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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 20 years 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.

1. 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

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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 10 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 (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 (Rodríguez and Targa, 2004). 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 percent, as compared to 8.5 percent 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 (Whitson, 2013). 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).
- 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 7–15- min 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).
- Creation of a transportation management organization for east Boulder in 2004 (Boulder East Transportation Management Organization, 2004).

2. 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 (1990–2009) 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

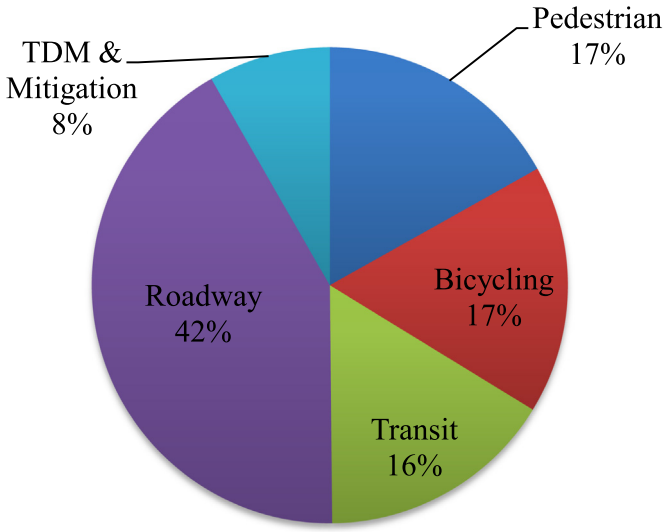

Fig. 1. Transportation approved budgeted investment by mode, 1990–2009.

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 Fig. 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 20-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 1000 survey respondents record travel activities and mode choices for a randomly assigned day during the third week in September, providing a ± 1.3 percent 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 including 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 1678 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 2005–2009 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 Fig. 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.

To further explore the supply of non-auto infrastructure, we examine each sustainable mode (pedestrian, bicycle, and transit) in more detail. Fig. 2 shows the annual investment budgets by mode, and Fig. 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 Fig. 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, Figs. 2 and 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.

As shown in Table 1 and Fig. 2, bicycling infrastructure investments varied from $2.4 to $5.7 million (in 2009 dollars) per year between 2000 and 2009, with a total of $84.7 million from 1990 to 2009. The percentage of the total budget allocated to bicycling infrastructure ranged from 10 to 20 percent, with a 17 percent average, for the study period. Fig. 3 illustrates that between 1990 and 2009, the city had approved over $45.5 million of bicycling infrastructure enhancements. Examples of bicycle infrastructure added during this time include the installation of bicycle lanes, multi-use path underpasses, and the addition of new multi-use paths.

Annual approved budgets for transit infrastructure and programs between 2000 and 2009 varied from $2.7 to $5.0 million (in 2009 dollars) per year, with a total of $79.4 million from 1990 to 2009. The percentage of the total budget allocated for transit infrastructure ranged from 9 to 18 percent with a 16 percent average across the twenty year period. As shown in Table 1, transit budgets present a different picture than pedestrian and bicycling budgets. For the first decade analyzed, all funding was strictly directed to O&M, with very low budget allocated to enhancements. In the second decade, higher levels of enhancement funding were allocated, and for the most part, O&M budgets remained higher. As a result, cumulative transit infrastructure enhancements ($12.3 million between 1990 and 2009, as shown in Fig. 3) is less than one-third of the cumulative budgets for pedestrian and bicycling infrastructure ($40.4 and $45.5 million, respectively). Infrastructure enhancements for transit include transit stop investments and improvements, new buses, and transit priority at signalized intersections. Regardless of the lower absolute values, O&M and enhancement funds allocated to transit infrastructure increased regularly between 2000 and 2009.

2.4. Analysis of demand (patterns of use)

Patterns of pedestrian, bicycling, transit, and SOV mode share are measured from the Boulder Resident Travel Diary Study, the Boulder Valley Employee (BVE) Survey for Transportation, and the

Table 1
Annual transportation approved budget by mode.

