,195	0.01%	0.53
Micro-mobility: Medium Adoption	PM_{10} (kg/day)	0.27	0.04%	0.65
	$PM_{2.5}$ (kg/day)	0.25	0.04%	0.65
	NO_x (kg/day)	5.50	0.03%	0.61
	Energy Consumption (MMBTU)	38,415	0.03%	0.73
	CO_{2e} (kg/day)	2,942	0.03%	0.72
	Total Delay (min/day)	2,497	0.02%	0.97
	VMT	3,940	0.02%	0.28
Micro-mobility: High Adoption	PM_{10} (kg/day)	0.82	0.12%	0.31
	$PM_{2.5}$ (kg/day)	0.74	0.12%	0.31
	NO_x (kg/day)	18.75	0.11%	0.26
	Energy Consumption (MMBTU)	496,714	0.39%	0.33
	CO_{2e} (kg/day)	37,732	0.38%	0.33
	Total Delay (min/day)	16,879	0.15%	0.81
	VMT	6,393	0.03%	0.11

* Value of 0.05 or less indicate statistically significant differences at 95% confidence level

Table 5 Rideshare Scenarios Compared to Baseline

Scenario	Metric	Total Reduction	Percent Change	P-value*
Ride-share: Low Adoption	PM_{10} (kg/day)	4.26	0.65%	0.00
	$PM_{2.5}$ (kg/day)	3.87	0.65%	0.00
	NO_x (kg/day)	89.85	0.53%	0.00
	Energy Consumption (MMBTU)	1,550,936	1.22%	0.00
	CO_{2e} (kg/day)	117,896	1.21%	0.00
	Total Delay (min/day)	401,930	3.63%	0.00
	VMT	265,429	1.35%	0.00
Ride-share: Medium Adoption 1	PM_{10} (kg/day)	6.72	1.03%	0.00
	$PM_{2.5}$ (kg/day)	6.10	1.03%	0.00
	NO_x (kg/day)	145.23	0.87%	0.00
	Energy Consumption (MMBTU)	2,519,934	1.99%	0.00
	CO_{2e} (kg/day)	191,545	1.98%	0.00
	Total Delay (min/day)	662,063	6.12%	0.00
	VMT	429,521	2.21%	0.00
Ride-share: Medium Adoption 2	PM_{10} (kg/day)	6.82	1.05%	0.00
	$PM_{2.5}$ (kg/day)	6.19	1.04%	0.00
	NO_x (kg/day)	146.97	0.88%	0.00
	Energy Consumption (MMBTU)	2,535,193	2.01%	0.00
	CO_{2e} (kg/day)	192,712	2.00%	0.00
	Total Delay (min/day)	671,154	6.21%	0.00
	VMT	429,356	2.21%	0.00
Ride-share: Medium High Adoption	PM_{10} (kg/day)	10.22	1.58%	0.00
	$PM_{2.5}$ (kg/day)	9.29	1.57%	0.00
	NO_x (kg/day)	223.75	1.34%	0.00
	Energy Consumption (MMBTU)	3,864,832	3.09%	0.00
	CO_{2e} (kg/day)	293,782	3.07%	0.00
	Total Delay (min/day)	1,067,474	10.25%	0.00
	VMT	645,725	3.36%	0.00
Ride-share: High	PM_{10} (kg/day)	15.89	2.48%	0.00
	$PM_{2.5}$ (kg/day)	14.43	2.46%	0.00

	NO$_x$ (kg/day)	353.68	2.14%	0.00
	Energy Consumption (MMBTU)	6,110,254	4.98%	0.00
	CO$_{2e}$ (kg/day)	464,469	4.95%	0.00
	Total Delay (min/day)	1,782,176	18.37%	0.00
	VMT	998,774	5.30%	0.00

* Value of 0.05 or less indicate statistically significant differences at 95% confidence level

The statistical test results show that micro-mobility and rideshare, though often discussed together as new mobility options, display very different emission reduction potential. Because the micro-mobility options tend to work better in high-density areas, their ability to reduce region-wide congestion or emissions is not readily observed. As indicated by the p-values, none of the metrics for any of the three micro-mobility scenarios show significant reductions compared to the baseline. The lack of statistical significance implies that one should not over interpret the differences, regardless of the direction of change. A plausible explanation of the lack of significant reductions from micro-mobility scenarios is the spatial constraints of micro-mobility options. As shown in Table 1, even in the high-adoption scenario, fewer than 4,000 trips were removed, constituting less than 0.2% of all daily trips region-wide. Moreover, micro-mobility options are only suitable for removing short trips. As a result, the VMT reduced are negligible in a regional analysis.

