Central New Mexico Climate Change Scenario Planning Project Task 2.1

Memo on Development of Methodologies

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1 INTRODUCTION

This memo responds to Task 2.1 as described in the RFQ for the Central New Mexico Climate Change Scenario Planning Project. The purpose of Task 2.1 is to develop methods for translating strategies aimed at climate change adaptation and mitigation into MRCOG's modeling environment so that the outcome of several planning scenarios (packages of individual climate change mitigation strategies) can be evaluated. Adaptation and mitigation strategies can be either infrastructure projects or policies that are designed to increase resilience to climate change and reduce greenhouse gas (GHG) emissions, respectively. UNM was provided with a descriptive list of potential GHG mitigation strategies developed by multiple stakeholders including the Mitigation Technical Committee. UNM was also provided with a list of performance measures that describe what quantities are to be used for evaluating each scenario. The evaluation methods described here will produce these quantities directly or provide output that can use used to calculate these quantities.

No specific list of adaptation strategies was provided; however, if adaptation strategies are considered they would generally be modeled in a similar way as the mitigation strategies. Adaptation strategies could include land-use policies that limit new development in flood prone or high fire risk areas which may expand with climate change. Adaptation strategies may also include policies requiring or encouraging high density housing in an effort to reduce water consumption and energy use from transportation. These policies may include increasing maximum densities, setting minimum densities, and providing development incentives such as reduced parking requirements or lower development fees. The effectiveness of these potential policies depends on local circumstances; for example, it has been found that allowable densities in zoning codes are not always a binding constraint on the density of new development but that many other factors including surrounding land-uses can play an important role (McConnell, Walls, and Kopits 2006). Finally, adaptation strategies may also affect where new transportation infrastructure is built to avoid floods and fires. Each of these strategy types, land-use policies, and infrastructure investments are also potential mitigation strategies and methods to evaluate them are described below though they may not be specifically framed as adaptation strategies.

This report provides an overview of mitigation strategies identified by MRCOG and Volpe, UNM's proposed analysis framework and methods, and proposed next steps. This report outlines UNM's current understanding of MRCOG's modeling capabilities. The project team's assessment is based on discussions with MRCOG and Synthicity staff, an analysis of the CUBE travel demand model which UNM has a copy of, SystraMobility's MRCOG travel demand model calibration report, a list of UrbanSim input/output files provided by MRCOG, UrbanSim documentation available at UrbanSim project and from a recent application of UrbanSim in the San Francisco Bay Area (Draft Release UrbanSim Documentation PDF), TranSight documentation available from Regional Economic Models, Incorporated, and the project team's experience. The UNM project team fully expects that after reviewing this report additional capabilities or limitations will be identified. This draft report therefore represents the project team's initial assessment of MRCOG's modeling capability and appropriate methods for applying the modeling environment to the Central New Mexico Climate Change Scenario Planning Project.

2 GREENHOUSE GAS EMISSION REDUCTION STRATEGIES

The UNM project team was provided with a descriptive list of potential GHG reduction strategies. For the most part, the strategies target reducing GHG emissions from on-road mobile sources. UNM reviewed the list of strategies and reclassified them into categories that follow a common evaluation methodology. Table 1 provides the reclassified list of strategies.

Table 1 UNM GHG Mitigation Strategy Classifications

Strategy Number	Strategy Name	Strategy Examples
1	Land-use	Zoning, infill development, transit oriented development, growth boundaries, development fees/subsidies
2	Non-motorized Transportation Facility Improvement	Building design standards, bicycle facilities, bike sharing, complete streets, pedestrian facilities
3	Transit	New BRT lines, new light rail, improved transit LOS, fare reduction
4	Road Pricing	Highway tolls, congestion charging
5	Parking Management	Parking prices
6	Car/Ridesharing	Carpooling and ridesharing incentives
7	Employer TDM Programs	Employer based carpool incentives, Rio Metro smart business partnership, employer based education/promotion
8	VMT Charging	Statewide mileage based tax
9	Incident Management	Plan for quickly clearing traffic accidents
10	Intersection Design/Operation	Traffic signal timing, roundabouts
11	Roadway Connectivity	Increase number of roadway intersections, more grid like street pattern
12	Vehicle Improvement Strategies	Subsidy for vehicle purchase or home charging infrastructure, increase network of charging stations, diesel retrofit incentive or regulation
13	Truck Stop Electrification	Provide electricity for trucks at truck stops for hoteling power needs
14	Construction Activities	Cleaner construction vehicle fleet
15	Electricity Generation	Change in utility fuel mix

The project team rated the individual strategies provided in the list to UNM by the expected mitigation potential of each strategy and the project team's current analysis capability (Table 2). The UNM project team used Table 2 to focus its research effort initially on strategies that have the highest potential GHG emission potential and which it can quantitatively model in the current modeling environment. Strategies with significant GHG emission reduction potential but which are difficult to model due to current MRCOG modeling capability, data availability, or limited scientific evidence will be evaluated either quantitatively using simplified off-model analysis methods or discussed and evaluated qualitatively. Finally, strategies with limited GHG mitigation potential and which the project team has no reliable modeling methods or data may be discussed but cannot be evaluated in a scenario analysis. Table 2 is based on UNM's current expert opinion and will be updated through the course of the project as the project team completes the literature review tasks and modeling work described below. A revised version of this table will be included in the final report. The revised table will be accompanied by a discussion describing the evidence supporting each GHG mitigation potential rating based on the modeling conducted for each scenario and on a review of prior published research findings.

Table 2 Strategy Effectiveness, Time Frame and Evaluation Ability with Current Modeling System, Data, and Scientific Understanding.

Strategy	GHG Mitigation Potential	Analysis Capability
Zoning changes	●●●●● L	●●●●● U
Infill development	●●●●○ L	●●●●○ U
Transit oriented development	●●●●○ L	●●●●○ U,C
Building design standards	●●○○○ L	●○○○○ Q
Urban growth boundaries	●●●●● M	●●●●● U
Bicycle and pedestrian infrastructure improvements	●●●○○ S	●●○○○ O,P,Q
Improving public transportation	●●●○○ S	●●●○○ C
Establishing a complete streets policy	●●○○○ L	●○○○○ Q
Road pricing (HOT lanes/congestion charging)	●●●○○ S	●●○○○ C,P
HOV facilities	●○○○○ M	●○○○○ Q,P
Parking management	●●●○○ S	●●●○○ C
Car sharing	●○○○○ S	●○○○○ Q
Bike sharing	●○○○○ S	●○○○○ Q
Ride sharing	●○○○○ S	●●●○○ Q,C
Travel demand management-educational	●○○○○ S	●○○○○ Q
Travel demand management-transit incentives	●●●○○ S	●●○○○ Q,P
"Wheels" tax (VMT charging)	●●●●● S	●●●●○ C
Traffic signal enhancement	●●●○○ S	●●●○○ C,P
Incident management	●●○○○ S	●○○○○ Q
Intersection improvement	●○○○○ S	●●●●○ P,C
Establishing roadway connectivity standards	●●●○○ L	●●●●○ C
Electric vehicle infrastructure support	●●○○○ M	●○○○○ Q,M
Heavy-duty vehicle retrofit	●○○○○ M	●●●●○ Q,M
Truck-stop electrification technologies	●○○○○ S	●●○○○ M
Construction activities	●○○○○ M	●○○○○*
Reduce emissions associated with electricity generation from fossil fuel	●●●●● M	●○○○○**

