Applying TEAM in Regional Sketch Planning:

Three Case Studies in:

ATLANTA
ORLANDO
ST. LOUIS

United States
Environmental Protection
Agency

Office of Transportation and Air Quality
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Transportation and Climate Division
Office of Transportation and Air Quality
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Executive Summary

EPA partnered with the metropolitan planning organizations in Atlanta, St. Louis, and Orlando to understand the potential of travel efficiency strategies to reduce greenhouse gases (GHG) and other air pollution. Travel efficiency strategies represent the broad range of strategies intended to reduce travel activity, especially single-occupancy vehicle (SOV) travel. Examples of travel efficiency strategies include travel demand management (e.g., telecommuting, transit subsidies), public transit fare changes and service improvements, road and parking pricing, and land use/smart growth. This builds on the description of Transportation Control Measures (TCMs) listed in Section 108(f)(1)(A) of the Clean Air Act (CAA) by adding other strategies such as pricing and smart growth. EPA has developed an approach to quantify the potential emission benefits of these strategies, identified as the Travel Efficiency Assessment Method (TEAM). TEAM uses available travel data and a transportation sketch model analysis to quantify the change in vehicle miles travelled (VMT) resulting from the strategies and, emission factors from EPA's MOVES2014 (Motor Vehicle Emission Simulator) model, to calculate corresponding emission reductions. The TEAM case studies described in this report confirm EPA's belief that travel efficiency strategies have the potential to significantly reduce GHGs and other pollutants and provide an alternative to highway oriented SOV travel.

Beginning in 2012, EPA issued a solicitation of letters of interest to partner with transportation planning agencies interested in applying TEAM in their area. Since that time, EPA has provided technical assistance to six agencies to evaluate the emissions reduction potential of alternative future transportation scenarios to compare against the emissions from the current transportation plan (i.e., the business-as-usual (BAU) future base case). EPA quantified the potential reductions of GHGs, fine particulate matter ($PM_{2.5}$), nitrogen oxides (NOx), and volatile organic compounds (VOCs) for several different scenarios.

After completing case studies with the initial three agencies[1], the second group of three agencies was selected in 2015 as case studies for testing the TEAM approach at a regional level. The Atlanta Regional Commission (ARC), East West Gateway Council of Governments (EWG), and MetroPlan Orlando Metropolitan Planning Organization (MetroPlan) partnered with EPA for this effort. Each agency selected strategies for improving travel efficiency that are of interest within the region and provided data to support the analysis. Strategies were grouped into four scenarios for the analysis. Both the strategies and their underlying assumptions represent a broad range of potential transportation futures for evaluating corresponding emissions reductions.

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[1] The previous three case studies were completed in Boston, Kansas City, and Tucson. See more information in *Estimating Emissions Reductions from Travel Efficiency Strategies: Three Sketch Modeling Case Studies*, EPA, https://www.epa.gov/otaq/stateresources/policy/420r14003a.pdf

With this second group of case studies, new approaches were also developed for TEAM to estimate benefits of land use changes and bicycle/pedestrian networks, outside the sketch model used for other strategies. EPA has a strong interest in understanding how land use changes, particularly smart growth principles, support emissions reductions. In the current study, two approaches to land use analysis were tested in the ARC and EWG analyses[2]. The details of both land use approaches and how they were applied in the ARC and EWG regions are included in this report. In addition, a bicycle and pedestrian network expansion was evaluated with a method used by local entities in California, and its application to TEAM is illustrated in the EWG case study. These new approaches supplement TEAM and further EPA's goal of developing methods for estimating the GHG and other benefits of a range of travel efficiency strategies in a simple, cost-effective way.

Analysis

This report is specific to the analysis task of the study, and covers data collection, VMT analysis, and emissions analysis. Each case study is reported independently with a focus on the technical attributes of the analysis and the lessons learned.

Analysis Tools

MOVES2014 was used to determine appropriate, regional average emission factors for all regions. MOVES was run in inventory mode based on regionally provided inputs to produce activity-weighted average emission factors for the four primary pollutants considered in this analysis: CO_2-Equivalent (CO_2e), NOx, $PM_{2.5}$, and VOCs.

EPA also used the TRIMMS sketch model developed by the Center for Urban Transportation Research (CUTR) as part of the TEAM approach.[3] TRIMMS offers a variety of features and is easy to use, making it highly appropriate for this type of analysis. However, the land use component of TRIMMS was not employed in this study as described later in this document. The regional analysis was conducted with TRIMMS 3.0, the latest version of this sketch model.

Land Use Analysis

Land use strategies are one of the most important—and one of the most complex—means by which regions can reduce VMT. Land use patterns affect how people travel, and therefore an area's geographic size and density have an impact on emissions. Areas that are more compact

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[2] MetroPlan Orlando elected not to evaluate an alternative land use strategy because they believe the most robust land use possible for the region is already incorporated into their travel demand model data, and thus would be reflected in their future BAU base case.

[3] TRIMMS™ (Trip Reduction Impacts of Mobility Management Strategies) was developed by the National Center for Transit Research and the Center for Urban Transportation Research at the University of South Florida under a grant from the Florida Department of Transportation and the U.S. Department of Transportation.

will have shorter average trip lengths and fewer vehicle trips. Supportive land use policies can provide for the commercial and residential densities to enable transit to be viable and cost effective.

The land use analysis from the previous case studies produced results that diverged from EPA's national study[4] and raised questions about the land use algorithms in TRIMMS 3.0. Therefore, EPA identified the need for a new approach to analyzing land use strategies within TEAM that is both simple and reasonably accurate, within the constraints of a sketch modeling approach.

Several land use analytical approaches were considered for this second set of case studies with respect to the following criteria:

- Transparency of methodology
- Availability and simplicity of inputs
- Compatibility with inputs and elasticities used in other TEAM strategy analyses

Two land use analytical approaches were selected for testing in the participating regions. These are identified as the Neighborhood Classification approach and the Multivariate Elasticity approach. These analyses were conducted outside of the TRIMMS analysis. As with the analysis of strategies conducted within TRIMMS, the resulting VMT reduction was used with the emissions factors from the MOVES analysis to calculate emissions reductions. The results are shown in Table ES-1. For complete details on the description and selection, see the Methodology section of this report.

Table ES-1. Percent VMT Change Relative to BAU

Strategy	2013 Approach (TRIMMS)	2016 Approach (Neighborhood)	2016 Approach (Multivariate)
Atlanta: Smart Growth	−0.50%	−5.97%	−6.43%
St. Louis: Transit Oriented Development	−0.08%	−0.16%	−0.54%
St. Louis: Work/Housing Balance	−0.16%	−1.97%	−1.12%

Selected Strategies

The combination of strategies in this report represents the broadest range tested to date, and application to specific geographies and populations illustrates the versatility of TEAM. The regions explored available data to support their strategy selection, and in the case of land use

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[4] https://www.epa.gov/otaq/stateresources/policy/420r11003.pdf

strategies, conducted additional analysis to provide required data. Table ES-2 provides an overview of the selected strategies and their individual geographical and population application.

Table ES-2. Summary of Travel Efficiency Strategies Selected

Area	Strategies	Geographic Area Covered	Applied to
MetroPlan (Orlando)	Expand employer programs including transit pass	Sub-population of 3 county area	309,637 additional employees covered by a variety of programs
	Improve transit access and travel times	Sub-population of 3 county area	515,425 employees
	VMT pricing for entire region (6 cents/mile)	3 county area	3,301,256 (regional population)
	Unlimited transit pass with tuition and university employment	Sub-population of 3 county area	205,000 students, faculty, and staff
ARC (Atlanta)	Expand telework and guaranteed ride home	Employees in 5 county core area of 20+ counties	875,000+ additional employees covered by a variety of programs
	Improve transit access times	5 county area	2 million+ regional employees
	Parking pricing ($7.50 for drive alone trips)	5 county area	26% of all parking, public and private
	Increase density and mixed use land use	5 county area	4.4 million+ people (regional population)
EWG (St. Louis)	TOD near existing light rail stations	3 county core area	1.6 million+ people
	Increase residential density and mixed development	Entire 5 county area	2.3 million+ people
	Complete bicycle and pedestrian network	Entire 5 county area	150% increase in bike lane miles (1,951 miles) Increase sidewalk coverage to 71% of local and arterial roads (10,579 sidewalk miles)
	Complete light rail system	Entire 5 county area	761,887 additional people

Both ARC and MetroPlan Orlando selected strategies for analysis that have been associated with TEAM since the beginning of its development: transportation demand management (TDM), pricing, and transit. The EWG team was more interested in strategies to evaluate land use and increased multimodal travel. This interest presented some new analytical challenges that have demonstrated the flexibility of TEAM with respect to the analysis approach used.

The strategies selected by EWG in the current study demonstrate the potential interest in alternative populations and geographies, as well as strategies that are not easily analyzed using TRIMMS. This test of the TEAM approach illustrates that it can be used independent of the analysis tool or method. As illustrated in the EWG results, the reduction in emissions may be very limited; however, TEAM allows staff to view the comparison of potential outcomes of various strategies. This allows informed decision making without the extensive cost and time of detailed travel demand model analysis – which may require a modeling sophistication beyond current capabilities of many agencies.

As in the past, the greatest benefit in emissions reductions can be seen using a combination of mutually supportive strategies over individual strategies modeled alone. All regions in this study applied the strategies cumulatively. For example, land use can enhance both transit and TDM improvements. However, when the strategy is applied to a subset of the population or geography of the region, the effects may be large for the target population, but smaller for the region as a whole. Applying the strategy to a larger geography or population would likely produce larger reductions.

Results and Conclusions

This study estimated VMT and emission reductions for each of the future year scenarios, expressed as a percent change as compared to the BAU baseline, as shown in Table ES-3.

Percent change is a useful measure when comparing strategy effectiveness across dissimilar regions and is necessary for continued evaluation of TEAM performance in various regions with specific interests. However, percent change does not fully represent the quantitative impact on VMT and emissions, which is more important to the individual region. For example, the effect of EWG scenarios appears relatively small in terms of percent change. For example, Scenario 4 represents a reduction of 1.9 million VMT/day, 440,000 kg/day CO_2 e, 16 kg/day $PM_{2.5}$, 103 kg/day NOx, and 80 kg/day VOC – a notable improvement for the region, especially when combined with other efforts to reduce pollutant emissions. Similarly, the other case study areas could expect reductions of as much as:

- 12 million VMT/day, 2.8 million kg/day CO_2e, 124 kg/day $PM_{2.5}$, 535 kg/day NOx, and 414 kg/day VOC (Atlanta)
- 4.6 million VMT/day, 1.1 million kg/day CO_2e, 39 kg/day $PM_{2.5}$, 201 kg/day NOx, 117 kg/day VOC (Orlando)

Participants in the case studies also pointed out that corresponding trip reduction is a measure that is important for decision makers. These common performance metrics used by staff and decision makers in a region can be a valuable way of observing the potential impact of strategies that have often been difficult to quantify.

The results in Table ES-3 also show that the VMT and emissions changes are very similar across each scenario. The regional average emission factors used in TEAM do not capture the finer points of emissions modeling that would be exhibited with more detailed analyses, including the differences between pollutants as functions of speed. However, this level of resolution is appropriate for a sketch modeling approach. Total emissions reductions are reported in Appendices B-D of this report.

Transit changes were more regionally significant in the MetroPlan Orlando and ARC regions than the effect of the light-rail buildout in EWG. The impact of a subarea strategy can be significant at the subarea scale, but is reduced when reflected at the regional scale. Although EWG transit expansion and TOD strategies support one another, the emissions reductions modeled in this analysis are related to only the area around the rail stations.

Table ES-3. Percent Regional VMT and Emissions Changes

Percent Regional Emissions Changes for Future Year Business as Usual Compared to Future Year Scenario					
Scenario	**Light-Duty VMT**	**GHGs (CO_2 equivalent)**	**$PM_{2.5}$**	**NOx**	**VOC**
MetroPlan Orlando					
Scenario 1: Expanded TDM	−0.65%	−0.65%	−0.65%	−0.65%	−0.65%
Scenario 2: Scenario 1 + Enhanced Transit	−0.92%	−0.92%	−0.92%	−0.92%	−0.92%
Scenario 3: Scenario 2 + Road Pricing	−4.75%	−4.75%	−4.75%	−4.74%	−4.73%
Scenario 4: Scenario 3 + University Transit Pass	−6.08%	−6.07%	−6.07%	−6.06%	−6.05%
ARC					
Scenario 1: Expanded TDM	−0.69%	−0.68%	−0.68%	−0.67%	−0.66%
Scenario 2: Scenario 1 + Transit Frequency Improvement	−0.86%	−0.86%	−0.86%	−0.85%	−0.83%
Scenario 3: Scenario 2 + Parking Pricing	−2.85%	−2.85%	−2.85%	−2.82%	−2.81%
Scenario 4: Scenario 3 + Land Use (Neighborhood)	−8.82%	−8.81%	−8.81%	−8.79%	−8.78%
Scenario 4: Scenario 3 + Land Use (Multivariate)	−9.28%	−9.27%	−9.27%	−9.25%	−9.24%
EWG					
Scenario 1: Regional TOD (Neighborhood)	−0.16%	−0.16%	−0.16%	−0.16%	−0.16%
Scenario 1: Regional TOD (Multivariate)	−0.54%	−0.54%	−0.54%	−0.54%	−0.54%
Scenario 2: Scenario 1 + Workforce Housing Balance (Neighborhood)	−2.13%	−2.13%	−2.13%	−2.13%	−2.13%
Scenario 2: Scenario 1 + Workforce Housing Balance (Multivariate)	−1.66%	−1.66%	−1.66%	−1.66%	−1.66%
Scenario 3: Scenario 2 + Bike / Ped Network (Neighborhood)	–2.21%	–2.22%	–2.24%	–2.37%	–2.56%
Scenario 3: Scenario 2 + Bike / Ped Network (Multivariate)	–1.73%	–1.75%	–1.76%	–1.89%	–2.08%
Scenario 4: Scenario 3 + Transit Expansion (Neighborhood)	–2.54%	–2.56%	–2.57%	–2.70%	–2.90%
Scenario 4: Scenario 3 + Transit Expansion (Multivariate)	–2.07%	–2.11%	–2.13%	–2.39%	–2.79%

TEAM is a data-led approach. Data collection, validation, and analysis continue to consume the majority of the effort. Agencies with easy access to the required data can support TEAM very efficiently. The required MOVES data is readily available for areas that conduct a transportation conformity analysis or otherwise develop mobile source emissions inventories for air quality planning purposes. For areas where local data availability is an issue, the use of MOVES default data is an adequate, although less precise alternative, to support analysis.

The results provide a very limited set of data points with which to compare the two land use results. It is notable that results from the Neighborhood approach are within 1% of results from the Multivariate approach for each strategy. The two approaches appear to produce results that are very similar in magnitude.

As with the previous TEAM case study regions, these areas selected some transit strategies that increase transit VMT. For these case studies, an off-model estimation approach was developed to consider both passenger vehicle emissions reduced by increased transit, and additional emissions produced by transit as a result of this increase. Estimating transit emissions accurately from this increase in VMT requires more detailed information on transit vehicle technology, fuels, and system operations than could be provided within the scope of this analysis. The report notes where transit emissions are a factor so that regions that wish to use the TEAM approach can identify how best to address these additional transit emissions.

EPA’s previous TEAM case studies showed a range of technical capability among the regions related to the use of MOVES. This was less true in the present iteration. Two regions were very comfortable with the model in similar applications, and understood the relationship between the present analysis and that conducted for regulatory purposes. The third region did not have current experience using MOVES.

These case studies add new methods to the TEAM, furthering its ability to analyze strategies that state and local governments could consider to reduce greenhouse gases and other air pollution from the transportation sector. TEAM continues to be a viable, relatively low-cost means for estimating the contribution that travel efficiency strategies can make to an area’s overall plan to reduce emissions and its carbon footprint, helping areas make choices in how they allocate funding to potential strategies.

1. Introduction

Over the past several years the U.S. Environmental Protection Agency (EPA) has supported research aimed at substantiating the strong potential to reduce emissions by reducing single-occupancy vehicle travel and correspondingly, vehicle miles traveled (VMT). Although this research was initially focused on national-level benefits, the approach developed to quantify the reductions was grounded in regional data that was then factored up to the national level. This resulted in the report, *Potential Changes in Emissions Due to Improvements in Travel Efficiency*[5] (2010 national study). Because the methodology relied upon data typically available in regional transportation planning and used a basic sketch-planning analysis technique, it appeared to be readily adaptable for regions of varying sizes and technical sophistication.

EPA calls this approach the **T**ravel **E**fficiency **A**ssessment **M**ethod (**TEAM**). The term "travel efficiency" is used to refer to those strategies defined in the Clean Air Act (CAA)[6] such as employer-based transportation management programs, transit improvements, smart growth and related land use strategies, as well as road and parking pricing, and other strategies aimed at reducing mobile source emissions by reducing vehicle travel activity. TEAM uses available travel data and a sketch model analysis to quantify the change in VMT, combined with the EPA MOVES (Motor Vehicle Emission Simulator) model's emission factors to calculate the emission reductions that can reasonably be expected.

In support of TEAM, EPA provided opportunities for testing the methodology at the regional scale. *Analyzing Emission Reductions from Travel Efficiency Strategies: A Guide to the TEAM Approach*[7] was issued in 2011 to support use of the methodology. This was followed in 2012 with a solicitation of letters of interest from agencies interested in applying TEAM in their local context and evaluating their selected strategies. Three case studies are presented in the resulting report, *Estimating Emission Reductions from Travel Efficiency Strategies: Three Sketch Modeling Case Studies*.[8]

For the latest effort and subject of this report, EPA provided technical assistance to implement TEAM and conduct analyses for three additional agencies. The three agencies selected for these case studies are the Atlanta Regional Commission (ARC), the metropolitan planning organization (MPO) for Atlanta, GA; East West Gateway Council of Governments (EWG), which does transportation planning for the St. Louis, MO-IL area; and MetroPlan Orlando Metropolitan Planning Organization (MetroPlan), which covers Orlando, FL. Each agency selected strategies of interest to the region and developed scenarios with these strategies based on their individual goals for the case study. Four scenarios were identified for each agency by combining the strategies of greatest interest to their region. The analysis was then conducted using the

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[5] http://www.epa.gov/otaq/stateresources/policy/420r11003.pdf

[6] CAA Section 108(f)(1)

[7] http://www.epa.gov/otaq/stateresources/policy/420r11025.pdf

[8] http://www.epa.gov/otaq/stateresources/policy/420r14003a.pdf

TRIMMS (Trip Reduction Impacts of Mobility Management Strategies) sketch-planning model and the MOVES2014 emissions model to estimate potential emissions reductions for the four primary pollutants considered in this analysis: $C0_2$ -Equivalent, NO_x, $PM_{2.5}$, and VOC.

This report provides the results, conclusions, and recommendations from the experience in conducting the analysis. The regions were diverse in their application of TEAM, and this provided more insights into how the approach might best be applied. The analysis also pointed out strengths and challenges of the analytical tools and methods used.

Analysis Tools

The TRIMMS model developed by the Center for Urban Transportation Research (CUTR) has been a standard feature of the TEAM approach. TRIMMS offers a variety of features, is easy to use, and is sensitive to many of the strategies that regions are interested in testing; making it highly appropriate for this type of analysis. The regional VMT analysis for the majority of the selected scenarios was conducted with TRIMMS 3.0, as used in the previous case study analysis.[9]

MOVES2014[10] was used to determine appropriate, regional average emission factors for all regions. MOVES was run in inventory mode based on regionally provided inputs to produce activity-weighted average emission factors for the pollutants reported.