By contrast, rideshare scenarios show statistically significant reductions for all scenarios, regardless of adoption levels. The magnitude of reductions increase as adoption level increases. Notably, total delay reduces by 18% in the high adoption rideshare scenario compared to the baseline, even though overall tripmaking, reflected by VMT, is only reduced by 5%. The reductions in traffic translate to about 2% in criteria pollutant emissions. The magnitude of emission reductions is small relative to congestion relief because rideshare only reduces travel from light-duty vehicles. Medium- and heavy-duty vehicles still constitute as a major source for on-road mobile source emissions.

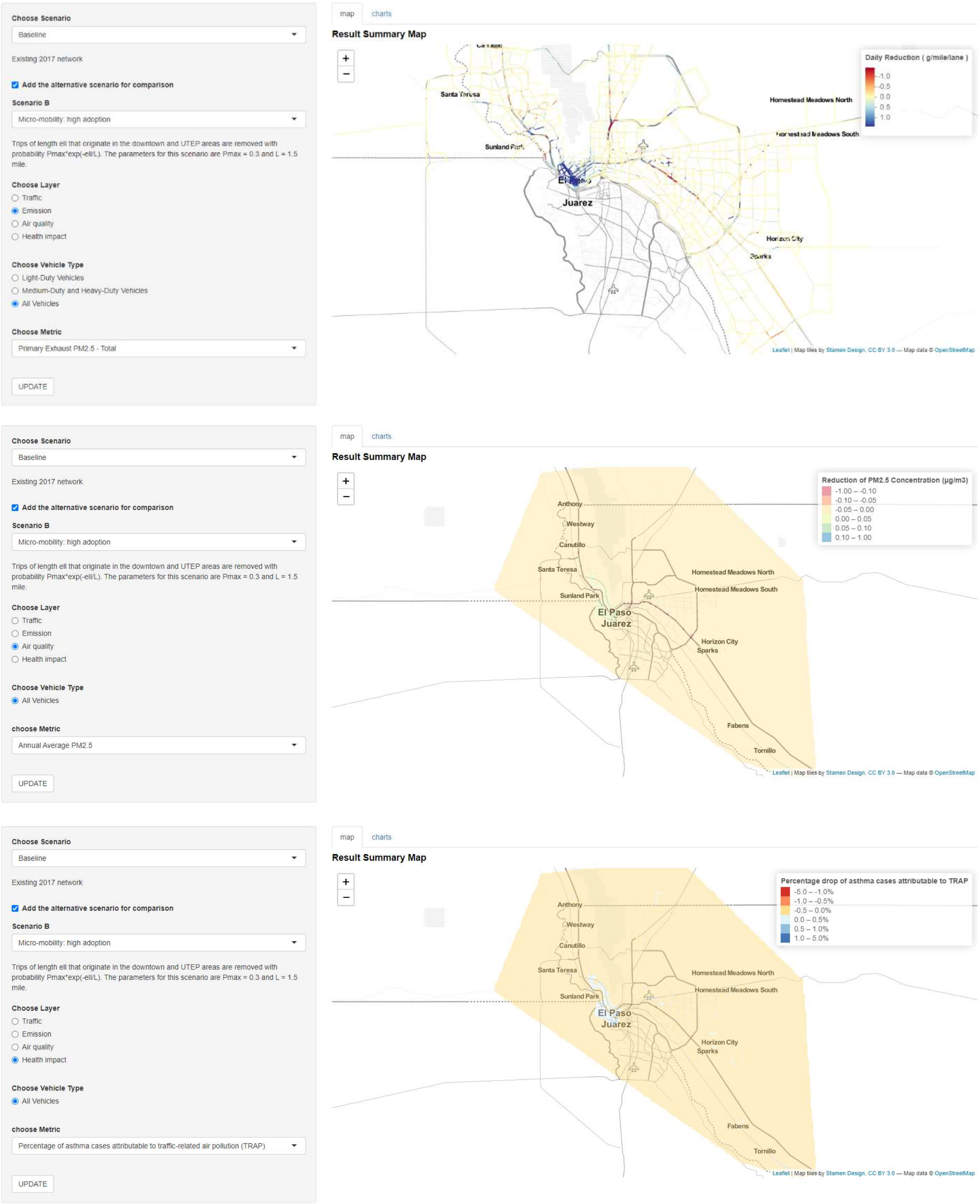
Pollutant Dispersion and Health Impacts

When evaluating a project, the significance of the total emission reduction in a region is not necessarily the only or the best criterion. The distribution of the project impacts constitutes another dimension for considerations, especially from a health outcome perspective. As shown below in project impact maps (Figure 6 and Figure 7), the micro-mobility and rideshare scenarios in this case study display very different spatial distributions of emission, pollutant dispersion, and public health impacts.

Figure 6 shows the changes in link-level emissions, pollutant dispersion, and percentages of asthma cases attributable to TRAP of the micro-mobility high adoption scenario as compared to the baseline, using $PM_{2.5}$ as an example pollutant. $PM_{2.5}$ was chosen to illustrate the dispersion and health impacts because of its well-documented linkage to asthma cases (Fan et al., 2016). Because micro-mobility options are most applicable in dense areas, the micro-mobility scenario under examination exhibited a noticeable reduction in emissions in downtown and university areas, as shown with blue links in the top map. The pollutant dispersion results reflect the emission reductions in downtown areas. The map in the middle shows that the concentration of $PM_{2.5}$ as a result of on-road emissions dispersion is slightly less than the baseline, compared to relatively no change in pollutant concentration in the rest of the metropolitan area. Relatedly, the percentage of asthma cases attributable to TRAP shows a slight improvement in the downtown areas.