●○○○○ → ●●●●●
Low → High

L = long term
M = medium term
S = short term

U = UrbanSim, C = CUBE,
M = MOVES, O = Off Model,
P = Post Process, Q = Qualitative

* This analysis would not use any of the MRCOG's existing models. The only available method would estimate emissions for all construction activities and would not be sensitive to changes in land-use and transportation systems.

**This is not difficult to consider if UNM is provided sufficient data by MRCOG or PNM. This analysis would not use any of the MRCOG's existing models and is not directly related to transportation and land-use.

3 SCENARIO EVALUATION METHODOLOGY

The methodology for incorporating each strategy into MRCOG's modeling environment is described below. Each subsection in section 3.3 corresponds to a specific category of strategies that share either a common objective or modeling approach. For each category of strategy, the project team discusses how the strategy can be translated to the modeling environment, specifically which data describing the strategy

enter the modeling environment and how that information cascades through various models to eventually produce output. The output is either one of the performance measures provided by MRCOG or are data that can be used to calculate the performance measures. The project team discusses uncertainties and limitations to extent that it knows of them. Not every strategy can be evaluated in MRCOG's modeling environment. It is beyond the scope of this project to develop new models or modify the logic of existing models, these tasks would require far more resources and time than are available. For strategies that cannot be directly modeled within MRCOG's existing modeling environment, the project team takes one of three approaches.

1. Integrated off-model analysis. In this approach, the project team supplements the existing modeling environment capabilities with additional calculation steps. These additional calculations adjust for known model limitations. The project team intercepts intermediate modeling results, adjust them using correction factors derived from prior case studies and the scientific literature, and then insert them back into the modeling environment. This method requires developing scripts to automate the adjustments during each model run which contains multiple iterations. It is the most robust procedure but may also be too time consuming to fully implement.

2. Post-processing. In this approach, the project team adjusts model output to correct for a known limitation, usually the lack of sensitivity to the strategy being considered. The project team does not modify the modeling environment in any way but more simply tries to correct the final output using correction factors derived from prior case studies and the scientific literature. This is generally a less robust method than integrated off-model analysis but in some cases necessary given the modeling environment, data limitations, and the project timeline. Post-processing methods are very common and correction factors (elasticities) are widely available.

3. For several strategies the modeling environment is completely insensitive to the strategy and there is also not enough scientific evidence available to perform integrated off-model analysis or post-processing. In these cases, the project team will discuss qualitatively the expected efficiency (magnitude of effect) and effectiveness (direction of effect or likelihood of success) of each strategy based on a review of currently available scientific literature. To the extent possible, the project team will discuss how local factors may make these strategies more or less effective than as reported in prior studies.

3.1 Overview of MRCOG's Modeling Environment

MRCOG uses three primary modeling tools to analyze the impacts of regional land-use and transportation planning decisions on mobility, accessibility, and economic growth (Figure 1). The first step in a typical analysis uses UrbanSim, an agent based land-use model, to determine the future population, employment, and land-use mix in each transportation analysis zone (TAZ). UrbanSim predictions are driven by modeling changes in land and housing value by considering changes in accessibility, land-use regulations, land availability, and the expected population and employment growth in the region.

To model the effect of accessibility, UrbanSim requires data from an external travel demand model. This dependence is indicated in Figure 1by the feedback loop from CUBE to UrbanSim. Accessibility is derived from travel demand model network "skims" which provide a matrix of costs for travel within and between each TAZ. MRCOG's current implementation of UrbanSim uses morning peak hour travel times as the cost input to measure accessibility. Initializing the modeling chain indicated in Figure 1 requires first running the CUBE model with the present day (or base year) population, employment, and land-use mix by TAZ to produce initial travel times. Subsequent year population, employment, and land-use patterns are then simulated by UrbanSim to evolve the land-use and transportation system forward through the forecasting horizon.

Land-use regulations, land availability, and expected population and employment growth are required inputs to UrbanSim. Land-use regulations and land availability are defined at the parcel level and are based on county tax records and other land-use data that MRCOG may have. Future year population and employment growth projections are also required. UrbanSim requires these projections to calibrate its own simulation of population growth. In this way, UrbanSim does not predict future population or employment totals but it models where this growth will occur and how it affects land-use development. While UrbanSim simulates land-use at the parcel level, it aggregates output for TAZs.