Land Use Analysis

Land use strategies are one of the most powerful—and also one of the most complex—means by which regions can reduce VMT. The land use analysis performed for the previous case studies yielded results that were considered overly conservative when compared to other peer reviewed studies, and raised questions about the reliability of the land use algorithms in TRIMMS 3.0. Subsequently, EPA identified the need to evaluate alternative methods to analyzing land use strategies within TEAM for this effort that is both simple and reasonably accurate, within the constraints of a sketch modeling approach.

Several analytical approaches were considered with respect to the following criteria:

- Transparency of methodology
- Availability and simplicity of inputs
- Compatibility with inputs and elasticities used in other TEAM strategy analyses

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[9] EPA 2014, EPA-420-R-14-003a. Available: http://www.epa.gov/otaq/stateresources/policy/420r14003a.pdf

[10] EPA released an updated version of the MOVES model, MOVES2014a, in November, 2015. Due to the project's schedule, the previous version, MOVES2014, was used in all analyses here. For criteria pollutant emissions from on-road vehicles, the models predict essentially the same level of emissions. See EPA-420-F-15-046, November 2015.

- Accuracy of estimation

Among the approaches considered, two approaches were selected for testing in this analysis. These are identified as the “Neighborhood Classification” approach and the “Multivariate Elasticity” approach. These analyses were conducted outside of the TRIMMS analysis, and the resulting VMT reduction was used with the emissions factors from the MOVES analysis. Both of these approaches are explained in the next section.

Bicycle and Pedestrian Analysis

At the request of EWG, an additional strategy was analyzed outside of TRIMMS. Expanding bicycle and pedestrian infrastructure is not incorporated in TRIMMS, but there are approaches available in the literature which were adapted for application in TEAM. The approach is simple enough to be used by any MPO. For additional information on this analysis, refer to Appendix D.1.

2. Methodology

Strategies, Scenarios, and Baselines

Strategies are the specific policy to be tested such as land use or transit changes. In contrast to previous case studies, participating regions in this study selected a wide range of strategies for analysis and were not constrained to those only appropriate for analysis using TRIMMS. This adaptation was made in part due to the use of “off-model” land use analysis approaches and in response to the availability of data within each region. This case study evaluation also allowed further consideration of using a standard analysis tool, such as TRIMMS, and the flexibility that TEAM might support with a variety of methods/tools. Some strategies of interest, such as expanding bicycle infrastructure were not previously considered because these cannot be modeled in TRIMMS. In this case study analysis, the bicycle system expansion strategy selected by EWG was evaluated off-model. Details of this approach are covered in later sections of the report.

Scenarios are groups of strategies to be tested for an overall combined benefit. The development of scenarios using TEAM has consistently combined strategies (through sequential application and modeling) to help identify how benefits may increase with additional actions over time. All agencies elected to use this approach. The specific strategies selected for each scenario, along with the data needed to model them, are provided for each agency in Section 3 of this report.

Strategy Selection for TEAM Analysis

The three regions selected individual strategies of interest that primarily fit within the TRIMMS capabilities. In general, these fall into the three strategy categories identified in Table 1. Many of the TRIMMS functions work by manipulation of travel times and travel costs, common factors in travel demand modeling. For example, to model an expansion of HOV lanes in TRIMMS, the user must input changes in typical travel times for carpool trips and possibly single occupancy vehicle trips. In order to use TRIMMS effectively, users must consider how to translate their strategy interest into the options within the model.

TRIMMS requires inputs such as target population, cost of parking or vehicle trips, transit travel time, and transit access time. For example, to model the MetroPlan Orlando ridesharing strategy (the TDM programs strategy in TRIMMS), data inputs were derived for number of employees covered by the strategy, existing cost per trip for public transit and cycling, new cost per trip for public transit and cycling based on per-employee subsidies for each mode, presence of a guaranteed ride home program, and presence of a telework and flex work schedule programs. Carefully translating the strategy into inputs that can be specified in the model is essential to confidence in the results.

Table 1 provides information about the analysis options that were used to analyze strategies selected. The table shows the data needs for each strategy to conduct the TRIMMS analysis (second column) and the TRIMMS modeling options relevant to each strategy (third column).

Other strategies of interest that are not easily transferable into model inputs were not suitable for TRIMMS. Land use and multimodal strategies were analyzed outside of TRIMMS. Table 2 provides the corresponding data needs for those strategies.

Table 1. VMT Reduction Strategy Analysis Options in TRIMMS

Strategy Categories	Strategies That Can Be Analyzed	Data Needs
TDM or Employer Incentives	• Subsidies for alternative modes • Guaranteed ride home, ride match, telework, and flexible work schedules	• share of regional employees covered • average subsidy offered to employees (by mode) – OR – whether or not subsidies are offered (by mode) • whether or not guaranteed ride home, ride match, telework, and flexible work schedules are offered
Transit	• Free or bundled transit passes • Reduction in transit travel times or wait times	• share of regional population affected • average decrease in transit trip cost • transit travel time and access time
Pricing	• Parking pricing • VMT pricing	• share of all parking (public and private) that is priced • average increase in parking cost per trip • average increase in trip cost

Table 2. Other VMT Reduction Strategy Analysis Options (not in TRIMMS)

Strategy Categories	Strategies That Can Be Analyzed	Data Needs
Land Use	• Shifting population and employment growth to more compact neighborhoods/lower VMT generating neighborhoods • Workforce-housing balance initiative • TOD program	**Neighborhood approach:** • share of regional population in affected areas • percent population by neighborhood type **Multivariate approach:** • share of regional population in affected areas • increase in weighted average residential density (persons per square mile) • increase in job accessibility by car • increase in job accessibility by transit • average decrease in distance to transit • average increase in land use mixing
Bicycle and Pedestrian	• expand sidewalk coverage • expand bike lane coverage	• share of regional population in affected areas • increase in sidewalk coverage • increase in miles of bicycle routes

Baselines

TEAM results provide a comparison of potential emissions reductions from selected strategies with the potential emissions from both a future business as usual (BAU) scenario, and baseline scenario that represents the current transportation system. The results are presented as percent reduction based on comparison with the area's BAU scenario. For this reason, the selected BAU and baseline are a critical component of using this approach. The BAU scenario represents likely emissions based on the future year anticipated transportation infrastructure outlined in each region's long-range transportation plan (without implementation of the *additional* TEAM strategies) along with future year demographic changes and may already include some types of travel efficiency strategies, while the baseline represents nearly current conditions. The general ability of agencies to provide this basic BAU is mixed, and the participating agencies provided a range of BAU scenarios for use in this study, illustrating this point. In most cases, the BAU represents the future year infrastructure and travel activity without *additional* travel efficiency strategies. This is typically the scenario, or vision, in the adopted long range transportation plan and is well suited for use with TEAM. It is essential to ensure that the scenarios analyzed for comparison match the geographic bounds, fleet characteristics, population, and other parameters of the BAU scenario.

It is important to note that the percentage reductions reported do not represent the full impact of travel efficiency strategies compared to current conditions, as in each case some aspects of travel efficiency are already included in the BAU. In the interest of completeness, the overall impact that travel efficiency strategies can have compared to the baseline is included in the Appendix.

Data Collection and Validation

Data collection and validation is the most important task within any analysis approach, and TEAM is no exception. One of the efficiencies of using TEAM is that it relies primarily on inputs or outputs from the travel demand model used for regional planning. The intent of TEAM is to support early decision making by providing a comparison of different strategies under consistent future conditions. Strategies that appear most effective and have the necessary public and political support can then be more rigorously analyzed for precise impacts using the travel demand model and other tools available to the region. When the data being used is consistent across these levels of analysis, it is more likely that confidence in the results can be maintained for the supported strategies.

Data collection involved receiving the actual data, processing as necessary, completing quality assurance reviews of any provided inputs, creating databases of default data, performing any necessary revisions to the data provided, and filling any gaps in the local data with default data to create a complete dataset. Locally specific data is preferred to default data, and efforts were made to obtain local data wherever possible. All three regions provided some local data that generally was used by the agencies for other purposes. EWG and ARC performed data collection unique to this analysis for land use.

ARC's Transit Frequency Improvement strategy provides a useful example to illustrate the level of effort required to prepare a strategy for analysis. The policy to be tested is a 50% reduction in average transit headways. ARC provided the following information:

- average total trip time for public transit of 57.4 minutes (which includes time to get to the vehicle, waiting time, and time to get to destination from vehicle);
- average transit travel time of 33.45 minutes;
- total system headway of 8.78 minutes; and
- number of people living in the transit zone (46% of the total regional population).

In order to model this strategy in TRIMMS, the transit access time for the BAU and strategy scenarios are needed. The average BAU access time was calculated by subtracting the total trip time from the travel time (23.95 minutes). A 50% decrease in headways corresponds to a new headway of 4.39 minutes; thus, the new total access time is 23.95 minutes minus 4.39 minutes or 19.56 minutes. To calculate the affected regional population, the total regional population was multiplied by 46% to determine a target population of 2,025,866 people. These calculated values were reviewed and approved by ARC and EPA before running the TRIMMS model.

The MOVES analysis within TEAM uses regional data to determine average emission factors, often from the same sources used for transportation conformity findings subject to regulation under the CAA. ARC and EWG are subject to these CAA regulations. These emissions factors are applied to the BAU case and future strategy VMT to estimate potential emissions reductions in each scenario.

Data was provided from the most recent regional transportation conformity analysis in the two of the participating regions, ARC and EWG. Therefore, while the TEAM analysis is a less rigorous analysis than that required for transportation conformity, it is consistent with the interagency policies and agreed-to approach for conformity. This consistency allows the results to inform the conformity discussion about potential emission benefits of particular strategies, but the results cannot be directly used in a regional transportation conformity analysis.

However, TEAM is not part of the transportation conformity process, and does not require the use of transportation conformity data. MetroPlan Orlando is not designated as a CAA nonattainment or maintenance area for any pollutant at this time and thus did not have locally specific emissions inputs from a transportation conformity determination to provide. Default data available in TRIMMS and MOVES2014 provided acceptable data to enable a relative comparison of emissions among scenarios and with the BAU for this region.

MOVES input data provided by the regions required some processing for use in TEAM. For example, for EWG two modifications were made to the provided data. In the first modification, the MOVES input databases provided by EWG were those used for regional planning and conformity by the responsible environmental organizations; the Missouri Department of Natural Resources (MODNR) and Illinois Environmental Protection Agency (ILEPA). Neither organization had updated their inputs from the original MOVES2010b format, and therefore the data required conversion to MOVES2014 format using EPA's converter tools. Second, the "unfactored" VMT values provided represented average weekday VMT, stratified only by county and HPMS facility (road) type. The EPA converter tool[11] was used to translate these values into annual VMT ("HPMSBaseYearVMT") for database input to MOVES.

Analysis

Results of this study, including reductions in trips, VMT, and emissions, are presented for light-duty vehicles only to be consistent with and allow comparison to previous TEAM analyses.

VMT Analysis

The analysis for the 2013 regional case studies was conducted with TRIMMS 3.0, which contained some significant changes from previous versions. The user interface was updated to reduce the number of steps required to conduct the analysis, and the outputs were expanded in detail. Most significantly, TRIMMS 3.0 added a new land use module that includes controls for increasing residential densities, land use mixing, transit station accessibility, and transit-oriented development (TOD). Although these changes to the land use component appear to provide more utility for EPA's land use interest, the 2013 case studies did not show a reasonable response to land use changes, when compared to other significant studies in the literature. This is the basis for the focus on land use analysis in the current group of case studies. TRIMMS 3.0 remained useful for other selected strategies.

A number of scenarios involve transit improvements, such as reducing headways. These improvements result in increased transit service with a corresponding increase in VMT, trips, and emissions for transit vehicles. However, TRIMMS is limited in its ability to estimate the corresponding increase in transit trips for transit strategies. Therefore, the impact of increased usage of transit vehicles due to an increase in transit trips was estimated off model.

Actual VMT from the National Transit Database (NTD) in 2013 for each agency was used to determine a corresponding increase in transit VMT for transit strategies. This was performed for all transit strategies that involve increased transit service.[12] Section A-1 of the appendices provides further explanation and presents the changes in transit VMT and emissions for relevant strategies. This supplemental analysis provides a more complete description of the impact of transit strategies, which not only reduce light-duty VMT and emissions, but also increase transit vehicle VMT and emissions.

Another limitation when using TRIMMS is that it does not consistently account for shifting trips between modes. In particular, TRIMMS does not adequately capture mode shift for TDM

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[11] Available at http://www.epa.gov/otaq/models/moves/documents/aadvmt-converter-tool-moves2014.xlsx.

[12] Not all transit strategies result in service increases. See the strategy detail table in each case study for those scenarios where transit VMT is expected to increase.

strategies where subsidies are offered for use of alternative modes. The “radio button” feature in TRIMMS proved the most successful way to analyze TDM strategies without the use of actual monetary values for subsidies. The radio button is a toggle that indicates if a strategy is present or not; there are no additional parameters to enter. For the radio button, TRIMMS applies reductions calculated in an evaluation of Washington State’s Commute Trip Reduction program. Strategies that can be modeled in TRIMMS using the radio button feature instead of cost inputs, such as rideshare/transit trip subsidies, were modeled using this feature and not actual cost figures from participating agencies.

Vehicle miles traveled and vehicle trips are needed to calculate emissions. TRIMMS outputs person miles traveled and person trips, assuming that each person makes one round trip (two one-way trips) per day. In order to derive VMT and vehicle trip estimates consistent with regional travel models, person miles traveled and person trips from TRIMMS were multiplied by a correction factor for each agency.

The correction factor was calculated as the ratio of the model estimated VMT per capita per day to the TRIMMS-derived person miles traveled (in an automobile) per day. For example, the TRIMMS modeled daily person miles traveled for EWG in 2045 is 38,885,791 for a population of 2,736,456. This equals a rate of 14.2 person miles per day. Actual total regional VMT are 74,336,862 (provided by EWG) for a daily rate of 27.2 VMT per person. The correction factor is thus 1.91 (27.2 ÷ 14.2). The calculated correction factors for each region were then applied to the TRIMMS VMT results to scale modeled person miles and person trips to VMT and vehicle trips for each agency.

Land Use Analysis

At the beginning of this second round of case studies, EPA identified the need for a new approach to analyzing land use strategies within TEAM that is both simple and reasonably accurate, within the constraints of sketch modeling. The land use analysis from the previous case studies produced results that diverged from the reference national studies and raised questions about the land use algorithms in TRIMMS.

The existing literature on the relationship between land use patterns and VMT generally focuses on ‘D’ variables, particularly those that have become known in the field as the ‘5Ds’:

- Density
- Diversity (land use mixing)
- Design
- Destinations (distance to regional destinations)
- Distance to transit

While the individual variables used vary from study to study, most fit under these five "D" categories. Comparison of individual studies illustrated that each used between three and five "D" variables. A 2010 Ewing and Cervero study[13] provides elasticities that are calculated as a weighted average of results from more than 50 studies, including both national and regional studies. An elasticity is a measure of how a change in the price of one good affects the demand for a related good. In the case of land use, elasticities measure how a change in a land use measure (which effectively changes the "price" of walking, transit, and other car-free modes in changing travel time) affects VMT. This approach of using a weighted average elasticity fits well with the TEAM approach, which is intended to be applicable to all U.S. regions. The weighted averages provided allow for immediate application to all regions. The analysis approach based on these elasticities is identified here as the "Multivariate Elasticity" approach.

Multivariate Elasticity Approach

The Multivariate approach calculates the change in VMT from land use strategies by comparing the following variables for the BAU and scenario cases:

- Household/ population density
- Job access by auto
- Job access by transit
- Distance to nearest transit stop
- Land use diversity (typically defined as the level of mixing of different land use types such as residential, commercial, and industrial)[14]

This method provides an estimate of reduced VMT by focusing on shifts in these land use variables. In order to use this method, the agencies supplied each variable under both the BAU and strategy scenarios.

The Design (street network density) variable is omitted for two reasons. First, regions whose travel demand models do not include local roads (e.g. East West Gateway) will not be able to accurately calculate this variable. Second, increasing street network density is a strategy that is only applicable in select local circumstances, like redevelopment of large commercial and industrial properties. It is beyond the scope of this regional analysis to estimate what increases might be reasonable.

Data for all traffic analysis zones (TAZs) is needed in order to create population-weighted averages for all 'D' variables. Population densities are first calculated for the Business as Usual (BAU) and Scenario for all TAZs. Then, a single regional population density is calculated for the

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[13] Ewing and Cervero, "Travel and the Built Environment: A Meta-Analysis", Journal of the American Planning Association, 2010

[14] Since there were no changes observed in land use diversity in the cases examined, this variable was not incorporated in the current analysis.

BAU by taking the population-weighted average of the TAZ population densities. The same steps are followed to obtain the Scenario values. This approach allows for meaningful variations in land use characteristics by shifting growth within the region; whereas calculating population density at a gross regional level would show no change without increasing regional population growth.

Gross Population Density vs. Population-Weighted Density

Suppose you have a region composed of two TAZs:

- TAZ A has an area of 1 square mile and a population of 10
- TAZ B has an area of 2 square miles and a population of 5

To measure the gross population density of the region, calculate the total regional area and population: 3 square miles with a population of 15. Gross population density is 5 people per square mile (15 people / 3 square miles).

To measure population-weighted density of the region, first calculate the population density of each TAZ individually:

- TAZ A population density = 10 people / 1 square mile = 10 people per square mile
- TAZ B population density = 5 people / 2 square miles = 2.5 people per square mile

Next calculate the proportion of regional population in each TAZ:

- TAZ A proportion of regional population = 10/15 = 0.66
- TAZ B proportion of regional population = 5/15 = 0.33

Finally, calculate the region’s population-weighted average density:

- 10 people per square mile * 0.66 + 5 people per square mile * 0.33 = 8.25 people per square mile

Notice that the weighted density is higher than the gross density. That’s because the weighted density accounts for the fact that the residents of TAZ A, who live at a higher density, make up a greater proportion of the region’s residents. So 8.25 people per square mile is more representative of what the typical regional resident experiences than 5 people per square mile.

Population weighted averages can be calculated for other D variables as well. The weighting factor is always proportion of regional population, while the calculated variable can be diversity, distance to transit, or something else.

The Multivariate approach was applied outside of TRIMMS in a simple spreadsheet analysis. Results from the spreadsheet analysis can be readily combined with results from other strategies analyzed in TRIMMS in a post-processing spreadsheet, a standard part of the TEAM approach. In the post-processing spreadsheet, percentage reductions in VMT calculated for each scenario or strategy are applied sequentially to the business as usual VMT projection for the region. These reductions were calculated by multiplying changes in land use variables (such as population density) by elasticity values. For specific elasticity values see Appendix Table A-2.

Neighborhood Classification Approach

The Neighborhood approach is significantly simpler in terms of data collection and calculation than the Multivariate approach. It relies on the idea that individual neighborhoods can be classified in terms of typical driving habits of their residents, and that land use planning can shift growth patterns away from more driving-intensive neighborhood types towards less driving-intensive ones. Using this approach identifies the change in VMT from land use strategies by comparing the percent of household, population, and jobs within separate neighborhood types before and after each strategy. Each neighborhood type has a unique VMT metric (such as VMT/ household or VMT/day). The land use strategies shift households, population, and/or jobs to from neighborhood types with higher VMT to neighborhood types with lower VMT, producing a net reduction in VMT. This method provides an estimate of reduced VMT just by focusing on shifts in populations among neighborhood types.

