SCENARIO PLANNING FOR SUSTAINABILITY AND RESILIENCE: CENTRAL NEW MEXICO AS NATIONAL EXAMPLE

Benjamin Rasmussen, MRP (benjamin.rasmussen@dot.gov, 617-494-2768), Community Planner, US Department of Transportation, John A. Volpe National Transportation Systems Center, 55 Broadway, Cambridge, MA 02142

Aaron Sussman, AICP, MA, MCRP (asussman@mrcog-nm.gov, 505-724-3631), Senior Planner, Mid-Region Council of Governments, 809 Copper Ave NW, Albuquerque, NM 87102

Chowdhury Siddiqui, PhD, EIT, CNU-A (siddiq@mrcog-nm.gov, 505-843-1707), Travel Demand Modeler/Land Use Modeler, Mid-Region Council of Governments, 809 Copper Ave NW, Albuquerque, NM 87102

Tina Hodges (tina.hodges@dot.gov, 202-366-4287), Environmental Protection Specialist, Federal Highway Administration, 1200 New Jersey Ave SE, Washington, DC 20590

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ABSTRACT
In the Albuquerque Metropolitan Planning Area, climate change analysis was incorporated into a land use and transportation scenario planning process. Through the Central New Mexico Climate Change Scenario Planning Project, the Mid-Region Council of Governments (MRCOG) and federal and local project partners utilized spatial analysis to test the benefits of a Preferred Scenario against climate change-related performance measures. The project found that in central New Mexico, incentivizing growth in priority development areas, such as activity centers and transit nodes, had a wider range of impacts than initially expected. In particular, smart growth policies were found to not only reduce vehicle miles traveled and greenhouse gas emissions, but to be more sustainable by attracting additional development to desired locations and reducing the amount of growth in crucial habitat areas and areas at risk to climate change. In other words, mitigation strategies were found to be effective in improving the region's sustainability and resiliency to climate change.

INTRODUCTION

Regional council of governments and metropolitan planning organizations (MPOs) are increasingly pursuing scenario planning as a means of demonstrating the costs and benefits associated with development schemes and existing trends and policies (*US Department of Transportation 2015*). Scenario planning is a particularly useful tool for generating regional discussion on sustainable development patterns and as a means of considering whether certain policies and investments are the most effective means of achieving regional goals. In addition to exploring the relationship between land use and transportation, scenario planning can inform other types of analysis, such as long-term water resource demands and the preservation of crucial habitat areas.

At the same time, there is growing consideration of climate change in public policy and the types of actions that can be pursued at a local or regional level. The clearest overlap between transportation, land use, and environmental planning practices lays in greenhouse gas (GHG) emission reduction, or climate change mitigation, where smart growth policies are critical in curbing mobile source emissions (*Cambridge Systematics 2009*). However, the need for adaptation planning is emerging as well. The Central New Mexico Climate Change Scenario Planning Project (CCSP) brought these considerations together and applied novel approaches for simultaneously testing the effectiveness of mitigation and adaptation strategies.

INTEGRATING CLIMATE CHANGE AND SCENARIO PLANNING

According to the Federal Highway Administration (FHWA), scenario planning is an analytical approach "designed to help citizens and stakeholders in the public and private sectors understand how demographic and land use changes could potentially impact transportation networks" across a region (*US Department of Transportation 2015*). In particular, scenario planning allows stakeholders to evaluate the impacts of several courses of action and identify the ways to best meet the goals of the region (*Bartholomew 2006*).

FHWA notes that "next generation" scenario planning for transportation can also take into account a range of factors that have not traditionally been considered in the transportation system, including climate change. However, climate change analysis is generally limited to GHG emissions and analysis of acres developed for residential and commercial purposes (*US Department of Transportation, 2015*).

The purpose of the CCSP was to build upon the FHWA-identified methodology and integrate climate change analysis into long-range regional scenario planning efforts. Such integration is relatively new. Several projects and studies exist on what multi-county regions can do to adapt to climate change. The most relevant of these resources stem from the FHWA's Climate Change Resilience Pilots. One additional effort, a climate change and scenario planning pilot project performed by US Department of Transportation (DOT) John A Volpe National Transportation Center (Volpe Center) on Cape Cod, Massachusetts in 2011, set an important example for the CCSP to follow (*US DOT Volpe Center 2012*). An explicit goal of the CCSP was to further broaden the scope of climate change-related scenario planning by focusing on an inland setting.

The CCSP was a partnership among the Mid-Region Council of Governments (MRCOG), the metropolitan planning organization for the Albuquerque, New Mexico area; the US DOT Volpe

Center; FWHA; federal land management agencies, including the Bureau of Land Management (BLM), US Fish and Wildlife Service (FWS), and the National Parks Service (NPS); and other federal agencies. Additional project participants included MRCOG member agencies, as well as representatives from natural resource management agencies that are not typically involved in the MPO process. Funding from FHWA, BLM, FWS, and NPS supported the project as well as consulting services from Albuquerque-based natural resource planning firm Ecosystem Management, Inc. (EMI) and the civil engineering department of the University of New Mexico (UNM). The CCSP was completed in 2015, along with the Futures 2040 Metropolitan Transportation Plan, the long-range transportation policy document for the Albuquerque Metropolitan Planning Area (AMPA), where many of the projects findings were incorporated.

