MPC-361

January 1, 2012 – December 31, 2013

Project Title:
Building a Framework for Transportation Resiliency and Evaluating the Resiliency Benefits of Light Rail Transit in Denver, Colorado

University:
University of Colorado Denver

Principal Investigators:
Wesley Marshall, PhD, PE
Asst. Professor
University of Colorado Denver
Department of Civil Engineering
Phone: 303-556-3741
Email: wesley.marshall@ucdenver.edu

Research Needs:
Justification for transportation infrastructure and major transit investments are often measured in terms of mobility improvements, congestion relief, environmental benefits, operating efficiencies, cost effectiveness, and/or economic impacts (ECONorthwest and PBQD 2002). Calculating such measures is an important step in alternative analysis; however, these same measures – even in combination – fail to properly illustrate the added resiliency provided by a diversity of mode options and compact, mixed-use, mixed-income, transit-rich developments.

Transit-based cities, for instance, have been shown to allocate between one-third and two-thirds less wealth on transportation as compared to automobile-based cities (Newman and Kenworthy 1999; Newman, Beatley et al. 2009). Accordingly, regions with a better transit infrastructure would be able to better cope with exogenous influences such as fluctuating gas prices. In other words, a community with considerable transit infrastructure – even if experiencing minimal ridership today – would be able to withstand a shock to the system such as rising gas prices far better than an auto-dependent city that has not invested in transit. More specifically, this conceptualization of resiliency to something like rising gas prices is not comparable to elasticity studies that have considered how relatively minor gas price adjustments have impacted travel behavior; rather, we are interested in how a city would respond to a *major* shift in gas prices. Such risks are by no means consistent as impacts would vary considerably across regions, cities, and neighborhoods, as well as between various socio-demographic populations (Huiping, Fernandez et al. 2005).

This research will investigate the resiliency value of transit infrastructure and transit-oriented developments (TODs). Much of the early resiliency research was qualitative and looked at resiliency primarily through the lens of natural disasters such as hurricanes, earthquakes, or tsunamis (Foster 1995; Chang and Nojima 2001; Bruneau, Chang et al. 2003; Pelling 2003) or terrorist attacks (Battelle 2007). More recently, the concept of resiliency has become more quantitative and expanded to transportation (Berdica 2002; Cova and Conger 2004; Husdal 2004; Murray-Tuite 2006; Heaslip, Louisell et al. 2010; Serulle, Heaslip et al. 2011). While overall resilience has been relatively well characterized as a result of the many different disciplines working on the issue, transportation resilience is less well defined. For instance, overall resilience represents the ability to perform under shock effects (shock-absorption), to avoid the shock altogether (vulnerability), or the ability to recover quickly from a shock (shock-counteraction) (Briguglio, Cordina et al. 2005); transportation resilience has to do with the ability of the transportation system to maintain a desired level of service or the time it takes to return to that level of service given a shock to the system (Heaslip, Louisell et al. 2009; Heaslip, Louisell et al. 2010). The transportation research that has looked beyond resilience related to natural disasters and terrorist attacks has most often been economic (Echeverry, Ibanez et al. 2004; Briguglio, Cordina et al. 2005; Zheng, Garrick et al. 2010) and focused on issues such as gas prices (Dodson and Sipe 2006), but there has also been a strand more focused on environmental issues such as climate change (Brenkert and Malone 2005). There are, however, social implications as well. Peter Newman, for instance, recalls some of the broader impacts of the 1973 oil crisis saying:

> *"Social disarray began to be displayed as people stole fuel, and across society there were myths about giant caverns of oil being stored by greedy oil companies and environmentalists were being accused of causing the deadline. What stay with me from this time was how suddenly a city can flip into a state of fear. It seemed to paralyze the city and lead to behavior you would never expect in normal times"* (Newman, Beatley et al. 2009).

Today's society has seen many low-income households relocate to the suburban fringe in an effort to find more affordable housing. Without options beyond the automobile, these are the very same households that are likely to experience the greatest negative impact of rising gas prices. The resultant issue is that such circumstances can lead to crime and political unrest (Newman, Beatley et al. 2009). Even if such drastic consequences fail to materialize, there are likely to be unwelcomed behavior changes. A 1975 study investigating travel behavior changes in the U.S. versus those in Europe during the oil embargo revealed that Europeans significantly increased their transit use while Americans were much more likely to stay home and forego essential travel (Pisarski and Terra 1975).

The key contributions of this research are that we will build upon the existing quantitative, transportation resiliency work by first developing a framework for assessing transportation resiliency under the broader scope of transportation sustainability, which includes the consideration of economic, environmental, and social impacts. Using this framework, we will quantify transportation resiliency with respect to the light rail transit system in the metropolitan Denver, Colorado region across four different geographic levels: regional, citywide, neighborhood-scale, and household-level. This work will also enable us to assess distance-decay effects around different types of transit stations as well as variation across different socio-demographic populations. In other words, this research will explore the varying impact of transit infrastructure and TODs on the ability of different households to be resilient to uncontrollable outside forces, such as rising gas prices.