The approach is similar to that used by the Atlanta Regional Commission in its 2014 study,[15] where all TAZs in the region were classified into quintiles based on average annual household automobile CO_2e emissions. Automobile CO_2e emissions are highly correlated with household VMT, and household VMT data is readily available in the same format. Neighborhoods closer to the urban core tend to have lower emissions per household, while neighborhoods further away have higher emissions per household.

In order to use this method, the agencies supplied average VMT metrics for each neighborhood type and the percent of households, population, and/or jobs within each neighborhood type under both the BAU and strategy scenarios. The resulting VMT reductions are very simple to calculate outside of TRIMMS. Calculating a weighted average of VMT per capita across the five classifications for both BAU and Scenario and then comparing these yields the percentage reduction in VMT for the entire analysis area. As with the Multivariate approach, this approach is conducted in a simple spreadsheet analysis, and the results combined with the results of other strategies in a post-processing spreadsheet.

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[15] Atlanta Regional Commission, "Understanding the regulatory environment of climate change and the impact of community design on greenhouse gas emissions," 2014.

Special Considerations in Sketch Planning Analysis

Elasticities

TRIMMS contains default elasticities that measure the relationship of travel costs and access times to travel patterns. Direct elasticities describe relationships between travel by one mode and the cost and time characteristics of that mode. For example, a direct elasticity of drive alone travel with respect to trip cost of -0.5 means that a 1% increase in drive alone trip cost is associated with a 0.5% decrease in drive alone travel. Cross elasticities describe relationships between different modes of travel. A cross elasticity of drive alone travel with respect to transit access times of 1.0 indicates that a 1% decrease in transit access times is associated with a 1% decrease in drive alone travel.

TRIMMS does not provide defaults for all elasticities. For example, TRIMMS 3.0 does not have a default elasticity to represent the shift in drive alone travel relative to the cost of carpool or vanpool travel. TRIMMS assumes that the values of these elasticities are zero, whereas their true values are most likely non-zero. TRIMMS allows the substitution of elasticities for its default values. The national-level research for EPA identified elasticities that are well supported in the literature. The research team relied upon these values to supplement and support what was available in TRIMMS. The TEAM user guidance [16] identifies the desired elasticities for a regional analysis as well as provides a list of elasticities in its Appendix C.

Still, there are several instances in which elasticities not supplied by either TRIMMS or the literature, and which therefore default to zero, can produce unreasonable analysis results. If the model is run with these values set to zero, the TRIMMS model may predict increases in trips for one mode of travel without corresponding decreases for another mode. TRIMMS automatically rebalances total trip numbers when evaluating employer-based strategies, but not for other strategy types. The user can correct for this by adjusting the outputs of TRIMMS to rebalance total trip numbers (the approach taken in this study, as described below) or by supplying a more complete set of elasticity values.

Alternative Populations and Geographies

Many strategies do not affect the entire regional population but instead focus on a sub-region and/or a subset of the total population, or target population. TEAM results are reported for the entire region in each case study analysis in order to make comparisons to previous case studies. However, all three agencies requested modeling strategies for application in a subset of the population and a limited geography within the region. For each region, there was a smaller core set of counties, sub-geographies, or sub-populations where application of the strategies is

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[16] EPA 2011, EPA-420-R-11-025. Available: http://www.epa.gov/otaq/stateresources/policy/420r11025.pdf

most reasonable and will most likely produce the greatest reduction in VMT and vehicle emissions.

Each strategy was modeled for the affected subarea and for the target population only. Once the impact on the subarea was determined, VMT reductions were compared to the total regional VMT to determine a reduction in regional VMT. For example, a strategy may reduce VMT by 10% for the target population but only 1% for the total regional population (the target population represents 10% of the total regional population).

Using TEAM for sub-geographies and sub-populations is more complicated, but certainly possible. Sub-geographies and populations sometimes require different baseline assumptions (e.g. mode shares and trip lengths for downtown vs. region), and sub-populations can be difficult to isolate (e.g. traveler population for a specific corridor). Combining strategies that apply to different sub-populations or sub-geographies requires that the effects of the strategies be summed together outside of TRIMMS as a post-processing step.

The value of the results using sub-geographies and sub-populations can be obscured when results are reported at the regional scale. The corresponding percent VMT and emission reductions are often quite small when applied to the entire region. For example, a strategy that reduces VMT by 0.1% among 10% of the regional population will reduce total regional VMT by just 0.01%. However, VMT and emission reductions can be significant for the sub-geography covered by a strategy even if the reductions are minor at the regional level. For example, ARC's parking pricing strategy reduces VMT by 11.4% for the target population, but regional VMT is reduced by only 2%.

The strategies selected in the current study demonstrate the potential interest in alternative populations and geographies, as well as strategies that are not easily analyzed using TRIMMS. This test of the TEAM approach shows that it can be used independent of the analysis tool or method. TEAM allows staff to compare potential outcomes of various strategies to inform decision making without the extensive cost and time of detailed travel demand model analysis. TEAM also does not require extensive reliance on modeling staff; instead, it uses data inputs that can be obtained from travel demand model inputs and outputs without additional analysis.

Throughout this report, it is essential to consider the target population for individual strategies when evaluating the impact. TDM strategies are an example of TEAM applied consistently to an employee sub-population. The number of employees or the geography of interest may vary, but TDM always applies to the working population. Other strategies may limit the penetration or the geographic area to which it applies. This information is available in the scenario descriptions. Results are reported as percent change at a regionwide scale with the corresponding impact in VMT/trips for the sub-geography or sub-population noted.

MOVES Analysis

MOVES is EPA's Motor Vehicle Emission Simulator, a state-of-the-science emission modeling system that estimates emissions for mobile sources at the national, county, and project level for criteria pollutants, greenhouse gases, and air toxics. It can estimate the total on-road emissions for a particular county or set of counties for a specific period. It can also answer "what if" questions, such as: "how would particulate matter emissions decrease in my state on a typical weekday if truck travel was reduced during rush hour?", or "how does the total hydrocarbon emission rate change if my fleet switches to gasoline from diesel fuel?" The purpose of MOVES is to provide an accurate estimate of emissions from cars, trucks and non-highway mobile sources under a wide range of user-defined conditions.[17]

MOVES2014 is a major new revision to EPA's mobile source emission model, replacing all versions of MOVES2010. It represents EPA's most up-to-date assessment of on-road mobile source emissions. MOVES2014 includes the regulations promulgated since the release of MOVES2010b that can affect the present analysis, including the Tier 3 emission standards that phase in beginning in 2017 for gasoline cars and light-duty trucks (among other categories) and the second phase of light-duty vehicle GHG regulations that phase in for model years 2017-2025 cars and light trucks. MOVES2014 also incorporates new and up-to-date emissions data from a wide range of test programs and other sources, and updates findings on the effects of fuel properties such as gasoline sulfur and ethanol, and new analyses of particulate matter (PM) data related to PM speciation and temperature effects, and substantial new data and updates for default vehicle population and activity, including new vehicle miles travelled (VMT) estimates based on updated FHWA Highway Performance Monitoring System values, new national average speed distributions based on global positioning system (GPS) data, new state supplied data from the 2011 National Emission Inventory, and many other population and/or activity related updates.[18,19]

MOVES runs were conducted, quality assured, reviewed internally and by EPA, and corrected as needed for any data issues. Data collection focused on each element required to perform the analysis at the county, multi-county, or custom domain resolution as identified in Table 3.

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[17] User Guide for MOVES2014, EPA-420-B-14-055, July 2014 https://www.epa.gov/otaq/models/moves/documents/420b14055.pdf.

[18] EPA Releases MOVES2014 Mobile Source Emissions Model, EPA-420-F-14-049, July 2014 https://www.epa.gov/otaq/models/moves/documents/420f14049.pdf

[19] Note that, while the MOVES2014a model was released during this period of performance, it was not used in the analyses. This should have a negligible effect on emissions. MOVES2014a includes minor updates to the default fuel tables, and provides a small correction to brake wear emissions. Other criteria pollutant emissions remain essentially the same as MOVES2014. https://www.epa.gov/otaq/models/moves/documents/420f15046.pdf.

Table 3. Data Inputs for MOVES Runs

Data Type Description	Data Elements	
Fields without default values available at the county scale[1]	Source (Vehicle) Type Population	
	Vehicle Type VMT	
	Road Type Distribution	
Local data, as available MOVES default data when local is unavailable[2]	Meteorological Data	Ramp Fraction
	Age Distribution	Fuel Supply, Formulation, Usage, Region and Alternative Vehicle and Fuel Technology (AVFT)
	Month, Day, Hour VMT Fractions	I/M (Inspection and Maintenance) Program
	Average Speed Distribution	Start Distribution Information
Modeling decision elements, typically not requiring local data	Domain/Scale	Geographic Bounds
	Calculation Type	Vehicle Type
	Time Aggregation	Road Type
	Calendar Year	Pollutants and Processes
	Evaluation Month	Strategies
	Type of Day	Activity
	Evaluation Hour	Emissions Detail

[1] MOVES2014 includes Retrofit Data in this category, which is not a required field and is not used in this analysis, so is not shown here.
[2] MOVES2014 updates inputs to include Hotelling Information, which applies only to heavy vehicles and is not applied or shown here.

Geographic Considerations for MOVES

The geographic scale selected for MOVES modeling was the county scale, consistent with EPA Guidance,[20] but the approach varied across the regions. Both EWG and ARC represent their multi-county domains through "representative" county inputs. In the case of ARC, inputs were provided for a single representative county, modeled as Fulton County, Georgia, representing the inputs for the 5-county domain considered here.[21] This representative county uses averaged inputs such as speed and meteorology to cover the modeled region and period. EWG performed a similar analysis, but provided inputs aggregated into 2 representative counties to accommodate the bi-state region: St. Louis, Missouri, and St. Clair, Illinois. The MetroPlan Orlando analysis was performed for each of the three counties in their planning domain individually and aggregated outside the model. Details about the collection, processing, sources, and quality assurance of each of these data items for each region appear in the regional discussions.

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[20] Analysis for scale and other parameters adhered to EPA's current guidance for estimating on-road greenhouse gas emissions: Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption – Final (EPA-420-B-16-059, June 2016). https://www.epa.gov/otaq/stateresources/documents/420b16059.pdf

[21] Note that ARC generally plans for a 13 county inner and 7-county outer domain for the 20-county nonattainment area.

Deriving Emissions Factors

The TEAM approach derives regionally specific emission factors from MOVES. It does not use MOVES in “Emissions Rates” mode to directly calculate emission rates nor does it directly calculate regional emissions within the model for the given scenarios. Instead, MOVES is run in “Inventory” mode for each of the regions with the available regional data, and then rates are calculated from a ratio of the resulting totals of emissions and activities. This ratio provides an activity-weighted, average emission factor for the region in the specified year. These emission factors are then applied to the strategy-determined VMT changes to indicate emission changes.

Four primary pollutants were considered in this analysis: CO_2e, NOx, $PM_{2.5}$, and VOC. Other pollutants necessary for the model to compute these four were also included in the analysis as done in the initial study. These are provided in Appendix A tables for each agency.

As noted above, TRIMMS uses composite vehicle types. Emission factors were derived by combining MOVES vehicle and fuel types to match the TRIMMS composite definitions. For the TRIMMS vehicle categories auto drive alone and auto rideshare, composite emission factors representing motorcycles, passenger cars, and passenger trucks were calculated from the MOVES model’s output. For the TRIMMS vanpool category, MOVES vehicle types for passenger truck and light commercial trucks were combined, representing the different types of vehicles that could be used.

All road types were included. Only running and starting emission processes are included: Start Exhaust, Crankcase Running Exhaust, Crankcase Start Exhaust, Running Exhaust, Brakewear, and Tirewear emission processes were included in the emissions totals from the MOVES runs.[22] All MOVES runs for this project were run without pre-aggregation; hourly analysis was performed. All analyses were made at the annual scale.

Emission factors were calculated as total running emissions from hourly outputs (in grams per year) divided by total running activity (in miles per year). A similar analysis was made for starting emissions. In both cases, the resulting emission factors, in grams of pollutant per average mile driven or grams of pollutant per average start were produced.

A single emission factor was derived for each (TRIMMS) vehicle type, year, and pollutant for both the starting and running processes. All MOVES emissions processes that contribute to these two aggregate processes, such as tailpipe and crankcase exhaust emissions, were summed to produce these totals. The resulting overall average emission factor was used for every scenario, pairing current year emission factors with baseline activity for baseline emissions, and future year emission factors with BAU activity and all scenario alternatives activity, for future year emissions. All calculations were made off model, with a combination of

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[22] Notably, evaporative emissions are not included. Evaporative emissions add significant complexity and run times to the analysis, and are not expected to be affected by any of the strategies considered here. Thus they would have negligible effect on the comparison of alternatives.

MySQL and spreadsheet calculations. Both starting emissions – based on TRIMMS-calculated number of trips – and running emissions – based on TRIMMS-calculated VMT – were included in computing the total emissions and emission changes. The calculation of total emissions was done in a simple, off-model spreadsheet calculation that assembled outputs from both the emission factor and VMT modeling results. This method is a very efficient approach to determining impacts of the strategies with the given resolution of the input data. Regionally specific details and results are presented in the following section.

3. Case Study Results

Three agencies were selected as case studies for testing the TEAM approach at a regional level: Atlanta Regional Commission (ARC), East West Gateway Council of Governments (EWG), and MetroPlan Orlando Metropolitan Planning Organization (MetroPlan Orlando). Each agency selected strategies for improving travel efficiency that are of interest within the region and provided data to support analysis.

The lead agencies worked with stakeholder groups to support their strategy selection and data collection as a part of their common agency practice. The selection of strategies has been grouped into four scenarios for each region based on their individual interests and data availability. For this study all agencies applied strategies to achieve a progressive increase in VMT reduction across scenarios. Both the strategies and their underlying assumptions represent a broad range of potential futures for evaluation of corresponding emissions reductions. Each of the regional analyses are examined in detail in the following sections.

In each of the three regions sub-geographies and sub-populations were used to target individual strategies. The results are reported at the regional level, consistent with previous TEAM case studies. In addition, the potential scenario impact for the target population or subarea is reported in the discussion. Additional detail on VMT and specific pollutant emissions reductions is provided in the Appendices, as noted in the text.

It is important to keep in mind that TEAM is used for the purpose of comparing potential travel efficiency strategies, and is not intended to replace the detailed technical analysis used in transportation planning. However, because the TEAM data inputs are consistent with the region’s travel demand modeling and transportation conformity process (where applicable), results are sufficiently accurate for decision making.

MetroPlan Orlando

Background

MetroPlan Orlando is a metropolitan planning organization (MPO) and regional planning partnership of three counties, two urbanized areas, 22 municipalities, two expressway authorities, two international airports, and a regional transit authority. The MPO region has doubled in population over the past 25 years, and strong population growth continues to be the trend. The diverse population of the region is accompanied by heavy tourist and business travel. In 2014 a new record was established with 59 million visitors.

The transportation sector contributes 40 percent of Florida’s greenhouse gas (GHG) emissions. More than 60 percent of the air pollution in Central Florida is related to transportation emissions; however, the region is well within current air quality standards. An Air Quality emissions inventory and Contingency Plan was developed in partnership with the University of Central Florida. The 2040 Long Range Transportation Plan focuses heavily on transit and improving bicycle and pedestrian access in recognition of the need to diversify transportation options. These factors led MetroPlan Orlando staff to consider using TEAM to evaluate air quality concerns as a proactive way to consider transportation-related emissions.

The MetroPlan Orlando base year is 2009 with a future year of 2040. MetroPlan Orlando no longer maintains a separate trend and vision forecasting process in their modeling. All forecasts are based on the vision included in the Long Range Transportation Plan (LRTP) which includes land use. MetroPlan Orlando has considered the impacts of land use changes during LRTP development; based on a no-build and on a cost-feasible case. The agency considers it unlikely that land use changes beyond what was included in the LRTP would be acceptable to decision makers. With no need to perform a land use analysis, all strategies were able to be modeled using TRIMMS. MetroPlan Orlando staff provided all local data that was included in the TEAM analysis.

Scenario Development

Scenarios were identified by MetroPlan Orlando staff based on policies that were likely to be considered in future planning activities; however, specific data to inform the analysis was very limited. Instead, default data within TRIMMS representing the Orlando-Kissimmee-Sanford Metropolitan Statistical Area (MSA) was used. The TRIMMS default data is drawn from two sources. Mode share data are drawn from the American Community Survey for the Orlando MSA. Trip length data by mode are drawn from the National Household Travel Survey (NHTS). These are the best national sources for the data; therefore TRIMMS default data points can be used with confidence.

Scenario 1 – Expand ridesharing and TDM programs

This scenario represents three policy changes that MetroPlan Orlando may consider in the future. In the 2040 BAU case, these policies apply to a subset of the regional commuter population, which equals 114,000. In the 2040 scenario case, this subset of the total commuter population is increased to 309,367. Each of the policies in this scenario is described below.

Policy 1: Subsidize work trips using alternate modes by $150 per employee per month for public transportation and by $35 per employee per month for cycling. Offer subsidies to 10% of employees. In order to attain this policy goal, several actions would be required.

Increase transit and cycling subsidies offered to employees

Expand the number of employees offered subsidies for alternate mode work trips from 2.8% to 10% of total employees

Expand carpool/vanpool/bike/walk incentive programs

Policy 2: Offer telework and flex work schedule programs to 10% of employees. To implement this policy, it will be necessary to expand the number of employees with access to telework and flex work from 6.3% to 10% of total employees

Policy 3: Expand guaranteed ride home program from 2.8% of total employees to 20%.

This scenario required three model runs with individual populations represented. The individual strategies represent both monetary and non-monetary benefits, and therefore must be considered individually and summed for the full VMT reduction impact. In each case, the target population is the number of additional employees offered the benefit in the future beyond the BAU case.

For non-monetary strategies, the radio buttons for TDM programs and subsidies for Guaranteed Ride Home and Ride Match and Telework and Flexible Work Schedules were used. The radio button feature is an option in TRIMMS to analyze TDM strategies without the use of actual monetary values for subsidies. The radio button method more accurately captures mode shift than the monetary method. For monetary subsidies, the BAU trip cost was provided by MetroPlan Orlando, and the strategy trip cost was calculated based on the policy. These values were entered into TRIMMS to estimate changes on VMT. MetroPlan Orlando did not provide trip costs for cycling.

Transit service is not changing under this scenario, so transit VMT will not increase. The shift in drive-alone and rideshare trips to transit trips will be supported by existing transit system capacity in the 2040 BAU scenario. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

Scenario 2 - Expand ridesharing and TDM programs along with transit network expansion and improvement

This scenario adds transit expansion and improvement to the TDM scenario by reducing transit trip times by one third. This improvement is accomplished by increasing the average speed of transit trips from 14.6 to 20 miles per hour and reducing average headways from 25.5 minutes to 15 minutes.

The target population for Scenario 2 is the same as the BAU population covered (515,425 commuters) because the change is with respect to travel time only, without increase in the number of commuters using public transit. Under this scenario, average transit travel time is reduced from 22.5 minutes (BAU) to 16.5 minutes and waiting time is reduced from 25.5 minutes (BAU) to 10.5 minutes due to the reduction in headways.

The impact of expanded ridesharing and TDM programs from Scenario 1 was summed with these TRIMMS model runs as a post-processing step.