MRCOG engages in a recurring long-range planning process that culminates in a metropolitan transportation plan (MTP) every four years. MRCOG had conducted a simplified scenario planning exercise in its previous plan, the 2035 MTP, and had initiated a more complex process when grant funding from the FHWA and technical assistance from the US DOT Volpe Center enabled the region to integrate an analysis of strategies to reduce GHG emissions and improve resilience to climate change impacts, such as wildfires and flooding.

The value of integrating climate change into the scenario planning process is evidenced by the development and environmental pressures facing the region in the coming decades. Located in the arid desert southwest, the AMPA region is projected to grow by more than 50 percent over the next 25 years to nearly 1.4 million people. Accommodating this growth is made more challenging by the decades-long drought period, environmental and political pressures over water resources, and increased frequency of wildfires (19 of the 20 largest wildfires in New Mexico recorded history have occurred since 2000) (*University of New Mexico 2015*).

Of particular interest to the CCSP was the question of whether MPOs could address mitigation (defined as “efforts to reduce or prevent emission of greenhouse gases” [*United Nations Environment Programme 2015*]) and adaptation (policies that “reduce vulnerabilities and build resilience to the impacts of climate change” [*United Nations Environment Programme 2015*]) at the same time. As with other scenario planning processes, MRCOG explicitly considered land use and transportation-based mitigation strategies. However, scenario development was also informed by the question of whether vehicle-miles traveled (VMT) reduction (i.e., mitigation) strategies could address adaptation needs and lead to a more resilient region through more sustainable land use policies and development patterns. Therefore, it was important that scenario evaluation be based on more sophisticated measures, not just the development footprint of the region, but the type and actual location of development within the region. In particular, the CCSP was able to measure the extent to which development occurred in vulnerable locations, which were identified based on projected climate conditions.

SCENARIO DEVELOPMENT PROCESS

The scenario planning process lasted 18 months, culminating in the approval of the Futures 2040 MTP in April 2015. The multiple step process began before the CCSP, but was expanded over time as additional resources became available and the scope of the planning process expanded to include both mitigation and adaptation strategies. Every MTP must produce a baseline socioeconomic forecast based on existing land use plans and policies. The baseline forecast for the 2040 MTP, referred to as the Trend Scenario, in general does not contain mitigation or adaptation strategies other than those policies already adopted. For example, current zoning in some jurisdictions provides modest increases in allowable densities and/or parking reductions to encourage transit-oriented development in some areas.

In addition to a Trend Scenario, the 2040 MTP contains a Preferred Scenario which presents an alternative vision for growth in the region. While the Trend Scenario is the officially-adopted forecast for the region, MRCOG is now working with member governments to implement the principles of the Preferred Scenario, including a greater range of mitigation strategies and adaptation considerations, with the hopes of shifting the baseline plans and policies over time and changing the region's trajectory toward one of improved mobility and increased resiliency.

Scenario development began with a comprehensive outreach process that included efforts to identify the greatest challenges perceived to be facing the region. The process included an MTP questionnaire (a sample size of 1,371), public meetings, and input from agency technical committees. The results were compiled and through an interagency Land Use-Transportation Integration (LUTI) Committee became the inspiration for a series of "scenario concepts" that related the challenges to general growth principles.

In consultation with member agency representatives, MRCOG staff then developed a set of preliminary scenarios that incorporated the scenario concepts into the MRCOG modeling environment where a series of performance measures could be applied. Two rounds of scenarios were presented at workshops held in summer 2014, where stakeholders from natural resource, land use, and transportation fields considered the benefits of the proposed scenarios and the extent to which the scenario addressed mitigation and adaptation needs, alongside more traditional land use and transportation measures.

Key Components of the Preferred Scenario

The scenario planning process revealed a broad set of future objectives, including: increased transit service, a mix of uses in key locations, a better balance of housing and jobs, emphasizing development in existing water service areas, enhanced preservation of open space and sensitive areas like floodplains and crucial wildlife habitat areas, and preservation of historic and cultural assets. Some of the objectives voiced by stakeholders appeared in conflict on the surface; for example, the desire for dense, unique activity centers, as well as the preservation of much of the region's rural character. It became clear through scenario planning efforts that these two interests can in fact support each other by targeting growth in key centers instead of developing on agricultural and other sensitive lands.

Ultimately, the Preferred Scenario emphasized development within major activity centers and along key commercial and transit corridors in order to create a mix of activity and create opportunities for a greater number of trips to be completed without a private vehicle. To achieve the effect of emphasizing development in desired locations, MRCOG utilized tools within the modeling environment to make these locations more attractive for development. More on this process can be found in the following section.

MODELING METHODOLOGY

Each of the scenarios was simulated using a land use model (UrbanSim) and a travel demand model (Cube). As land use and transportation are proven to influence one-another, the models were run iteratively (see FIGURE 1). More specifically, the land use model was operated from the 2012 base year through the 2025 timeframe. Results were fed to the travel demand model, where outputs, or skims, were generated for the year 2025, which were subsequently fed into the land use model so that accessibility and network conditions could inform development patterns between the 2025 interim year and the 2040 forecast year. Final travel demand model runs were then performed for the year 2040. The accuracy of the forecasted data relied on the professional expertise and judgment of the land use and travel demand modeling group at MRCOG, where both models are housed and operated. The following sub-sections discuss more on each of these models.

