Title: Sustainable Transportation Infrastructure Investments and Mode Share Changes: A 20- year background of Boulder, Colorado.

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## ABSTRACT

This case study examines transportation infrastructure investments along with data revealing mode share in order to highlight correlations between investments in sustainable transportation infrastructure ('supply') and patterns of non-automobile mode share ('demand'). The analysis assesses data from Boulder, Colorado, a city that has made substantial efforts to improve its multi-modal transportation infrastructure and services by investing in pedestrian, bicycle, and transit infrastructure and services. We aim to describe connections between supply and demand by measuring two phenomena: the extent of transportation infrastructure investments supporting pedestrian, bicycle, and transit modes made between 1990 and 2009; and the share of these modes during the same twenty year period. Results illustrate an overall increase in transit and bicycle mode share and a decrease in single occupancy vehicle share, with consistent pedestrian share. We conclude that Boulder's investments in improving mode choices through new infrastructure and services supporting non-automobile modes are associated with increasing share of non-automobile modes. This is despite national trends that indicate an increasing automobile mode share. Regardless of the reasons for the positive trends experienced in Boulder, the presence of robust pedestrian, bicycling, and transit infrastructure has clearly coincided with evolving travel preferences. Boulder therefore serves as an example for other cities desiring to focus on developing policies and infrastructure that expand the availability of non-automobile modes.

## KEYWORDS

Multi-modal Transport; Sustainability; Infrastructure Policy; Mode Share

# 1.0 INTRODUCTION

Communities across the United States (US) are increasingly promoting walking, cycling, and transit as sustainable modes of transportation in an effort to achieve a wide range of benefits including reduced congestion, lower levels of air pollution, decreased fuel dependency, and improvements to human health. Such outcomes, however, require substantial shifts away from auto-dependence, which few cities in the US have achieved. Boulder, Colorado is one of the few cities (along with other outliers such as Portland, Oregon; Davis, California; and Cambridge, Massachusetts) that has invested heavily in sustainable transportation infrastructure over recent decades and simultaneously experienced increased share of these modes. The city has been recognized as a "Platinum" bicycle-friendly community ('League of American Bicyclists,' 2012) and boasts an extensive local and regional transit system. Interestingly, travel behavior in Boulder did not differ appreciably from neighboring communities as recently as the early 1980s ('Pedestrian and Bicycling Information Center,' 2012), but a series of policy decisions and infrastructure investments over the past 30 years have coincided with Boulder's rise to outlier status among US cities for non-auto travel (Krizek and Langegger, 2009).

This paper systematically reviews transportation investments made between 1990 and 2009 in Boulder along with data on mode share in order to highlight correlations between investments in sustainable transportation infrastructure and increased use of these modes. The study first examines funding allocated to pedestrian, bicycle, and transit infrastructure, and then evaluates changes in mode share for pedestrian, bicycling, transit, and single occupancy vehicle (SOV) modes using data from multiple local and national sources. We hypothesize that there will be evidence of increased pedestrian, bicycling, and transit use (i.e. mode share) while SOV mode share decreases. We do not attempt to identify causal relationships; rather, we expect to observe a pattern in which infrastructure investments over the last twenty years are associated with increased rates of non-auto travel. Indeed, results support this hypothesis: we find that Boulder invested heavily in the 'supply' of non-auto infrastructure while simultaneously experiencing an increase in 'demand' as measured by the mode share of non-auto modes. We conclude by comparing mode shifts in Boulder to national trends and identifying informed recommendations for communities looking to invest in sustainable transportation.

## 1.1 BACKGROUND

Benchmarking and evaluating investments in sustainable transportation is critical for cities interested in promoting these modes, but available data is sparse ('Alliance for Walking and Biking,' 2010). Consequently, academic literature evaluating such investments is even sparser. Another reason for the existence of few studies is the difficulty of examining trends over time with respect to municipal transportation investments and travel behavior (Krizek, et al., 2009). For example, how does one control for complementary land use development resulting from initial transportation investments? Challenges associated with confounding factors make establishing causality extremely difficult (Krizek, et al., 2009). The literature points out that these potential pitfalls are common when the timespan examined is ten years or less but can be reduced by investigating longer periods of time (Dueker and Bianco, 1999; Ratner and Goetz, 2013). Drawing upon a unique dataset that provides supply and demand side data over twenty years, our analysis of Boulder, Colorado offers insights into long-term outcomes associated with sustainable transportation investments.