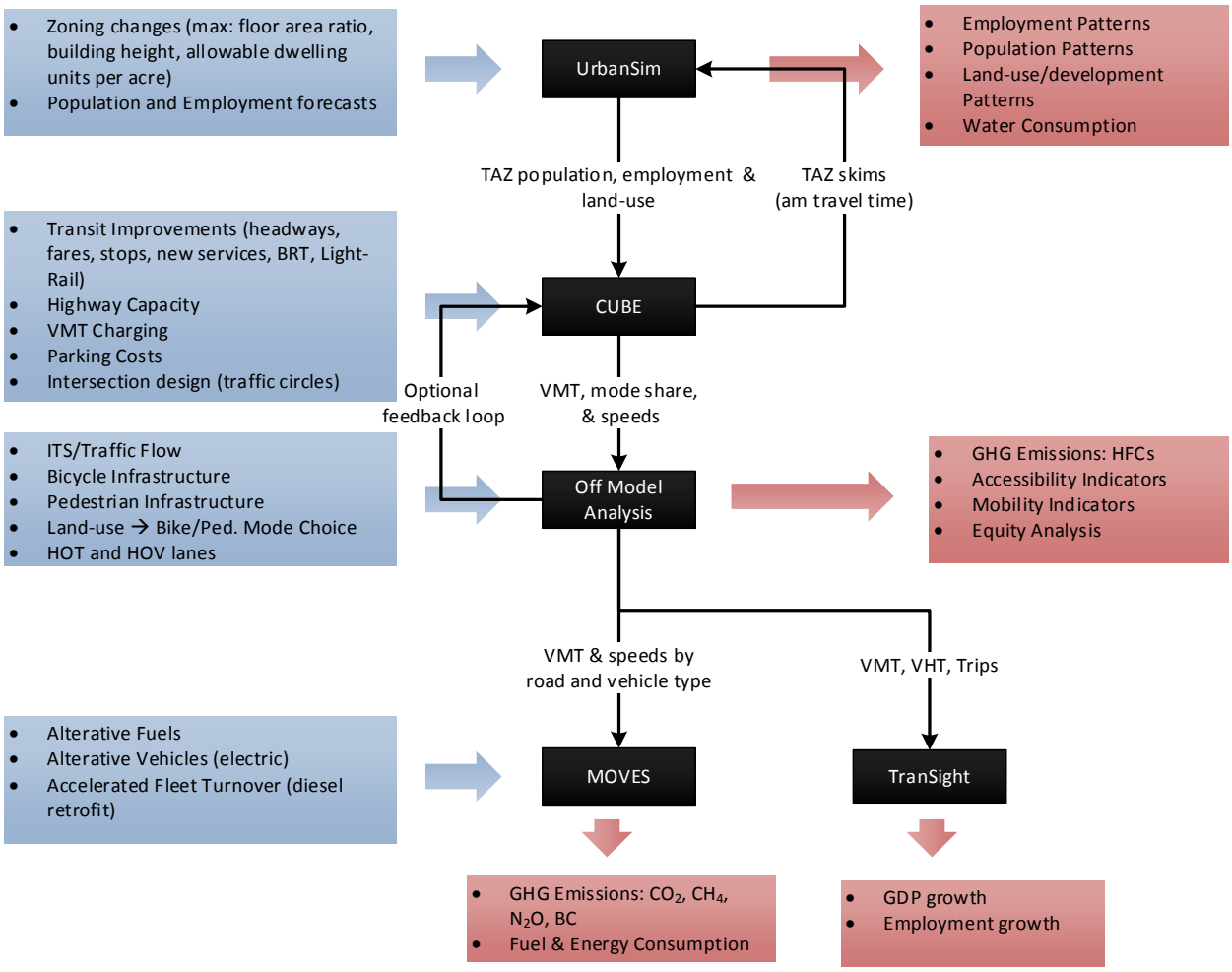

Figure 1 MRCOG Modeling Environment Overview and Scenario Inputs (blue) and Performance Measure Outputs (red)

TAZs are the basic geographical analysis unit of traditional 4-step travel demand models such as MRCOG's travel demand model, which is implemented in Citilab's CUBE software. The travel demand model has 4 basic steps. The first step predicts the number of trips produced in each TAZ based on population and housing characteristics and the number of trips attracted to each TAZ based on employment and other non-residential land-uses such as retail and schools. The second step allocates the trips generated by each TAZ to other TAZs with the goal of matching supply (production) with demand (attraction). A gravity model is used to distribute trips between TAZs based on the number of trips produced and attracted in each TAZ (e.g., the mass in the gravity analogy) and the generalized cost of travel between TAZs (e.g., the distance in the gravity analogy). The generalized cost of travel considers both out of pocket costs (e.g., parking and automobile operating costs) and travel time costs. The third

step determines the mode(s) by which trips between each TAZ will take place using discrete choice models. Data from MRCOG's 1992 regional household travel surveys is used to estimate a nested logit model for each trip purpose which predicts the probability of choosing each mode based primarily on vehicle ownership (none, 1, 2, 3+), which itself is estimated from household size and income, trip distance, and trip cost. The final step assigns trips to the physical transportation network and then calculates the resulting travel speed and traffic volume for each network link. Speeds are based on volume delay functions which define the expected speed on a roadway link given its designed capacity, the predicted travel demand, and traffic control devices. The assignment procedures attempts to find a solution where no shorter paths are available for any trip accounting for the fact that travel times change as additional trips are added to each link.

MRCOG predicts the economic outcome of changes in the performance of the transportation network using the TranSight model. TranSight takes as input aggregate trips, travel time, and vehicle miles traveled from CUBE and uses these to estimate how changes in the region's mobility will affect economic growth indicators such as GDP and employment.

The current MRCOG modeling environment does not include a vehicle emission model to estimate how changes in travel demand, congestion, and vehicle fuels and technology will affect GHG emissions. UNM proposes using the U.S. EPA's Motor Vehicle Emission Simulator (MOVES) model as shown in Figure 1. MOVES can estimate a wide range of GHG, criteria, and toxic air pollutant emissions based on changes in the vehicle fleet overtime, changes in speed, and changes in vehicle use. The MOVES model is available for free from the U.S. EPA but requires regional data to obtain an accurate representation of the region's vehicle fleet. UNM has been working with MRCOG to request vehicle registration records from the New Mexico Department of Transportation to specify the MOVES model for the region but has not obtained any records to date. UNM has also been working with MRCOG to determine if air quality analysis conducted for the City of Albuquerque for the Paseo Del Norte interchange project used a regionally tailored version of the MOVES model.

3.2 Model Integration for Climate Change Scenario Analysis

3.2.1 On Model Analysis

As indicated in Figure 1 and explained above, UrbanSim and the CUBE travel demand model can work together to model the interaction between land-use and transportation systems. Many potential elements of the climate change planning scenarios that will be developed through the Central New Mexico Climate Change Scenario Planning Project can be modeled by altering the input or parameters of these two models as indicated by the blue boxes in Figure 1. Zoning and other land-use regulations can be changed to accommodate infill and transit oriented development and urban growth boundaries can be implemented by restricting land-uses around the periphery of the urban area. These land-use policies can be modeled by changing input files provided to UrbanSim. UrbanSim will simulate new distributions of population, employment and land-use mix by TAZ which then become the basis of traffic forecasts made in the CUBE model. The physical roadway and transit networks in the CUBE model can be edited to include new or expanded roadways or transit systems as well as changes to those systems such as speed limits, transit headways, and basic traffic control systems. Scenarios which forecast infrastructure damage or unavailability, such as the flooding of roadways or transit lines, can also be modeled in CUBE by removing the damaged links or reducing their capacity. This type of analysis can be used to assess the resiliency of the transportation system to different climate futures and climate change impacts. The cost functions which are used in CUBE's trip distribution, mode choice, and assignment steps can also be altered to model the effects of VMT charges, tolls, parking costs, and other types of fees and taxes that may be considered. Changes to these parameters would affect the mode choice, trip routing, and trip length, affecting congestion levels, but not the overall number of trips. When the model skims from the current CUBE modeling run are fed back to the UrbanSim model, updated population, employment, and

land-use data is generated that are then fed back into the CUBE model for the next time period and which then affect the number of trips generated by CUBE.