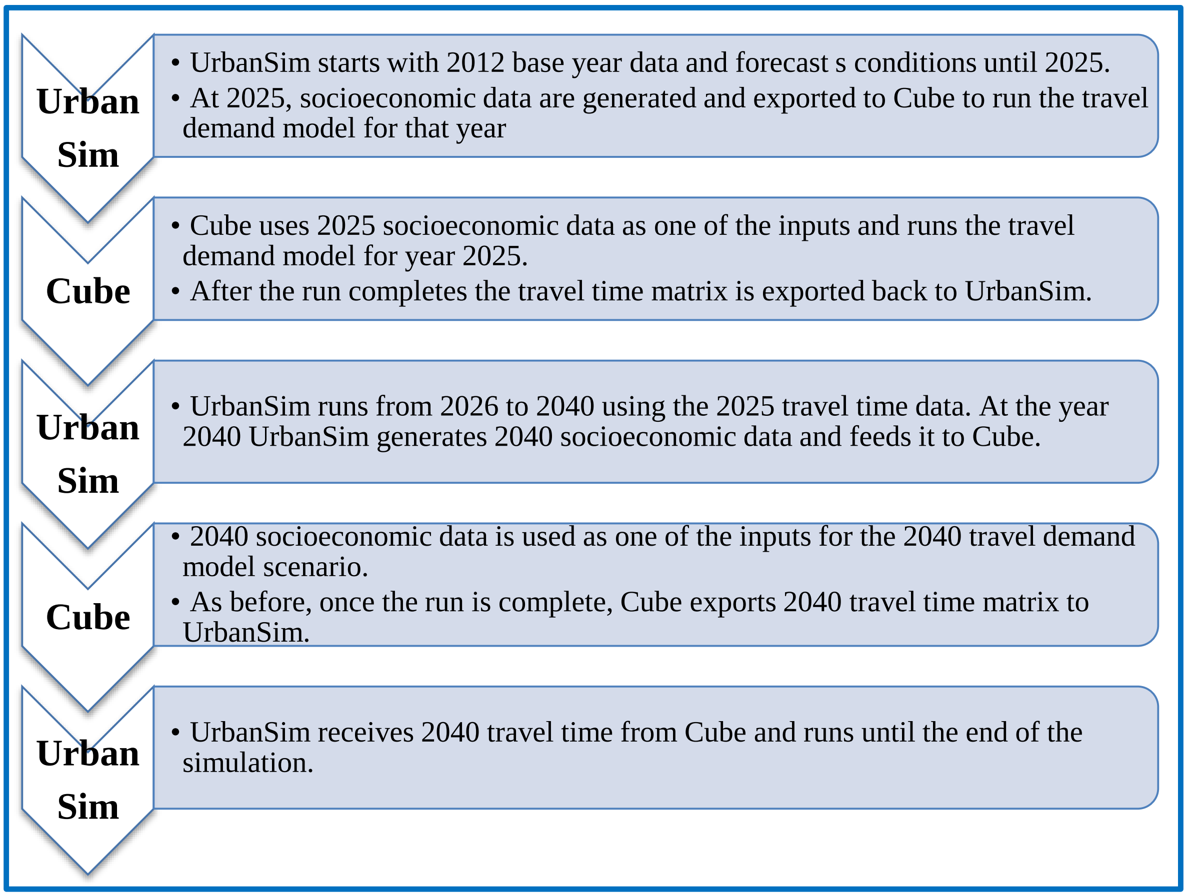

FIGURE 1 UrbanSim-Cube Interaction Used for MRCOG Modeling Purposes.

To reflect stakeholder feedback emphasizing development in major activity centers that could be connected via public transit, MRCOG worked with member agency staff to identify a set of locations where development would be incentivized, as well as an expanded transit network to support the proposed land uses. This “conceptual” network includes the implementation of three recently studied Bus Rapid Transit routes, expanded local service, and increased frequencies across the existing transit network. To maintain fiscal constraint, service levels were based on the improvements possible under a potential gross receipts tax (GRT) increase of 3/8-cent. (The Rio Metro Regional Transit District, which serves all of the AMPA, currently levies a 1/8-cent GRT to fund operations for a regional commuter rail service and other bus transit routes. Rio Metro

RTD may levee up to ½-cent in GRT, though all increases are subject to voter approval.) Due to the desire to maintain fiscal constraint and the support of the policy board during the MTP development process, the Trend and the Preferred Scenarios are based on the same infrastructure network and set of proposed transportation projects.

Land Use Model

The UrbanSim land use model is a software-based simulation system that incorporates the interactions between land use, transportation, economic conditions, and the environment to assign new growth over time. UrbanSim supports planning and analysis of urban development and helps explore the effects of infrastructure and policy choices on development and land use patterns. The model is estimated and calibrated based on historical trends and development theory. It is important to note that, unlike some sketch planning tools often used in scenario planning that rely on the user to allocate growth, UrbanSim is a predictive forecasting model. In practice, UrbanSim allows users to test whether locations are attractive for development based on market and accessibility-related factors, or whether additional incentives must be applied to incentivize development in particular locations.