This paper presents a methodologically-novel investigation of the relationship between investments (in terms of city transportation budget allocations) and mode share. Existing literature tends to focus on investments in mode-specific infrastructure, or alternately, considers the impacts of transportation investments in predictive scenario-analyses. Investments in city-scale bicycling infrastructure (Krizek, et al., 2009) and the implementation of light rail systems (Dueker and Bianco, 1999; Bhattacharjee and Goetz, 2012) have each been analyzed using a "case study" approach to assess the investment's impact

on a variety of outcome measures. There is even a case study paper that considers the differing mode share impacts of a city that invested heavily in limited access highways and off-street parking as compared to one that did not (McCahill and Garrick, 2010). However, we are not aware of any studies that consider walking, bicycling, and transit – and their respective investments – simultaneously.

'Supply' measures in these existing case study papers tends to focus on physical infrastructure (e.g., miles of rail lines or bicycle lanes), rather than investment dollars, which is the focus of this paper. On the other hand, 'demand' measures tend to focus on mode share shifts in all cases. Examples of studies utilizing comparable supply and demand measures similar to this study are largely limited to cost-benefit analyses of proposed investments in sustainable transportation. Cavill et al. (2008) provides a review of economic analyses of transportation infrastructure and policies on health. Gotschi, et al. (2011) present a more recent approach measuring the economic impacts of bicycle investments on health outcomes. Other studies have considered the future impacts of transportation policies on energy use and carbon emissions (Poudenx, 2008). Investments in specific modes, such as bus rapid transit, have also been examined for possible impacts on carbon emissions (Hook et al., 2010) and land development (Rodriguez and Targa, 2003). Taken together, the existing literature underscores the need for research into the relationship between investments in sustainable transportation and travel behavior outcomes at the city-scale.

### 1.2 CASE STUDY SELECTION

Boulder, Colorado, a city of just over 100,000 people, is located approximately 30 miles northwest of Denver at the foothills of the Rocky Mountains. Boulder is home to the University of Colorado, whose 30,000 students swell the city's population during the academic year. Boulder is an ideal case study because it represents a "pilot case" (Yin, 2009) or "atypical case" (Flyvbjerg, 2006) with its high levels of investment in sustainable transportation modes and extensive data collection efforts, thus providing maximum information on promoting sustainable transportation through budgetary investments. The city meets three important criteria needed for this investigation: i) the city has invested heavily in infrastructure supporting non-auto modes; ii) data on mode share and investments over time are widely available; and iii) Boulder has been recognized nationally for their multi-modal transportation system. Until the recent past, Boulder has a history of being relatively auto-dependent, making its experience generalizable to other auto-oriented cities over the long-term.

Over the years, Boulder has made significant investments in the multi-modal network. The city is now well known for its grade-separated bicycle and pedestrian paths, which are integrated into a network of bicycle lanes, cycle-tracks, and on-street bicycle routes. Boulder also provides an innovative community transit network that connects downtown, the University of Colorado campuses, and local shopping amenities. While the city has no rail transit, local and regional shuttle busses are funded by a variety of sources and emphasize minimal headways, enhanced route identity, easy fare payment, and community input in design (RTD, 2005). Due in part to these investments in pedestrian, bicycle, and transit infrastructure, Boulder has been recognized both nationally and internationally for its transportation system. In 2005, the city won the "Best Workplaces for Commuters District" award from the International Downtown Association for its innovative downtown employee Eco Pass Program, which encourages transit use ('City of Boulder,' 2011b). In 2009, the Federal Highway Administration recognized Boulder as an "Exemplary Human Environment Initiative" for one of its multi-modal redevelopment projects ('City of Boulder,' 2008). The city is also one of the first three cities to receive the League of American Bicyclists' "Platinum Bicycle Friendly Community Award" ('League of American Bicyclists,' 2012). Numerous additional accolades recognize the city's unique efforts to promote multi-modal travel ('City of Boulder,' 2011b).