This work will be done in the Denver metropolitan region. Denver is a valuable case study, as it represents a second-generation mass transit light rail system in a region that was, and still is in many cases, extremely auto-dependent (Regional Transportation District 1982). The initial results will therefore be more applicable to a greater number of cities than results from cities such as New York City, Boston, or Washington, DC. However, the methodology itself will be applicable to cities across the country as valuable tool toward increasing our transportation-related resiliency. The results will offer a better understanding of the risks mitigated by diverse transportation infrastructures and, in turn, help shape more resilient, and more livable, cities. Resiliency with respect to transportation is about risk management and that which threatens a community's ability to sustain high livability for its residents, and research to advance livable communities is one of the strategic goals of the Mountain Plains Consortium as well as the University Transportation Center program and USDOT in general. This research will help increase our understanding of transportation resiliency with respect to our transit investments, how we design around our transit systems, and how those investments affect different communities and populations.

Research Objectives:

This research effort will further develop the concept of transportation resiliency and build a framework for evaluating the resiliency benefits and value of a major transit investment. Rather than the traditional definition of as a community's ability to withstand and bounce back from a natural disaster, resiliency will be defined as a subset of an overall sustainable transportation framework and examined at several levels or geographic scales: regionally, citywide, neighborhood-scale, and at the household level. The analysis will also explore beyond current behaviors and examine the resiliency benefits of certain transportation infrastructures on the populations that have access to them, even if they are not currently being utilized. The analysis will also not be constrained to simply an evaluation of transit infrastructure, as there are also resiliency-related benefits of TODs and, for example, mixed-income and mixed-use neighborhoods.

The objectives and key contributions of this research are that we will build upon the existing quantitative, transportation resiliency work by:

1. Developing a quantifiable framework for assessing transportation resiliency under the broader scope of transportation sustainability, which includes the consideration of economic, environmental, and social impacts;
2. Investigating transportation resiliency variation across four different geographic levels: regions, cities, neighborhoods, and households;
3. Evaluating the distance-decay effect around transit infrastructure
4. Assessing transportation resiliency variation across different socio-demographic populations; and
5. Incorporating the varying impact of TOD typologies and the impact of features such as station area land uses and street networks

These results can be used in planning transportation infrastructure, developing regional resiliency plans, and for future studies on related topics.

Research Methods:

This research will initiate with a thorough literature review of both transportation resiliency and transportation sustainability. The intent is to study resiliency as a subset of an existing sustainable transportation framework so that a broader range of impacts can be considered. Quantifiable performance measures will be then proposed under the transportation resiliency framework with the related goal of collecting the data needed to achieve the above objectives. These performance measures will be carefully selected so that transportation resiliency can truly be considered. For instance, vehicle miles traveled (VMT) is commonly used a proxy for issues such as resiliency or sustainability. VMT is important because it is typically considered a good proxy for low automobile ownership, better proximity to jobs, and higher walking, biking, and transit usage. All of these factors do indeed relate to resiliency; however, using VMT as the basis for resiliency-related performance metrics has limitations that often fail to distinguish between the successful and not-so-successful locations. For instance, while some VMT contributes to economic and social prosperity, there is also what is known as "empty VMT" without the same merits. Moreover, low VMT per capita does not necessarily mean there is a regional benefit and could be more indicative of high unemployment rates. On the other hand, high VMT per capita does not necessarily mean that people do not have access to transportation alternatives other than driving. While certain outcomes – such as the fact that households in the Atlanta region consume 1,050 gallons of gas each year while those in the New York City region only use 480 each year – are often interesting and sometimes telling, numbers based on VMT estimates offer an incomplete view of the true issues (Helman 2011). Accordingly, the goal is to find transportation resilience performance metrics that are neither too coarse-grained nor dependent upon exogenous factors.

Beyond national datasets such as the U.S. Census and the American Community Survey, data will be collected from a variety of primary and secondary sources across the Denver region including the transit provider, the Regional Transit District (RTD), and the MPO, the Denver Regional Council of Governments (DRCOG). Both RTD and DRCOG have signed letters of support for this study and have agreed to provide data and resources as necessary. For instance the Front Range Travel Survey, a 12,000 household effort recently completed by DRCOG, will be leveraged in order to help associate disparities in transportation infrastructure with travel behaviors. Existing survey data such as the FRTS survey will be geocoded into a GIS database and, if necessary, supplemented with more targeted surveys and interviews. Additional GIS data will be collected from the aforementioned agencies as well as from individual cities and towns within the region. Since the Denver light rail infrastructure is relatively recent (lines opened in 1994, 2000, 2002, and 2006) and still under construction (lines are scheduled to open in 2013, 2016, and 2018), the associated TODs are also evolving. Thus, additional field data will be collected at TODs throughout the region so that the GIS data, for factors such as the built environment, corresponds with the travel behavior data.

