Portland GREEN LOOP Economic Analysis

NeRC

Northwest Economic Research Center
College of Urban and Public Affairs

DRAFT FINAL REPORT
AUGUST 2016

Portland State University

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ACKNOWLEDGEMENTS

This report was researched and produced by the Northwest Economic Research Center (NERC) in collaboration with the Portland Bureau of Planning and Sustainability (BPS) with support from the PSU Institute for Sustainable Solutions (ISS) and the Bullitt Foundation. We would like to thank Mark Raggett and Tyler Bump from Portland BPS, and Beth Gilden and Fletcher Beaudoin from PSU ISS for their input and feedback in developing and preparing this research.

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NERC is based at Portland State University in the College of Urban and Public Affairs. The Center focuses on economic research that supports public-policy decision-making, and relates to issues important to Oregon and the Portland Metropolitan Area. NERC serves the public, nonprofit, and private sector community with high quality, unbiased, and credible economic analysis. Dr. Tom Potiowsky is the Director of NERC, and also serves as the Chair of the Department of Economics at Portland State University. Dr. Jenny H. Liu is NERC's Assistant Director and Assistant Professor in the Toulan School of Urban Studies and Planning. The report was researched and written by Dr. Jenny H. Liu. Research support was provided by Michael Paruszkiewicz, Wei Shi and Emma Willingham.

Cite as: Liu, Jenny H. (2016) Portland Green Loop Economic Analysis. Northwest Economic Research Center (NERC) Report. http://www.pdx.edu/nerc/projects/

Executive Summary

The Portland "Green Loop" is a proposed 6-mile linear open space running through the heart of the city, connecting existing and new open spaces, parks, gathering areas, and walking and biking pathways. As envisioned, the Green Loop concept requires significant infrastructure investments, and would result in both short-term and long-term impacts on transportation (for all travel modes), environment and economic development. The goal of this project is to characterize, quantify and analyze these costs, benefits and impacts, particularly focusing on case studies of similar infrastructure investments in active transportation and analyses of property value impacts, economic (input-output) impacts and preliminary business/retail activity impacts. Our key findings are as follows:

Case Studies & Interviews

The research team examined eight case studies in North American cities that have or plan to undertake significant active transportation infrastructure investments. We then conducted in-depth interviews with planning officials in three cities to obtain further insight into their planning, implementation and evaluation processes. We find that significant public outreach, often to underserved areas, is highlighted as key to both development and success of the infrastructure investments. By integrating new infrastructure improvements with preexisting networks, these cities both reduced the cost of improving active transport and arguably smoothed adoption by users. Finally, performance and outcome measurements are cited as key to assessing and understanding the effectiveness, efficiency and equity of these programs and investments.

Property Value Impacts

We find that introducing advanced bicycle and pedestrian infrastructure like the Green Loop provides positive amenity values for nearby residential properties, even after controlling for other factors that influence property values. We estimate that average property values will increase by approximately 0.05% for single-family homes, and between 6.46% and 7.96% for multi-family homes. The most significant impacts will be concentrated in neighborhoods that are located closest to the Green Loop, allowing for easier access to the amenity.

Economic Impacts

IMPLAN, an input-output (I/O) based economic model, is utilized to estimate macroeconomic impacts of two hypothetical test scenarios that illustrate a range of impacts associated with different levels of infrastructure investments. The Low Investment test scenario is estimated at $10,427,929 in general infrastructure investments with 2% going towards public art installations, and the alternative High Investment test scenario is estimated at $67,973,039 with seven potential signature park sites. The scenarios create 156 to 783 full-time equivalent jobs, and generates $22 to $114 million in economic output, concentrated in construction, architecture, engineering, and related services, and food services industry sectors.

Business Activity Impacts

Research has shown that active transportation infrastructure has potentially positive impacts on business activities and economic vitality in a region, and a preliminary benefits transfer analysis based on estimates from Clifton et al. (2012) and Dill and Carr (2003) is conducted to understand how local businesses might be affected. Our preliminary analysis shows small increases of 0.18% to 0.20% in annual sales in supermarkets, convenience stores, drinking places and restaurants that are located in close proximity to the Green Loop. Further research that specifically examines changes in both bicycle and pedestrian mode share in conjunction with business activity impacts before and after street infrastructure improvements or conversions will be necessary to accurately characterize how active transportation infrastructure affects businesses and economic development. Additional impacts may be likely if additional consumers or tourists are attracted to the Green Loop.

Table of Contents

I. Introduction and Context

This economic analysis is envisioned as a two-phase project with Phase I incorporating elements of a cost-benefit analysis and economic impact analysis funded through ISS, and with a Phase II focusing on a citywide greenway network (Green Loop would be one component of this citywide network) economic analysis with additional livability, equity and sustainability components funded through a competitive proposal at the National Institute for Transportation and Communities (NITC). This report is the culmination of Phase I of the project.

The "Green Loop" concept is an approximately 6-mile linear open space proposed through the heart of Portland. It would include and connect open spaces, parks, gathering areas, and walking and biking pathways attractive to walkers and bikers who may be uncomfortable using the current facilities downtown. It would run north-south on both sides of the Central City, approximately 10 blocks in from the riverfront trail system, and be linked to the bridges, surrounding districts and neighborhoods by east-west connections. The project is intended to spur additional economic development in the Central City and make it easier for pedestrians and cyclists to explore the area.