In addition to being the home of a large institution of higher education, Boulder is also a regional population and employment center situated on the western edge of Colorado's Rocky Mountain Front

Range region, a 40-mile wide by 200-mile long area that is home to about 80-percent of the state's population. The Denver-Boulder metropolitan area accounts for approximately two-thirds of the regional, Front Range population.

Between 1990 and 2000, Colorado registered the third fastest state growth rate (Ingram et al., 2009), and between 2000 and 2010, Colorado ranked ninth with a 19-percent growth rate ('U.S. Census Bureau,' 2011b). Unlike the rest of Colorado, Boulder has limited its growth geographically through its own version of an urban growth boundary and internally through zoning control (Krizek and Langegger, 2009; Talucci 2011). While Boulder's population growth rate has been limited to less than one-percent per year, higher growth rates in surrounding communities have shaped regional travel patterns. For example, the population of Boulder approximately doubles during weekdays due to regional in-commuters. The resulting dynamic creates significant peak-hour congestion challenges and strains the local and regional transportation network.

Boulder is now widely recognized within the US as an exemplar in promoting non-automobile travel. The 2009 American Community Survey confirms that Boulder has achieved distinctively high levels of non-auto travel compared to national averages: pedestrian, bicycling, and transit combined transport to work share in Boulder is 32%, as compared to 8.5% nationally ('U.S. Census Bureau,' 2011a).

The city of Boulder's successes in promoting non-auto travel can be attributed to a wide range of social, political, and geographic factors that began to converge in the mid-1960s (Krizek and Langegger, 2009). Many US cities with similar mode shares – Davis, California; Eugene, Oregon; Madison, Wisconsin; and Cambridge, Massachusetts – also share similar characteristics. All top the League of American Bicyclists' rankings, and all are homes to major universities (Krizek and Langegger, 2009). Like Davis, California, the City of Boulder has long been home to a progressive and advocacy-oriented populous that has worked closely with city planners to create an extensive multi-modal transportation network (Buehler and Handy, 2008; Krizek and Langegger, 2009). For example, one of the most significant factors paving the way for Boulder's current transportation system was a 1967 policy dedicating a sales tax to purchasing open space around Boulder and funding the city's transportation infrastructure (Krizek and Langegger, 2009). Limiting the city's growth forced planners to seek creative solutions to serving travelers with varying needs within a confined system. Coordinated protection of open space, a history of advocacy, and a large student population help explain Boulder's history of sustained investment in non-auto transportation infrastructure and continued use of the resulting multi-modal transportation network.

The first Boulder Transportation Master Plan (TMP) was adopted in 1989 and has been updated several times since (1996, 2003, 2008, and 2011). The most recent TMP identifies a goal of developing *"an integrated, multimodal transportation system emphasizing the role of the pedestrian mode as the primary mode of travel,"* as well as an objective of reducing *"single-occupancy-vehicle travel to 25-percent of trips"* ('City of Boulder,' 2011c). Another key objective of these plans has been *"continued progress toward no growth in long-term vehicle traffic."* Specific initiatives call for infrastructure that attends to the needs of pedestrians, bicyclists, transit riders, and motorists.

In 1990, political support from the city council for transit, cycling, and walking was so strong that a new division of the city's transportation department, GO Boulder (Great Options Boulder), was created to focus attention and innovation on the needs of those walking, biking, and taking transit. Specific policies and programs that have addressed these needs from 1990 to 2009 are detailed below.

The following programs and policies were started before 1990 and continue throughout the city (unless otherwise noted):

- Completion of missing links in the sidewalk system throughout the city;
- Continued construction of a greenway network of grade separated bicycle and pedestrian paths;
- Annual bicycle to work day encouragement event (Nordback, 2013);

- Expansion of the neighborhood parking permit program (mostly in central Boulder neighborhoods, along with one program in south Boulder); and
- The addition of 40 miles of bicycle lanes or paved shoulders and 38 miles of shared bicycle and pedestrian paths.