Year	Pedestrian			Bicycling		
	Operations and maintenance	Enhancements	% of Transport budget	Operations and maintenance	Enhancements	% of Transport budget
1990–1999[a]	$1,904,739	$1,531,054	15	$2,564,255	$1,706,033	19
2000	$2,421,701	$1,605,414	17	$1,484,815	$1,899,935	14
2001	$2,817,300	$3,538,261	20	$1,450,590	$3,011,940	14
2002	$2,964,523	$3,370,300	19	$1,571,184	$2,929,019	13
2003	$2,424,073	$3,724,613	22	$1,204,154	$4,107,024	19
2004	$2,365,674	$1,581,881	17	$1,130,877	$2,402,914	15
2005	$2,429,491	$2,165,365	18	$1,153,434	$3,974,452	20
2006	$2,405,742	$1,353,655	19	$1,099,868	$1,250,328	12
2007	$3,183,528	$2,398,806	18	$2,001,141	$3,679,333	18
2008	$2,529,646	$2,302,982	18	$1,276,975	$2,143,735	12
2009	$2,583,165	$3,081,861	21	$1,212,686	$3,045,060	16
Total (1990-2009)	$45,172,232	$40,433,677	17	$39,228,276	$45,504,073	17

Year	Transit			Ped. bicycling and transit % of transport budget	Roadway		
	Operations and maintenance	Enhancements	% of Transport budget		Operations and maintenance	Enhancements	% of Transport budget
1990–1999[b]	$4,200,210	$9,611	19	52	$5,232,349	$3,040,448	36
2000	$1,522,253	$1,211,598	11	42	$9,232,438	$2,983,832	50
2001	$1,739,239	$1,490,404	10	45	$12,063,093	$3,128,633	50
2002	$1,428,518	$1,438,463	9	41	$14,482,257	$3,500,026	54
2003	$1,451,492	$2,298,964	12	53	$8,092,036	$3,075,073	40
2004	$2,488,279	$2,382,634	21	53	$7,770,966	$1,827,547	41
2005	$2,578,872	$1,375,632	15	53	$8,120,286	$2,842,269	44
2006	$2,577,558	$269,927	14	45	$7,674,491	$1,406,543	45
2007	$3,328,124	$375,162	12	48	$13,993,740	$1,283,437	49
2008	$3,963,102	$426,720	16	46	$11,095,742	$2,259,718	48
2009	$4,069,373	$899,530	18	55	$9,546,230	$1,481,719	41
Total (1990–2009)	$67,148,909	$12,265,141	16	50	$154,394,763	$54,193,270	42

[a] Budget per year.
[b] Budgets adjusted for inflation (2009 dollars).

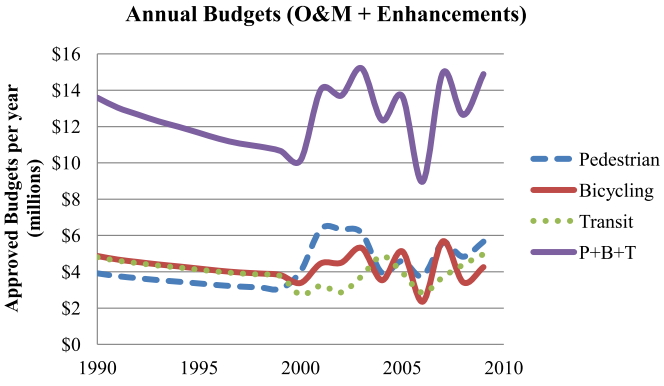

Fig. 2. Approved budgets in Boulder, 1990–2009.

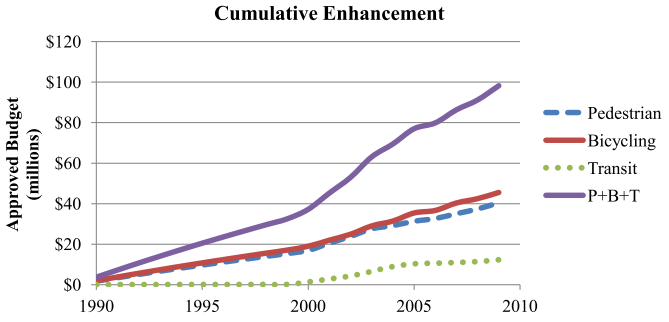

Fig. 3. Cumulative enhancements pedestrian, bicycling, and transit budgets.

US Census and ACS. For pedestrian, bicycling, and transit, we assemble and graph mode share data from five different sources. We rely upon multiple sources of data to best establish trends and guard against, for example, mode share changes resulting from changes in survey focus or public awareness. The two local survey efforts and the national-level data provide insight into different aspects of travel behavior. The Boulder Residents Travel Diary Study provides data for "all trips" and "commute trips". The BVE Survey provides data for "residents" alone and "residents and non-residents" combined. US Census and ACS data provides information only for commute trips. In order to assess demand for each mode, we present data from each of the data sources separately, along with a cumulative trend line, which is calculated across all data sources.