As envisioned, the Green Loop concept requires significant infrastructure investments, and would result in both short-term and long-term impacts on transportation (for all travel modes), environment and economic development. The goal of this project would be to characterize, quantify and analyze these costs, benefits and impacts in a comprehensive and unbiased manner. In addition, this research serves to establish an analytical foundation for the impacts of urban greenways for further research.

As part of this research process, the NERC team first conducted a thorough literature review of the current state of research on the economic impacts of infrastructure investment, traffic changes, bike facility investment, and similar infrastructure projects, among other topics, as well as a comprehensive methodology review to assess various approaches to the quantification of costs and benefits of bike and pedestrian infrastructure. Then, we draw key lessons from case studies of North American cities with similar urban greenway or bicycle/pedestrian infrastructure projects and/or bicycle/pedestrian plans. These case studies are complemented by semi-structured interviews of several key planners from selected urban areas. Finally, based on the literature and methodology reviews, case studies and interviews, in addition to scenarios developed by BPS and Portland Bureau of Transportation (PBOT), we analyze property value impacts, economic impacts of infrastructure investments and preliminary quantitative sustainability impacts.

II. Literature and Methodology Review

Regions investing in active bicycle infrastructure have seen considerable economic impacts, including increased economic activity, job creation, business vitality, tourism, and property value improvements. The wider usage of active transport modes that follows infrastructure improvements for both commuting and recreation may bring additional impacts to public health, environment, and household finances. The following discussion of recent studies and the experiences of regions making such investments covers each of these interrelated impacts.

II-1. Economic Impacts

Investment into bicycle and pedestrian related transportation infrastructure introduces new spending into the local economy, which has a well-established multiplier effect throughout the entire regional economy. Typically, input-output models are used to evaluate this overall economic impact, which can take the form of direct infrastructure investment, indirect bicycle-related industry effects (including tourism), and general impacts on businesses serving the area of investment.

Infrastructure Investment Impacts

There are two main infrastructure project costs: capital costs and operating costs (Transportation Research Board, 2006). Capital costs are expenditures directed to the construction of facilities and equipment such as on-street facilities (bike lanes, wide curb lanes, striping, and signed routes), off-street facilities (like shared-use trails and paths), and the equipment such as signs, signals, barriers, and parking. In practice, identifying the cost for bicycle and pedestrian-related infrastructure is challenging, since much of this infrastructure - like roadway shoulders and sidewalks - are incorporated with overall roadway projects (Vermont Agency of Transportation, 2012). Operating costs for this type of infrastructure typically include securing, policing, and maintaining the facilities, including maintenance of pavement, drainage, traffic controls and landscape (Transportation Research Board, 2006).

Both the direct and indirect economic impacts of constructing and operating active transport facilities in can be estimated using a macroeconomic input/output (I/O) model such as REMI and IMPLAN. One such analysis of bicycle infrastructure in Vermont indicated that the expenditure on such facilities creates construction jobs as well as supports the professional/technical services sectors. Every one million dollars of active transport program/planning spending was found to support nearly 32 workers (Vermont Agency of Transportation, 2012). The study estimated total economic contributions to be $17 million in output, 233 jobs and $10 million in labor income.

Bicycle Industry Impacts

Investments in bicycle infrastructure are generally positively correlated with an increase in the usage of bicycles (Pucher et al., 2010), which can impact related businesses' bottom lines. Many regions and cities, including Wisconsin, Iowa, Minnesota, and Colorado, have conducted studies to evaluate these impacts (Flusche, 2012). Bicycle industry subsectors include manufacturing, wholesale and distribution, retail and service, and other services[1]. Taking into account spill-over effects to other bicycle-related

[1] The manufacturing subsector includes manufacturing of bicycles, parts and accessories; wholesale and distribution also includes importing; retail and service is usually the largest subsector and includes sales and repair; other services include event promotion, industry representation and other ancillary services (Dean Runyan Associates Inc., 2014).

activities like entertainment and recreation, one study estimated that nationally, bicycle-related activities produce a $133 billion economic contribution, $17.7 million in federal and state taxes, and 1.1 million jobs (Outdoor Industry Foundation, 2006).

Impacts of the specific subsectors of the bicycle industry are expressed in terms of employment, personal income and output through input/output economic impact models. These types of economic impact studies are a way of characterizing the economic contribution or economic significance of the existing bicycle industry within a geographic area. For example, the Wisconsin Department of Transportation used REMI to estimate that the Wisconsin bicycle industry contributes over 2,102 jobs directly in the state, and another 1,316 jobs indirectly. This corresponds to approximately $377 million in annual economic output and $108 million of personal income (Bicycle Federation of Wisconsin & Wisconsin Department of Transportation, 2011). A similar approach was taken to evaluate the economic impacts of bicycle-pedestrian oriented business in Vermont, which found a contribution of $56 million of output, $26 million in earnings and 1,025 jobs (Vermont Agency of Transportation, 2012). A recent Oregon bicycle industry study used an industry survey to show that there are over 400 bicycle retail and service businesses, and several emerging manufacturers in Oregon, especially in the Portland metropolitan area. They found a total of 2,645 jobs, both full-time and part-time, were engaged in the bicycle industry, contributing $83.3 million in industry earnings in 2012 (Dean Runyan Associates Inc., 2014).