Figure 7 shows the same set of impacts from the rideshare high adoption scenario. The link-by-link emission map shows that the emission benefits concentrate on major highway corridors. This phenomenon makes intuitive sense because it is these highly trafficked and delayed corridors that expect most congestion relief, and therefore, pollutant emissions from region-wide travel demand reduction. By contrast, the pollutant dispersion and asthma impacts are uniformly distributed, indicating that the relationship between emissions and dispersion is not linear.

Even though the maps provide a visual assessment of the spatial distribution of the effects, they do not currently indicate the significance of the differences as the results in the previous section do. The TTI team is working on presenting the statistical significance of spatial distributions as a topic of future efforts. The patterns shown in these maps should not be interpreted as direct evidence for decision making. Instead, these maps provide an additional view for potential further considerations of potential health impacts or environmental justice implications.



Choose Scenario

Baseline

Existing 2017 network

☑ Add the alternative scenario for comparison

Scenario B

Micro-mobility: high adoption

Trips of length ell that originate in the downtown and UTEP areas are removed with probability Pmax*exp(-ell/L). The parameters for this scenario are Pmax = 0.3 and L = 1.5 mile.

Choose Layer

○ Traffic
● Emission
○ Air quality
○ Health impact

Choose Vehicle Type

○ Light-Duty Vehicles
○ Medium-Duty and Heavy-Duty Vehicles
● All Vehicles

Choose Metric

Primary Exhaust PM2.5 - Total

Choose Scenario

Baseline

Existing 2017 network

☑ Add the alternative scenario for comparison

Scenario B

Micro-mobility: high adoption

Trips of length ell that originate in the downtown and UTEP areas are removed with probability Pmax*exp(-ell/L). The parameters for this scenario are Pmax = 0.3 and L = 1.5 mile.

Choose Layer

○ Traffic
○ Emission
● Air quality
○ Health impact

Choose Vehicle Type

● All Vehicles

choose Metric

Annual Average PM2.5

Choose Scenario

Baseline

Existing 2017 network

☑ Add the alternative scenario for comparison

Scenario B

Micro-mobility: high adoption

Trips of length ell that originate in the downtown and UTEP areas are removed with probability Pmax*exp(-ell/L). The parameters for this scenario are Pmax = 0.3 and L = 1.5 mile.