The land use model utilizes parcels as the smallest geographic entity for analyzing, aggregating, and creating the database structure. Base year data for 2012 data were used as initial inputs for starting each scenario simulation. Zoning, planned developments, and land use constraints also serve as inputs to UrbanSim. UrbanSim was used to produce a socioeconomic forecast for every five year interval between 2015 and 2040.

Travel Demand Model

MRCOG utilizes a travel demand model that was developed using the Cube modeling software suite. Unlike the land use model, travel model scenarios were built for years 2025 and 2040 only. The model inputs corresponding to the 2025 Trend Scenario included 2025 socioeconomic data, a highway network for 2025, and a base-year transit network reflecting the fact that no transit improvements were assumed between 2012 and 2025. The inputs to the 2040 Trend Scenario included socioeconomic and highway network data for year 2040, and a 2012 transit network with limited improvements.

The model inputs corresponding to both the 2025 and 2040 Preferred Scenario differed from the Trend Scenario in terms of expanded transit networks. The differences in the transit network characteristics, therefore, played the primary role in distinguishing the Trend from the Preferred Scenario in the travel demand model.

Incentives and Disincentives for Growth

To reflect development incentives, policies, and other unobserved factors that may impact development activity, a series of “levers” were applied within the UrbanSim model. These levers act as proxies for various elements that may encourage or discourage growth in particular locations. In practice, the levers are asserted variables in the various location choice models that scale probability of development upward or downwards in various ways.

Areas identified for incentivizes were chosen by regional stakeholders and were represented by activity centers and transit nodes. Activity centers were stratified by three tiers and reflected a hierarchy of prioritization defined by stakeholder input. The tiered levers were applied to data analysis subzones (DASZs) that roughly defined each center (a DASZ is the geographic unit of analysis used in the MRCOG modeling environment). A parcel-based lever was also developed that operated by tagging parcels within a user-defined radius of transit nodes and major commercial corridors and increasing the level of attractiveness. Wherever shifters are applied in UrbanSim, the level of development is capped by amount of land available and the existing zoning capacity.

Motor Vehicle Emission Model

The EPA Motor Vehicle Emission Simulator (MOVES) was used to estimate GHG emissions for each scenario. Traffic volume, speed data, and the composition of regional vehicle fleet are among the main factors affecting vehicle emission rates. The vehicle fleet composition was collected from the City of Albuquerque's Environmental Health Department and used as an input to MOVES in order to calculate emission rates for carbon dioxide, methane, and nitrogen dioxide for summer and winter times. Seasonal rates were averaged to estimate annual average emission rates. Depending on the roadway type and average speed, appropriate annual average emission rates were selected and multiplied with the vehicle-miles traveled (VMT) to obtain the daily emission for a roadway segment. System-wide emission for a pollutant was calculated simply by summing up its link level emissions (*EMI and UNM 2015*).

INCORPORATING CLIMATE CHANGE CONSIDERATIONS INTO THE SCENARIO PLANNING PROCESS

Mitigation

Different techniques were applied to incorporate mitigation and adaptation considerations into the Preferred Scenario. Mitigation strategies were explicitly incorporated into scenario inputs through changes in zoning and incentives for development in locations that support compact development, alternatives modes of transportation, and reduction of trip lengths. The conceptual transit network also expanded options for non-single-occupancy vehicle travel. This approach is consistent with the Transportation Research Board's Driving and the Built Environment, which states that: "The greatest opportunities for building more compact, mixed-use developments (and therefore reducing travel demand and GHG emissions) are likely to lie in new housing construction and replacement units in areas already experiencing density increases, such as inner suburbs and developments near transit stops and along major highway corridors or interchanges" (*TRB 2009*). The results of these policies were significant improvements in key transportation and accessibility indicators in the Preferred Scenario relative to the Trend Scenario (see

TABLE 1).

TABLE 1 General Performance Measures- Trend and Preferred Scenarios

Performance Measure	Trend Scenario vs 2012	Preferred Scenario vs 2012	Difference: Preferred vs Trend
Access			
Households Activity Centers	77%	125%	27%
Households near Transit	66%	120%	32%
Households near Employment Sites	28%	47%	15%
Transportation			
Systemwide Speed (MPH)	-40%	-31%	15%
Vehicle Hours Traveled	162%	117%	-28%
Vehicle Miles Traveled	56%	49%	-17%
Transit Ridership	34%	138%	78%
River Crossing Trips	29%	102%	-3%
Average Commute Time	50%	24%	-17%
Sustainability			
New Land Developed (acres)	27%	19%	-17%
Emissions (CO_2)	31%	22%	-8%

The effects of mitigation strategies are most commonly calculated through analysis of emissions reduction benefits. Future scenarios for transportation use in the AMPA show large increase in GHGs from current levels; the Trend Scenario results in a 42 percent increase in CO_2 emissions while the Preferred Scenario results in a 30 percent increase. When compared directly, however, the Preferred Scenario results in an eight percent reduction in overall CO_2 emissions compared to the Trend Scenario. While the total quantity of GHGs increase, mainly due to the region's population growing by 50 percent over the next 25 years, GHGs per capita decline in each scenario. Therefore, the strategies contained in the Preferred Scenario are somewhat effective in curbing mobile source emissions compared to the baseline. Further benefits can be achieved through additional bicycle and pedestrian infrastructure, travel demand management programs that reduce the total volume of trips or change the time of day those trips occur, and roadway efficiency improvements that reduce idling and improve speeds. These strategies and their potential applicability in the AMPA are discussed in more detail the CCSP final project report (*EMI and UNM 2015*) and the Futures 2040 MTP (*MTB 2015*).