Other important components of the economic impact of the bicycle-related industry are tourism, events and recreation. Measuring the economic impacts associated with these components typically begin with characterizing expenditures from visitors and event participators for lodging, retail purchases, entertainment and goods and services (Bicycle Federation of Wisconsin & Wisconsin Department of Transportation, 2011). Many international and domestic cities these types of impacts ("Implement a US Bicycle Route: Economic Impacts," 2015). For example, a study in Quebec, Canada showed that cycle tourists spend 6% more than other types of tourists with an average expenditure of $214 per day. Colorado's economy benefits from $250-300 million stemming from bicycle tourism and bicycle-focused events, particularly in ski resort areas (Argys & Mocan, 2000). A recent economic benefit study of bicycling in Michigan created an analytical framework to evaluate tourism impacts of bicycling ("Community and Economic Benefits of Bicycling in Michigan," 2015). The authors conducted intercept surveys at six bicycle-related events (as case studies for all bicycle-related events in the state) and online surveys for other events to gather information on trip expenditure patterns, which provided input data for IMPLAN modeling. They found that out-of-state participants in bicycling events spent approximately $15.6 million dollars in Michigan, translating to a total of $21.9 million in total economic impacts for the state.

Business Vitality/Consumer Spending

Evidence shows that active transportation infrastructure might positively impact business districts' prosperity and economic vitality (Drennen, 2003; Flusche, 2012). There are many case studies from North American and European cities that compare sales and customers' expenditures before and after the construction of bike facilities, which collectively establish that cyclists and pedestrians indeed enhance retail activity in shopping districts that support regional business (Flusche, 2012; Jaffe, 2015). Jaffe's 2015 study further summarizes 12 case studies from cities around the world that illustrate the effects of losses in parking spaces and conversions to bike lanes on business opportunities, and found that there is little to no impact on local business, and in some cases bike lanes might even increase business. On the other hand, although the majority of the research in this area points to positive business impacts of active transportation infrastructure, one short-term impact study of Vancouver, B.C. found a small net decrease in sales after the implementation of a separated bike lane (Stantec, 2011).

In addition, travel mode choice has been shown to be correlated with different consumer expenditure behaviors. An analysis of 78 businesses in the Portland metropolitan area found that people who bike or walk spend similar amounts or more on average than their counterparts who drive, since non-drivers tend to travel more frequently to these destinations than drivers. Specifically, cyclists tend to spent less on grocery trips, but more at restaurants, bars, and convenience stores (Clifton et al., 2012). A survey of the East Village in New York City found that cyclists spend an average of $163 per week compared to an average of $143 in spending by drivers (Jaffe, 2015).

II-2. Property Value Impacts

In general, the literature supports the hypothesis that bicycle and pedestrian related facilities or greenway infrastructure tend to have positive impacts on property values (Cortright, 2009; Lindsey, Man, Payton, & Dickson, 2004a; Nicholls & Crompton, others, 2005). Hedonic pricing analysis is the most commonly used methodology to explore the impacts of bicycle facilities and greenways on property value (Brander & Koetse, 2011; K. Krizek, 2007; Lindsey et al., 2004a).

Cortright (2009) analyzed 15 different housing markets around United States, and found that walkability had positive impact on home values in 13 out of 15 housing markets. Another study found that proximity to trails and greenways (trails with greenbelts) are correlated with 2%, 4%, and 5% increases in home price (Asabere & Huffman, 2009). Even after controlling for spatial autocorrelation between greenspaces and property values – that is, the correlation between the values of neighboring homes or likelihood of green spaces - empirical studies have found that greenspaces had a significant positive impact on residential property values (Conway, Li, Wolch, Kahle, & Jerrett, 2010). Other efforts have expanded beyond single-family property impacts and found that walkability benefits commercial as well as multi-family residential property values, but the same benefits were not evident in industrial properties (Pivo & Fisher, 2011).

Research has shown that proximity to green space predicts an increase in land value. Coupled with the existence of recreation travel to green areas and its associated travel costs, this change in market price identifies recreational green space as a source of economic value. A 2011 'metaregression' of thirty-eight contingent valuation studies regarding urban and peri-urban green space found that areas with a recreation use component are valued approximately 322% more highly than land that serves preservation or aesthetic uses (Brander & Koetse, 2011). A 2001 Vermont park user survey also found that 64% of respondents stated that they valued recreational use most highly (out of eleven possible uses), and analysis of a subsequent willingness-to-pay survey question resulted in an allocation of 28.3% value to recreation, over twice the allocation of the next most-valued use (Manning & More, 2002).

The below hedonic property value model represents the general form for such models:

$$P_i = \beta_0 + \beta_1 H_i + \beta_2 S_i + \beta_3 N_i + \varepsilon_i$$

Here, the dependent variable is P_i, home sale price. H_i is a vector of property characteristics (which would include proximity to advanced bike facilities and density of these facilities in a buffer zone), S_i is a vector of school characteristics, and N_i is a vector of neighborhood characteristics (Liu & Renfro, 2014). Furthermore, the unique structure of Oregon's property tax system via Measure 5 and Measure 50 has led to large heterogeneity across properties in terms of property tax liabilities, this analysis follow's Liu and Renfro's (2014) specification to also include an AV/RMV-ratio (assessed value to real market value ratio) variable to capture the capitalization effects of varying property tax liability. This model utilizes an ordinary least squares (OLS) mixed-effects approach to incorporate a combination of time-variant and –invariant variables, and each coefficient describes the marginal value to the homeowner of improvements or amenities in each vector. A prior effort to construct a model relating walkability (in strict terms of proximity) to property value found no impact of walkability on property values in industrial zones, so it is likely that green space or other active transportation infrastructure will be similarly irrelevant; our estimation and analysis will not include an industrial component (Pivo & Fisher, 2011).