Choose Layer

○ Traffic
○ Emission
○ Air quality
● Health impact

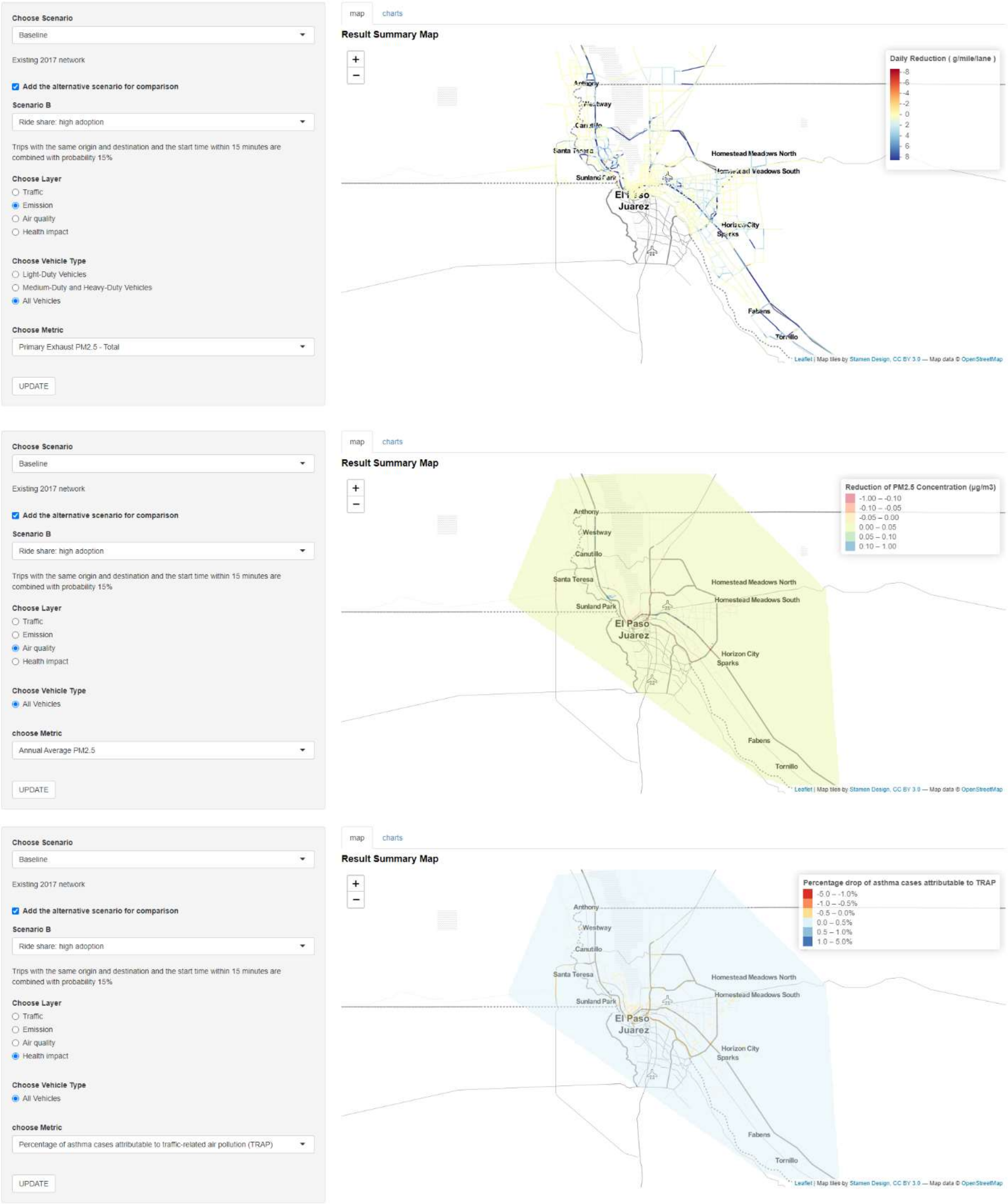
Choose Vehicle Type

● All Vehicles

choose Metric

Percentage of asthma cases attributable to traffic-related air pollution (TRAP)