3.2.2 Off Model Travel Demand Analysis

The current implementation of the MRCOG model in CUBE includes only limited functionality for modeling bicycle or pedestrian trips. The model does consider walk trips necessary to complete a transit trip and lumps other walk and bicycle trips into a single non-motorized category. The current CUBE model is not sensitive to any of the bicycle or pedestrian strategies being considered by MRCOG. Improving the modeling environment would require developing new discrete choice models which would require collecting new survey data, extensive data analysis, and re-coding CUBE modeling scripts. These tasks are far outside the scope and timeframe of the current project. Similarly, the current MRCOG travel demand model has only limited ability to consider different types of signal controls. Modeling of various ITS strategies is not possible. The current MRCOG travel demand model is also not well suited for analyzing HOT lanes and other managed lane strategies. While CUBE can model these, it would require extensive model development work and data collection efforts that fall outside the scope of work and time frame for this project.

While some transportation system attributes, travel modes, and policies cannot currently be modeled in CUBE, they can be considered in an "off-model" analysis or "post-processing" as shown in Figure 1. Off-model analysis and post-processing refer to various analytical methods and supplemental modeling that may be necessary to make up for limitations in MRCOG's current travel demand model. For example, the number of trips estimated on each link can be adjusted to account for trips that are likely to be made by bike based on application of mode choice elasticities derived from prior studies. Similarly, the predicted travel times can be adjusted to account for improvements made by implementing various ITS strategies. The amount of improvement could be estimated by applying adjustment factors based on prior research findings or the region's own experience on Alameda Boulevard. There are many options available for off-model and post-processing analysis of specific network design features and policies, the application of specific methods will depend on data availability, time constraints, and the specific policies or strategies that each scenario includes.

The CUBE model output can also be "post-processed" to develop additional transportation performance measures such as access to jobs, transit, health care, and other important services. Most post-processing can be accomplished by writing scripts within CUBE that work with the output of the main travel demand modeling steps. Various post-process procedures can also be developed to create visual displays of the model output for additional analysis and presentation. Many of the performance measures that MRCOG would like to evaluate related to access and congestion a) are already implemented in MRCOG's travel demand model as scripts written in CUBE, b) can be estimated using MRCOG's TRAM model, or c) can be estimated in UrbanSim's accessibility engine. UNM will develop additional scripts in CUBE and also ArcGIS to estimate access, congestion, and operations performance metrics that are not already estimated by MRCOG.

3.2.3 Water Consumption Analysis

Additional post-processing will be used to estimate water consumption for each scenario. Unit water consumption rates for each land-use type described in Task 1.2 will be applied to future land-use projections from the UrbanSim model. For example, the Albuquerque Bernalillo Water Authority data indicates that people living in multi-family households consume less water per capita than those living in single family households. The project team can use this information to estimate the change in water consumption from UrbanSim output which indicates changes in the distribution of population by housing type. Similarly, the project team can apply water consumption rates to changes in the amount of commercial, industrial, and agricultural land output by UrbanSim. Water consumption rates are based on current water authority and state water records. These rates will be adjusted over time to account for increasing efficiency in water use. The Albuquerque Bernalillo Water Authority provides projections of

expected water consumption per capita (see Task 1.2) that indicates a continuation of increasing water use efficiency through 2024. The project team can use this trend to adjust current water consumption rates by each land-use.

UNM was also recently provided with disaggregate water billing records from the Albuquerque Bernalillo Water Authority. These data have not yet been inspected; however, the project team may be able to use them to (1) estimate more precise and disaggregate water consumption rates by land-use type and (2) determine the difference in water consumption rates by new and old residential and commercial buildings. The project team could use information about the water consumption rate of newer building in its forecasts rather than relying on aggregate rates which include the water efficiency of older buildings. The project team's ability to use this data will depend on an analysis of data quality and the ease in which it can be aligned with parcel level land-use data. MRCOG and UNM discussed this analysis and will work jointly to evaluate the feasibility of this approach.

3.2.4 Emission Analysis

While MRCOG's performance measures include GHG emission reductions, MRCOG currently has no model to perform this analysis; however, GHGs including carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (N_2O), and black carbon can be estimated using U.S. EPA's MOVES emission factor model. MOVES estimates gram-per-mile and regional inventories (grams/year) of regulated air pollutants and GHGs. The main input to MOVES is the distribution of traffic volume by vehicle speed and roadway type. These input data are derived from the travel demand model output that has been adjusted by any off-model and post-processing analysis. Local climate and fuel property data are also input into MOVES. Typically, and as recommended by US EPA, MOVES should also be tailored to specific regional conditions. For estimating GHG emissions, the most important consideration is updating the default MOVES vehicle fleet with data representing the regional in-use vehicle fleet (model year distribution and vehicle type). This is usually done by analyzing state vehicle registration records.

As described above, UNM is working with MRCOG to obtain vehicle registration records; however, the quality of the data received will affect the project team's ability to process the data in time to perform scenario analysis. The data may also need to be cleaned and VIN decoded by a third party depending on what data fields are available in the registration records. The decoding can be accomplished quickly if needed but is fairly expensive and is not included in the project's budget.

Whether or not the MOVES model is updated for specific application to the Albuquerque area, it can be used in at least a relative sense to understand how changes in the vehicle fleet and travel demand (speed and volume by roadway type) will affect future GHG emissions. MOVES has a default vehicle retirement and replacement function; however, custom future year vehicle fleets can be specified to analyze the impacts of programs that accelerate turnover in the vehicle fleet (e.g., "cash for clunkers") or lead to a greater share of electric vehicles. Vehicle retrofit programs can also be modeled by replacing older vehicles with newer model year vehicles which meet the targeted level of emissions performance.

Emissions of hydrofluorocarbons (HFCs) occur from leaking vehicle air conditioning units or their improper disposal. These emissions are not estimated by MOVES and are instead typically estimated as a function of the number of total vehicles in an area. The number of vehicles used can be derived from the trip generation step of the CUBE travel demand mode which estimates the number of vehicles owned by each household, which is a function of income and household size.

3.2.5 Flood, Fire, and Ecosystem Risk Analysis

Areas identified as being prone to flood and fire risk or critical habitat will be identified over the course of the project. These areas can be excluded from development by updating the land-use policies in UrbanSim (explained in 3.3.1 below). If this is not done, the output of UrbanSim can be used to evaluate the amount and type of development that is projected to occur in these areas if development restrictions are not in place. Parcel or zonal level UrbanSim land-use output can be overlaid with these high risk or

critical habitat areas in ArcGIS to assess the relative amount of development occurring on each area for each climate change scenario.