While many property value models that relate green space (and trail infrastructure) and walkability to residential property values have been developed, there are fewer empirical studies that consider commercial or industrial property. A commercial property value model can take on the same form as above, with a modified set of explanatory variables. One previous effort to analyze the value of office space in Peoria, Illinois included Moody's commercial property price index (CPPI), "green" building elements, floor size, parking ratio, existence of food service facilities, number of stories, years of construction and renovation, proximity to transit, location (urban or suburban), and class of building (Monson, 2009). Additionally, prior studies have found that traffic-calming measures, including changes to roadways that intend to reduce traffic speeds or motor vehicle traffic volume or to improve safety for all users, improve business in commercial zones (Drennen, 2003; Jaffe, 2015). For commercial properties, building characteristics may include square footage, LEED certification, and age. The neighborhood characteristics (N_i) vector is the location of the key greenspace and walkability variables, as well as proximity measures (greenspace and CBD or neighborhood centroid), median income by census tract (as a proxy for consumer spending), and crime rate.

For property value models, a semi-logarithmic approach is preferred, because in addition to narrowing output value range and minimizing heteroscedasticity, this form provides coefficients that directly represent percent impact on the dependent variable (Gulyani, Bassett, & Talukdar, 2012). Our proposed model takes the following form, and can be applied to both residential and commercial property types, given adequate property sales data:

$$\ln P_i = \beta_0 + \beta_1 H_i + \beta_2 S_i + \beta_3 N_i + \varepsilon_i$$

In following sections, we will apply the above hedonic price property value model to properties sold in the City of Portland. The estimated coefficients can subsequently be used to predict property value changes impacted by the Green Loop concept. However, due to limited data and sample size of commercial and industrial property sales, we focus only on residential properties in this study.

II-3. Additional Sustainability Impacts

There are many social and environmental benefits that the proposed Green Loop project would provide that are not accounted for in the property value, economic impact or business activity analysis. This section provides a brief overview of these benefits and a basic benefits transfer framework through which they can be analyzed.

Mode Shift

The literature shows that construction of new bike lanes and paths increases the percentage of recreational and commuting cyclists, and improvements to existing facilities draw increased active transportation traffic as well (Barnes, Thompson, & Krizek, 2006; Dill & Carr, 2003; Nelson & Allen, 1997; Tilahun, Levinson, & Krizek, 2007). A 2006 study of mode shift in the Minneapolis-St. Paul area following the construction of extensive new urban bicycle facilities in the 1990s found that bicycle mode share increased by 0.3 percentage points (an increase of 17.5% - from 1.7% to 2.0%), and a cross-sectional 1997 analysis of data from 18 U.S cities found that each mile of bikeway per 100,000 residents was associated with a 0.069% increase in bicycle commuting (Barnes et al., 2006; Nelson & Allen, 1997). In 2003, Dill and Carr (2003) repeated that same methodology, incorporating more explanatory factors and data from 35 cities, and found a rate of almost 1% increase in mode share per additional mile of bikeway per square mile.

Additionally, Dill and Carr found that infrastructure improvements were the **only** class of explanatory variable with a statistically significant impact on bicycle mode share — socioeconomic traits, public support for cycling, and even weather patterns proved ultimately irrelevant. The authors caution that no cause-and-effect relationship can be inferred, but nonetheless affirm that if new facilities are constructed they will certainly be used (Dill & Carr, 2003). A stated preference study conducted in Minneapolis-St. Paul found that cyclists are willing to travel for up to twenty minutes longer in order to use a path separated from automobile traffic and on-street parking (Tilahun et al., 2007).

It is worth noting that there is a countervailing force at work: in heavily congested urban areas, any reduction in traffic resulting from modal shift towards bicycling is likely to be quickly dissipated, as driving commuters respond to increased lane space and shift their behavior accordingly (Cervero, 2002; Noland, 2001). This phenomenon results from latent demand — demand that expands with supply. It is probable that any free lane space or reduction in traffic will be short-lived at best, leaving greenhouse gas and congestion impacts nullified. If latent demand is not a factor, the reduction in vehicle miles traveled can be estimated by applying mode substitution factors and transportation elasticities to estimate mode shift (Litman, 2013). This ratio is more difficult to determine for cycling, because bicycle trips do not automatically replace car trips — individuals are more likely to choose an active mode of transport for shorter trips. A 2001 study of shopping trip transport choice in Austin, Texas, found that 73% of walking trips were substitutes for driving trips, but all such trips were very short in duration, totaling an average of 2.1 miles per individual per month (Handy & Clifton, 2001).

Assuming any reduction in motor vehicle miles traveled and increases in active transportation mode shares persist in the long run, the additional sustainability-related benefits derived from these investments into active transportation infrastructure and resulting mode share shifts can be categorized into the following: greenhouse gas emission (GHG) savings, congestion time savings, public health benefits, social benefits and ecosystem services. While these potential benefits may not be easy to quantify, they may nonetheless be significant.

GHG Emission Savings

It has been documented that carbon dioxide and carbon dioxide-equivalent emissions have negative environmental, economic and societal impacts, and these impact may be measured by quantifying the economic costs of coastal destruction, increased disease, decreased food production, and other factors. These impacts are typically aggregated and measured as the marginal cost of an additional metric ton of CO_2 emissions, and termed the social cost of carbon, or SCC. A U.S government interagency working group consisting of scientific and economic experts from Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy, EPA, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury publishes estimates starting in 2010 with updates and revisions in 2013 and 2015. These estimates were created by averaging predictions from the three prevalent integrated assessment models (DICE, FUND, and PAGE), and Figure X below presents the SCC forecast out to 2050 at varying discount rates (Interagency Working Group on Social Cost of Carbon, 2013).