Scenario 3 - Expand ridesharing and TDM programs plus transit network expansion and improvement and road pricing

Scenario 3 adds VMT pricing at 6 cents per mile to the effects of Scenarios 1 and 2. The charge is anticipated to apply to the full BAU regional population of 3,301,256. Current trip costs for drive-alone and rideshare are increased by 6 cents per mile within TRIMMS to represent the strategy change from the BAU condition. Per mile cost based on fuel, tires, and maintenance were obtained from the RITA database for 2013.[23]

The impact of Scenario 2 policies was summed with the road pricing results from the TRIMMS model runs as a post-processing step. VMT pricing does not result in a change in transit service and therefore transit VMT will not increase. The shift in drive-alone and rideshare trips to transit trips due to road pricing will be supported by the BAU transit system capacity. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

Scenario 4 - Expand ridesharing and TDM programs plus transit network expansion and improvement and road pricing along with a university transit pass

The final scenario adds a university transit pass at no perceived cost to the user. Free transit is bundled with tuition and university employment, making it available to 205,000 students, faculty, and staff. This scenario does not result in any increased transit service VMT. The shift in drive-alone and rideshare trips to transit trips will be supported by the BAU transit system capacity.

The impact of previously considered policies was summed with the university transit pass TRIMMS model runs as a post-processing step.

Scenario Summary

Input parameters are provided in Table 4 below for current conditions, a business as usual (BAU) future, and the four scenarios selected by MetroPlan Orlando. Specific input values are provided for each of the scenarios. The MetroPlan Orlando scenarios apply across the entire region without any sub-geographies considered. The resulting VMT reductions for each scenario are included in the table. In each scenario, the specific target population is identified.

For each case study region, a comparison Cluster from the 2010 national study was selected based on regional population size and transit mode share. This comparison was performed to validate the reasonableness of the results in this analysis. In addition, the first group of case studies provides a basis for comparison. Results for each strategy type for the case study regions were expected to be similar to these previous results. Where results for case study regions were dissimilar to those of the comparison region, discrepancies are noted. In some cases, the comparison helped to identify necessary adjustments to the TRIMMS inputs.

MetroPlan Orlando is compared to San Diego, California in Cluster 2. The MetroPlan Orlando strategies were matched as closely as possible with the strategies in the 2010 national study, and the results of this comparison are presented in of Appendix B. This comparison does not imply that MetroPlan Orlando values will match exactly those of San Diego. However,

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[23] United States Department of Transportation. 2015. *National Transportation Statistics*. Table 3-17. Available: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/NTS_Entire_15Q4_0.pdf.

comparisons made between the two regions supported the reasonableness of the MetroPlan Orlando results.

Table 4. MetroPlan Orlando Scenario Details

Scenario	Description	Data Inputs	Daily Regional VMT Reduction
Current Conditions	Existing conditions across all strategies in 2009	• mode shares • average vehicle occupancy • average vehicle trip lengths • regional population and employment	NA
Business as Usual	2040 conditions with BAU levels of employer program, transit, and road pricing	• mode shares • average vehicle occupancy • 2040 regional population and employment • current employer-based incentives for alternative commute modes • current travel times (22.52 minutes for transit) • current access times (25.5 minutes for transit) • average trip costs ($1.98 for drive alone, $0.61 for rideshare, $3.75 for transit without current employer-based incentives, and $2.05 for transit with current employer-based incentives)	NA
Scenario 1: Expanded TDM	Expand access to telework and flexwork programs, Guaranteed Ride Home and ridematching services.	• share of *additional* regional employees covered (162,891 for guaranteed ride home program, 80,934 for guaranteed ride home and monetary subsidies, and 65,182 for guaranteed ride home, monetary subsidies, and telework and flexwork programs; 309,637 total additional employees covered) • average monthly subsidy offered to employees ($150 for transit and $35 for bike) • guaranteed ride home program toggle buttons • telework and flexible work program toggle buttons	0.65% auto VMT reduction (502,039)
Scenario 2: Scenario 1 + Enhanced Transit	Improve transit and expand transit pass program.	• 27% transit travel time reduction (to 16.5 minutes) • 41% transit access time reduction (to 15 minutes) • Number of regional employees covered (515,425)	0.92% auto VMT reduction (708,069); Note: transit VMT increase
Scenario 3: Scenario 2 + Road Pricing	Implement mileage pricing.	• Regional population covered (3,301,256) • 6 cents per mile charge for drive alone and rideshare trips • 31% increase in average cost per trip (from $1.98 to $2.61 for drive alone and from $0.61 to $0.80 for rideshare)	4.75% auto VMT reduction (3,649,898)
Scenario 4: Scenario 3 + University Transit Pass	Implement unlimited transit access pass to be bundled with student tuition and given to all faculty and staff as an employee benefit	• Number of regional students, faculty, and staff covered by university transit pass program (205,000) • average transit trip cost for university transit pass (from $3.75 to $0)	6.08% auto VMT reduction (4,666,465)

Emissions Analysis

Regions that have used the MOVES model to conduct a transportation air quality conformity analysis or develop an emissions inventory required by the CAA will have readily available data to provide for the TEAM emissions analysis. However, those requirements do not apply to MetroPlan Orlando. As a result, the MPO has little experience with MOVES analyses, and does not have input data readily available for such analyses. While TEAM is able to rely on all default inputs within the MOVES model, EPA's GHG Guidance notes that relying exclusively on MOVES default database information for an analysis reduces the precision of the emissions analysis since the default data may not be the most current or best available information for any specific county.[24] Nevertheless, default data is acceptable for an analysis to allow comparisons of relative emissions reductions among different scenarios.

MOVES2014 was run at the county scale for each of the three counties (Osceola, Seminole, and Orange) and each year (2009 and 2040). The emissions and activity for each county were then aggregated to regional totals and these sums ratioed to determine the representative emission factor. The final emission factors were then extracted and applied to the regional VMT reductions to estimate the corresponding emissions reductions. The data used in the MOVES simulations is listed in the previous section (see Table 3.); for MetroPlan Orlando, all MOVES data is default.

The post-processing of MOVES outputs to determine the activity weighted, average emission factors representing the MetroPlan Orlando region was done with database and spreadsheet analysis methods. In these methods, emissions and activities are aggregated into the source types required by TRIMMS, and the ratio of emissions and activities is taken. The emissions and activity values are first summed from the outputs of the three individual counties from the MOVES simulation. This is done using database methods to combine the separate tables from each county's simulation into a single set of emissions and activities. Those resulting composite, regional emission and activity values are then ratioed, to produce regional emission rates for the composite vehicle types. These database values are then output into spreadsheets where the presentation of values is simplified into tables and presented for use in the spreadsheet models used in the scenario analyses. The resulting average emission factors for the MetroPlan Orlando region and TRIMMS vehicle types are shown in Table B-2.

MOVES was run in inventory mode for each of the regions to produce activity-weighted, average emission factors each the region. These emission factors were coupled with the predicted changes in activity to produce net emissions changes by scenario for each region. The corresponding relative reductions are presented for each region in this section of the report.

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[24] Because there is no federal requirement for creating on-road GHG inventories or conformity analyses for attainment areas, EPA guidance including its GHG Guidance, is entirely voluntary. However, it may be considered best practice to follow this guidance for analyses such as these.

MetroPlan Orlando Scenario Results

The results of the VMT and emissions analysis for light-duty vehicles at a regionwide scale are presented below in Table 5, following a discussion of the results for each scenario.

Scenario 1 for Expanded TDM has a moderate impact on a target population of approximately 300,000. The regional VMT reduction represents shifts from drive-alone to rideshare, cycling, walking and transit. For MetroPlan Orlando this represents a reduction of approximately 500,000 VMT and 50,000 trips for light-duty vehicles, and is consistent with results for TDM strategies for other regions. Scenario 1 represents a total regional VMT reduction of 0.65% for light-duty vehicles.[25] To increase the impact of this strategy, MetroPlan Orlando may consider increasing the number of regional employees to receive these benefits.

Scenario 2 adds transit improvements to the Expanded TDM scenario. This has a relatively small impact on the target population (515,425) for transit trip times and access time reductions. This is equivalent to a reduction in light-duty VMT of 206,000 and light-duty auto trips of 22,000, which are shifted to public transit.[26] The combined strategies under Scenario 2 represent a total regional VMT reduction of 0.9% for light-duty vehicles.[27]

The reported VMT reduction does not include any potential increase in transit VMT, although this is anticipated to occur. Increasing the frequency of transit service reduces wait times and travel times for vehicles and makes riders more likely to choose transit. The strategy will also result in additional transit vehicle trips and VMT. However, the limited penetration of the improved transit system (only 16% of the total regional population is affected) reduces its regionwide impact. Reducing transit wait times or travel times even further will not induce many more trips by transit with this limited population. Land use changes to bring more people closer to transit stops could be more effective than service improvements alone. For the potential impact of the anticipated transit VMT increase, see Table A-1 in Appendix A.

From previous analyses using TEAM, it is clear that pricing strategies are consistently the most effective at reducing emissions, and that is confirmed with the MetroPlan Orlando **Scenario 3** results. Road pricing is applied to the full population of the region, and demonstrates a 3.8% regional VMT reduction for light-duty vehicles (see Table B-1 in the Appendix) for a total combined VMT reduction of 4.75% for the scenario. This equals 2.9 million VMT and 300,000 trips for mileage pricing with shifts from drive-alone and rideshare to transit, vanpool, cycling, and walking.

In **Scenario 4**, there is a large impact on the specific target population for the university transit pass. Again, the target population is small, but the effect is significant to that group. This results

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[25] For the target population, the VMT reduction is 7%.

[26] An increase in transit vehicle VMT is anticipated (see Appendix A)

[27] For the target population, the VMT reduction is a moderate 1.7%.

in a decrease of 1.0 million VMT and 100,000 trips for light-duty vehicles with shifts from drive-alone and rideshare to transit. The target population includes 205,000 university students, faculty, and staff. A free transit pass provides a very strong incentive for the target population, but at a regional level, the auto VMT reduction is only 1.3% (see Table B-1 in the Appendix) for a total combined VMT reduction of 6.08% for the scenario.[28]

The incremental reduction for the university transit pass is stronger than that of the employer-based TDM strategy because the university transit pass makes taking transit essentially free for any given trip. Even if there is a cost increase bundled with tuition, the perceived cost is free, since the cost has been paid. When both TDM and the university transit pass are combined with a highly successful strategy like road pricing, the outcome is optimal – as Scenario 4 illustrates.

The MetroPlan Orlando case study is a good example of how TEAM can be employed in a region without any MOVES capabilities or experience. No locally specific MOVES input data was available from MetroPlan Orlando, and thus all defaults were used. Recent, local data is always preferable over defaults, since it is expected to offer the best representation of local conditions. The method used in TEAM of deriving emission factors from MOVES that are coupled with TRIMMS VMT is an acceptable approach to support comparison of strategies, even with the use of default data.

Table 5 provides the results of the VMT and emissions analysis for light-duty vehicles at a regionwide scale. As previously discussed, individual strategies were applied to the appropriate population group that is targeted by the strategy, which is often a subset of the regional population. For example, TDM strategies are always applied to a sub-population of regional employees, targeted by the geography or the limitations of the strategy (such as 10% of all employees).

Atlanta Regional Commission

Background

The Atlanta Regional Commission staffs a 20-county MPO that supports a population over 5 million. The Atlanta region has a strong TDM community focused on improving both air quality and quality of life. The agency is a recognized leader in transportation data collection and analysis, and has both developed and used sketch planning tools. ARC expressed an interest in TEAM to test strategies not easily captured using travel demand modeling, and because the agency has an ongoing interest in climate change at the regional level. ARC is also interested in comparing TEAM to an off-model emissions calculator developed for use in CMAQ project selection. The calculator has some similarities to the TEAM approach, but is applied at a project scale.

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[28] For the target population, the VMT reduction is large at 21.3%.

Table 5. MetroPlan Orlando Regionwide Percent VMT and Emissions Changes for Light-Duty Vehicles

Percent Regionwide Emissions Changes for 2040 BAU Compared to 2040 Scenario						
Scenario	**Target Population***	**Light-Duty VMT**	**GHGs (CO_2 equivalent)**	**$PM_{2.5}$**	**NOx**	**VOC**
Scenario 1: Expanded TDM	10% of employees Regionwide (309,637)	−0.65%	−0.65%	−0.65%	−0.65%	−0.65%
Scenario 2: Scenario 1 + Enhanced Transit	16% of employees Regionwide (515,425)	−0.92%	−0.92%	−0.92%	−0.92%	−0.92%
Scenario 3: Scenario 2 + Road Pricing	3,301,256 Regionwide population	−4.75%	−4.75%	−4.75%	−4.74%	−4.73%
Scenario 4: Scenario 3 + University Transit Pass	Students, faculty, and staff (205,000)	−6.08%	−6.07%	−6.07%	−6.06%	−6.05%

*The identified target population is for the additional strategy only. For the total Scenario population, previous scenario populations must be considered.

With such a large planning region, ARC often focuses analysis at a sub-area or project level. TDM strategies are generally carried out in scattered locations across the region. A 13-county core is designated for ozone non-attainment, and MOVES has been used for air quality planning purposes and performing transportation conformity analyses for that area since 2012. TEAM is best applied at a regional scale, and determining the appropriate geography for this case study required some discussion. Ultimately, it was determined that strategies would apply to a 5-county geography (Fulton, DeKalb, Cobb, Gwinnett, and Clayton) within the 13 county “core.” In order to conform to the approach used in the region’s conformity analysis, emission factors were determined from the “representative” county approach described earlier in this report. These five counties represent 64% of the population and 75% of the jobs for the full MPO region in the base year. In the BAU, the numbers are 56% and 70% respectively.

Stakeholders are an essential part of the ARC decision making process. Staff engaged the technical transportation committee, a stakeholder TDM committee, and the policy committee on the selection of strategies. Other stakeholders were engaged by staff on an as-needed basis. The TDM committee provided feedback and pricing information for some of the related strategies. The other two committees were informed and provided answers to questions raised.

The ARC base year is 2015 with a future year of 2040 to match the current regional transportation plan (RTP). Data was readily available for the TEAM analysis from existing travel demand modeling, and the emissions analysis was consistent with conformity analysis assumptions and data. Base year data was provided by the activity-based model, and some transit data was provided by the Metropolitan Atlanta Regional Transit Authority (MARTA).

Scenario Development

The TEAM analysis considers travel activity in 5 out of 20 counties modeled by ARC. ARC's travel demand model provided parameters for BAU mode shares, trip lengths, and trip costs by mode. Regional models estimate much greater population growth in the outer counties, but job growth is predicted to stay more centralized. The models predict slight decreases in average trip lengths, possibly due to higher densities of population and employment and increasing congestion.

Scenario 1 – Expand ridesharing and TDM programs

The three policies in this scenario represent potential changes from the BAU in the 5-county subarea under consideration. The commuter population of the five counties is 873,193 in the BAU case. The total commuter population in 2040 targeted to this scenario is increased to 1,746,386. This scenario required three model runs with individual populations represented.

1. The first policy is to require all employers with 100 employees or more to provide carpool/vanpool/transit/bike/walk incentives. Incentive programs currently offered by employers would be expanded without changing the dollar amount of subsidies. This policy expands the share of regional employees with access to these incentives by 92%.

The second policy is to expand alternate work schedule programs by doubling the number of employees with access to telework and flex work.

The final policy is to expand the guaranteed ride home program by increasing the number of employees with access to the program by 50%.

TRIMMS uses a simple approach to analyzing TDM strategies. As in the previous case studies, the radio button feature was used to collect basic information about the TDM strategy features. However, this approach does not account for trips shifting to other modes

Since ARC is able to provide actual trip costs and subsidy amounts to support a more rigorous TDM analysis, the agency was interested in a rebalancing analysis using TRIMMS to account for trips that shift to other modes. However, the rebalancing analysis overestimated the number of drive-alone trips reduced. As such, the radio button feature in TRIMMS proved the most successful way to account for these changes. Appendix C discusses the rebalancing process and presents the subsidy values that ARC provided for this scenario in Table C-1. This information was not used in the analysis.

The individual TDM strategies represent both monetary and non-monetary benefits, and therefore must be considered individually and summed for the full VMT reduction impact. In each case, the target population is the number of *additional* employees offered the benefit in the future beyond the BAU case. For non-monetary strategies, the radio buttons for TDM programs and subsidies for *Guaranteed Ride Home and Ride Match* and *Telework and Flexible Work*

Schedules were used. For monetary subsidies, the radio buttons for *Program Subsidies* by mode were used.

Transit service does not change under this scenario, so transit VMT will not increase. The shift in drive-alone and rideshare trips to transit trips will be supported by the capacity of the BAU transit system. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

Scenario 2 - Expand ridesharing and TDM programs along with transit frequency improvement

This scenario adds transit expansion and improvement to the TDM scenario by reducing transit access time; accomplished through reduced headways. In this strategy, average transit headways are reduced by 50%, which corresponds to a decrease in access time of 18%. There is no change in transit travel time assumed.

As previously noted, increased transit service results in increased VMT, trips, and emissions for transit vehicles that are not accounted for in the light-duty analysis. Transit service does not include demand response service or paratransit.

The target population for transit improvement is the same as the BAU population. This number represents the total 5-county regional population living within ½ mile of a transit stop (2,025,866). This transit strategy does not increase the population covered by transit, it just reduces headways and access time for the BAU population. MARTA service has recently been added in one of the five counties, and the suburban systems are expected to continue to grow. These changes are the basis for the reduction in access and egress time from 23.95 minutes to 19.56 minutes; 18.3% reduction in access time consistent with a 50% decrease in headways.

Scenario 3 - Expand ridesharing and TDM programs plus transit frequency improvement and parking pricing

Scenario 3 adds a policy to increase average cost of parking by 74% and remove parking subsidies in major activity centers. This increased parking cost is $165 per month for drive alone ($7.50 per day for 22 days) and $2.73 for rideshare ($2.73 per person per day for 22 days and 2.75 persons per vehicle) consistent with the national average. The assumption is that 100% of employers in major activity centers will be subject to parking pricing.

This scenario required two TRIMMS model runs to separate those currently paying for parking (30,110) from those not currently paying who will pay in the future (738,662). ARC provided monthly parking costs for both drive alone and rideshare which were divided by 22 workdays to determine the daily cost input needed for TRIMMS.

Transit service is not changing under this scenario, so transit VMT will not increase. The shift in drive-alone and rideshare trips to transit trips will be supported by the capacity of the BAU transit system. Although VMT for non-motorized modes (e.g., walking, bicycle) will increase, there are no emissions associated with these modes.

Scenario 4 - Expand ridesharing and TDM programs plus transit frequency improvement, parking pricing, and smart growth land use

ARC's land use strategy is to encourage new residents in the five county core area to locate in compact areas with the outcome of producing lower transportation emissions as investigated in their 2014 climate change study.[29] The strategy does not include shifting population growth from outlying counties to the inner 5 counties. The target population for the land use strategy is equal to the BAU population for the 5-county subarea (4.4 million). ARC has been using a land use analysis approach that is similar to the Neighborhood Classification method tested in this study. As a result, the agency was able to provide the required data for this analysis. The Multivariate approach was new to the agency and they were equally interested in providing data and getting results for both approaches.

This scenario combines all previous strategies tested with population growth more concentrated in travel efficient neighborhood types. For the Neighborhood Classification analysis it was assumed that 50% of total population will be living in the two neighborhood types with the lowest average VMT per person (out of 5 total neighborhood types), versus 37% in the BAU. These neighborhood types include areas close to major activity centers, areas with good transit access, and/or areas that are walkable. They also have the fewest average daily miles traveled per person (9.8 and 15.9), while the other neighborhood types range from 18 to 31 daily miles/person.