Additionally the following programs or policies were implemented after 1990 and throughout the city (unless otherwise noted):

- Institution of a business- and neighborhood-based deeply discounted transit pass program, called the Eco Pass Program began in 1991 (Nuworsoo, 2004);
- Gradual creation of a network of high-frequency bus routes with 7- to 15-minute headways starting with the Hop circulator route in 1992 (Go Boulder, 2009);
- Addition of a bicycle system plan to the transportation master plan in 1996 (City of Boulder, 1996); and
- Creation of a transportation management organization for east Boulder in 2004 (Boulder East Transportation Management Organization, 2004).

## 2.0 DATA AND ANALYSIS

This study explores the relationship between investments made in sustainable transportation infrastructure ('supply') and associated mode share levels ('demand'). We aim to draw connections between supply and demand by measuring two phenomena: i) the extent of transportation infrastructure investments for pedestrian, bicycle, and transit modes in Boulder; and ii) the percent use of these modes. We measure the extent of transportation infrastructure financially by examining pedestrian, bicycle, transit, and roadway infrastructure investments allocated in city of Boulder annual budgets between 1990 and 2009. To measure patterns of use (demand), we examine mode shares between 1990 and 2009 using three data sources: i) Boulder Resident Travel Diary Study; ii) Boulder Valley Employee Survey for Transportation; and iii) US Census and American Community Survey data.

### 2.1 MEASURES OF SUPPLY

In order to examine supply of non-auto infrastructure, we identify funds allocated in Boulder's annual budgets (1990 to 2009) for pedestrian, bicycling, transit, and roadway investments. The city divides budgeted funds into two types: i) operation and maintenance (O&M); and ii) enhancements. The O&M budgets include funds allocated to maintain and operate current infrastructure, while the enhancement budgets include funds allocated to new infrastructure and improvements to current infrastructure. The enhancement budget includes funds specified in the Capital Improvements Program, which sets spending priorities, schedules projects, and coordinates public physical improvements ('City of Boulder,' 2011a). GO Boulder, the pedestrian, bicycle, and transit organization within the city's transportation department, provided financial information on related improvements. Funds provided for transportation investments by other city departments or outside agencies were not included.

Financial information provided by the city separately reports funds approved for O&M and for infrastructure enhancements attributed to each mode. As enhancement funds may benefit multiple modes, Boulder apportioned funds based on relative expenses for each mode for budgets allocated from 2000 to 2009. For the years 1990 through 1999, budgets were fairly steady and the city estimates that distribution between modes was relatively consistent. For specific projects that include investment in more than one mode (e.g., bridge investment into share of road, share of sidewalk, and share of bike lane) the city used its best judgment to estimate of the division of budget by mode. It is important to

note that the budget reflects the date when dollars were budgeted and approved, not when the dollars were actually spent. Projects were typically completed two to three years after budgeting.

We use the term “investments” to represent the total funds from both the O&M and enhancements budgets. Additional funds for promotional campaigns, deeply discounted transit pass program (Eco Pass), marketing or external transit resources are not included under specific pedestrian, bicycling, or transit budget. These items are listed under the TDM category (see Figure 1).

### 2.2 MEASURES OF DEMAND

Three data sources are used to assess demand, as measured by changes in mode share between 1990 and 2009. First, we use the Boulder Resident Travel Diary Study, which was undertaken on eight occasions during the twenty-year study period and provides benchmarks related to Boulder residents’ travel behavior. The study is conducted with the goal of providing feedback to city staff and council members on the effectiveness of city program goals such as those to reduce SOV travel. At least 1,000 survey respondents record travel activities and mode choices for a randomly assigned day during the third week in September, providing a ±1.3% margin of error for most survey results ('City of Boulder,' 2010).