Social Cost of CO_2, 2015-2050 [a] (in 2007 Dollars per metric ton CO_2)

Source: Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015)

	Discount Rate and Statistic			
Year	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

[a] The SC-CO_2 values are dollar-year and emissions-year specific.

Figure X. Estimate of Social Cost of CO_2 (2010-2050)

Regardless of the dollar amount attributed to the known damage caused by increased GHGs, transportation contributes to total emissions. According to a 2010 report for the Transportation Research Board, the United States collectively emits 7,150 million metric tons of CO_2e per year, and over a quarter of that comes from the transportation sector. Of that quarter, 61% comes from passenger cars and light trucks — approximately 18% of total U.S. emissions (Gallivan & Grant, 2010). The United States Environmental Protection Agency (EPA) produces similar estimates, reporting that in 2013, transportation was responsible for 27% of total emissions, and points out that this number has increased 16% since 1990 (although new fuel economy standards implemented in 2005 have partially reversed this trend) ("Greenhouse Gas Emissions," 2015). Reducing automotive travel, and thus GHG emissions, is a vital part of the effort to control global warming. The proposed Green Loop concept, as investments into active transportation infrastructure that can potentially increase cycling and pedestrian mode shares, can contribute towards reducing GHG emissions and lowering social costs of carbon.

Congestion Time Savings

Reducing the number of vehicles on the road provides another benefit—savings in the form of time for commuters. The value of travel time, or VTT, is calculated as the product of time spent traveling and a given unit cost. This unit cost varies depending on a variety of factors, including trip characteristics and individual traveler preferences, but is usually estimated at 25-50% of the prevailing wage (Victoria Transport Policy Institute, 2013). Congestion imposes additional costs in the form of uncertainty, because the perceived value of time, especially when commuting, increases if delays are unexpected (Economic Development Research Group Inc., 2005).

One interesting exception to the standard VTT model occurs when individuals choose to walk or bicycle to work: many who do so report that they actually derive value from their commute, enjoying the first 20-40 minutes (although this effect decreases or disappears after 90 minutes) (Victoria Transport Policy Institute, 2013). By facilitating easier active transport commutes in the central Portland area and decreasing congestion, the Green Loop potentially increases VTT savings in two different ways.

Public Health Benefits

"The built and natural environment in which they live, by the social environment and by personal factors such as gender, age, ability and motivation" (Edwards & Tsouros, 2006) are essential factors in people's decision to participate in physical activities such as bicycling, jogging or walking. Infrastructure investments such as the proposed Portland Green Loop serves a crucial role in the promotion of active transport by "creating environments and opportunities for physical activity and active living" (WHO, 2006), leading to lower inactivity rates, which tend to decrease healthcare costs and productivity costs related to poor health. A 2006 report published by the National Cooperative Highway Research Program (NCHRP) looked at ten different attempts to quantify these costs on an annual basis and produced a median result of $128 worth of health cost savings per capita per year (the lowest value was $19, and the highest was $1,175) (Transportation Research Board, 2006).

In order to determine the value of public health benefits derived from the Green Loop Project, it would be necessary to identify the total number of new users, and multiply that by estimated annual health benefit (Atlanta Beltline Community Connector, 2013). Individual willingness to engage in cycling in Portland can be characterized along a continuum, ranging from "unwilling to bike at all" to "fearless" of even the most dangerous routes. The majority (about 60%) falls into a group termed "Interested but Concerned" in a report for the Portland Office of Transportation (Geller, 2009). These individuals like the idea of cycling, but safety concerns keep them off of roads. By creating a more welcoming and car-free environment, the Green Loop Project has the potential to attract new cyclists from this demographic.

Social Benefits

There is a large body of recent literature that investigates the social benefits of green space (Kuo, 2011). Such studies indicate that green spaces, especially in urban environments, are linked to reductions in crime, increased perceptions of connectivity and support and stronger community engagement.

Kuo and Sullivan (2001) found conducted regression analysis of the relationship between vegetation and number of police reports filed in 98 inner-city apartment buildings in the Ida B. Wells public housing project in Chicago over the course of two years. They showed that the existence of vegetation outside of buildings was connected to significant reductions (approximately 40%) in both violent crime and property crime. A 1992 comparison of violent incident rates in Alzheimer's patients across five assisted living facilities in British Columbia found that facilities that had recently been remodeled to provide residents with access to green space halted the conventionally-expected increase in violence over time (due to the degenerative nature of the disease). At facilities without green space, violent incidents increased by 681%, while at those with gardens, the rate actually declined by 19% (Mooney & Nicell, 1992).

An analysis of information compiled in the 2000-2001 Los Angeles Family and Neighborhood Study across sixty-five census tracts in Los Angeles determined that residents in areas with parks (as identified using county geographical data) report higher levels of mutual trust and willingness to help one another, even when a variety of other demographic and locational attributes are taken into account (Cohen, Inagami, & Finch, 2008). In 2009, Dutch researchers examining data from the second Dutch National Survey of General practice (DNSGP-2) in comparison to the National Land Cover Classification (NLCC) database found that, over a sample of over 10,000 individuals, proximity of less than 1km to green space was related to a higher perception of social connectivity and support and lower reported levels of loneliness. A wide variety of controls were used, including actual level of social engagement (as measured by reported interactions), and proximity to green space was the only reliable predictor of perceived social support and decreased loneliness (Maas, van Dillen, Verheij, & Groenewegen, 2009).