Adaptation

Adaptation must be considered in a somewhat less direct manner than mitigation and in the CCSP was assessed primarily through the scenario outputs. That is, the Trend and Preferred Scenarios were developed first then tested for their resiliency to a set of anticipated impacts.

To consider resiliency, the CCSP had to first establish how climate change will manifest itself in central New Mexico and identify the geographic areas that will be most affected. An important and innovative aspect of the CCSP was the identification of changes in average temperature and precipitation levels and an assessment of the impacts those changes would have. According to analyses of CMIP-3 climate data, average annual temperatures will increase 3-4^{0}F by the year 2040 (*US DOT Volpe Center 2015*). In addition to greater overall average temperatures, the number of days with temperatures over 100^{0}F is expected to increase over time. CMIP-3 data also indicates that annual precipitation is likely to decrease, but perhaps only by a small margin (*US DOT Volpe Center 2015*). The true impact of changes in precipitation will be felt in the variability. Climate experts anticipate that central New Mexico is likely to experience increased frequency of droughts as well as increasingly extreme precipitation events. As a result, annual precipitation may not change greatly, but the nature of precipitation is expected to change (*BoR 2013*).

The combined impacts of warmer average temperatures and variable precipitation levels have important implications for central New Mexico. A report by the Bureau of Reclamation, West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment, found there to be likely decreases in overall water availability, observed through changes in the timing of river flows, and increases in the variability of flows along the Rio Grande. Higher average temperatures and higher freezing altitudes mean that the form of precipitation will shift from snow to rain and result in earlier melting of snowpack.

Ultimately, supplies of all native sources to the Rio Grande, which is utilized across much of New Mexico for agricultural purposes and domestic uses, are projected to decrease on average by about one third by 2100, while flows in the San Juan-Chama Project system, which imports water into the Rio Grande, are projected to decrease on average by about one quarter (*BoR 2013*). This work was adapted to the 2040 timeframe through partnerships between MRCOG and the Bureau of Reclamation and Sandia National Labs, which found that flows in the Rio Grande and San Juan-Chama river systems are expected to decrease by seven percent and three percent respectively.

Further impacts of the combined effect of higher temperatures and more variable precipitation include wildfires, as risks increase following long periods without rainfall. Extreme precipitation events that follow periods of prolonged drought also pose the risk of flooding events.
The impacts of such events extend beyond property damage and transportation infrastructure to include water quality. There is also evidence that precipitation events may become more extreme, meaning rainfall events that may have had a one percent annual probability (i.e. a 100-year design storm) may occur more frequently (*BoR 2013*).

DEVELOPMENT PATTERNS AND ADAPTATION TO CLIMATE CHANGE

Incorporating climate change impacts into the scenario planning process requires simplified tools and performance measures that can draw broad regional connections between development patterns and adaptation needs. Many scenario planning efforts consider the development footprint of a region under different scenarios; for instance, in the MRCOG region the Preferred Scenario results in about 12,600 fewer acres and five percent less overall land developed than the Trend Scenario. Four additional climate change-related components were considered through the MRCOG scenario planning process and evaluated using performance measures. These include:

- Forest fire risk areas: level of development in wildland-urban interface areas
- High flood risk areas: level of development in designated 100-year floodplains
- Crucial habitat areas: level of development in high ranking areas using the Western Governors' Association Crucial Habitat Assessment Tool
- Water consumption: number of gallons of water consumed by residential users per year

All of these measures were assessed through spatial analysis, making it possible to observe differences between current and future year land use conditions in different scenarios and the extent to which households and other structures are located in vulnerable locations. In this way the Trend and Preferred Scenarios could be evaluated for their relative resiliency to climate change impacts. Of particular interest was whether emphasizing development in certain locations, such as generally low-risk but regionally significant activity centers, could result in decreased levels of development in at-risk locations. The sections below describe how the CCSP project team utilized available resources to translate climate change impacts into analytical tools and measures.

Forest Fire Risk Areas

According to the University of Wisconsin's SILVIS Lab, wildland-urban interface (WUI) refers to the "area where structures and other human development meet or intermingle with undeveloped wildland" (*University of Wisconsin 2015*). It is because of the inherent, and growing conflicts in these areas that the "WUI highlights the need for ecological principles in land-use planning as well as sprawl-limiting policies to adequately address both wildfire threats and conservation problems" (*Radeloff et al. 2005*).