The Multivariate approach analyzes the same policy stated in terms of specific land use variables. In this analysis, four specific changes were anticipated:

- Increase population-weighted density by 59%
- Increase job access by auto by 3%
- Increase job access by transit by 56%
- Reduce distance to nearest transit stop by 12%

Both land use analysis methods were conducted outside of TRIMMS. Transit VMT and non-motorized modes were not included in the VMT reduction. ARC provided the average VMT per person per day for each of the five neighborhood types as well as the percent of households in each type for the BAU and scenario.

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[29] See: http://atlantaregional.com/environment/air/climate-change

For the Multivariate approach analysis, elasticity values from Ewing and Cervero (2010) were used to determine total percent VMT change for each type of change. See Table A-2 in Appendix A for the elasticity values used for this analysis.

Transit service is not changing under this scenario, so transit VMT will not increase.

Scenario Summary

Input parameters are provided in Table 6 for current conditions, a business as usual future, and the four scenarios selected by ARC. Specific input values are provided for the scenarios. The ARC scenarios were applied only to the 5-county region. The resulting VMT reductions for each scenario are included in the table. In each scenario, the specific target population is identified.

ARC is compared to San Diego, California in Cluster 2. The ARC strategies were matched as closely as possible with the strategies in the 2010 national study; the results of this comparison are presented in Table C-2 of Appendix C. This comparison does not imply that ARC values will match exactly those of San Diego. All comparisons made between the two regions supported the reasonableness of the ARC results.

Emissions Analysis

Many regions have now conducted a transportation conformity analysis using the MOVES model; however, for many regions the 2014 version seems to be less widely used at present. ARC had developed extensive databases for use in its transportation conformity analyses to comply with Clean Air Act requirements and therefore had existing data to provide for the emissions analysis; it provided this data as a series of individual spreadsheets as well as a custom set of statewide inputs in MOVES2014 format for this analysis. These model input values are consistent with those used by the region in its conformity process.

ARC is a participant in the Interagency Committee for air quality planning as part of the conformity process. The agency has been using MOVES to model emissions since 2012, but has not yet performed conformity analysis with MOVES2014.

In TEAM the MOVES analysis is focused on extracting activity-weighted, regional average emissions factors from the model that represent the general parameters of the study region, as discussed above. ARC initially provided a custom database built on custom extractions of activity data from their travel demand model within the five-county study area. ARC provided inputs based on its travel demand model and its current conformity analyses along with a new Georgia-specific MOVES default database to use in these simulations; illustrating the consistency of the TEAM analysis with other analytical processes in the region. These were all loaded into new, MOVES2014 input databases. MOVES2014 input runspec files were created to match the provided inputs. Model simulations were then conducted for years 2015 and 2040 with these input databases and runspecs.

Table 6. ARC Scenario Details

Scenario	Description	Data Inputs	Daily Regional VMT Reduction
Current Conditions	Existing conditions across all strategies in 2010	• mode shares • average vehicle occupancy • average vehicle trip lengths • regional population and employment	NA
Business as Usual	2040 conditions with BAU levels of employer program, parking pricing, land use, and transit	• mode shares • average vehicle occupancy • 2040 regional population and employment • current travel times (33.45 minutes for transit) • current access time (23.95 minutes for transit) • average parking costs ($4.32 for drive-alone and $1.57 for rideshare)	NA
Scenario 1: Expanded TDM	Expand access to telework and flexwork programs, Guaranteed Ride Home and ridematching services.	• share of additional regional employees covered (271,194 for flexwork and telework programs, 590,236 for flexwork and telework and monetary subsidies, and 11,763 for telework and flexwork, monetary subsidies, and guaranteed ride home; 873,193 total additional employees covered) • No change in average monthly subsidy offered to employees • Program Subsidies radio buttons by mode for monetary subsidies	0.69% auto VMT reduction (867,544)
Scenario 2: Scenario 1 + Transit Frequency Improvement	Reduce transit trip times	• 18.3% access time reduction (to 19.6 minutes) based on 50% decrease in headways • Number of regional employees covered (2,025,866)	0.86% auto VMT reduction (1,093,477); transit VMT will increase
Scenario 3: Scenario 2 + Parking Pricing	Increase and expand coverage of parking costs.	• 26% of all parking (public and private) is priced • 74% increase in average parking cost per trip (to $7.50 for drive-alone and to $2.73 for rideshare)	2.85% auto VMT reduction (3,602,286)
Scenario 4: Scenario 3 + Land Use	Increase residential density and mixed use land uses for entire regional population	**Neighborhood approach** applies to entire regional population (4,404,057 people): • 50% of population in neighborhood types 1 (9.76 average daily per capita VMT) and 2 (15.9 average daily per capita VMT) • 50% of population in neighborhood types 3 (18.8 average daily per capita VMT), 4 (21.82 average daily per capita VMT), and 5 (31.10 average daily per capita VMT) **Mulitvariate approach** applies to entire regional population: • Increase population-weighted density by 59% • Increase job access by auto by 3% • Increase job access by transit by 56% • Reduce distance to nearest transit stop by 12%	8.82% auto VMT reduction (11,147,396) for Neighborhood approach; 9.28% auto VMT reduction (11,728,876) for Multivariate approach

ARC includes the effects of inspection and maintenance (I/M) programs in their MOVES modeling for transportation conformity analysis, including for future years. To be consistent with the ARC transportation conformity process, the I/M program described in the input dataset provided by ARC was used. Previous TEAM case studies have omitted I/M in the analysis. Although we did not conduct sensitivity simulations to assess the impact of including this program on the emissions, the affect is expected to be small, and likely to somewhat reduce the predicted overall emissions change. Relative emission changes should not be affected.

All data used for this analysis was as provided by ARC. The agency is familiar with MOVES analysis and was prepared to provide all required inputs. Although ARC has not yet conducted formal analyses in MOVES2014, the data provided have been modified to include any necessary changes from MOVES2010 to MOVES2014. All regional inputs were provided in spreadsheet format and imported into new MOVES2014 input databases. Some custom inputs were crafted by ARC for use in the smaller, five-county domain considered here, such as VMT, while all others, such as fuels and meteorology, are consistent with ARC's approach in its conformity analyses and have undergone development and review through the Interagency Planning process.

The post-processing of hourly MOVES outputs to determine the activity weighted, average emission factors representing the ARC region was done with database and spreadsheet analysis methods. In these methods, emissions and activities are aggregated into the source types required by TRIMMS, and the ratio of emissions and activities is taken. These database values are output into spreadsheets where the presentation of values is simplified into Table C-3 and presented for use in the spreadsheet models used in the scenario analyses. The resulting average emission factors for the ARC region and TRIMMS vehicle types are shown in Table C-3.

ARC Scenario Results

The results of the VMT and emissions analysis for light-duty vehicles at a regionwide scale are presented below in Table 7, following a discussion of the results for each scenario.

Scenario 1, expanding the Atlanta region's existing TDM programs, would reduce regional VMT by 0.7% for light-duty vehicles (representing approximately 870,000 VMT and 66,000 trips).[30] As discussed previously, the radio-button feature in TRIMMS used for TDM strategies simplifies the analysis. Although an alternate approach using actual dollar values for monetary subsidies was attempted, this did not provide reasonable results from TRIMMS. With improved rebalancing across modes, the strategy may produce greater reductions for the entire region.

Another factor restricting this strategy is limited deployment. Only about half of the region's employees will be offered subsidies as the strategy is currently specified. However, reaching

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[30] For the target population, the VMT reduction is a moderate 3.5%.

more employees would be increasingly challenging, as it would require engaging businesses under 100 employees.

Scenario 2 adds system-wide transit frequency improvements, which provide an additional regional VMT reduction of 0.2% for light-duty vehicles. The total combined regional VMT reduction is 0.86% for the scenario.[31] This is equivalent to a 43,000 reduction in light-duty auto trips or 226,000 VMT, which are shifted to public transit.[32] Increasing the frequency of transit service reduces wait times for vehicles and makes riders more likely to choose transit. However, the regionwide impact is still limited by the extent of the transit system.

In **Scenario 3**, adding parking pricing reduces regional VMT by an additional 2% for light-duty vehicles, which is equivalent to a 475,000 decrease in light-duty auto trips and 2.5 million VMT. The total combined regional VMT reduction is 2.85% for the scenario.[33] Pricing policies tend to be an effective strategy, because this can affect a large proportion of trips. In this case, ARC's proposed strategy would price approximately 25% of all employment-based parking at around $4 per trip. The remaining 75% of employment-based parking is unlikely to be priced, given its location outside of major activity centers. For potentially larger reductions using a pricing strategy approach, ARC may consider VMT or congestion pricing.

In **Scenario 4**, adding land use strategies reduces regional VMT by an additional 6% to 6.4% for light-duty vehicles, depending on the analysis method used. This is equivalent to a reduction of 1.5 to1.6 million light-duty auto trips or 7.5 to 8.1 million VMT. The total regional scenario VMT reduction is 8.8% to 9.3%, again based on the land use analysis method.

Land use produces the largest reduction of any strategy examined by ARC, thanks to an aggressive shift towards compact development patterns. ARC's land use strategy would increase the density of the average resident's neighborhood by 59% and increase the average number of jobs accessible by transit within 45 minutes for each resident by 56%. Those represent dramatic changes in the land use environment and transportation options available to many residents.

ARC could potentially reduce VMT even further through land use by considering increasing land use mixing. The current multivariate analysis showed no projected increase in land use mixing. Adding explicit measures to collocate housing, retail, and job opportunities in mixed-use districts reduces the need to make long car trips and helps to encourage shorter trips by walking and biking.

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[31] For the target population, the VMT reduction is 0.4%.

[32] For the corresponding increase in transit vehicle VMT see Appendix A

[33] For the target population, the VMT reduction is 11.4%.

Table 7. ARC Regionwide Percent VMT and Emissions Changes for Light-Duty Vehicles

Percent Regionwide Emissions Changes for 2040 BAU Compared to 2040 Scenario						
Scenario	**Target Population***	**Light-Duty VMT**	**GHGs (CO_2 equivalent)**	**$PM_{2.5}$**	**NOx**	**VOC**
Scenario 1: Expanded TDM	20% of Regionwide population (873,193)	−0.69%	−0.68%	−0.68%	−0.67%	−0.66%
Scenario 2: Scenario 1 + Transit Frequency Improvement	46% of Regionwide population (2,025,866)	−0.86%	−0.86%	−0.86%	−0.85%	−0.83%
Scenario 3: Scenario 2 + Parking Pricing	17% of Regionwide population (768,772)	−2.85%	−2.85%	−2.85%	−2.82%	−2.81%
Scenario 4: Scenario 3 + Land Use (Neighborhood Approach)	4,404,057 Regionwide population	−8.82%	−8.81%	−8.81%	−8.79%	−8.78%
Scenario 4: Scenario 3 + Land Use (Multivariate approach)	4,404,057 Regionwide population	−9.28%	−9.27%	−9.27%	−9.25%	−9.24%

*The identified target population is for the additional strategy only. For the total Scenario population, previous scenario populations must be considered.

East-West Gateway

Background

East-West Gateway Council of Governments (EWG) is the metropolitan planning organization (MPO) for the St. Louis bi-state region. EWG serves a region of approximately 2.6 million people over a five-county geography in Missouri and Illinois. The agency is well known for its data-driven planning process, and EWG staff supports data collection and analysis for all planning activities in the region including Geographic Information Systems (GIS), Land use Evolution and Assessment Model (LEAM), the regional travel demand model, and the MOVES model. Recent efforts in sustainability and climate change make it an ideal test for TEAM.

EWG participated in the OneSTL planning process, funded by a HUD Sustainable Communities Grant, from 2010 to 2013. EWG's Board of Directors approved the plan, which provides a framework of goals and strategies for fostering sustainable development in the St. Louis region. Unlike a long range transportation plan, OneSTL does not include a program of investments or assumptions about land use patterns.

EWG's latest long range transportation plan (LRP), Connected2045, was approved in 2015. Many of the metrics, goals, and strategies included in OneSTL are incorporated in Connected2045. As required of LRPs, Connected2045 adds a program of transportation investments including roads, transit, and bicycle facilities.

The EWG stated interest in participating in the TEAM case study is to allow decision makers and partners in the region to make more informed decisions in efforts to meet the goals outlined in the LRP and in OneSTL. The goals in these plans are not binding in a decision-making or investment context, nor are there specific targets set for future years. The TEAM analysis provides an opportunity to quantify the GHG benefits of specific policies and investments, which will in turn help build support among regional stakeholders for taking action in support of the plans' stated goals.

Concurrent with the TEAM analysis, EWG has received a grant from the Federal Highway Administration (FHWA) to facilitate GHG analysis of transportation related emissions using the MOVES model. Both of these efforts will support a better understanding of GHG emissions and potential strategies to reduce them.

EWG plays a significant role in the region by facilitating and coordinating interagency groups focused on air quality issues and emissions reduction. The Missouri Department of Transportation has expressed an interest in the TEAM analysis to inform a current Planning and Environmental Linkage study on a 40-mile corridor along I-70. EWG staff work closely with local air quality agencies and established the Air Quality Advisory Committee along with the Inter-Agency Consultation Group that supports the air quality conformity process. The region is designated non-attainment for ozone. EWG has coordinated with these broad partnerships in the selection of strategies and data inputs to inform the TEAM analysis.

EWG has no experience using sketch planning tools, and this is one reason for the interest in TEAM. Requests for GHG planning support from local municipalities as well as from the two State DOTs conducting corridor studies, provides the agency with an incentive to analyze at the sub-regional scale. Sketch planning tools are a natural fit for this interest by supporting decision making while requiring limited detailed analysis. This approach also fits well for implementing the OneSTL plan for sustainable development.

Scenario Development

During initial discussion of potential strategies to test, EWG expressed an interest in expanding the light rail system, and this was ultimately selected for analysis. Because the agency works across two-states, analysis at the county scale was also an interest.

Scenarios selected by EWG represent a combination of geographies: at both the regional (5-county) scale and for a sub-region of three counties. The three-county area includes the City of St. Louis (which functions as its own county), St. Louis County, and St. Clair County. Together these three counties contain the entire urban core of the region, along with all of the existing and planned rapid transit infrastructure.

The 5-county area includes the 3 core counties along with St. Charles and Madison Counties. Growth patterns in the region are expected to shift towards these counties in the future. While the 2 outlying counties are not slated for rapid transit infrastructure, they are ripe for inclusion in other types of land use strategies.

The strategies selected for analysis reflect a strong multimodal interest with supporting land use. Two different land use strategies were selected—one covering the three-county core and one covering all five counties, and EWG agreed to test both the Neighborhood Classification and the Multivariate analysis approach for both. This resulted in 4 different ways of analyzing the potential for land use to contribute to reducing emissions in the EWG region. The two other strategies, one for transit and one for bicycle and pedestrian transportation, represent a full build out of the light rail and bike/ped networks. Scenarios were developed by adding strategies to see the combined effect. Only the transit strategy was appropriate to model using TRIMMS. The bicycle and pedestrian analysis was accomplished with a simple spreadsheet analysis.

Scenario 1 – Regional Transit Oriented Development Initiative

This scenario is aimed at creating pedestrian and bicycle-friendly communities as outlined in OneSTL, and increasing population and jobs located near light rail stations, with most of the growth going to transit oriented development (TODs). The policy support required for this strategy is to increase the population and jobs located near light rail stations in a three-county core. This is a land use strategy and therefore two approaches were applied for analysis.

For the Neighborhood Classification approach, the analysis shifts 1% of population and 2% of jobs within the 3 core counties to more compact neighborhood types clustered around light rail stations.

For the Multivariate approach, access and density were increased as follows:

- Increase population-weighted density by 4%
- Increase job access by auto by 2%
- Increase job access by transit by 7%
- Reduce distance to nearest transit stop by 2%

This scenario required two separate spreadsheet analyses using data provided by EWG. Both land use analysis methods were conducted outside of TRIMMS. The TOD scenario was analyzed to determine potential VMT reductions for light-duty vehicles and did not consider increased transit service as part of the scenario. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

The Neighborhood Classification approach is based on the total employment and population for each area type assumed in the scenario. Total VMT is calculated by summing the average daily VMT for each area type. This allows comparison to the VMT in the BAU case to determine VMT reductions. EWG provided the average VMT per person per day for each of the five neighborhood types as well as the percent households in each type for the BAU and the scenario.

For the Multivariate approach the percent change between the BAU and the scenario in each of the parameters, provided by EWG and listed above, was determined and multiplied by the elasticity values from Ewing and Cervero (2010) to identify a total percent change in VMT.

For both approaches, the shift in drive-alone and rideshare trips to transit trips will be supported by BAU transit system capacity, without additional transit VMT. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

Scenario 2 - Regional Transit Oriented Development Initiative and Workforce Housing Balance Initiative

The Workforce Housing Balance Initiative is an attempt to bring jobs and workers closer together by providing good balance of residential, retail and non-retail land uses in the five-county region. While the Regional TOD initiative is focused at existing centers of high transit use in the inner 3 counties, the Workforce Housing Balance applies to the broader five-county area. The additional policy implication for this scenario is to focus growth in jobs and population in a manner that increases the local balance in individual counties.

As with the Regional TOD scenario, both land use analysis methodologies were applied to this scenario and the same analysis approach was used. As in Scenario 1, the two analysis approaches yielded comparable results.

For the Neighborhood Classification approach, the analysis shifts 2% of the population to more compact neighborhood types near existing job centers. In addition, 17% of jobs are shifted to neighborhood types that have higher concentrations of housing.

For the Multivariate approach, access and density (provided by EWG) were increased as follows:

- Increase population-weighted density by 2%
- Increase job access by auto by 3%
- Increase job access by transit by 2%
- Reduce distance to nearest transit stop by 11%

The same approach described above for Scenario 1 was used to calculate VMT reductions for Scenario 2. As in Scenario 1, the shift in drive-alone and rideshare trips to transit trips will be supported by the BAU transit system capacity, without additional transit VMT.

Scenario 3 - Regional Transit Oriented Development Initiative and Workforce Housing Balance Initiative with support for alternative modes of travel

Scenario 3 adds a complete bicycle and pedestrian network in the five-county region. The policy basis for this scenario is to increase sidewalk coverage on local and arterial roads from 56% to 71% and to expand miles of bicycle facilities by 150%. This represents a full build out of the bicycle and pedestrian networks currently in local and regional plans. As such, it includes construction of some facilities that are already included in the LRP and, therefore, the BAU. We allowed some overlap in this case for several reasons. First, there are additional bicycle facilities included in this strategy that are not included in the LRP. Second, the LRP makes clear that inclusion of bicycle facilities is not a commitment to funding. Presumably then, the case still needs to be made for building those facilities. Third, removing the bicycle facilities in question from the BAU would not result in any measurable difference in BAU travel patterns.

For sidewalk coverage, EWG staff estimated aspirational increases based on expected urbanization patterns in each county.

Analysis of this scenario is based on resources and assumptions developed by the San Diego Association of Governments (SANDAG).[34] The method is simple to apply, applicable at the regional level, and based on empirical research. It therefore fits with the overall TEAM concept. The general concept of this approach is to predict mode shifts based on the increased infrastructure provided for bicycling by expanding the lane miles. The bike lane method assumes a 1% increase in bike mode share for every 1 bicycle lane mile per square mile of area.[35] In this case, bicycle lane miles were increased by 150% for the same area.

The pedestrian method assumes the increase in pedestrian commuters (and the walk mode share) is equal to the percent increase in sidewalk miles after applying an elasticity value of 0.27 (from Ewing et al. 2009). After the bicycle and pedestrian strategy is applied, new mode shares are computed for all modes. This redistribution of trips supports an increase in bike and walk trips and a decrease in drive-alone trips. See Table D-1 in Appendix D for comparisons.