UNM and MRCOG recently met to discuss how to best identify flood risk areas in the future for this analysis. The simplest approach would just consider development occurring in existing 100 year flood plains; however, this does not reflect expected changes in 100 year flood plains. Initial discussions concluded that modeling changes in the flood plains could not be completed with available resources and in the available time frame. UNM is now considering a more simplified approach to evaluating changes in flood risk posed by changes in land-use. One potential metric is the change in the population weighted distance to existing flood plains. Essentially this metric is based on the logic that having more development further away from existing flood plains would be less risky than having more development closer. The metric obviously ignores that fact that new flood plains may be identified in the future and that risk is not a linear function of distance to a flood plain but involves many local factors. UNM is continuing to assess the potential metrics and will provide a supplemental memo that describes the proposed approach for assessing the resiliency of each scenario to flood risks posed by climate change.

3.3 Integrating Land-Use and Transportation Strategies into the Modeling Environment

This section describes in detail how each mitigation strategy identified by MRCOG can be integrated into MRCOG's modeling environment, evaluated off-model, or evaluated qualitatively.

3.3.1 Land use strategies

Infill development, transit orientated development, and urban growth boundaries are similar in that they are all policies aimed at changing land-use development patterns. There are two general mechanisms for implementing these strategies: (1) lowering the cost of infill development by lowering fees (e.g., impact fees) or providing development subsidies and (2) changing zoning classifications or creating new zoning classifications. The second strategy can be modeled in the existing MRCOG modeling environment using UrbanSim as shown in Figure 2. Zoning regulations affecting the maximum floor area ratio, allowable number of dwelling units, maximum building height, and building type can be updated to reflect changes in zoning classification or the creation of new zoning codes for areas being targeted for infill development or where municipalities are willing to allow infill development.

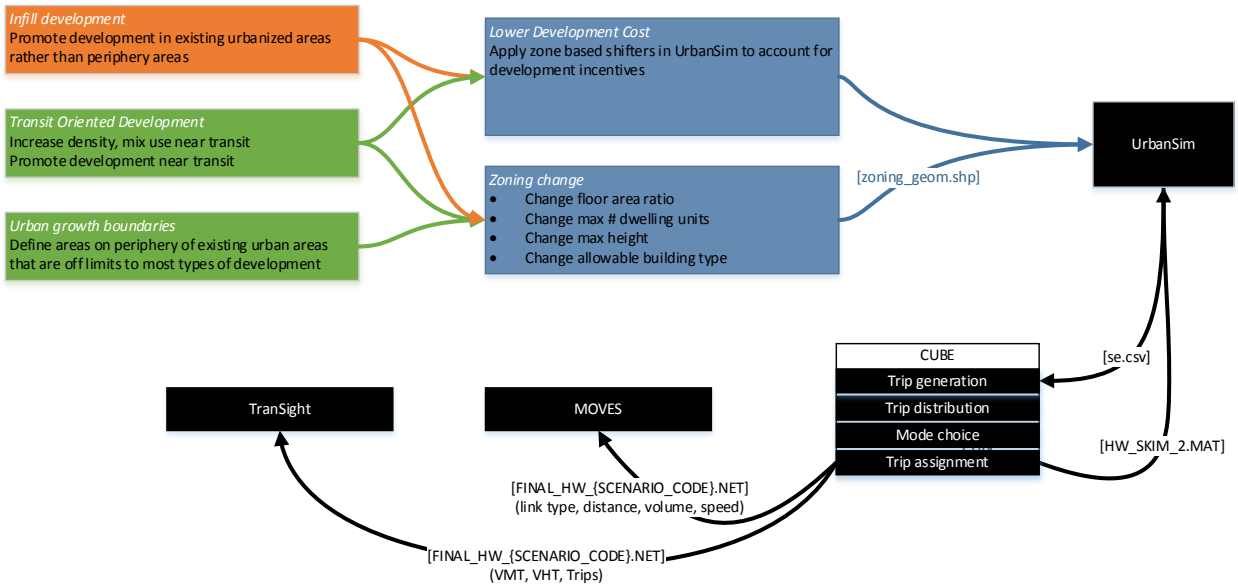

Figure 2 Analysis Framework for Land-use Strategies

Development patterns can also be influenced by changing the cost of developing land. The current implementation of UrbanSim at MRCOG does not have this capability. Synthicity can apply zone-based "shifters" to increase the probability of particular types of development occurring in certain areas of the region where development is being incentivized. This approach is similar to the post processing methods described for the CUBE model. The UrbanSim model can also include particular development projects that are known or widely expected to occur, potentially as a result of development incentives.

Changing zoning and development cost inputs to UrbanSim will result in a new distribution of development types, population, and employment. These data are aggregated by TAZs by UrbanSim and then serve as input to the CUBE travel demand model.

MRCOG provided the UNM project team with a list that describes potential strategies aimed at infill, transit oriented development, and growth boundaries in New Mexico that cannot be directly modeled in the current modeling environment. These include expedited development review processes, allowing accessory dwelling units, minimum parking requirements, improved pedestrian environments in transit oriented development areas, and better accounting for lifecycle costs of new development. Expedited development review processes could be modeled by applying zone-based "shifters" in UrbanSim which would increase the probability of development in areas targeted for expedited review. One challenge with this method is determining how much to adjust the development probability. Zoning changes to allow accessory dwelling units could be modeled by increasing the number of dwelling units on each parcel. Relaxing minimum parking requirements could be modeled as a change in development fees or subsidies (by applying zone-based shifters are described above) and/or the maximum floor area ratio. These would allow more of the parcel to be developed into conditioned space (and not parking lots) and lower the development cost (do not have to build a parking lot or structure). To implement this approach would require determining how much space typically goes towards parking, how much parking construction costs in different areas (e.g., require structures in high density areas and surface lots in other areas), and how changes in these costs affect the probability of development. The project team currently has no information on these parameters. An improved pedestrian environment can be modeled following the non-motorized improvement analysis framework described in section 3.3.2.

3.3.2 Non-motorized improvements strategies

The CUBE model predicts the number of non-motorized trips but does not distinguish between bicycling and walking trips. Non-motorized trips are estimated using a nested logit model estimated with 1992 household survey data. In the current CUBE model, non-motorized trips are a function of household vehicle ownership, trip distance and time, and trip costs (transit and driving). This presents several challenges. The first limitation is the vintage of the data. This now out of date data are unlikely to reflect current attitudes towards cycling which have likely changed due to changing views or concerns about the natural environment and climate change, improved bicycle technology, increased awareness of health benefits, changes to the quality or availability of pedestrian and bicycle infrastructure, and many other factors not captured in the nested logit model. The current model is somewhat sensitive to changes in street connectivity (decreased travel times and distances increase probability of choosing non-motorized mode), changes in vehicle costs (increased costs increase probability of choosing a non-motorized trip), and changes in transit fares (lower fares increase probability of choosing a transit mode), which are outcomes of other strategies aimed at mitigating GHG emissions that the region may consider.