Taken together, the above studies offer support for the social and psychological value of green space.

Ecosystem Services

The proposed Green Loop Project is described as featuring a "dense, tree-lined path" for cyclist and pedestrian use. A widely-cited article from the 1997 edition of *Nature* identifies seventeen different types of economic benefits that can be derived from natural environmental features, and of these seventeen, six are considered to have major importance in urban areas: air filtration, micro-climate regulation, noise reduction, rainwater drainage, and recreational or cultural values (Bolund & Hunhammar, 1999; Costanza, 1997). A lined path of the type proposed offers all of these services, and although these benefits will be small in scope when compared to others described in this section, this distinct benefit type remains notable.

III. Case Studies

III-1. Overview

As part of our background research for this project, NERC reviewed reports on similar active-transport infrastructure initiatives across the nation, and interviewed key individuals who were involved in both the preliminary and implementation phases of each city plan to better understand the costs, benefits and impacts associated with the initiatives. We examined eight North American cities: Austin, TX; Chicago, IL; Denver, CO; Indianapolis, IN; Minneapolis, MN; New York, NY; Vancouver, BC; and Washington, DC, all of which had either updated their bicycle/pedestrian plans in the last five years or have implemented pilot infrastructure projects for cyclists or pedestrians.

In general, all plans researched featured community outreach prominently—it appears that the lowest-cost way to determine what a community needs is to ask. Almost all plans used bicycle and pedestrian counts to measure success, and three cities—Indianapolis, New York City, and Vancouver BC—conducted economic impact analyses of some part of their plan. Complete summaries of the above active transportation plans can be found in Appendix A1 of this report.

The city of Austin, Texas, has long sought to improve active transportation with a series of city plans, the most recent of which is the 2014 Austin Bicycle Master Plan. In this plan, the city describes improvements that took place following the previous Plan (issued in 2009), including 84 miles of bikeway construction and a documented 100% increase in bicycle mode share throughout the city, bringing the share of commuters choosing bikes to as high as 13% in some areas. Proposed future improvements include construction of 247 additional miles of bikeway (featuring physically protected lanes), increased efforts to shift short trips from automotive to bicycle mode by improving facilities, and connection of all desirable destinations to further increase mode share. These new improvements are estimated to cost $161 million, and such funds have traditionally been provided by the city general fund, voter-approved bonds, federal grants, and the local transportation fund (2014 Austin Bicycle Master Plan, 2014).

The Chicago Streets for Cycling 2020 plan includes the ambitious goal of providing bicycle facilities within a half-mile of every Chicagoan, and emphasizes the greater need for bikeways in more densely-populated areas. Additionally, the plan notes that improved infrastructure is best located in areas where ridership is already fairly high. When complete, their active transport network will be 645 miles long. Funding is will be derived from a federal grant, as well as various local sources. Notably, the city plans to pair bike lane installation with arterial resurfacing projects, thereby minimizing costs (Chicago Streets for Cycling 2020, 2012).

In Denver, Colorado, the Denver Moves Plan (2011) lays out a $119 million plan to construct an additional 270 miles of active transport paths, in addition to many “ease-of-use” improvements (such as intersection treatments) and removal of existing barriers. Funding is anticipated to come from state and federal grants. Metrics for success include traffic counts, mode shift estimates, crash data, geographic equity, and active transport infrastructure spending (Denver Moves, 2011).

Indianapolis, Indiana, is home to the Indy Cultural Trail, one of the first projects of its kind: an urban trail designed to create a sense of place and community while uniting all corners of the city. This trail, which cost approximately $63 million dollars to complete, was funded initially using $27.5 million from local investors and stakeholders, and later with $35.5 million in federal grants (including a $20.5 million Transportation Investment Generating Economic Recovery, or TIGER, grant from the Federal Department of Transportation) ("FAQs," Indyculturaltrail.org). In our interview with an involved city official, it was emphasized that the two-phase construction of the trail was essential—the first section (about 4 miles) allowed planners to learn from the experience and construct the second half more efficiently. Additional greenways improvements are discussed in the Indy Greenways Full Circle Master Plan, which focuses on enhancing access to the Cultural Trail (referred to as an "engine" of the greenway system). Major plan objectives include completing and improving existing bikeways, creating a 64-mile circle that connects four parks at each corner of the city, and working to close existing network gaps. New construction is anticipated to total 139 miles, and cost a total of $44.2 million. An economic impact analysis conducted as part of the Full Circle Plan estimates that 90% of that cost will be recouped via increased property tax revenues (Indy Greenways Full Circle Master Plan, 2014).

The Minneapolis Bicycle Master Plan, released in 2011 and updated in 2015 to emphasize the importance of protected bikeways, sets the goal of constructing 183 miles of bikeways at a cost of $270 million, over the course the next 30 years. Progress is to be assessed by a wide variety of counts, including traffic counts, mode shift calculations, crash data, bicycle theft data, complaint counts, and counts of events designed to provide bicycle-related education and outreach (Minneapolis Bicycle Master Plan, 2011).

New York City released their comprehensive transportation strategy, Sustainable Streets, in 2008. Although this is a plan that includes all types of transportation, the goal of doubling bicycle commuting by 2015 is explicitly stated. Improvements include 200 miles of new bicycle facilities by 2009 and completion of the 1997 New York City Bicycle Master Plan (which delineates 909 miles of bikeways). Metrics for success include overall measures, such as number of bicycle commuters, number of crashes, and number of active transport facilities. Additionally, the New York City Department of Transportation funded an economic impact analysis, which used sales tax data to calculate economic activity before and after bicycle facility implementation. In general, the study finds that active transportation infrastructure improves economic activity (NYCDOT, 2008; 2012).