The national average bike and walk trip lengths from the 2009 National Household Travel Survey (NHTS) (2.26 miles and 0.70 miles, respectively) was then used to calculate the change in VMT by mode. For the purposes of this analysis, only the reduction in auto-drive alone trips and VMT were included (other modes were not included). For both bicycle and pedestrian infrastructure, the total decrease in drive-alone, one-way trips is 20,062 with a corresponding total decrease in drive-alone VMT of 29,255.

For both approaches, the shift in drive-alone and rideshare trips to transit trips will be supported by the BAU transit system capacity, without additional transit VMT. Although VMT for non-motorized modes will increase, there are no emissions associated with these modes.

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[34] San Diego Association of Governments. 2011. *2050 Regional Transportation Plan*. Technical Appendix 15: SANDAG Travel Demand Model Documentation. Available: http://www.sandag.org/uploads/2050RTP/F2050RTPTA15.pdf

[35] Dill, J., and T. Carr. 2003. *Bicycle Commuting and Facilities in Major U.S. Cities: If You Build Them, Commuters Will Use Them – Another Look.* Transportation Research Board 1828, National Academy of Sciences, Washington, D.C. Available: http://www.ltrc.lsu.edu/TRB_82/TRB2003-002134.pdf

Scenario 4 - Regional Transit Oriented Development Initiative and Workforce Housing Balance Initiative with support for alternative modes of travel and transit expansion

The final scenario adds the light rail expansion after all other supportive policies are in place. The strategy represents a complete build-out of the planned light rail system in the five-county region. The impact for the region is an increase of the population living within 1 mile of light rail from 257,000 to 1,019,000.

The transit strategy is the only EWG strategy that was modeled using TRIMMS. The approach was to determine access and travel time improvements for public transportation that reduce VMT. National data from the 2009 NHTS for average travel and access time for transit was used because specific travel data from EWG was not available. An evaluation using the assumed difference in service levels between the light rail system expansion and bus service in the BAU scenario proposed that both access time and travel time are reduced by 25%. This assumption is supported by EWG staff as reasonable.

According to EWG, the transit buildout strategy would involve a 354% increase in light rail miles from 61 miles to 275 miles. The 354% increase in light rail miles was used to estimate new VMT and trips and associated emissions (see Appendix A for a detailed discussion of these methods).

The analysis also includes an evaluation of changes in transit-supportive land use using the Multivariate approach. In this analysis, it was assumed that the population-weighted density for the 1-mile transit buffer zone[36] increased by 1% (based on accompanying population projections provided by EWG). The land use analysis method was conducted outside of TRIMMS. Elasticity values from Ewing and Cervero (2010) were used to determine total percent VMT change.

Scenario Summary

Input parameters are provided in Table 8 for current conditions, a business as usual future, and the four scenarios selected by EWG. Specific input values are provided for the scenarios. The EWG scenarios were applied only to the three-county or five-county region. The resulting VMT reductions for each scenario are included in the table. In each scenario, the specific target population is identified.

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[36] The 1-mile transit buffer zone is defined as the area within 1 mile of the expanded light rail system.

Table 8. EWG Scenario Details

Scenario	Description	Data Inputs	Daily Regional VMT Reduction
Current Conditions	Existing conditions across all strategies in 2010	• mode shares • average vehicle occupancy • average vehicle trip lengths • regional population and employment • 782 bike lane miles • 8,374 sidewalk miles • vehicle ownership (1.7 vehicles/household) • residential population density (578 persons per square mile) • retail establishment density (3.1 per square mile)	NA
Business as Usual	2040 conditions with BAU levels of employer program, land use, HOV lanes, and transit	• mode shares • average vehicle occupancy • 2040 regional population and employment • current travel times (12.78 minutes for transit) • current access times (14.92 minutes for transit) • vehicle ownership (1.7 vehicles/household) • residential population density (612 persons per square mile) • retail establishment density (3.5 per square mile)	NA
Scenario 1: Regional Transit Oriented Development	Increase transit oriented development	• Share of regional commuters covered (1,646,886) **Neighborhood approach** • 11.6% of population and employment in neighborhood type 1 (20.9 average daily VMT per population + job) • 19.9% of population and employment in neighborhood type 2 (15.9 average daily VMT) • 26.1% of population and employment in neighborhood type 3 (14.8 average daily VMT) • 25.8% of population and employment in neighborhood type 4 (12.1 average daily VMT) • 9.3% of population and employment in neighborhood type 5 (18.4 average daily VMT) • 7.3% of population and employment in neighborhood type 6 (21.2 average daily VMT) **Mulitvariate approach:** • Increase population-weighted density by 4% • Increase job access by auto by 2% • Increase job access by transit by 7% • Reduce distance to nearest transit stop by 2%	0.16% auto VMT reduction (121,121) for Neighborhood approach; 0.54% auto VMT reduction (400,252) for Multivariate approach

Scenario	Description	Data Inputs	Daily Regional VMT Reduction
Scenario 2: Scenario 1 + Workforce Housing Balance	Increase residential density and mixed use land uses for entire regional population.	• Share of regional commuters covered (2,387,956) **Neighborhood approach** • 13.2% of population and employment in neighborhood type 1 (20.9 average daily VMT per population + job) • 20% of population and employment in neighborhood type 2 (15.9 average daily VMT) • 26.6% of population and employment in neighborhood type 3 (14.8 average daily VMT) • 30.1% of population and employment in neighborhood type 4 (12.1 average daily VMT) • 5% of population and employment in neighborhood type 5 (18.4 average daily VMT) • 5.1% of population and employment in neighborhood type 6 (21.2 average daily VMT) **Mulitvariate approach:** • Increase population-weighted density by 2% • Increase job access by auto by 3% • Increase job access by transit by 2% • Reduce distance to nearest transit stop by 11%	2.13% auto VMT reduction (1,584,406) for Neighborhood approach; 1.66% auto VMT reduction (1,231,322) for Multivariate approach
Scenario 3: Scenario 2 + Bike / Ped Network	Complete bicycle and pedestrian network in the five-county region	• 150% increase in bike lane miles (to 1,951) • Increase in sidewalk coverage on local and arterial roads to 71% (to 10,579 sidewalk miles)	2.21% auto VMT reduction (1,640,332) for Neighborhood approach; 1.73% auto VMT reduction (1,287,248) for Multivariate approach
Scenario 4: Scenario 3 + Transit Expansion	Light rail expansion	• 25% travel time reduction (to 9.58 minutes) • 25% access time reduction (to 11.19 minutes) • share of *additional* regional population covered by transit expansion (761,887) • For the Multivariate approach, an increase in population-weighted density of 1%	2.54% auto VMT reduction (1,890,772) for Neighborhood approach; 2.07% auto VMT reduction (1,537,687) for Multivariate approach; 66.2% Transit VMT will increase

EWG strategies are compared to those of Sacramento, California in Cluster 4. The EWG strategies were matched as closely as possible with the strategies in the 2010 national study. The results of this comparison are presented in Table D-2 of Appendix D. All comparisons made between the two regions supported the reasonableness of the EWG results.

Emissions Analysis

The emissions analysis in a bi-state region has many stakeholders. EWG has experience working with both the Missouri and Illinois agencies for environmental protection: Missouri Department of Natural Resources (MODNR) and Illinois Environmental Protection Agency (ILEPA), respectively. The two agencies have different data to contribute, but the transportation conformity interagency agreements establish a context for jointly considering emissions.

In this process, a single representative county in each state is modeled. This is identical to the process described for ARC, except that two counties are used, one for each represented state. Those are St. Louis (County), Missouri, and St. Clair, Illinois. EWG provided these aggregated inputs consistent with their conformity analysis (other than VMT). Accordingly, this same approach and data was used in the TEAM analysis.

Only two modifications were made to the data provided by EWG: MOVES input databases were converted from MOVES 2010b format to MOVES2014 using EPA's converter tool, and current regional VMT data provided by EWG were used in the MOVES input databases. The updated MOVES input databases include 2015 and 2045 values from the regional travel demand model; representing current conditions and including the addition of a new unrestricted access roadway. Calibration factors have not been determined, and EWG confirmed that minor effects from calibration will be minimized by the emission factor method used in the TEAM approach. However, these data represent average weekday VMT stratified only by county and HPMS facility (road) type. The EPA converter tool[37] was used to translate data into annual VMT values ("HPMSBaseYearVMT") for the input databases. As with ARC, the existing inspection and maintenance ("I/M") program was included in this analysis.

MOVES was run at the county scale for both representative counties and years (2015, 2045). The final emission factors were determined from the MOVES inventory-mode outputs using MySQL and spreadsheet analyses to create tables for further analysis. All data used for this analysis was provided by EWG.

Although EWG provided all required data inputs, the analysis is slightly complicated by the fact that it is a bi-state region, requiring two distinct MOVES analyses to determine emissions and activities. However, these two sets of values were aggregated off-model to produce combined, regional average emission factors. Also, the analysis relies on a "representative county"

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[37] Available at http://www.epa.gov/otaq/models/moves/documents/aadvmt-converter-tool-moves2014.xlsx.

approach to simulate the counties in each state. The fact that the two representative counties are in two states adds negligibly to the complexity of the MOVES modeling.

In addition, this case provided an exercise in use of some ancillary tools EPA provides for MOVES analysis. The two state agencies provided all inputs from prior transportation conformity modeling. However, neither agency had updated the inputs to MOVES2014 format. This modification was straightforward with the converter application in MOVES2014. Additionally, using EPA's VMT converter tool was straightforward once the methodology was agreed upon with EWG.

The post-processing of hourly MOVES outputs to domain-average emission factors for the EWG region was done with database and spreadsheet analysis methods. In these methods, emissions and activities are aggregated into the source types required by TRIMMS, and the ratio of emissions and activities is taken. The emissions and activity inputs are first pre-aggregated into a single value from the outputs of the two individual representative counties from the MOVES simulation. This is done using database methods to combine the separate tables from each state's simulation into a single set of emissions and activities. Those are then ratioed into emission rates for the composite vehicle types. These ratios are then output into spreadsheets where the presentation of values is simplified into tables and presented for use in the spreadsheet models used in the scenario analyses. The resulting average emission factors for the EWG region and TRIMMS vehicle types are shown in Table D-3 of Appendix D.

EWG Scenario Results

Table 9 provides the results of analysis for light-duty vehicles. Additional explanation is provided below and detailed numerical results are included in Appendix A and D.

For the EWG analysis, both land use approaches yielded small reductions in total VMT. The multivariate approach requires TAZ level data and was a good methodological fit for EWG. The agency's modeling staff were comfortable manipulating land use projections at the TAZ level in order to specify their land use strategies.

Applying the neighborhood approach was less straightforward for EWG. Since EWG does not have an activity-based travel demand model,[38] it was impossible to produce estimates of total VMT generated by the traveler's place of residence. As a workaround, EWG analyzed VMT generated by trips originating from both homes and workplaces to provide the inputs needed. In addition, aggregating population and job projections by neighborhood types required several more steps beyond the TAZ level analysis.

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[38] EWG uses a traditional 4-step model, which estimates simple 1-way trips by zone of origin and destination. Newer activity-based models treat trips as a function of activities such as work, school, and shopping. These models are capable of estimating trips taken by people that live in a certain zone, regardless of whether the trip itself begins or ends in that zone.

Table 9. EWG Regionwide Percent VMT and Emissions Changes for Light-Duty Vehicles

Percent Regionwide Emissions Changes for 2040 BAU Compared to 2040 Scenario							
Scenario	**Target Population***	**Approach Type**	**Light-Duty VMT**	**GHGs (CO_2 equivalent)**	**$PM_{2.5}$**	**NOx**	**VOC**
Scenario 1: Regional TOD	60% of Regionwide population (1,646,886)	Neighborhood	–0.16%	–0.16%	–0.16%	–0.16%	–0.16%
		Multivariate	–0.54%	–0.54%	–0.54%	–0.54%	–0.54%
Scenario 2: Scenario 1 + Workforce Housing Balance	87% of Regionwide population (2,387,956)	Neighborhood	–2.13%	–2.13%	–2.13%	–2.13%	–2.13%
		Multivariate	–1.66%	–1.66%	–1.66%	–1.66%	–1.66%
Scenario 3: Scenario 2 + Bike / Ped Network	87% of Regionwide population (2,374,467)	Neighborhood	–2.21%	–2.22%	–2.24%	–2.37%	–2.56%
		Multivariate	–1.73%	–1.75%	–1.76%	–1.89%	–2.08%
Scenario 4: Scenario 3 + Transit Expansion	37% of Regionwide population (1,018,960)	Neighborhood	–2.54%	–2.56%	–2.57%	–2.70%	–2.90%
		Multivariate	–2.07%	–2.11%	–2.13%	–2.39%	–2.79%

*The identified target population is for the additional strategy only. For the total Scenario population, previous scenario populations must be considered.

Scenario 1 regional TOD land use has a small impact with a 0.2% to 0.5% reduction in regional VMT for light-duty vehicles. This is equivalent to a 15,000 to 51,000 decrease in light-duty auto trips and 120,000 to 400,000 VMT.[39] The target population includes 60% of the regional population. The impact of this strategy is relatively small, because the policy change affects a small population. This strategy shifts only 2% of regional jobs and 1% regional population to a small number of light rail station areas. The vast majority of jobs and population in the region remain unaffected.

Scenario 2 adds workforce housing balance as a land use strategy to regional TOD land use for an additional moderate 1.1% to 2.0% reduction in regional VMT for light-duty vehicles. This is equivalent to a 106,000-186,000 decrease in light-duty auto trips and 830,000 to 1.5 million VMT.[40] The combined strategies under Scenario 2 represent a total regional VMT reduction of 1.7% to 2.1%. The reduction for this strategy is larger than that for the TOD strategy, because this strategy shifts jobs and population throughout a five-county area, affecting a much higher share of the regional population.

Scenario 3 adds bicycle and pedestrian network expansions. This has a small additional impact of 0.08% reduction in regional VMT for light-duty vehicles, equivalent to a 38,000 decrease in light-duty auto trips and 56,000 VMT.[41] The combined strategies under Scenario 3 represent a total regional VMT reduction of 1.7% to 2.2%.

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[39] For the target population, the VMT reduction is 0.3-0.9%.

[40] For the target population, the VMT reduction is 1.3-2.3%.

[41] For the target population, the VMT reduction is 0.09%.

This modest reduction reflects empirical research on the impact of bicycle and pedestrian infrastructure. Studies of infrastructure's impact are necessarily conservative, and analyzing the impact of infrastructure alone tends to produce very small results. However, there are many examples of regions worldwide that have seen much higher growth in bicycling and walking through a combination of infrastructure investment, safety campaigns, and cultural trends shifting towards a preference for non-motorized modes.

Scenario 4 adds transit expansions, and the accompanying transit supportive land use. Changes include reductions in transit travel and access times along with changes in household / population density, along with shifts from drive-alone and rideshare trips to transit trips. This has an additional impact on regional light-duty VMT of 0.3% reduction.[42] This is equivalent to a decrease in VMT of 250,000 and 29,000 trips for light-duty vehicles for a total combined regional VMT reduction of 2.1% to 2.5% for the scenario.[43]

This is a relatively small impact, consistent with the results for similar strategies. Reduced transit travel and access times only affects 29% of the total regional population, so the regional VMT and emissions reduction is limited. Likewise, this strategy only includes a 1% change in household / population density, which produces a small regional effect on VMT and emissions.

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[42] For the target population, the VMT reduction is 1.1%.

[43] For the corresponding increase in transit vehicle VMT (see Appendix A)

4. Results and Conclusions

Analysis results for each individual region were evaluated in Section 3 of this report. In this section, the larger comparisons and lessons learned across regions is provided. Significant changes in the analytical approach are also noted along with related conclusions. Table 10 provides an overview of the relative cumulative regional VMT and emissions changes across all regions studied for the pollutants of primary interest to support these comparisons.

Table 10. Percent Regional VMT and Emissions Changes—MetroPlan Orlando, ARC, and EWG

Percent Regional Emissions Changes for Future Year Business as Usual Compared to Future Year Scenario					
Scenario	**Light-Duty VMT**	**GHGs (CO_2 equivalent)**	**$PM_{2.5}$**	**NOx**	**VOC**
MetroPlan Orlando					
Scenario 1: Expanded TDM	−0.65%	−0.65%	−0.65%	−0.65%	−0.65%
Scenario 2: Scenario 1 + Enhanced Transit	−0.92%	−0.92%	−0.92%	−0.92%	−0.92%
Scenario 3: Scenario 2 + Road Pricing	−4.75%	−4.75%	−4.75%	−4.74%	−4.73%
Scenario 4: Scenario 3 + University Transit Pass	−6.08%	−6.07%	−6.07%	−6.06%	−6.05%
ARC					
Scenario 1: Expanded TDM	−0.69%	−0.68%	−0.68%	−0.67%	−0.66%
Scenario 2: Scenario 1 + Transit Frequency Improvement	−0.86%	−0.86%	−0.86%	−0.85%	−0.83%
Scenario 3: Scenario 2 + Parking Pricing	−2.85%	−2.85%	−2.85%	−2.82%	−2.81%
Scenario 4: Scenario 3 + Land Use (Neighborhood)	−8.82%	−8.81%	−8.81%	−8.79%	−8.78%
Scenario 4: Scenario 3 + Land Use (Multivariate)	−9.28%	−9.27%	−9.27%	−9.25%	−9.24%
EWG					
Scenario 1: Regional TOD (Neighborhood)	−0.16%	−0.16%	−0.16%	−0.16%	−0.16%
Scenario 1: Regional TOD (Multivariate)	−0.54%	−0.54%	−0.54%	−0.54%	−0.54%
Scenario 2: Scenario 1 + Workforce Housing Balance (Neighborhood)	−2.13%	−2.13%	−2.13%	−2.13%	−2.13%
Scenario 2: Scenario 1 + Workforce Housing Balance (Multivariate)	−1.66%	−1.66%	−1.66%	−1.66%	−1.66%
Scenario 3: Scenario 2 + Bike / Ped Network (Neighborhood)	–2.21%	–2.22%	–2.24%	–2.37%	–2.56%
Scenario 3: Scenario 2 + Bike / Ped Network (Multivariate)	–1.73%	–1.75%	–1.76%	–1.89%	–2.08%
Scenario 4: Scenario 3 + Transit Expansion (Neighborhood)	–2.54%	–2.56%	–2.57%	–2.70%	–2.90%
Scenario 4: Scenario 3 + Transit Expansion (Multivariate)	–2.07%	–2.11%	–2.13%	–2.39%	–2.79%

Of the three regions, ARC's scenarios achieved the greatest reductions in VMT and emissions—9%. Most of these reductions come from an aggressive land use strategy. Scenario 4 increases the percent of the population living in low-VMT neighborhoods from 37% to 50%, in terms of the Neighborhood Approach. In Multivariate terms, population-weighted density increases by nearly 60%. This scale of change in land use is made feasible by the rapid growth expected in the region. ARC expects the five core counties, which are the subject of the analysis, to add 900,000 residents and 1.2 million jobs by 2040.

MetroPlan has the second highest reductions, at 6%. Most of these reductions come from a road pricing policy. Road pricing policies have consistently produced the highest reductions in TEAM analyses, so it is not surprising that MetroPlan's road pricing scenario adds significantly to its total reductions.

EWG achieved the smallest reductions, at 2% for two reasons. First, EWG chose to include bicycle and pedestrian infrastructure as a strategy. While this is an important policy for multi-modal accessibility, current analytical methods do not predict a strong causal effect between bike/ped infrastructure and VMT reduction.