The second limitation is that the nested logit model does not contain variables that account for any of the proposed strategies. There are no parameters that consider infrastructure quality, traffic speed (traffic calming), perceived level of safety, or typical "complete streets" designs. Addition of pedestrian or bicycle only infrastructure could be considered in the current model by adding new links that restrict motorized travel. To the extent that the additional non-motorized links are shorter than existing roadway links, this would increase the share of non-motorized trips between certain origins and destinations.

A third limitation is the grouping of walking and bicycle trips into one non-motorized group. Clearly the factors affecting the decision to bicycle and walk to a destination are very different, most importantly the distance that can be covered. With this limitation in mind, as well as the household travel data collected before bicycle paths were as developed as they are today, changing the network to include bicycle and pedestrian paths would not be worthwhile as it would require a lot of effort for very little model improvement.

Given these limitations, the project team recommends two approaches. For several of the strategies, such as providing bicycle infrastructure, the project team can use elasticities from the published academic literature to estimate the change in mode share given a change in some element of the built environment (TRB 2009; R. Ewing and Cervero 2010; Reid Ewing et al. 2007). The most efficient method to apply the elasticities would be post processing the model results (Figure 3). The post processing method would adjust the volume of vehicles on routes in the final loaded network where bicycle and pedestrian improvements were made. The adjusted vehicle volume would then be used in the MOVES model, producing GHG emission estimates that reflect the greater bicycle mode share (e.g., fewer vehicle trips). This method is applied after running the full CUBE model and contains no feedback mechanism that reflects how a change in mode choice would affect traffic patterns by removing some vehicle trips from the network, decreasing travel times on some links. A more sophisticated off-model analysis that adjusts the mode choice output could account for these affects (Figure 4); however, given the time constraints of the current project and likely very small affect this would have on the emission estimates, the simpler post-processing method will be used.

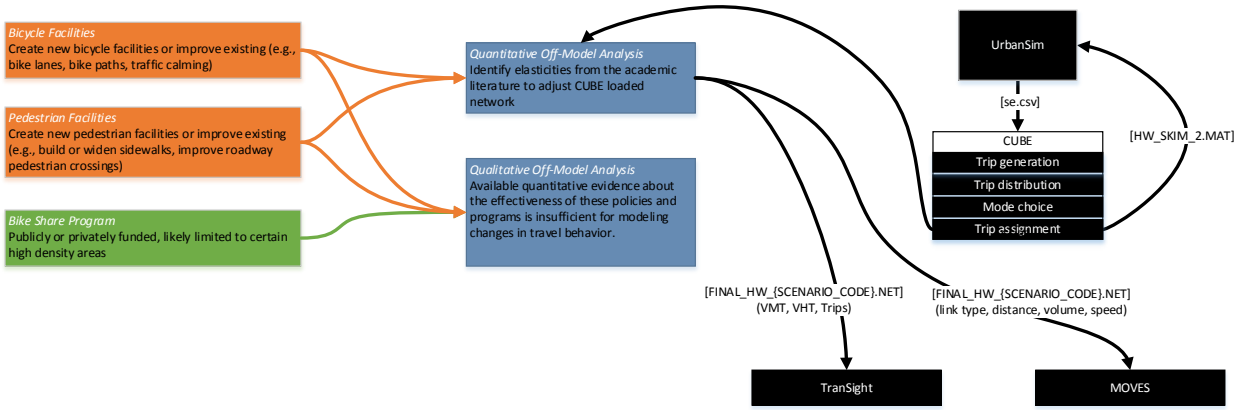

Figure 3 Analysis Framework for Non-motorized travel strategies (post-processing)

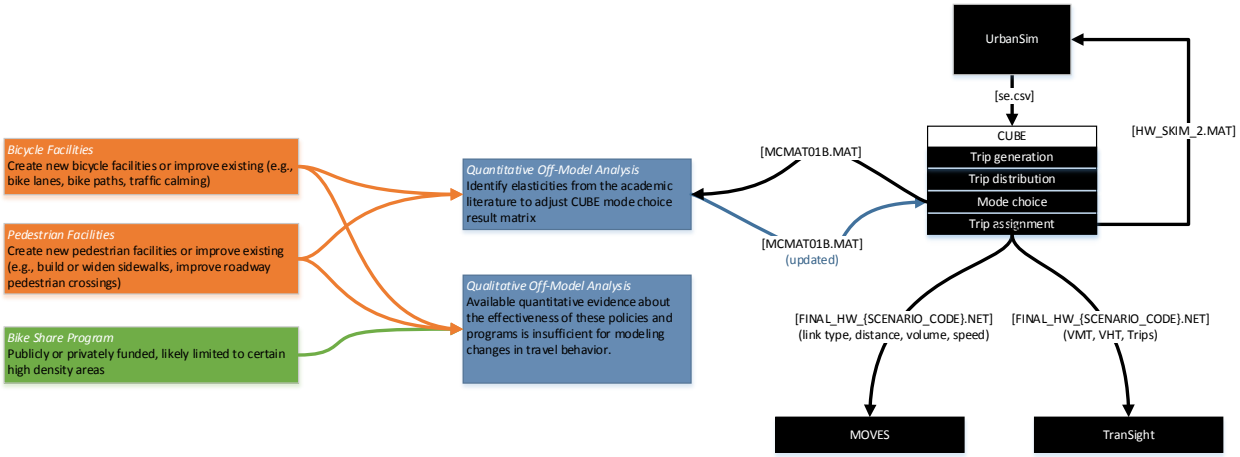

Figure 4 Analysis Framework for Non-motorized travel strategies (off-model analysis with feedback)

For strategies where there is insufficient information to develop elasticities, the project team will make a qualitative assessment of the strategy based on a literature review. The qualitative assessment will review any results from prior case studies or research and discuss, based on these findings, the relative affect that could be expected in the MRCOG region. This approach will be used for a potential bike share program and some elements of the built environment.

3.3.3 Transit strategies

Transit strategies may involve increasing the level of service on existing bus routes (e.g., reducing headways), adding/removing stops, adding additional bus routes, changing fares, or adding new transit modes such as bus rapid transit and light rail. These strategies can be modeled directly in CUBE. The existing transit network files (AM_TNET15.LIN and OP_TNET15.LIN) can be edited to change level of service characteristics, add/remove stops, and add new transit services. Light rail and bus rapid transit would be added to the transit network following the same procedures used to add the current bus routes. These premium services would be represented in CUBE as transit links that have fewer stops and higher speeds. The fares for each type of transit service can also be adjusted in the fare files (FARE.FAR).