The city of Vancouver, British Columbia, most recently updated their greenways plan in 2010. The goal is to create a city-wide network of 17 bike routes, totaling 87.5 miles in length, that will combine with neighborhood-funded and -maintained greenways to create a complete network that leaves no resident with no more than a 25-minute walk or 10-minute bike ride away from such a facility. An additional notable goal is the city's effort to integrate public transportation and active transport, making all parts of the city accessible without the use of a car ("Greenways for walking and cycling", Vancouver.ca). In 2011, a short-term (two-month) impact analysis was conducted in order to determine the impact of two separated bike lanes built in the downtown area. This study indicated a small negative impact, but due to its short-term nature, it is unclear whether this negative impact was sustained. Evidence from other such studies indicates that it probably was not, but nonetheless, this short-term negative impact must be taken into consideration (Stantec, 2011).

In Washington, D.C., the 2005 Bicycle Master Plan, which focuses on improving existing bikeways and decreasing collisions, was followed in 2010 by a downtown bike lane pilot project that sought to monitor the success of three separate infrastructure improvements with the goal of applying the findings to future projects. Results for each of the three areas were distinct and are presented separately, but across all locations, public perception of the projects was favorable and bicycle improvements did not appear to come at a cost of automotive inconvenience.

III-2. Lessons from Interviews

Following our examination of active transportation plans in various cities around North America, we conducted semi-structured telephone interviews with planning officials in Chicago, Austin and Indianapolis in order to obtain further insight into their individual planning, implementation and evaluation processes. The subsequent paragraphs describe key lessons gleaned from these interviews.

Chicago

Chicago is of particular interest due to the emphasis on equity and distinct neighborhood traits—both concepts emphasized by the city contact, who sees the greenway plan as part of achieving broader social welfare goals. Additionally, young professionals—a demographic associated with economic growth--are typically more attracted to areas with healthy active transport systems.

The conversation hinged on Chicago's broad and inclusive approach to design: multiple public engagement events are continuously underway (including the "Slow Roll" neighborhood movement, originally out of Detroit, which organizes weekly bike rides geared towards riders of all ability levels), and our contact made particular note of the differing needs and traits of Chicago's nine neighborhoods, and indicated that spending time "on the ground" in each is vital to a successful plan. Chicago tracks mode share on a number of different levels—traffic counts occur in each neighborhood (at both rush hour and on a 24-hour basis), in addition to monthly counts at six downtown locations and quarterly counts at twenty locations along arterial routes. Infrastructure improvements are simultaneously noted, in order to connect changes in patterns with such improvements.

Austin

In our interview with a contact in Austin, public engagement was similarly key to developing the updated bike plan. An online survey was use to capture citizens' attitudes towards bicycling (similar to Geller's "Four Types of Cyclists" report referenced in Section XX). Specific efforts were made to hold planning meetings in neighborhoods with higher minority populations, in the interest of promoting equity. Most notably to our purposes, the city has put extraordinary effort into quantifying the impacts and benefits of bike facilities via the "Think Bike" workshop, a collaborative effort between the city of Austin and the Dutch Bike Embassy. The primary quantitative tool used was a new web-based transportation planning software called the MOVE Meter (developed by Dutch consulting team MOVE Mobility) that creates detailed maps showing congestion levels, trip lengths, and more; which can then be used to run hypothetical infrastructure scenarios and predict the changes that may occur in response. Using preexisting data, these predicted changes can then be translated into quantified impacts on health, time-saving, decreased costs, and more.

Indianapolis

To see a close parallel to the Green Loop concept, we look to Indianapolis, where the success of the Indy Cultural Trail described by our contact offers an example of the way in which a well-designed pedestrian thoroughfare can increase both active transport and sense of community and place. This trail, originally conceived as an urban version of the popular local Monon Trail, was funded by a variety of stakeholders, including local merchant associations and nonprofit organizations, all of which joined voices with the public in creating the initial design. Even during implementation, the plan remained dynamic, changing in accordance with community input.

III-3. Case Study Conclusions

In conclusion, all of the cities we examined as case studies significantly increased their bicycle facilities, and experienced increasing bicycle mode share in the past decade. Key lessons from these case studies are summarized in the table below, and detailed summaries of each city's bicycle/pedestrian infrastructure background, active transportation plans and evaluation methods are included in Appendix A1. Most cities consider safety, equitable accessibility, economic vitality, and health and environmental impacts as important goals in their plans. Some cities, such as New York, Austin and Minneapolis, also conducted multi-dimensional evaluation processes for their active transport plans or projects. However, we did not find consistent practices for the evaluation of urban greenways, thus limiting the comparability of projects and impacts. However, common themes do have significance for this project and are summarized below:

- **Public Engagement:** All cities engaged in significant public outreach, often to underserved areas. This technique was highlighted in the interviews, where our contacts unanimously cited this as key to both development and success.
- **Integration into Existing Networks:** By pairing new infrastructure improvements with preexisting networks, these cities both reduced the cost of improving active transport and arguably smoothed adoption by users.
- **Performance and Outcome Measurements:** Assessment is key to determining the efficacy of any public service. The cities that we researched noted plans to engage in a wide variety of assessment techniques, usually emphasizing changes in mode share and traffic counts.

By learning from other cities' greenway improvement experiences, the City of Portland can approach this infrastructure change in a way that is both equitable and efficient.