Second, EWG's land use strategies are limited in scope by the expected slow growth in the region. EWG expects to add 150,000 residents and 150,000 jobs to the five-county area by 2045—about 1/5 of the growth forecast in the fast growing ARC region. In both the Neighborhood Approach and the Multivariate Approach, EWG's land use scenarios result in shifts of population and population-weighted density of only a few percent each. Greater population shifts would require relocating existing jobs and housing, which the agency does not anticipate. The TOD policy is also limited by the extent of the light rail system, which is only planned to serve the three-county core.

Comparison of the strategy results across regions illustrates that TEAM continues to provide similar results with respect to strategy effectiveness for each specific strategy type. For example, road pricing is much more aggressive than parking pricing, and continues to make the most significant changes in the region.

Other noteworthy comparisons are:

- Transit changes were more significant in the MetroPlan Orlando and ARC regions than the effect of the light-rail buildout in EWG. This outcome is the impact of a subarea strategy change reflected at the regional scale. The transit expansion and TOD strategies in the MetroPlan Orlando and ARC regions support one another, but the emissions reductions of the light-rail buildout in EWG are related to the area around the rail stations and not the full EWG region.
- The university pass change in MetroPlan Orlando is similar to the impact of parking pricing in Atlanta. Again, the sub-population effect is large, but not regionally significant.

- The EWG strategies focused on the multimodal aspect of their transportation system coupled with supportive land use changes in a geographical subarea of the region. The combination of these strategies does a good job of representing what can reasonably be expected from this type of approach.
- MetroPlan Orlando strategies build on their underlying land use assumptions already included in the BAU through the data drawn from the travel demand model; however, without a direct comparison of land use strategy, it is impossible to see what the land use is contributing to emissions reductions.

Data for Use in TEAM

VMT Analysis

TEAM is a data-led approach. Data collection, validation, and analysis continue to comprise the majority of the effort. In the current study, EWG and MetroPlan Orlando represented opposite ends of the data-intensity spectrum. With respect to data, ARC represents a strong example of how TEAM can be applied most efficiently.

EWG's process was led by the modeling team, and all strategies were defined in a data-rich environment. As a result, EWG provided a very high level of detail for input data. The volume of input data provided by EWG, along with custom approaches to several strategies, required extra analytical effort. This effort was justified because the analysis yielded more reasonable results consistent with detailed strategy data from EWG, which would have otherwise been overlooked.

MetroPlan Orlando was not able to engage modelers in its process. The MPO contracts for modeling services and including these modelers would have added significant cost for participating in the TEAM study. As a result, the MetroPlan Orlando inputs to TEAM were informed estimates in most cases. Although the analysis time was decreased by using the limited data available, the MetroPlan Orlando inputs are also more aspirational and less reflective of actual policy and planning discussions.

MOVES Analysis

Both ARC and EWG were familiar with MOVES analyses and had data available from recent transportation conformity determinations to adapt for this analysis. The agencies were able to describe their typical process as well as provide necessary data. ARC prepared and delivered study-specific data, while EWG provided previously available data and guidance for its use. No unique data collection was performed for this MOVES analysis.

MetroPlan Orlando is not an air quality nonattainment area engaged in air quality planning and analysis. Relevant data from the region's travel demand model was not available during the TEAM study period, and therefore the agency relied on default data for the MOVES analysis.

As expected from the previous analysis, MOVES familiarity and expertise is becoming less of an issue as agencies become better coordinated around model needs. TEAM could become an even more relevant and useful tool as the barriers to its use are identified and addressed.

Strategy Analysis and Conclusions

The current study has continued to test and refine the TEAM approach—in many cases pushing TEAM beyond the limits of TRIMMS. As of 2013, CUTR planned to develop an enhanced web-based version of TRIMMS. However, further updates to the model have not occurred. As a result, an important function of this study has been to consider several points of departure from TRIMMS. In addition to providing meaningful analyses for the three regions involved, this analysis also suggests ways that TEAM can continue to evolve even if TRIMMS does not. While TEAM has relied on using TRIMMS to determine potential VMT reductions, other sketch models may also prove useful, depending on the strategies of interest. Other tools are available for sketch planning and some regions use in-house analysis techniques for this purpose. In selecting an appropriate tool for use in the TEAM analysis, agencies may want to evaluate their options based on the individual strategies of interest.

- Areas of refinement for TEAM tested or considered in this study include:
- Two new land use analysis approaches
- A simple approach to analyze bicycle and pedestrian infrastructure expansion
- Consideration of an alternate approach for analyzing TDM subsidies
- A new approach to account for estimated emissions increases resulting from transit expansion

Two New Land Use Analysis Approaches

This study introduced the Neighborhood Classification approach and the Multivariate Elasticity approach. Two regions, ARC and EWG, tested both approaches in order to provide a direct comparison of the methods.

ARC previously conducted a land use visioning process that used an approach very similar to the Neighborhood approach. As a result, this approach was a natural fit for the agency.

ARC also agreed to test the Multivariate approach; however, doing so required ARC to reanalyze its land use scenario using the land use and travel demand models in order to derive values for the ‘D’ variables required for this approach. This placed a significant amount of additional effort on the part of ARC staff. Because the primary contact at ARC for the TEAM process was not in the modeling group, the Multivariate approach also required additional intra-agency coordination.

For EWG, the situation was nearly reversed. EWG had not conducted a prior land use visioning study, and TEAM provided the impetus for considering future land use scenarios. The primary contact for TEAM at EWG was the head of the modeling group. As a result, EWG tended to take a very data intensive approach to providing inputs to TEAM. The Multivariate approach was a natural fit for EWG, because the staff lead was very comfortable working with TAZ level data and deriving inputs from the travel demand model. To create land use scenarios, modeling staff moved projected growth across individual TAZs; effectively predicting population shifts that would impact land use.

In contrast to ARC, it was the Neighborhood approach that required extra work for EWG. EWG translated the land use scenarios described at the TAZ level (using the Multivariate approach) into neighborhood types for that purpose. However, translating TAZ level land use changes into higher-level shifts between neighborhood types proved challenging and confusing. The logic of shifting growth between neighborhood types was not transparent to staff that were used to dealing with land use at the TAZ level.

Results from the two approaches are comparable, because each approach was applied to the same underlying policy and land use scenarios. In the case of ARC, results from the two approaches were almost identical: 6.0% VMT reduction from the Neighborhood approach and 6.4% from the Multivariate approach.

Differences were more pronounced in EWG's analysis. The regional TOD land use strategy produced VMT reductions of 0.2% and 0.5% from the Neighborhood and Multivariate approaches, respectively. The workforce-housing balance strategy produced reductions of 2.3% and 1.3% from the Neighborhood and Multivariate approaches, respectively.

These results provide a very limited set of data points with which to compare the two results. It is notable that results from the Neighborhood approach are within 1% of results from the Multivariate approach for each strategy. It appears that the two approaches produce results that are very similar in magnitude.

The most important distinction between the two approaches was the 'fit' with existing agency knowledge and resources. Practitioners using TEAM may simply select whichever land use approach matches best with the data and modeling practices in use at the agency.

Bicycle/Pedestrian Infrastructure

A new approach to analyzing bicycle and pedestrian infrastructure improvements as part of this study was implemented at the request of EWG. As highlighted in the previous TEAM study, bicycle and pedestrian improvements cannot be analyzed in TRIMMS, but they are of interest to many MPOs. The approach used is based on recent improvements in bicycle and pedestrian analytical processes, as described in the Methodology section of this report. The approach can be applied by other MPOs desiring to calculate the impacts of bicycle and pedestrian infrastructure on VMT and emissions. For details, see Table D-1 in the Appendix.

Analyses of the impacts of bicycle and pedestrian infrastructure produce consistently conservative results. As expected, the VMT reductions from EWG's strategy were very small—0.1%. However, EWG believes that there is value in demonstrating quantifiable impacts from bicycle and pedestrian improvements to support decision making.

Investments in bicycle/pedestrian infrastructure generally produce very small GHG reductions and are rarely justified on the basis of emissions reductions alone. However, the current transportation interest in quality of life benefits such as access to healthy transportation modes will continue to increase practitioner interest in examining bicycle and pedestrian improvements.

Analyzing TDM Subsidies

As in the previous study, two different approaches to analyzing TDM subsidies were considered; using subsidy dollar amounts, and using the radio button analysis function for subsidies. The radio button function was used for both ARC and MetroPlan Orlando, because using the dollar amounts tends to produce unreasonable results. This happens because the elasticity values provided with TRIMMS are incomplete, and TRIMMS does not contain any inherent controls for the total number of trips made by a given population.

The radio button function produces consistently reasonable—if relatively small—VMT reductions. For both ARC and MetroPlan Orlando, the total impact of TDM strategies including both subsidies and non-monetary benefits was a 0.7% reduction in regional VMT.

Developing a reliable option to analyze actual dollar amounts of TDM subsidies may enhance confidence in the results. It is relatively simple to conduct such an analysis and compare the results to those of TRIMMS. Similar to the land use comparison, this may be considered for further improvements to TEAM.

Emissions from Transit Expansion

The previous study stopped short of quantifying emission increases from expanded transit service. Many of the case study regions have analyzed a strategy to enhance transit service in a way that would increase the number of transit vehicle miles traveled. However, TRIMMS does not reliably predict transit VMT resulting from these strategies. In TRIMMS, change in transit VMT is proportional to change in transit passenger miles traveled. This convention misses the distinction between strategies that add passengers to existing transit vehicles and strategies that increase the amount of transit service provided.

When transit is considered as a GHG reducing strategy, it is important to consider both emissions reduced (displaced) by transit and emissions produced by transit. In an attempt to begin consideration of both, an off-model estimation of transit emissions was developed. Adding this information advances the analysis of transit strategies, but it will also place heightened scrutiny on the net impact of transit strategies. This study estimated emissions generated from increased transit service using data from the National Transit Database. However, several complications were encountered in obtaining data needed to estimate the percent increase in transit service.

While this study does account for both sides of the transit equation, and is therefore an improvement on the previous study, we consider the approach used in this study a work in progress. Future studies should clarify the inputs needed to estimate transit emissions and request these from the regions at the beginning of the TEAM process. It will also be necessary to scrutinize all parts of the analytical process for transit strategies. This includes the elasticities that have been used with TEAM for several years. Elasticities toward the low (conservative) end of the range were selected for use in TRIMMS for this analysis. Further consideration of whether these elasticities best represent the benefits of transit improvement strategies is warranted.

See Appendix A for a detailed discussion of the methods used to asses transit VMT and emissions outside of TRIMMS.

MOVES Support of TEAM

MOVES is the best model for estimating emissions for TEAM. MOVES2014 is EPA's current mobile source emission inventory tool, and is required to be used by many regions to develop related regulatory analyses, such as for State Implementation Plans (SIP) and transportation conformity determinations.[44] These uses of the model are addressed in other EPA guidance, and this project has shown that regions are becoming increasingly familiar with its use. Accordingly, many are developing their own, custom MOVES inputs.

Although the inputs developed for those purposes may be used for TEAM, the use of the MOVES model for TEAM differs somewhat.[45] Primarily, as a sketch analysis, detailed emission factors are not required, and the additional complexity in producing and using them is not warranted. Instead, overall regional, average emission factors representing the activity-weighted mean of all starting and running emissions activities in the region is produced and coupled with the TRIMMS VMT and trips outputs. These emission factors are calculated as total running emissions from hourly outputs (in grams per year) divided by total running activity (in miles per year) across the modeled region; a similar analysis is made for starting emissions. Output emission factors have units of grams of pollutant per average mile driven or grams of pollutant per average start. This is explained further in the TEAM User's Guide and in Section 2.3, above. Additionally, EPA has provided tools to assist with MOVES analyses. Together, this approach and available tools greatly simplify the required MOVES analysis.

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[44] E.g., MOVES2014 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity, EPA-420-B-15-007, January 2015. https://www.epa.gov/otaq/models/moves/documents/420b15007.pdf

[45] More explanation in the use of this approach is given in: Analyzing Emission Reductions from Travel Efficiency Strategies: A Guide to the TEAM Approach, EPA-420-R-11-025, September 2011. Available at: http://www.epa.gov/otaq/stateresources/policy/420r11025.pdf.

Previously, we found a range of technical capability among the regions related to the use of MOVES. This was less true in the present iteration. Although MetroPlan Orlando was unfamiliar with the model and had no available inputs, this was the exception. The other two regions were very comfortable with the model in similar applications, and understood the relationship between the present analysis and that conducted by regulation to meet air quality conformity.

Selection and Use of Base and Future Years

Base and future years in MOVES should be selected to agree with those of the strategies being analyzed. A common issue encountered was the discrepancy between baseline year selected for the TRIMMS and strategy analysis, and information that has been prepared by the regions for regional emissions analysis. In these cases, the emission inputs for the baseline year had to be modified (or default values extracted) to agree with the strategy baseline year. In the present analysis, TEAM strategies were selected to agree with inputs prepared for other MOVES-based analyses, as expected under the previous case studies.

Appendix A. Additional Technical Details for the TEAM Analysis

A.1. Implications of Increased Transit

The results presented in the main document include reductions in trips, VMT, and emissions for light-duty vehicles for making comparisons to previous TEAM analyses. Changes in transit VMT and emissions for relevant strategies were not included above, but are presented in this appendix for informational purposes. Doing so provides a more complete description of the impact of transit strategies, which not only reduce light-duty VMT and emissions, but also increase transit vehicle VMT and emissions.

Transit improvement strategies will result in increased transit service and increases in VMT, trips, and emissions for transit vehicles. Because TRIMMS is limited in its ability to estimate the corresponding increase in transit trips for transit strategies, the impact on transit trips was estimated off model using actual VMT from the National Transit Database (NTD) in 2013 for each agency. These data were used to determine a corresponding increase in transit VMT for all transit strategies that involve increased transit service (see discussion in Section 3 above).

Total fuel consumption and VMT for 2013 was obtained from the NTD for the following transit agencies for each study agency:

- MetroPlan Orlando:[46]
    - Central Florida Regional Transportation Authority (LYNX)
- ARC:
    - Cobb County Department of Transportation Authority (CCT)
    - Georgia Regional Transportation Authority (GRTA)
    - Gwinnett County Board of Commissioners (GCT)
    - Hall Area Transit (HAT)
    - Metropolitan Atlanta Rapid Transit Authority (MARTA)
- EWG:
    - Madison County Transit District(MCT)
    - Rock Island County Metropolitan Mass Transit District(MetroLink)

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[46] Although SunRail also operates within the MetroPlan Orlando region, it wasn't included in this analysis because there was no data for SunRail in the NTD.

- Bi-State Development Agency of the Missouri-Illinois Metropolitan District, d.b.a.(St. Louis) Metro(METRO)

To estimate transit VMT for these agencies in the year 2040, NTD VMT data was multiplied in by the growth rate in transit VMT modeled in TRIMMS for each agency (MetroPlan Orlando = 2.69; ARC = 1.43; EWG = 1.05). Although the transit expansion strategies apply to only a portion of the regional population, the entire transit system in each region is affected. So, the growth factors were multiplied by the total NTD VMT for 2013 to estimate future BAU 2040 transit VMT for each agency.

The increase in transit VMT for each agency was calculated as follows:

- **MetroPlan Orlando**: the 41% reduction in transit access time for Strategy 2 (25.5 min for BAU and 15.0 min for strategy), represents a 70% increase in transit vehicles per hour (2.35 vehicles/hr for BAU and 4.0 veh/hr for strategy). 2040 transit VMT was multiplied by a 70% increase to determine new VMT for the new transit vehicle service.
- **ARC**: the 50% reduction in headways for Strategy 2, corresponding to an 18% decrease in access time (23.95 min for BAU and 19.56 min for strategy), represents a 22.47% increase in transit vehicles per hour (2.51 vehicles/hr for BAU and 3.07 veh/hr for strategy). 2040 transit VMT was multiplied by a 22.4% increase to determine new VMT for the new transit vehicle service.
- **EWG**: only light rail emissions were considered. This is because the strategy only includes expansion of the light rail system. The expansion in light rail miles under this strategy is 354% (representing an increase from 61 miles to 275 miles), provided by EWG. 2045 transit VMT was multiplied by a 354% increase to determine new VMT for the new transit vehicle service.

Total transit VMT for each agency was split into two categories: buses and rail (electric). VMT for rail was taken from the NTD; the portion of total VMT that is due to electric rail was calculated for each agency (MetroPlan Orlando = 0%; ARC = 33.5%; EWG = 18.7%). The total increase in transit VMT for each agency, as described above, was multiplied by these fractions to determine rail VMT and bus VMT. The MOVES EFs presented above were applied to the increase in bus VMT. For rail VMT increases, new electricity emission factors were derived and applied. The electricity emission factors were calculated as follows:

1. The regional electricity emission factor in pounds CO_2 per megawatt hour (MWh) was obtained from the EPA eGRID database.[47] The SERC South region (1,154.32 lbsCO_2e/MWh) was used for ARC and the SERC Midwest region (1,719.68 lbsCO_2e/MWh) was used for EWG.

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[47] See: https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf

2. Total electricity use for rail from the NTD for 2013 was multiplied by the eGRID emission factors to determine grams CO_2e emitted for each agency.
3. Total rail CO_2e emissions were divided by total rail miles to calculate an electricity emission factor in grams per mile for each agency (2,275.8 gCO_2e/mile for ARC and 4,213.3 gCO_2e/mile for EWG).
4. These emission factors were multiplied by the percent reduction in transit bus emission factors from MOVES to estimate a future year electricity EF incorporating increased fuel efficiency.
5. The resulting CO_2e emission factors for rail were then applied to the increase in rail VMT as indicated above. Only CO_2e emissions for rail was estimated; other pollutants were not included.

Table A-1. ARC, EWG, and MetroPlan Orlando Transit Vehicle Percent VMT and Emissions Changes

Agency	Strategy	Change in Regional Transit VMT	GHGs (CO_2 equivalent) kg/day	$PM_{2.5}$ (kg/day)	NOx (kg/day)	VOC (kg/day)
ARC	Transit Frequency Improvement	22.4%	258,517	128	4	9
EWG	Transit Buildout	66.2%	514,674	0	0	0
MetroPlan Orlando	Transit Improvement	70.0%	160,857	133	4	8

A.2. Travel and Emissions Changes by Region and Scenario

As discussed previously, MOVES was run in inventory mode for each of the regions to produce activity-weighted, average emission factors each the region. These emission factors were coupled with the predicted changes in activity to produce net emissions changes by scenario for each region. The corresponding relative reductions are presented for each region in the body of the report.

All available MOVES vehicle and fuel types were included in the simulations. In characterizing the vehicle types used in the TRIMMS model, the following were included:

- Passenger Car
- Passenger Truck
- Transit Bus
- Light Commercial Truck
- Motorcycle

All available fuels were included. The available list includes E-85, Gasoline, Diesel, LPG, CNG, and electricity. Note, however, that not all fuel-vehicle combinations are included in the MOVES model, and thus would not be included in the final results.

For all specific emissions changes in each region, see Tables B-3, C-4, and D-4.

A.3. Additional Land Use Calculation Details

For the Multivariate approach analysis used to estimate VMT and emission reductions for the land use strategies, elasticity values from Ewing and Cervero (2010) were used to determine total percent VMT change for each type of land use change.[48] This study provides elasticities that are calculated as a weighted average of results from more than 50 studies, including both national and regional studies. This approach fits well with the TEAM approach, which is intended to be applicable to all U.S. regions. The weighted averages provided allow for immediate application to all regions. These values are presented in Table A-2.