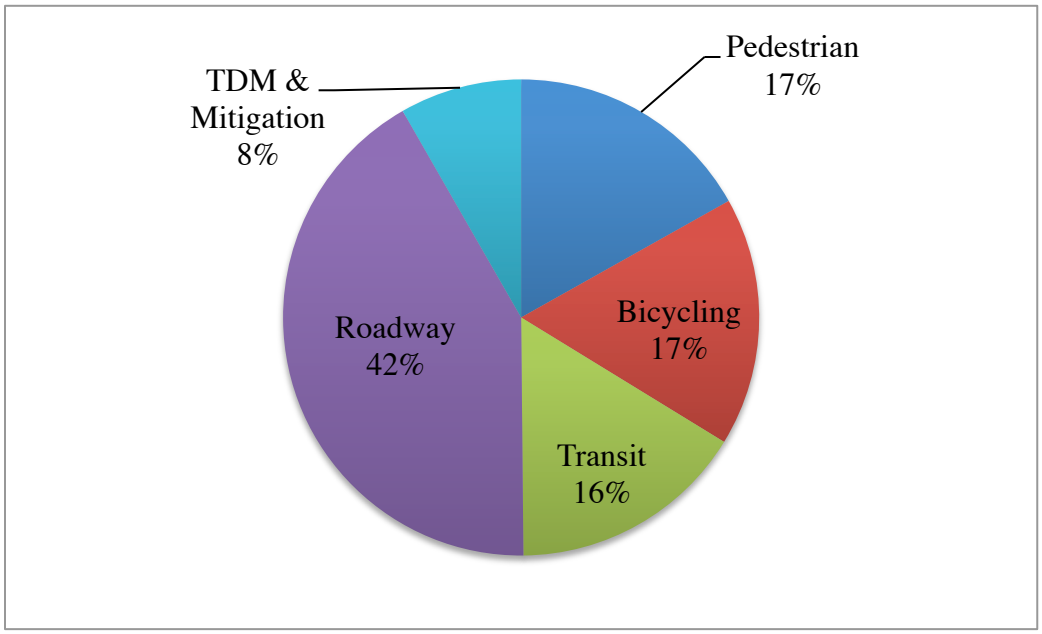
Second, we employ the Boulder Valley Employee Survey for Transportation, which has been conducted on seven occasions between the years 1990 and 2009. The survey measures the modal split of work commute trips for workers within the Boulder Valley, an area which includes the city of Boulder and surrounding communities. The survey employs a two-stage sampling process that first randomly selects employers and then employees within each selected organization. These two samples are drawn from a database of employers and employees from businesses in both downtown Boulder and Boulder Valley. Results are reported for residents and non-residents. During the most recent survey conducted in 2008, a total of 1,678 surveys were collected from employees in 276 organizations. Employer response rates were 15-percent in the downtown area and 32-percent in the rest of Boulder Valley; and employee response rates were 13-percent in downtown and 15-percent in Boulder Valley ('City of Boulder,' 2009).

Finally, we use the U.S. Decennial Census and American Community Survey (ACS) to estimate mode share for employed persons. Data from the 1990 and 2000 Decennial Census, as well as from the ACS 2005-09 Five-Year Estimates were employed. The percent mode share for those commuting by foot, bicycle, and transit are compared over the study period.

### 2.3 ANALYSIS OF SUPPLY (EXTENT OF INFRASTRUCTURE INVESTMENT)

The extent of Boulder’s investment in infrastructure, which we have characterized as the ‘supply’ of infrastructure, is examined using the city of Boulder budget allocations. The cumulative percentage of Boulder’s budgeted investments (1990-2009) related to infrastructure by mode is shown in Figure 1. Table 1 provides detailed information about Boulder’s annual approved budgets disaggregated for the study period for pedestrian, bicycling, transit, and roadway. All values are adjusted for inflation, in 2009 dollars.

**Figure 1. Transportation Approved Budgeted Investment by Mode, 1990-2009**




To further explore the supply of non-auto infrastructure, we examine each sustainable mode (pedestrian, bicycle, and transit) in more detail. Figure 2 shows the annual investment budgets by mode, and Figure 3 shows the cumulative enhancement budget by mode over the studied period.

A net increase in pedestrian infrastructure investments is seen over the twenty year study period in Table 1 and Figure 2. Between 2000 and 2009, pedestrian infrastructure investments varied from $3.1 to $6.4 million (in 2009 dollars) per year, with a cumulative total of $85.6 million ($40.4 million correspond to enhancements) from 1990 to 2009 (see Table 1, Figure 2, and Figure 3). On average, the percentage of the total budget allocated to pedestrian infrastructure ranges from 15 to 22 percent. One example of pedestrian infrastructure investments during this time is the installation of sidewalks that were considered missing links in the pedestrian network and multi-use path network expansion.