The nested logit model that is used in the mode choice step is built on now out dated household survey data as described in section 3.3.2. UNM will test the sensitivity of the CUBE model to changes in the level of service described above and compare the resulting change in mode share to expectations based on published studies (e.g., elasticities) and the project team's expectations. If the model is found to be insensitive or inaccurate, the project team will apply a post processing method to correct the mode share at the end of the model run using elasticities from published reports and the academic literature.

3.3.4 Road pricing (congestion charging) strategies

Road pricing strategies provided to the UNM transportation team include high occupancy toll (HOT) lanes where single occupancy vehicles are charged a toll and carpools are charged either a reduced toll or no toll and congestion charging schemes where vehicles entering a specific region on any road are charged a toll. Under either charging scheme, the toll may change by hour of the day, level of traffic congestion, and day of the week. The current CUBE model is not configured to model these strategies. Extensive research and model development would be required to update the network, mode choice model, and traffic assignment model.

The project team could, however, model a highway toll that applies to all vehicles by changing the cost function used to estimate generalized travel costs for each roadway type. The project team would define a new roadway type and then update the cost function to include a fixed toll. This may give some indication

of how pricing strategies could lead to more carpooling, less travel demand, or a change in travel patterns. A qualitative analysis can also be performed that discusses the emerging evidence about the performance of HOT lanes in other regions at reducing GHG emissions.

3.3.5 Parking Management and Pricing

CUBE and UrbanSim do not contain explicit representations of parking capacity or the location of parking. As discussed in 2.3.1, the project team can model policies to relax parking requirements by lowering development costs and minimum floor area ratios. The project team can also model policies that manage parking spaces by reducing their availability or charging more for them by increasing the cost of parking. The current CUBE model contains a parking cost matrix (PARKING_COST.MAT) which includes the cost of parking for trips between each TAZ. This matrix can be updated to reflect changes in parking costs for individual TAZs by including the costs in the PARK$_12.dbf file which can be edited in Excel and specified in the CUBE model user interface when setting up a new model run.

3.3.6 Car/ridesharing

The current CUBE travel demand model is not configured to model car sharing services. Updating the CUBE model to consider this strategy would require new household survey data asking about the use of car sharing services and information about the availability and cost of these services in the MRCOG region. This research is beyond the scope of this project. The project team believes there is insufficient evidence to provide any quantitative measure of the effects of this strategy and therefore proposes a qualitative assessment. The project team will review the current literature and any available case studies and describe how their findings may apply to the MRCOG region.

Ridesharing is modeled in CUBE during the mode choice step, which includes two carpool choices (2 and 3+). The probability of choosing to carpool is influenced by car ownership (function of income and household size), travel costs, parking costs, travel time, and trip type. Strategies that affect these parameters will affect the share of trips made by carpooling. Like the discussion about non-motorized mode choice, the carpool mode choice is made using a nested logit model estimated from 1992 household survey data. It is very likely that attitudes towards carpooling have changed due to concerns about the environment and climate change and new technology that makes it easier to coordinate rides. There is currently insufficient evidence to adjust the carpool mode share based on potential changes in carpooling attitudes driven by generation or technological changes. The project team can provide a qualitative discussion about the potential effect of new technology and ridesharing services. The project team also expects that many of the newer rider sharing services (e.g., Lyft and Uber) are competing more heavily with traditional taxi service than with other modes.

3.3.7 High Occupancy Vehicle Lanes (HOV)

The current CUBE model setup does not include an HOV network or the traffic assignment logic required to limit carpools to using certain network links. While setting this up would be possible using CUBE software, it would likely be very time consuming as the project team would need to code in a new assignment procedure. The UNM project team also does not believe there is a significant GHG mitigation potential from providing HOV lanes (Kwon and Varaiya 2008; Johnston and Ceerla 1996; Shewmake 2012). Given these limitations, the project team plans on conducting a qualitative analysis that will focus on identifying any newly published studies that describe the effectiveness (or ineffectiveness) of HOV lanes in reducing VMT, increasing average traffic speed, or decreasing GHG emissions.

3.3.8 Employer commuter programs and transportation management associations

Travel demand management programs that are either educational, incentivize carpooling, or provide discount transit fares cannot be directly modeled in the MRCOG modeling environment. While the UNM project team can adjust transit fares, this can only be done for an entire transit line in the current model and not for some portion of potential riders. The UNM project team can use information from either the academic literature or the mode choice model in CUBE to develop a post processing method to adjust

transit mode shares using an elasticity for trips between certain TAZs where TDM policies would be implemented. This would be done following the same general procedure as described in 2.3.2.

3.3.9 A statewide mileage-based user fee or “wheels” tax (VMT tax)

A flat distance based tax or fee is easily implemented by changing the auto operating cost, which is one of the inputs to estimating the generalized cost of trips between each TAZ. The auto operating cost is entered in a dialog box in the user interface when specifying a new model run. Costs should be set to at a minimum capture the expected cost of maintaining highway infrastructure and accommodating expected demand, and ideally include the cost of externalities including congestion and environmental damages. These costs can be estimated by reviewing the state’s current highway budget and reviewing the academic literature for estimates of marginal external costs. An extensive VMT tax pilot test was recently conducted in Oregon (Oregon's Road Use Charges) and can be used to design a potential strategy for New Mexico.

3.3.10 Incident management

Incident management can be effective at decreasing congestion and therefore reducing GHG emissions. MRCOG’s current modeling environment is not able to model this strategy. The project team can provide a qualitative assessment based on a review of the academic literature and prior case studies. The effectiveness of an incident management program would depend heavily on its design, the design of the highway facility, and congestion levels.

3.3.11 Intersection/traffic signal improvement

Delay at intersections and along congested arterials is affected by the type of traffic control and its operation. Reducing delay at intersections minimizes idling and therefore GHG emissions. Smoothing the flow of traffic through congested corridors and increasing the average speed can also reduce GHG emissions. MRCOG’s modeling environment is unable to estimate the benefits of signal optimization/coordination strategies. However, since the region has some experience that provides information on the change in travel speed and delay after implementing adaptive traffic controls, the project team can use this information to post-process speeds in the loaded network after the CUBE model run. The post processing would increase speeds and reduce idling on links where similar traffic control changes are anticipated. The post processing would also be informed by findings based on a review of prior case studies and the scientific literature. The post-processed speeds and idling would then become input to the MOVES model which considers both of these factors in estimating GHG emissions.