Figure 6 PM2.5 Emission (Top), Dispersion (Middle), and Asthma (Bottom) Impacts of Micro-mobility High Adoption Scenario



Choose Scenario
Baseline
Existing 2017 network
☑ Add the alternative scenario for comparison
Scenario B
Ride share: high adoption
Trips with the same origin and destination and the start time within 15 minutes are combined with probability 15%
Choose Layer
○ Traffic
● Emission
○ Air quality
○ Health impact
Choose Vehicle Type
○ Light-Duty Vehicles
○ Medium-Duty and Heavy-Duty Vehicles
● All Vehicles
Choose Metric
Primary Exhaust PM2.5 - Total

Choose Scenario
Baseline
Existing 2017 network
☑ Add the alternative scenario for comparison
Scenario B
Ride share: high adoption
Trips with the same origin and destination and the start time within 15 minutes are combined with probability 15%
Choose Layer
○ Traffic
○ Emission
● Air quality
○ Health impact
Choose Vehicle Type
● All Vehicles
choose Metric
Annual Average PM2.5

Choose Scenario
Baseline
Existing 2017 network
☑ Add the alternative scenario for comparison
Scenario B
Ride share: high adoption
Trips with the same origin and destination and the start time within 15 minutes are combined with probability 15%
Choose Layer
○ Traffic
○ Emission
○ Air quality
● Health impact
Choose Vehicle Type
● All Vehicles
choose Metric
Percentage of asthma cases attributable to traffic-related air pollution (TRAP)

Figure 7 PM2.5 Emission (Top), Dispersion (Middle), and Asthma (Bottom) Impacts of Rideshare High Adoption Scenario

Summary

The statistical tests of congestion and emission metrics and the impact maps of pollutant dispersion and asthma cases have showcased that rideshare and micro-mobility projects, both of which are frequently considered as new mobility options, display different patterns of impacts on the transportation system, air quality and public health, as summarized in Table 6. Rideshare at a high adoption level demonstrates region-wide congestion relief and emission reduction. Micro-mobility, by contrast, shows localized traffic, emission, and health benefits.

Table 6 Summary of Impacts for Rideshare and Micro-mobility Scenarios

	Rideshare	**Micro-mobility**
Region-wide benefits	Yes	No
Localized benefits	No	Yes

DISCUSSION AND FINDINGS

This report provided an overview of the current practice of CMAQ benefit quantification in Texas and nationwide. In doing so, the report identified the needs, gaps and opportunities to improve CMAQ benefit quantification methods. State-of-practice CMAQ assessments rely mostly on spreadsheet-based tools to estimate emissions reduction, which is the primary modeled performance measure. The scan of current practices revealed that innovative methods and tools are needed to address three major challenges in CMAQ reporting and assessment:

1. **Project types that are non-traditional and/or require network-wide assessments:** There are projects that lend themselves to network-wide assessments, especially ones concerning new mobility options such as rideshare and micro-mobility. While some CMAQ project types, for example, intersection improvements, work better with traditional tools, projects that are regional in nature require more sophisticated tools.

2. **Expanded performance measures that meet and exceed the minimum federal reporting requirements:** New tools are needed to quantify performance measures that go beyond emissions, such as human exposure to pollution, health, delay, and cost effectiveness.

3. **Programmatic approaches that can summarize the benefits of a portfolio of projects in a region or state:** These approaches are

needed to improve the stewardship and transparency of CMAQ funds and can indicate the significance of such benefits.

The case study assessment presented in this report shows an approach with an emissions to health modeling pipeline that addresses the three challenges summarized above. The case study has showcased the very different emission reduction potential of two project types that have captured much of the public's attention recently – micro-mobility and rideshare. The results show that micro-mobility options tend to show localized emission, pollutant concentration, and respiratory disease benefits, whereas technology-based rideshare programs tend to show significant congestion relief and emission reductions region-wide.

Currently, it is relatively more resource intensive to perform analysis in TEMPO compared to traditional spreadsheet models. It is also set up to handle only network level analyses. In the future, similar approaches can be developed for the project-level, allowing more traditional CMAQ tools to be updated to include additional performance measures relating to aspects such as exposure and health. The web-based interface of the platform would also aid communications among stakeholders and outreach to the public.

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