Table A-2. Ewing and Cervero (2010) Elasticity Values for the Multivariate Land Use Analysis

"D" Category	Variable	Elasticity Value
Density	Household/ population density	−0.04
	Job density	0
Diversity	Land use mix (entropy)	−0.09
	Jobs−housing balance	−0.02
Design	Intersection/ street density	−0.12
	% 4−way intersections	−0.12
Destinations	Job access by auto	−0.2
	Job access by transit	−0.05
	Distance to downtown	−0.22
Distance to Transit	Distance to nearest transit stop	0.05

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[48] Ewing and Cervero, "Travel and the Built Environment: A Meta-Analysis", Journal of the American Planning Association, 2010

Appendix B. MetroPlan Orlando

B.1. Regional Comparison of VMT Reductions

The MetroPlan Orlando strategies were matched as closely as possible with the strategies in the 2010 national study for San Diego, California in Cluster 2. The results of this comparison, in terms of percent VMT reduction, are presented in Table B-1 below.

Cluster 2 represents regions with a population greater than 2.9 million (the MetroPlan Orlando regional 2040 population is 3.3 million) and a transit share of 9% or less (MetroPlan Orlando 2040 transit share is 2.9%). The representative area for Cluster 2 used in this comparison is San Diego, which had a future population of 4.0 million in 2030 and a transit share of 1.6% in the national study.

Table B-1. MetroPlan Orlando Comparison of Regional VMT Reductions with Cluster 2

Strategy	% Auto Regional VMT Reduction – MetroPlan Orlando	% Auto Regional VMT Reduction – 2010 National Study, Cluster 2, San Diego
Strategy 1: Expanded TDM	0.65%	1.01%
Strategy 2: Enhanced Transit	0.27%	0.18%
Strategy 3: Road Pricing	3.83%	3.94%
Strategy 4: University Transit Pass	1.32%	1.16%

The values in the table represent the regional VMT reductions for each individual strategy component, not for the cumulative scenarios, to ensure comparability between strategies from TEAM and strategies from the 2010 national study. As shown in the table, all four strategies are very similar to Cluster 2 in terms of regional VMT reductions. This validates the approach taken for MetroPlan Orlando. Auto VMT reductions for expanded transportation demand management (TDM) programs are similar to Cluster 2: 0.65% versus 1.01%. The enhanced transit VMT reductions are also reasonably close: 0.27% compared to 0.18%. Road pricing has a very similar percent VMT reduction to Cluster 2 at 3.83% versus 3.94%, and the University transit pass strategy reduces VMT by 1.32% while the Cluster 2 transit fare strategy reduces VMT by a similar 1.16%.

B.2. Emission Factors and Detailed Results

Table B-2 presents the emission factors used for MetroPlan Orlando for the base year (2009) and the future year (2040) for both vehicle travel and vehicle starts.

Table B-2. Emission Factors for MetroPlan Orlando

Categories	Grams per mile		Grams per start	
	Base Year (2009)	Future Year (2040)	Base Year (2009)	Future Year (2040)
Auto (Motorcycles+Passenger Cars+Passenger Trucks)				
GHGs (CO_2-equivalent)	454.46	239.33	114.60	69.11
NOx	0.87	0.03	1.60	0.14
$PM_{2.5}$	0.01	0.01	0.01	0.004
VOCs	0.23	0.01	1.98	0.16
Vanpool (Passenger Trucks+Light Duty Trucks)				
GHGs (CO_2-equivalent)	554.30	286.15	138.91	79.68
NOx	1.16	0.04	2.07	0.16
$PM_{2.5}$	0.02	0.01	0.02	0.005
VOCs	0.30	0.01	2.57	0.17
Transit Vehicles (buses)				
GHGs (CO_2-equivalent)	1,491.17	1,344.28	115.60	120.26
NOx	14.01	1.12	0.04	0.01
$PM_{2.5}$	0.73	0.03	0.02	0.003
VOCs	1.00	0.06	0.17	0.07

Table B-3 presents the calculated total emission and travel changes for each of the main pollutants for MetroPlan Orlando.

Table B-3. MetroPlan Orlando Comparison of VMT Reductions and Emission Changes by Scenario

Resulting Travel (VMT/day) and Emissions Changes for Selected Pollutants (kg/day), relative to BAU or Baseline Level, by Scenario										
Scenario	Travel and Emissions Changes–2040 BAU to 2040 Scenario					Travel and Emissions Changes–2009 Baseline to 2040 Scenario[1]				
	Light-Duty VMT	GHGs (CO_2 equivalent)	$PM_{2.5}$	NOx	VOC	Light-Duty VMT	GHGs (CO_2 equivalent)	$PM_{2.5}$	NOx	VOC
Scenario 1: Expanded TDM	−502,039	−123,515	−4	−22	−13	29,581,583	−2,969,454	−81	−44,434	−17,924
Scenario 2: Scenario 1 + Enhanced Transit	−708,069	−174,236	−6	−30	−18	29,375,554	−3,020,175	−83	−44,443	−17,929
Scenario 3: Scenario 2 + Road Pricing	−3,649,898	−898,018	−31	−157	−91	26,433,725	−3,743,956	−107	−44,570	−18,003
Scenario 4: Scenario 3 + University Transit Pass	−4,666,465	−1,148,238	−39	−201	−117	25,417,158	−3,994,177	−116	−44,613	−18,029

[1] Emissions decrease even though VMT increase because emissions per mile are much lower in 2040 than in 2009.

Appendix C. Atlanta Regional Commission

Appendix C presents supplemental information about the TDM strategy analysis for ARC, along with a regional comparison of VMT reductions to the 2010 national study.

C.1. TDM Strategy Analysis Supplemental Information

ARC provided actual trip costs and subsidy amounts to support a more rigorous TDM analysis; therefore, the agency was interested in a rebalancing analysis using TRIMMS to account for trips that shift to other modes. The rebalancing process is discussed below.

The steps below outline a rebalancing analysis attempted using the values in Table C-1, provided by ARC. The rebalancing analysis overestimated the number of drive-alone trips reduced, and therefore this analysis was unsuccessful (the radio button feature in TRIMMS was used instead). The information is provide here only for reference.

1. Transit/rideshare cross-elasticities in TRIMMS were set to zero to remove the effect of shifting trips from transit to rideshare.
2. Trips were rebalanced by redistributing the increase in rideshare/transit trips to other modes based on the BAU mode shares for ARC.
3. The results were compared using the TRIMMS radio buttons for trip subsides (rideshare, vanpool, transit, and cycling). The rebalancing analysis showed a decrease in drive-alone trips of 182,000 and an increase in rideshare trips of 209,000, while the TRIMMS radio button approach showed a decrease in drive-alone trips of 31,000 and an increase in rideshare trips of 17,000.

Table C-1. ARC Transit Subsidies

Mode	Monthly Subsidy	Average Trip Cost - BAU	Average Trip Cost - Scenario
Auto-Drive Alone	$0	$1.12	$1.12
Auto-Rideshare	$48	$0.99	$0.00
Vanpool	$60	$4.50	$3.14
Public Transport	$75	$2.34	$0.64
Cycling	$20	$0.00	$0.00

C.2. Regional Comparison of VMT Reductions

The ARC strategies were matched as closely as possible with the strategies in the 2010 national study for San Diego, California in Cluster 2. The results of this comparison, in terms of percent VMT reduction, are presented in Table C-2 below.

Cluster 2 represents regions with a population greater than 2.9 million (the ARC regional 2040 population is 4.4 million) and a transit share of 9% or less (ARC 2040 transit share is 2.8%). The representative area for Cluster 2 used in this comparison is San Diego, which had a future population of 4.0 million in 2030 and a transit share of 1.6% in the national study.

The values in the table represent regional VMT reductions for each individual strategy component, not for the cumulative scenarios, to ensure comparability between strategies from TEAM and strategies from the 2010 national study.

As shown in Table C-2, regional auto VMT reductions for ridesharing and TDM programs are similar to the Cluster analysis, 0.7% versus 1.0%. The transit improvement VMT reductions are essentially identical at 0.18%. Parking pricing has a larger effect for ARC than for the Cluster analysis (2% versus 0.6%), which is likely because San Diego had a relatively high baseline parking charge ($5.94 for drive-alone and rideshare) compared to the baseline parking charge for ARC ($4.32 for drive-alone and $1.57 for rideshare).

Table C-2. ARC Comparison of Regional VMT Reductions for Regional Populations

Strategy	% Auto Regional VMT Reduction – ARC	% Auto Regional VMT Reduction – 2010 National Study, Cluster 2, San Diego
Strategy 1: Expand Ridesharing and TDM programs	0.69%	1.01%
Strategy 2: Transit Frequency Improvement	0.18%	0.18%
Strategy 3: Parking Pricing	1.98%	0.63%
Strategy 4: Smart Growth Land Use	5.97% (Neighborhood) 6.43% (Multivariate)	2.66%

The reduction in VMT for the land use strategy varies widely between ARC and the Cluster: 6-6.4% reduction for ARC compared to a 2.7% reduction for the Cluster. The large variation in VMT reductions for the land use strategy may reflect the new land use analysis methods used in this case study. Results are not directly comparable to the results from the 2010 analysis because a different methodology was used. The 2010 land use analysis was done in TRIMMS 2.0, while this land use analysis was performed outside of TRIMMS using the Neighborhood and Multivariate approaches.

C.3. Emission Factors and Detailed Results

Table C-3 presents the emission factors used for ARC for the base year (2009) and the future year (2040) for both vehicle travel and vehicle starts.

Table C-3. Emission Factors for ARC

Categories	Grams per mile		Grams per start	
	Base Year (2010)	Future Year (2040)	Base Year (2010)	Future Year (2040)
Auto (Motorcycles+Passenger Cars+Passenger Trucks)				
GHGs (CO_2-equivalent)	391.73	230.24	115.72	81.43
NOx	0.34	0.02	0.94	0.16
$PM_{2.5}$	0.01	0.01	0.01	0.005
VOCs	0.07	0.01	1.14	0.20
Vanpool (Passenger Trucks+Light Duty Trucks)				
GHGs (CO_2-equivalent)	462.08	277.35	136.39	93.26
NOx	0.53	0.03	1.39	0.17
$PM_{2.5}$	0.02	0.01	0.01	0.01
VOCs	0.11	0.01	1.59	0.19
Transit Vehicles (buses)				
GHGs (CO_2-equivalent)	1,301.93	1,238.12	131.78	129.89
NOx	6.52	1.19	0.02	0.01
$PM_{2.5}$	0.34	0.04	0.01	0.003
VOCs	0.57	0.07	0.21	0.12

Table C-4 presents the calculated total emission and travel changes for each of the main pollutants for ARC.Table C-4. ARC Comparison of VMT Reductions and Emission Changes by Scenario

Table C-5. ARC Comparison of VMT Reductions and Emission Changes by Scenario

Resulting Travel (VMT/day) and Emissions Changes for Selected Pollutants (kg/day), relative to BAU or Baseline Level, by Scenario										
Scenario	Travel and Emissions Changes–2040 BAU to 2040 Scenario					Travel and Emissions Changes–2015 Baseline to 2040 Scenario[1]				
	Light-Duty VMT	GHGs (CO_2 equivalent)	PM$_{2.5}$	NOx	VOC	Light-Duty VMT	GHGs (CO_2 equivalent)	PM2.5	NOx	VOC
Scenario 1: Expand Ridesharing and TDM programs	–867,544	–209,507	–9	–39	–29	29,753,678	–8,710,582	–121	–39,158	–18,180
Scenario 2: Scenario 1 + Transit Improvement and Promotion	–1,093,477	–264,204	–11	–49	–37	29,527,744	–8,765,278	–123	–39,169	–18,188
Scenario 3: Scenario 2 + Parking Pricing	–3,602,286	–871,534	–38	–163	–126	27,018,936	–9,372,608	–149	–39,283	–18,277
Scenario 4: Scenario 3 + Smart Growth Land Use (Neighborhood Approach)	–11,147,396	–2,698,504	–117	–508	-394	19,473,826	–11,199,579	–229	–39,628	–18,545
Scenario 4: Scenario 3 + Smart Growth Land Use (Multivariate Approach)	–11,728,876	–2,839,303	–124	–535	-414	18,892,346	–11,340,378	–235	–39,655	–18,565

[1] Emissions decrease even though VMT increase because emissions per mile are much lower in 2040 than in 2015 (see Table C-3).

Appendix D. East-West Gateway

Appendix D presents supplemental information about the bicycle and pedestrian strategy analysis for EWG, along with a regional comparison of VMT reductions to the 2010 national study.

D.1. Bicycle and Pedestrian Strategy Analysis Supplemental Information

Table D-1 presents the mode shares associated with Scenario 3 for the bicycle and pedestrian network. The table shows the BAU mode shares, the mode shares after the bike lane expansion only, and the mode shares after the bike lane expansion and increased sidewalk coverage combined (for the year 2040). As shown in the table, the redistribution of trips supports an increase in bike and walk trips and a decrease in drive-alone trips.

Table D-1. EWC Bicycle and Pedestrian Analysis

Mode	BAU Mode Share	Mode Share after Bike Lane Expansion	Mode Share after Bike Lane Expansion and Increased Sidewalk Coverage
Auto-drive alone	52.41%	52.21%	51.99%
Auto-rideshare	38.00%	37.86%	37.70%
Vanpool	0.00%	0.00%	0.00%
Public transit	3.43%	3.42%	3.41%
Cycling	0.34%	0.73%	0.72%
Walking	5.55%	5.52%	5.92%
Other	0.27%	0.27%	0.27%

D.2. Regional Comparison of VMT Reductions

The EWG strategies were matched as closely as possible with the strategies in the 2010 national study for Sacramento, California in Cluster 4. The results of this comparison, in terms of percent VMT reduction, are presented in Table D-2 below.

The comparison for EWG is Cluster 4 based on comparable population and transit share. Cluster 4 represents regions with a population of 1.5-2.9 million (EWG's regional 2045 population is 2.7 million) and a transit share of 4% or less (EWG's 2045 transit share is 3.4%). The representative area for Cluster 4 used in this comparison is Sacramento, which had a future population of 1.9 million in 2030 and a transit share of 3.3% in the national study.

Table D-2. EWG Comparison of VMT Reductions for Regional Populations

Strategy	% Auto VMT Reduction – EWG	% Auto VMT Reduction – 2010 National Study, Cluster 4, Sacramento
Strategy 1: Regional Transit Oriented Development (TOD)	0.16% (Neighborhood) 0.54% (Multivariate)	1.86%
Strategy 2: Workforce Housing Balance	2.26% (Neighborhood) 1.28% (Multivariate)	1.86%
Strategy 3: Bike / Ped Network	0.09%	N/A
Strategy 4: Transit Expansion	0.90%	0.15%

The values in the table represent the regional VMT reductions for each individual strategy component, not for the cumulative scenarios, to ensure comparability between strategies from TEAM and strategies from the 2010 national study. As shown in Table D-2, regional auto VMT reductions populations for land use programs vary compared to the Cluster analysis; for TOD, EWG's strategies reduce auto VMT by 0.16%-0.54%, while the Workforce Housing Balance reduces auto VMT by 1.28%-2.26%, versus 1.86% for Sacramento. The Workforce Housing Balance strategy is much closer to the Sacramento regional VMT reduction, likely because this strategy applies to most of the EWG region (87% of the regional population is affected) while the TOD strategy applies to a smaller part of the region (60% of the regional population is affected). The Sacramento land use strategy applies to the entire region. In addition, the large variation in VMT reductions for the land use strategy reflects the new land use analysis methods used in this case study. Results are not directly comparable to the results from the 2010 analysis because a different methodology was used. The 2010 land use analysis was done in TRIMMS, while this land use analysis was performed outside of TRIMMS using the Neighborhood and Multivariate approaches described in Section 2.3 below.

The transit expansion VMT reduction for EWG is much higher than the Sacramento reduction: 0.9% for EWG versus 0.15% for Sacramento. This is likely because the EWG strategy includes an aggressive reduction in headways of 25%, while the Sacramento strategy is much less aggressive. TRIMMS 2.0 was used for the Sacramento analysis and the 3.0 version for the EWG analysis. An analysis to determine the differences in results between these two versions of TRIMMS was not conducted, so it is unknown what affect the different models have on results.

There was no comparable Cluster strategy for bike/pedestrian measures. The comparison between EWG and Sacramento is useful for EPA to consider with respect to analytical approaches and improvements in TEAM over time.

D.3. Emission Factors and Detailed Results

Table D-3 presents the emission factors used for EWG for the base year (2009) and the future year (2040) for both vehicle travel and vehicle starts.

Table D-3. Emission Factors for EWG

Categories	Grams per mile		Grams per start	
	Base Year (2015)	Future Year (2045)	Base Year (2010)	Future Year (2040)
Auto (Motorcycles+Passenger Cars+Passenger Trucks)				
GHGs (CO_2-equivalent)	404.83	220.80	133.42	95.33
NOx	0.39	0.03	0.97	0.18
$PM_{2.5}$	0.01	0.01	0.02	0.01
VOCs	0.08	0.01	1.36	0.30
Vanpool (Passenger Trucks+Light Duty Trucks)				
GHGs (CO_2-equivalent)	478.02	263.51	155.60	109.28
NOx	0.58	0.04	1.27	0.20
$PM_{2.5}$	0.02	0.01	0.02	0.01
VOCs	0.12	0.01	1.72	0.30
Transit Vehicles (buses)				
GHGs (CO_2-equivalent)	1,436.48	1,306.60	118.91	115.64
NOx	12.93	1.31	0.04	0.01
$PM_{2.5}$	0.72	0.04	0.02	0.003
VOCs	0.96	0.05	0.48	0.25

Table D-4 presents the calculated total emission and travel changes for each of the main pollutants for EWG.Table D-4. EWG Comparison of VMT Reductions and Emission Changes by Scenario.

Resulting Travel (VMT/day) and Emissions Changes for Selected Pollutants (kg/day), relative to BAU or Baseline Level, by Scenario

Scenario	Land Use Approach	Travel and Emissions Changes – 2045 BAU to 2045 Scenario					Travel and Emissions Changes – 2015 Baseline to 2045 Scenario[1]				
		Light-Duty VMT	GHGs (CO$_2$ equivalent)	PM$_{2.5}$	NOx	VOC	Light-Duty VMT	GHGs (CO$_2$ equivalent)	PM$_{2.5}$	NOx	VOC
Scenario 1: Land Use: Regional TOD (3 counties)	Neighborhood	–121,121	–27,859	–1	–6	–5	9,353,096	–10,087,033	–355	–28,166	–11,402
	Multivariate	–400,252	–92,060	–3	–21	–15	9,073,966	–10,151,235	–357	–28,181	–11,412
Scenario 2: Scenario 1 + Land Use: Workforce-Housing Balance (5 counties)	Neighborhood	–1,584,406	–364,423	–13	–81	–59	7,889,811	–10,423,597	–367	–28,241	–11,456
	Multivariate	–1,231,322	–283,212	–10	–63	–46	8,242,895	–10,342,386	–364	–28,223	–11,443
Scenario 3: Scenario 2 + Bike/Ped Network (5 counties)	Neighborhood	–1,640,332	–380,428	–14	–90	–71	7,833,885	–10,439,602	–367	–28,250	–11,468
	Multivariate	–1,287,248	–299,216	–11	–72	–58	8,186,969	–10,358,390	–364	–28,232	–11,455
Scenario 4: Scenario 3 + Transit Buildout (5 counties)	Neighborhood	-1,890,772	-438,030	-16	-103	-80	7,583,445	-10,497,205	-369	-28,263	-11,477
	Multivariate	-1,537,687	-356,819	-13	-85	-67	7,936,530	-10,415,993	-366	-28,245	-11,464

[1] Emissions decrease even though VMT increase because emissions per mile are much lower in 2040 than in 2015 (see Table D-3).