MRCOG evaluated the composite number of households plus employees located in WUI intermix areas, which are generally located in more peripheral parts of the metropolitan area, in particular the East Mountains area adjacent to sections of the Cibola National Forest. Intermix communities are places where housing and vegetation intermingle. In intermix areas, wildland vegetation is continuous, more than 50 percent of the land is vegetation, and density is greater than 1 house per 16 hectare (*University of Wisconsin 2015*). MRCOG found that emphasizing development in the urban core directly lead to more limited development in these areas: the Trend Scenario projects a 96 percent increase in the composite number of households and jobs in intermix, while the Preferred Scenario projects a 77 percent increase in these areas. When compared directly, there are 10 percent fewer households and jobs in 2040 in WUI intermix areas in the Preferred Scenario than in the Trend Scenario (TABLE 2).

TABLE 2 Adaptation Performance Measures:
Change versus 2012, Trend, and Preferred Scenarios

Performance Measure	Trend Scenario vs 2012	Preferred Scenario vs 2012	Difference: Preferred vs Trend
Growth in Fire Risk Areas	96%	77%	-10%
Growth in Flood Risk Areas	56%	52%	-2%
Growth in CHAT Rank 1 Areas	39%	38%	-1%
Residential Water Consumption	45%	36%	-6%

Flood Risk Areas

The Federal Emergency Management Agency (FEM) designates 100-year floodplains based on the extent of impact likely from a 24-hour 100-year precipitation event. In the AMPA, floodplains are generally located along the Rio Grande and arroyos that flow into the river system. Although the frequency and intensity of extreme events may increase and some individual floodplains may become enlarged, existing FEMA-designated floodplains are the best tool for assessing the risks associated with extreme precipitation events across the region and were used for analysis in the CCSP and 2040 MTP. The Trend Scenario projects a 56 percent increase in the composite amount of housing and jobs in floodplains, while the Preferred Scenario projects a 52 percent increase in these areas (TABLE 2). The relatively minor reduction in growth in the Preferred Scenario reflects the fact that many floodplains are already home to existing communities but that the total amount of new development in these areas was not large in either scenario. Many floodplains have been highly engineered to ensure extreme precipitation events can be properly managed. The most important consideration, therefore, is the concentration of development in floodplains, and whether growth takes place in floodplains that already have flood control infrastructure, or whether that growth occurs in locations where no such improvements have been made. In both the Trend and Preferred Scenarios, the majority of growth in floodplains occurs in the already developed Rio Grande Valley in Valencia County to the south of the city of Albuquerque.

Crucial Habitat Areas

Increased temperature and variable precipitation levels place greater strain on native plant and wildlife species. Beyond basic resource mapping, the CCSP allowed MRCOG and regional stakeholders to further examine the relationship between development patterns and crucial wildlife and vegetated areas. The principal tool used for this analysis is the Western Governors' Association Crucial Habitat Assessment Tool (CHAT). The purpose of CHAT is to inform regional planning across multiple jurisdictions and to "improve analysis of landscape-scale energy, land use and transportation projects as well as land conservation and climate adaptation strategies" (*Western Governors' Wildlife Council 2013*). Crucial habitats are "places containing the resources, including food, water, cover, shelter and 'important wildlife corridors,' that are necessary for the survival and reproduction of aquatic and terrestrial wildlife" (*Western Governors' Wildlife Council 2013*). CHAT rankings, which range from one (most crucial) to six, consider a range of criteria, such as species of concern, freshwater integrity, and natural vegetation areas of concern and are applied a ranking to one-square mile hexagons.

The most crucial habitat areas, and therefore the locations most vulnerable to development impacts, can be found in locations along and near the Rio Grande (FIGURE 2). This means that many high ranking crucial locations for native wildlife and aquatic species are in the region's urban core and historically-settled areas. Relatively undeveloped areas are frequently lower in the CHAT rankings. Unlike most performance measures, the Preferred Scenario produces no significant benefits compared to the Trend Scenario (there is about 40 percent increase in the total number of households and jobs in rank 1 CHAT areas in the Trend Scenario compared to a 38 percent increase in the Preferred Scenario) (TABLE 2).