Pedestrian mode share (i.e., demand) in Boulder is presented in Fig. 4a. The negligible slope of the trend line indicates no appreciable change in mode share for the period analyzed, suggesting that pedestrian activity has remained relatively stable. It is important to note that many transit trips often include substantial walking, which is not necessarily captured in the surveys. Therefore, pedestrian trips may be underestimated by the surveys. Regardless, a constant pedestrian mode split is a positive outcome when compared nationally, as pedestrian mode share in the US

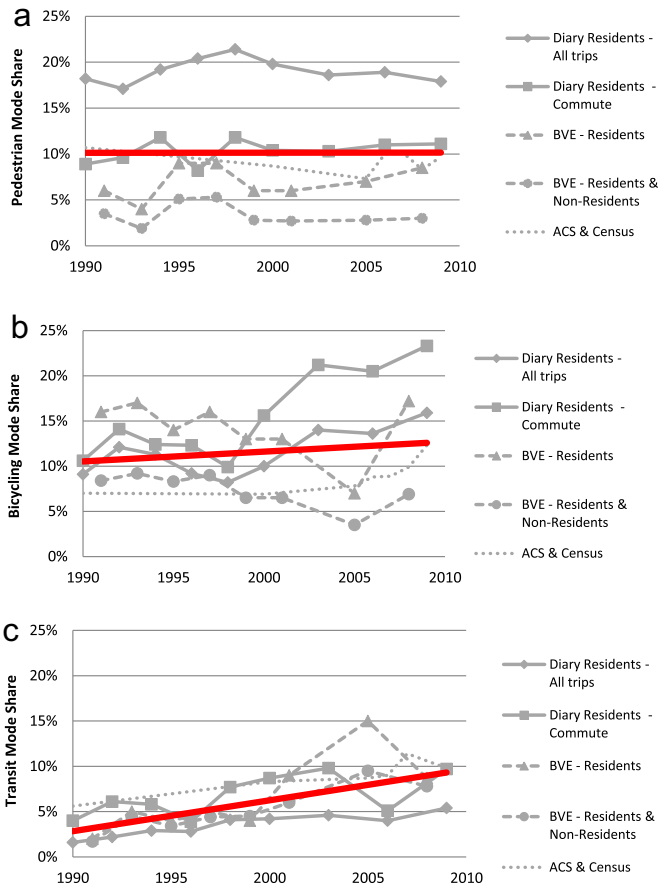

Fig. 4. Mode share in Boulder, 1990–2009. (a) Pedestrian, (b) Bicycling and (c) Transit.

decreased during the study period (3.9-percent in 1990 compared to 2.9-percent in 2009) (U.S. Census Bureau, 2011a; U.S. Census Bureau, 2011b).

Bicycling mode share has increased steadily between 1990 and 2009. The linear trend line is equivalent to a 0.11-percent increase per year (Fig. 4b), or around 2-percent across the study period. The BVE Survey fails to reveal a consistent increase in bicycling mode share for both residents and non-residents, especially in 2005. Differences in survey administration between the years may explain part of this discrepancy. In the pre-2005 surveys, data was collected in the summer months and was administered by a research division within the City of Boulder. In 2005 and 2007, the surveys were collected in the fall and were administered by a different agency.

Transit mode share in Boulder for the past two decades is shown in Fig. 4c. The trend line for transit mode share is 0.34-percent per year, or around 6.5-percent for the entire study period. The transit mode share reported by the BVE survey in 2005 shows increases in direct contrast to the bicycling decreases.

While the focus of this study is an exploration of pedestrian, bicycling, and transit mode share, it is also important to review SOV mode share and compare travel behavior changes over the two decades. As shown in Fig. 5, a consistent decline in SOV share has been experienced over the twenty year study period, which aligns with the goals of Boulder TMP to "*reduce single-occupancy-vehicle travel to 25-percent of trips*" and suggests that Boulder is succeeding in its efforts to reduce SOV mode share through investment in non-auto infrastructure.

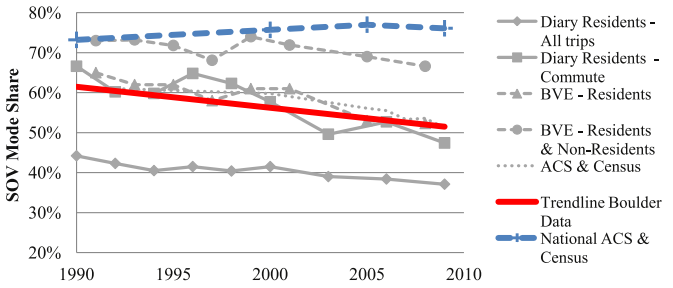

Fig. 5. Single occupancy vehicle mode share in Boulder and National, 1990–2009.