Current measurements that evaluate feasibility of transit investment – such as mobility improvements, congestion relief, environmental benefits, operating efficiencies, cost effectiveness, and/or economic impacts – fail to illustrate the added resiliency provided by a diversity of mode options and compact, mixed-use, transit-rich developments. There is however a value to the transit system, even in cases when ridership is low. Sometimes called the "option value" of transit, the basic concept is that the availability of transit holds a certain value to people. Methods of quantifying this value are typically similar to how an insurance company derives their life insurance premiums. The problem is that resiliency risks tend to be far more unpredictable than figures such as mortality rates. Even a seemingly simple to quantify risk such as gas prices, where the popular press and most experts predict that prices will continue to rise, is too volatile and unpredictably to produce reliable long-term models (Mackay 1991). As a result, we will also investigate assessing transit more similarly to how a Wall Street options trader might assess stock volatility (ECONorthwest and PBQD 2002). Options traders do not work in stocks directly but rather in the volatility of stocks by attempting to calculate the probability that a particular stock will drop below a certain price or move higher than a certain price (Gladwell 2002). In terms of driving, the cost and convenience of driving can fluctuate similarly to stock prices. At some point, the transit option has value and estimating that value, despite the volatility in the conditions, can assist in establishing a resiliency value. Accordingly, resiliency will be measured ad aggregated across four geographic levels:

1. Household
2. Neighborhood
3. Citywide
4. Region

Assessments will be considered for these areas with respect to existing light rail transit infrastructure versus a scenario without such transit investments. Results of such a comparison will be useful in planning future transit services. As mentioned before, all data collected will be geocoded so that distance decay effects can also be considered. To assist us in testing the resiliency of various transportation and land use scenarios, DRCOG has granted us access to their region-wide, activity-based transportation planning model as part of this effort. Resiliency to potentially adverse events – such as the ability to accommodate, withstand, or handle stresses unexpected link disturbances, accidents, infrastructure construction/repairs projects, major sports and cultural events, adverse weather, disasters, or economical impacts such as energy supply disruptions, gas price increases, or individual economical impacts (i.e. job loss or loss of driver's license) – will be quantified across the four geographic scales with respect to transportation infrastructure differences and considered in terms of impact on different socio-demographic populations.

Current travel behaviors and transit usage play a role in the resiliency variations across different geographic and populations, but it is also expected that transit capacity will also be an important factor (Morlok and Chang 2004). In preliminary investigations into possible methods for quantifying this type of resiliency, we have started to examine the transit capacity flexibility literature. For instance, Figure 1 – adapted from the transit capacity flexibility work of Chen and Kasikitwiwat (Chen and Kasikitwiwat 2011) – is an example of how we might being to measure added resiliency due to currently unused transit capacity using bi-level network capacity models. While their study did not consider resiliency, for our purposes, 1st level resiliency begins with current transit usage but expands with increasing demand up to a maximum transit capacity.

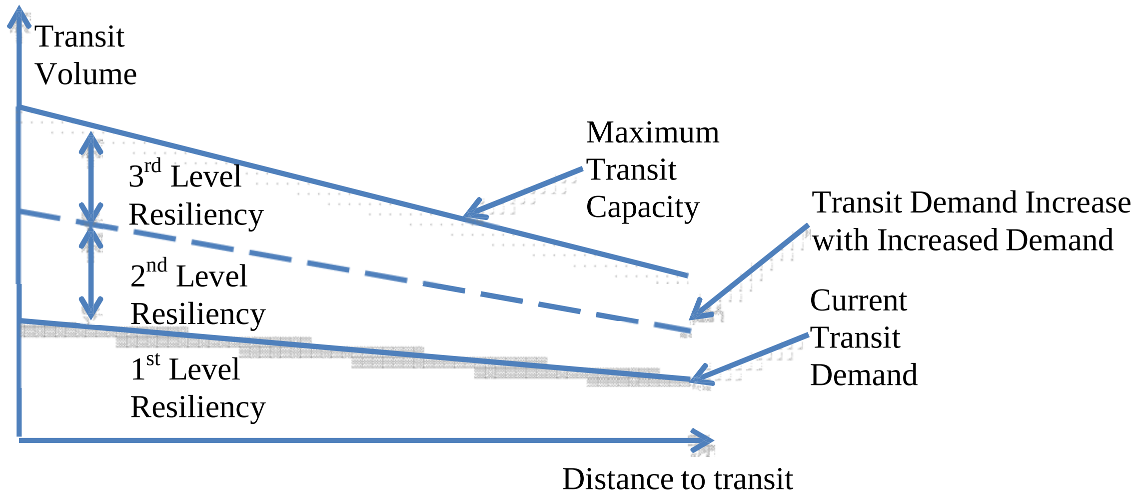

Figure 2 Transit-related resiliency measures benefits with gas price increases and distance decay effects (adapted from Chen and Kasikitwiwat, 2010)