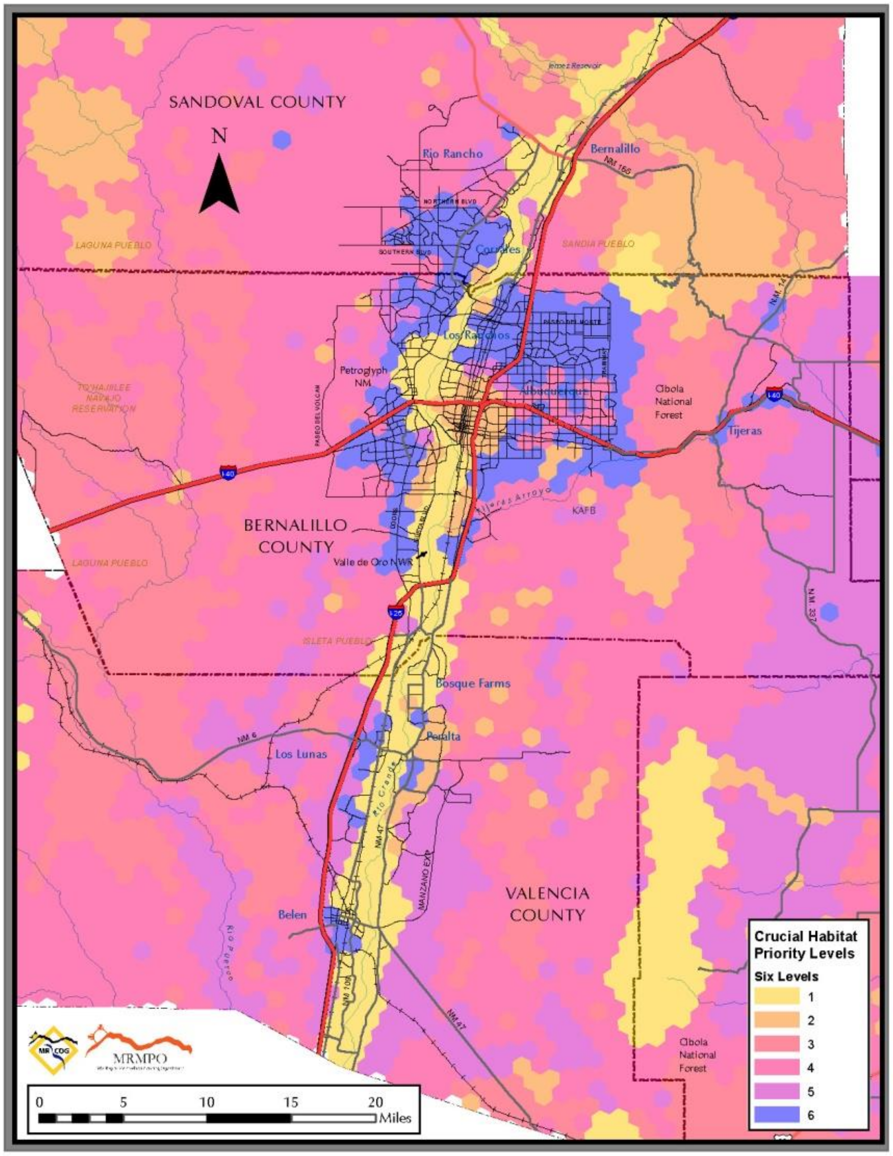

FIGURE 2 Crucial Habitat Priority Levels in the Albuquerque Area

Water Consumption

Given that the region faces diminished water supply over time, the CCSP also considered the relationship between projected land use patterns and future water demand. The first step was an evaluation of water consumption data provided by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) and the New Mexico Office of the State Engineer to create water consumption rates for major land use categories. Water use accounts were provided by the ABCWUA and were linked to parcel-level land use data to determine how water consumption varied by land use, lot size, and year of construction. The analysis found that residential water consumption per housing unit increases as lot sizes increase, most notably for single family homes with less than half-acre lot sizes. The analysis also found that single-family housing units use far more water than multi-family housing units, and that there is a sharp drop in water consumption rates for homes built after 2009 due to the fact that lot sizes are getting smaller and tend to have less irrigated landscaping.

Due to the fairly strong correlation between lot size and water consumption rates, a per-acre water consumption rate was created to calculate overall residential consumption levels. Since the Preferred Scenario results in 12,600 fewer acres required to meet residential housing needs than the Trend Scenario, the Preferred Scenario leads to significantly lower annual water demands.

DISCUSSION

Although the magnitude varies by performance measure, the Preferred Scenario consistently resulted in lower levels of development in sensitive locations than the Trend Scenario. This is significant because only minimal efforts were made to prevent development from taking place in locations that were considered at risk due to climate change. Instead, the primary mechanism for limiting development in at-risk areas was to incentivize development in regionally-significant activity centers and near transit nodes.

In response to stakeholder input, additional policy levers were applied to the final scenarios to reduce the probability of development in these at-risk locations. Specifically, the zoning capacity of parcels within FEMA-designated floodplains and in intermix areas of the wildland-urban interface were reduced by 20 percent. This downward shift was an attempt by MRCOG to reflect the fact that costs of development and insurance rates for parcels in these locations are likely to increase given the prediction that flooding events and wildfires will occur with increased frequency over time. While this step further reduced the amount of development that took place in at-risk locations, reducing zoning capacity had less of an impact than emphasizing development in other locations.

In general, the areas in central New Mexico most at risk to climate change are locations that also promote sprawl and greater travel distances between households and common destinations. Therefore, it can be asserted that in the central New Mexico region, pursuing smart growth strategies is an effective means of increasing the region's resiliency through reductions in growth in previously undeveloped areas. Although much depends on the topography of the region and the existing built environment, these findings indicate that addressing mitigation (i.e. reducing VMT and GHG emissions) can be a simultaneous strategy in some locations for climate change adaptation.

Limitations

The project did, however, reveal some limitations to assessing climate change resiliency primarily through existing spatial analytical tools. For example, to reflect the increase in severity of extreme events 100-year floodplains should logically be buffered out and extended. However, floodplains are a function of topography and the presence of other natural features and cannot be easily adjusted. Thus the CCSP was forced to assume increased risk within existing floodplains only. Similarly, analyses of wildfire risk and crucial habitat areas are based on somewhat crude spatial layers. Water consumption estimates are based on residential demands only, due largely to data quality and the scope of analysis required for full evaluation of all demands across the region. Overall, water demands would presumably be lower in a more compact development scenario as fewer acres of parks or landscaping are required, but such analysis was outside the scope of the project and proxy values were not readily available. Other factors matter; in particular the conversion of water intensive land uses such as agriculture to less intensive uses or to more efficient agricultural techniques and products.