3. Results and discussion

The share of all three modes in combination – pedestrian, bicycling, and transit (Fig. 6) – indicates that percent use of non-auto modes consistently increased over the twenty year study period (walking mode share has remained constant). Findings suggest that increased capacity and availability have supported the travel changes when they occurred. The trend line for combined non-auto modes indicates a 0.45-percent increase per year, or approximately 8.5-percent for the study period.

Results suggest that Boulder is making significant progress towards its overall goal of becoming less auto-dependent. Boulder has maintained and increased non-auto mode shares over the study period, despite national trends that show increasing automobile mode share. A comparison of SOV demand in Boulder and nationwide indicates that while Boulder has experienced a 9.9-percent decrease in SOV mode share, the national average has increased 2.9 percent from 1990 to 2009 (Fig. 5). Comparatively, pedestrian, bicycling, and transit combined mode share in Boulder shows an 8.5-percent increase (Fig. 6) compared with the national average of 1.1-percent *decrease* during the same period (U.S. Census Bureau, 2011a; U.S. Census Bureau, 2011b). Thus, the data assessed for Boulder in this analysis indicates a noteworthy departure from national trends.

Due to the limitations of our data sources and the lack of disaggregated data for the period between 1990 and 1999, it is not prudent to conduct elasticity calculations or draw conclusions on lag time between the availability of supply and patterns of use. However, a comparison of trends suggests that while investing in increased "supply" of non-auto infrastructure, Boulder has simultaneously experienced an increase in "demand" as measured by the percent use of non-auto modes. Fig. 7 illustrates this finding: the cumulative budget allocations for pedestrian, bicycling and transit combined, as well as and the combined share of trips made by foot, bicycle and transit increased between 1990 and 2009. The results suggest that Boulder's investments in improving mode choices through new infrastructure and services supporting

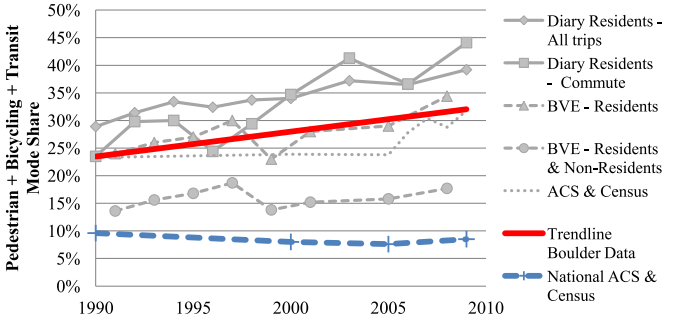

Fig. 6. Combined pedestrian, bicycling, and transit share in Boulder and National, 1990–2009.

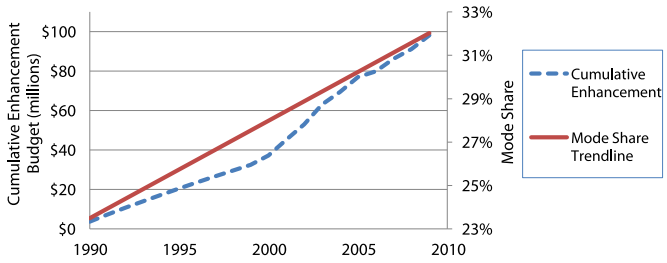

Fig. 7. Combined (pedestrian, bicycling, and transit) cumulative enhancement budgets and combined mode share in Boulder, 1990–2009.

pedestrian, bicycling, and transit is associated with increases in levels of non-automobile mode shares.

Fig. 7 suggests that a $10 million investment is related to a 1 percent change in combined non-auto mode share. Since investments are often a reflection of policies and goals of the citizens of a municipality, this elasticity estimate tends to oversimplify the travel behavior changes. In other words, mode share shifts over time tend to result from a combination of forces that cannot simply be captured in the municipal transportation budget. For instance, changes in parking policy, including expansion of the Neighborhood Permit Parking Program in Boulder, may also have influenced mode choice (City of Boulder, 2013a) but are not included in the budgets assessed here. Other factors that may influence mode choice but that are not accounted for in city budgets include: municipal regulations, taxes, matching funds from other agencies, and the selection of specific projects for funding.