Expected Outcomes:
As discussed in the research needs and objectives, the expected outcomes of this work include:

1. A quantifiable framework for assessing transportation resiliency;
2. A better understanding of transportation resiliency across regions, cities, neighborhoods, and households;
3. An evaluation of the distance-decay effect around transit infrastructure;
4. An assessment of transportation resiliency variation across different socio-demographic populations; and
5. An understanding of the varying impacts of different TOD typologies.

Potential adverse events - such as gas price increases - will likely increase transit demand as allowed by the capacity of the system; thus, we expect to find an increase in resiliency in areas better served by transit. We also expect to find a decrease in resiliency and potential benefits as the distance to major transit infrastructure increases, also known as the distance decay effect, as well as varying effects on different socio-demographic populations. Station area type (ranging from a full park-n-ride facility to a TOD that is highly integrated into the surrounding community) will also likely play a role in resiliency across geographies, distance decay, and varying populations (Bernick and Cervero 1996; Dittmar and Ohland 2004; Evans and Pratt 2007). Since Denver represents a second-generation light rail transit system in a region that is still very auto-dependent, these results will be more applicable to a greater number of cities than results from cities with older, more established mass transit systems. The results of this work will be published in peer-reviewed journals, and/or peer-reviewed conference proceeding, as well as presented at national conferences. This work will also be used to develop future proposals on related topics, such as similar studies in other regions across the U.S. or even internationally.

Relevance to Strategic Goals:

The work primarily falls under the heading of livable communities as discussed above, but it also highly relates to both economic competitiveness and environmental sustainability. A framework for evaluating resiliency benefits, including economic competiveness, provided by a diversity of mode options in transportations, mixed-use, transit-rich developments allows major transit infrastructure proposals to be more competitive with other project options. Major transit investments, in turn, provide cities to be more environmental sustainable. In many cities, the majority of the population drive because they have few other viable alternatives; thus, the results will offer a better understanding of the risk mitigated by diverse transportation infrastructure and, in turn, help shape more resilient and more livable cities.

Educational Benefits:

This study will be integrated into Dr. Marshall's "Sustainable Transportation Systems" graduate course through a case study approach that will not only present research materials to the students, but since the study is local, students can be involved in data collection and analysis as part of their term projects. The course is based in the Civil Engineering Department but cross-listed in Urban and Regional Planning as well as Public Administration. The GIS data will also be made available to students in the Master's of Engineering GIS program for use in term projects or master's reports. As a result, this project will influence students from a variety of disciplines that comprise our future transportation professionals.

Work Plan:

The proposed scope of work is scheduled for a one year timeframe, beginning with notice to proceed from the Mountain Plains Consortium. Major project steps include the following:

Task	Timeline
Initiate secondary data collection efforts	Ongoing (beginning in month 1)
Literature review	Months 1-2
Stakeholder meetings with RTD and DRCOG	Months 1-2
Develop resiliency framework	Months 3-6
Build GIS database	Months 3-6
Collect field data	Months 3-6
Develop and conduct survey and/or interview work	Months 3-6
Organize and geocode data	Months 6-7
Preliminary data analysis	Months 7-8
Run DRCOG activity-based model scenarios	Months 8-9
Conduct analyses and generalize findings	Months 9-10
Disseminate key findings and publish results	Months 11-12

Findings will be published in peer-reviewed journals, and/or peer-reviewed conference proceeding, as well as presented at various conferences. This work will also be disseminated to both RTD and DRCOG with the intent of helping them better guide future development.

Project Cost:
Total Project Costs: $251,749.59
MPC Funds Requested: $125,000
Matching Funds: $126,749.59

Source of Matching Funds: For this project, the Dean of Engineering at the University of Colorado Denver has pledged $10,000 in matching funds in addition to the return of the College of Engineering's share of overhead return to the project itself. Combined with the overhead return from the P.I. that will be put back into the project itself, the estimated cost share amount is $4,000. Total hard matching funds for this project are $14,000. The remaining cost share will be use a combination of academic year research time from Drs. Marshall and Janson. Each will contribute nine months of academic year research time, which will be combined with $1,200 in staff time that was donated by RTD. Drs. Marshall & Janson will contribute 50% of academic year research time for both years. The total soft match is $112,749.59, which when combined with the $14,000 in hard match, totals $126,749.59 in matching funds.

TRB Keywords:

Transit, light rail, transit-oriented developments, resiliency, livability, travel behavior, street networks, capacity, active transportation

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