However, it is important to keep in mind the scale of analysis that is appropriate for long-range regional scenario planning. Many adaptation strategies take place at too small of a scale to have a regional impact, or are incorporated into the existing infrastructure, such as green infrastructure. On the other hand, many mitigation strategies, particularly related to alternative modes or roadway efficiency improvements cannot be effectively incorporated into regional-scale travel demand models. Therefore spatial analysis of the kind performed in the CCSP provides important indications of resiliency at a regional level, and is an effective means of assessing the relative benefits of general land use patterns and the interaction between the built and natural environments.

Benefits of Climate Change Scenario Planning

Scenario planning is not meant to identify an ideal future (a key difference with visioning exercises) but to test whether some policies lead to better outcomes than others (or what currently exists). The CCSP demonstrates that scenario planning can be taken further than traditional transportation indicators and that the same socioeconomic forecast used for transportation planning purposes can be applied to a range of natural resource contexts. The real benefit of the CCSP, and perhaps future efforts to integrate climate change into scenario planning, is the ability to draw new connections and link land use and transportation policy choices to as broad a range of impacts as possible.

Consideration of climate change impacts can also be a useful way to frame regional policy discussions, in some cases to instill a sense of urgency for jurisdictions to take action, and to appeal to a broader set of stakeholders. Very simply, addressing climate change may not resonate or appeal to some policymakers, just as addressing congestion or improving transportation options may not be the foremost consideration of others. But if these objectives can be achieved simultaneously and the discussion can be framed in terms of co-benefits, there may be a greater chance of achieving meaningful policy changes. Reducing VMT becomes a co-benefit of limiting growth in areas increasingly at-risk to wildfires and vice versa. Likewise, addressing residential water resource demands is a co-benefit of increasing mobility through policies designed to improve mobility and reduce trip lengths.

BIOGRAPHICAL INFORMATION

Benjamin Rasmussen is a community planner with expertise in transportation in parks and public lands, climate change mitigation and adaptation, and regional transportation planning. In addition to having managed the Volpe portfolios for the U.S. Fish and Wildlife Service, the U.S. Forest Service, and the NPS Midwest Region, Benjamin also managed projects for the Federal Highway Administration, the Federal Transit Administration, and local, regional, and state transportation planning agencies. Before joining Volpe, Rasmussen worked as a senior program officer for an international environmental non-profit organization and as a transportation planner for a metropolitan planning organization. He is a member of the Transportation Research Board's Metropolitan Policy, Planning, and Processes Committee and the Special Task Force on Climate Change and Energy. Benjamin holds a master's degree in Regional Planning from the University of North Carolina.

Aaron Sussman is a senior planner for the Mid-Region Council of Governments where he recently managed the long-range transportation plan update for the Albuquerque metropolitan area. Aaron is also involved in a variety of transit planning and data collection activities, and led the development of the Project Prioritization Process that helps determine how federal transportation dollars are allocated in the region. He holds master's degrees in Latin American Studies and Community and Regional Planning. Aaron is also an adjunct lecturer at the University of New Mexico.

REFERENCES

Bartholomew, K. Land Use-Transportation Scenario Planning: Promise and Reality. *Transportation: Planning, Policy, Research, Practice*, Vol. 34, Issue 4, 2006, pp. 397-412.

Bureau of Reclamation. *West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment*, Executive Summary, December 2013.

Cambridge Systematics. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Urban Land Institute, Washington, D.C., 2009.

Ecosystem Management, Inc. and University of New Mexico. *Central New Mexico Climate Change Scenario Planning Project Final Report*, March 4, 2015.

Metropolitan Transportation Board. *Futures 2040 Metropolitan Transportation Plan*, Albuquerque, NM, April 17, 2015.

Radeloff, V.C, B. Hammer, S. I. Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. The Wildland-Urban Interface in the United States. *Ecological Applications*, 2005, p. 79805.

Transportation Research Board. *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and* CO_2 *Emissions*, Special Report 298, Washington D.C., 2009.

United Nations Environment Programme. http://www.unep.org/climatechange/mitigation/. Accessed on July 30, 2015.

United Nations Environment Programme. http://www.unep.org/climatechange/adaptation/. Accessed on July 30, 2015.

U.S. Department of Transportation. *FHWA Scenario Planning Guidebook*. http://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/. Accessed July 15, 2015.

U.S. Department of Transportation Volpe Center. *A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning: Lessons Learned from an Interagency Pilot Project on Cape Cod*, March 2012.

U.S. Department of Transportation Volpe Center. *Integrating Climate Change in Transportation and Land Use Scenario Planning: An Inland Example, Climate Futures Analysis for Central New Mexico*, March 2015.

University of New Mexico. *Center for Water and the Environment*, http://cwe.unm.edu/research/watersheds.html. Accessed July 29, 2015.

University of Wisconsin SILVIS Lab. silvis.forest.wisc.edu/maps/wui_main. Accessed July 29, 2015.

Western Governors' Wildlife Council. *Western Governors' Crucial Habitat Assessment Tool (CHAT): Vision, Definitions and Guidance for State Systems and Regional Viewer*, July 2013, p. 3.