The choice of which projects to fund or not to fund can be a function of either existing needs or policies and future mode share goals. Unlike neighboring communities in Colorado, Boulder has chosen to divert funds from motor vehicle projects toward non-auto infrastructure to support long-term policy and planning directives. Boulder decided to limit investments in limited access highways and instead focus on more sustainable transportation infrastructure. This has likely strengthened the existing connection between increasing non-auto mode share alongside increasing investment in supportive infrastructure. Similarly, the specific bicycle, pedestrian, and transit projects chosen by the city may have had a greater or lesser impact on mode share than other programs. For example, the city chose to invest in rubber-tired buses instead of a street car line and roughly half of the bicycle facility lane miles added were off-street instead of on-street. Had the city invested differently, the mode share change may not have been the same.

Funds from sources other than municipal transportation including regional, state, and federal partners were not included in the budget presented in this paper, though they may have also influenced mode choice. For example, a third of the city's greenways program, which was responsible for constructing many of the bicycle and pedestrian paths and underpasses, was funded by the city's transportation budget. The remaining funds were leveraged from other municipal funds such as the flood mitigation program and state lottery funds (City of Boulder, 2013b). Similarly, various partners including the city transportation budget, the university, and the regional transportation district (RTD) provided funding for transit.

4. Conclusions

During the twenty year study period (1990–2009), Boulder invested heavily in walking, cycling, and transit and saw a return on its investment with a reduction in SOV mode share. This result supports the one of the objectives laid out in the city's transportation master plan. Bicycling and transit mode shares showed a marked increase between 1990 and 2009, while walking rates have increased in accordance with population growth. While we are unable to capture pedestrian travel to and from transit, we can infer that walking, as part of the overall commute trip, is likely to have increased along with increases in transit use.

While these research efforts aim to document these co-varying factors at the aggregate scale for a city, we would be remiss if we did not acknowledge the potential roles that gas prices, economic conditions, land use policies, an increasingly progressive environmental culture, and education and encouragement programs are likely to have played with mode shares in Boulder. For example, the role of multi-modal infrastructure in prompting increases in non-auto travel is difficult to differentiate from the effect of the public lobbying for its construction (Krizek et al., 2009), or complementary land use development in conjunction with multi-modal investments (Dueker and Bianco, 1999; Ratner and Goetz, 2013).

Sustainable transportation infrastructure investments parallel the evolution of Boulder mode share away from the auto during the last two decades. We cannot confirm that these shifts happened as a result of these investments, but we can conclude that regardless of the reasons, the presence of robust non-auto infrastructure has supported evolving travel preferences. Boulder's record of investing in infrastructure matches residents' overall goal of becoming a more sustainable community through the city's transportation system. Cities can learn from Boulder's focus on developing policies and infrastructure that expand the number and capacity of non-auto transportation choices available, efforts which have contributed to an evolution in the use of non-auto modes. The more general travel behavior literature suggests that increased non-automobile mode share is correlated with a myriad of positive outcomes including health benefits and safer conditions (Ewing et al., 2003; Marshall and Garrick, 2011). The availability and increased capacity of non-automobile modes also makes mode shift possible when economic conditions change, such as increases in gas prices, providing greater resilience of the transportation system. Adequate infrastructure creates and supports travel shifts while providing residents opportunities to walk, bicycle, or take transit, activities which stem from and contribute to the flexibility and livability of communities.

This study is the first step toward future research into three corollary impact areas of infrastructure investments. First, how do total infrastructure costs and resulting roadway levels of service of a system focused solely on vehicular travel compare to the cost of delivering the same level of service with multiple modes? Second, what are the economic benefits associated with the three modes of transportation? For example, what effect do infrastructure investments have on land value? What economic savings associated with health benefits are achieved with mixed infrastructure? Has Boulder's investments led to changes in household vehicle use or ownership rates? The available transit, pedestrian, and bicycle improvements may allow a household to drastically reduce their automobile use or may support reductions in total vehicles per household. Finally, exploring the resiliency of communities based on investments made in pedestrian, bicycling and transit infrastructure may yield important results. Investment in non-auto infrastructure may help to improve the ability of a transportation system to perform or to recover quickly from price fluctuations in a particular resource, such as petroleum. Results of such a study could yield important insight into how walking, bicycling, and transit may offset challenges of rising fuel costs. With these topics in mind, the work presented in this paper provides the basis for future study along many relevant and interesting lines of inquiry.

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