The project team can also edit the delay functions for individual intersections to represent different types of traffic control devices. The current mode has several basic delay functions for signalized and un-signalized intersections which are specified in the ZVMAT00B.S script. The project team can include new delay functions from the academic literature or prior case studies to model other intersection types such as traffic circles which generally smooth the flow of traffic.

3.3.12 Establishing roadway connectivity standards

Improving roadway connectivity has a number of potential benefits to which the CUBE has some sensitivity. Roadway connectivity can be increased or made to follow a grid pattern for new development with in the MRCOG region or some portion of it. A what if scenario could also be developed where existing unconnected neighborhoods are given greater connectivity by adding new links (likely on top of existing homes or businesses). Connectivity is simply added by drawing and defining new links in CUBE so that there are more intersections, new streets follow a grid pattern, etc. Because the CUBE model does not include local streets, increased connectivity can be represented by adding additional virtual links to the centroids of TAZs which feed into arterial and collector links or changing the distance of the virtual links. The increased connectivity will increase the non-motorized and transit mode share by decreasing trip distances and the gridded street network may also help relieve congestion.

3.3.13 Vehicle Improvement Strategies

Changes to the vehicle fleet can be made in the MOVES model. The MOVES model vehicle fleet database can be edited to change the share of vehicles by model year and fuel type. The share of electric vehicles in the future can be increased based on assumptions about the effectiveness of various policies to incentivize their use such as increasing gas taxes or introducing VMT or carbon taxes, providing subsidies to purchase new vehicles or use them (free parking), or providing subsidies or strategies to create charging networks. There is some evidence available in the current academic literature to provide rough estimates to develop scenarios that assume an increased share of electric vehicles if any of these policies were adopted. The best approach would be to assume several potential changes in mode share; for example, 1 percent, 5 percent, and 10 percent to express the degree of uncertainty and understand the GHG mitigation potential of these policies.

A heavy duty diesel retrofit program can be modeled by changing the model year distribution of heavy duty diesel trucks. Emission in MOVES is based on a truck's model year which defines the emission standards it was built under and the amount of emission control deterioration that has likely occurred. A retrofit program can be modeled by replacing a portion of the target vehicles (e.g., diesel trucks more than 10 years old) with the latest model year trucks. One limitation of the MRCOG modeling environment for evaluating policies that affect trucks is that the model does not currently break out truck trips from other vehicle trips and truck trips are estimated in a very rudimentary way. The share of trucks used in the MOVES model by type and model year is based solely on vehicle registration records from the state (or nation) and is not a function of any land-use or transportation system changes in the MRCOG region.

3.3.14 Truck-stop electrification (TSE) technologies

The UNM transportation team does not believe this is an effective strategy to mitigate GHG emissions. While idling trucks do waste fuel, there are very few truck stops that the project team is aware of in the MRCOG region and the fuel that idling trucks waste and which would be mitigated by auxiliary power units or truck stop electrification would be a very small portion of the region GHG emissions. On top of this, the project team has very little information available to project future truck trips in the region and no information about the number of trucks using truck stops and how long they typically idle. If this information is provided to UNM, the project team could estimate the expected benefits of truck stop electrification assuming truck stop visits grow proportionally to traffic volumes on adjacent highway corridors.

3.3.15 Construction activities

Construction activities are modeled as off-road area sources. Construction activity is not modeled in CUBE or any other model in the MRCOG modeling environment. It is not possible to model the difference in emissions resulting from different levels of road building activity or land-use in the MRCOG region given current resource availability and since no standard methods are available. It would be a major research effort. The UNM transportation team can estimate county wide inventories from construction activity using EPA's NONROAD2008 model and project future emissions based on different control strategies using national default construction equipment fleets and scrappage rates. The construction emissions would not be limited to roadway construction but would represent any type of construction.

3.3.16 Reducing emissions associated with electricity generation from fossil fuel use

UNM can estimate changes in GHG emissions if provided with projections of future electricity demand and the grid's energy mix. It is beyond the scope of this task to model electricity demand and the power grid's energy mix. Similarly, if supplied with detailed information about the region's current street lights and their use and the specifications for replacements, the project team could estimate the change in electricity demand and GHG emissions.

4 NEXT STEPS

Upon agreement that the methods proposed here are sufficient/feasible and that UNM correctly understands MRCOG's modeling environment, the project team proposes the following next steps to implement the analytical methods described above.

The first priority should be setting up the MOVES model with either regional vehicle fleet data or using the national defaults. Procedures and scripts for formatting the CUBE model output for input into MOVES should be developed. UNM recommends using MOVES to develop a look-up table which lists emission rates by vehicle speed, roadway type, and temperature/humidity. The lookup table can then be used with the loaded transportation network exported from CUBE into ArcGIS and a Python script that will apply the emission rates from the lookup table to each roadway link. The emissions from each link can then be aggregated to obtain region GHG emission totals. This allows the emission modeling process to explicitly model the effect of changes in roadway congestion levels and the distribution of travel across the network. The process would also have value for any air quality analysis (criteria air pollutants) the region may want to consider in the future. UNM can develop the scripts and lookup table.

The next priority is developing any changes to the CUBE model that would require changing code or off-model analysis of intermediate steps. For example, one of the proposed methods for adjusting limitations in the mode choice step requires developing a script to apply elasticities between the mode choice and traffic assignment steps in the CUBE model. These changes could be time consuming to develop and test; the project team may ultimately abandon them in favor of a simpler post-processing alterative.

The UNM project team will begin immediately conducting a literature review for elasticities and qualitative evidence about the performance of strategies that cannot be modeled directly in the current modeling environment. The project team will focus on strategies expected to have the greatest GHG mitigation potential (Table 2) and as time permits research strategies that have less potential or for which little information currently exists. The literature review will help us prepare for the public workshop and will be used in post processing and qualitative assessment of each scenario. The project team is already familiar with many of the strategies and many high-quality reports and literature reviews currently exist. The literature review will focus on identifying more recent research findings and summarizing what is currently known for inclusion in the final report.

UNM will work with MRCOG to determine who will complete various modeling and analysis tasks. UNM has the ability to run the CUBE and MOVES model but does not currently have access to the UrbanSim and TranSight model. UNM will work with MRCOG modeling staff to ensure that the project team is ready to implement changes to the UrbanSim and CUBE model for on-model analysis of expected strategies. These should be relatively quick to implement; however, the project team will pilot test the proposed methods to ensure that everything works as expected before modeling actual scenarios.

The UNM water resource team will continue to evaluate water data as it becomes available to refine forecasting methods. The UNM water resources team will also continue to develop flood risk methods for scenario analysis.

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