Table 1. Key Lessons from Case Study Cities

City	Total Active Transportation Infrastructure	Key Lessons
Austin	210 (2014)	• Implemented protected bike lanes • Captured short trips into bike trips • Built a comprehensive bicycle network • Multidimensional benefits analysis covers topics of mobility, environment, public health and livability.
Chicago	645 (by 2020)	• More focus and experience on protected bike facilities • Separate pedestrian plan provides tools and strategies for safer streets
Denver	270 (by 2020)	• Multiple facility types manual • 80% of moderate to high ease-of-use facilities
Indianapolis	250 (by 2024)	• Bike facility economic impact analysis examined impacts to property value, property tax, job creation, economic potential and retail sales • Cultural trail – connecting existing greenways system
Minneapolis	210 (2014)	• Public engagement during planning process • 6E strategy: education, encouragement, enforcement, engineering, equity and evaluation
New York	431 (2014)	• Multidimensional evaluation metrics of street redesign treatments • Economic impacts analysis of pilot projects
Vancouver, BC	88 (by 2020)	• Bicycle/pedestrian safety treatments study • Business impact study of pilot project
Washington, DC	131 (2014)	• Pilot study of evaluating facility treatments

IV.Economic Analysis

IV-1. Property Value Impacts

Following the traditional housing hedonic pricing model described previously in the literature review section, property values are typically determined by a combination of characteristics such as property characteristics (property size, age, taxation, etc.), regional and location characteristics (public school quality, safety, distance to central business district (CBD), land use pattern, etc.), and overall regional economic conditions. In addition to these characteristics, many studies identified access to transportation, especially access to bicycle and pedestrian facilities, as having potentially positive impacts on property values (Asabere & Huffman, 2009; Cortright, 2009). Therefore, we extend the general form of the hedonic pricing model to the following: $\ln P_i = \beta_0 + \beta_1 H_i + \beta_2 S_i + \beta_3 N_i + \varepsilon_i$

$$P_i = \beta_0 + \beta_1 H_i + \beta_2 N_i + \beta_3 B_i + \delta Y_i + \varepsilon_i$$

where, the dependent variable P_i is the property sale price, H_i is a vector of property characteristics, R_i is a vector of neighborhood characteristics include schools, neighborhood amenities and location, B_i is a vector of bicycle facility characteristics, and Yi is a vector of sale year dummy variables that captures the overall economic conditions. The estimators β_i and δ represent the marginal value of these factors to a homebuyer, and the ε (error) term represents the remaining residuals.

In order to construct the dataset for our estimation, Multnomah County residential property tax rolls (including property sales) from 2010-2013 were collected and aggregated. Basic property characteristics are included for each property in this dataset, including property square footage, year built, property code (indicating type of property), as well as property taxes assessed. In addition, we include a property tax variable, AV/RMV ratio (property assessed value (AV) divided by real market value (RMV)), which describes the percentage of a property's real market value on which property taxes are assessed. Previous studies (Liu & Renfro, 2014) have found that differential property tax liabilities such as those posed by Oregon's Measure 5 and Measure 50 have significant effects on property values. Typically, higher AV/RMV ratios, indicating relatively higher property tax liabilities, result in lower property sale prices, even after controlling for all other property and neighborhood characteristics. We also include the property sale year variable as a dummy variable to reflect general market and economic conditions during the year when the transaction took place.

Using the geo-location of each property, additional neighborhood and location amenity variables for each property were matched and joined. For example, literature has shown that school quality as an important determinant for property values. Each property in our dataset was matched to an elementary school catchment area, and standard testing reading and math scores, which served as proxies for school quality, were assigned to properties within catchment areas. A dataset showing incidence of crime in 2012 (number of crimes per 1000 residents) were assigned to each neighborhood in Portland to serve as a measure of neighborhood safety. Additionally, distance to CBD (central business district), representing access to jobs and public services, and population density, as a measure of the urban form of the area, are also determinants of property value. The distance from the each neighborhood centroid to downtown was assigned to properties to measure distance to CBD. Similarly, the population density of each Census block group was assigned to the spatial matched properties.

Two key variables are constructed to represent advanced bike facilities[2] characteristics at each property: distance to nearest advanced bicycle facility and advanced bike facility density within a half-mile radius (half-mile is a commonly used buffer zone distance for measuring bike facility accessibility in bike/greenways studies (Lindsey et al., 2004a)). The first variable represents the availability and ease of access to advanced bike facilities from each property, and the second variable represents the extent of the advanced bike facility network around the property. Figure X shows the geographic distribution of advanced bike facilities in Portland (both distance to nearest facility and density of bike facilities). Although properties are, on average, only 0.68 miles (3,602 feet) away from the nearest advanced bike facility and have more than 0.74 miles (3,896 feet) of facilities within a half-mile radius, the spatial distribution of the bike amenities are not equally spread within the city boundaries, and drop off significantly along the edges of the city.

Transactions which did not accurately reflect actual market value of properties were dropped from the dataset, including “distressed” transactions such as foreclosures and short sales or transactions not classified as “arm’s length”. Finally, because we will only consider residential properties, including both single-family homes (SFH) and multi-family homes (MFH: townhomes or individually owned condominiums), all other property types were dropped from the dataset. The distribution and value of property transactions by neighborhoods between 2010 and 2013 is shown in Figure X below.

[2] Given the types bike/pedestrian facilities proposed in the Green Loop concept, we will only consider the impact of prioritized bike facilities, which include cycle tracks, buffered or separated bike lanes and Bike Boulevards, on property values in order to property characterize the potential impacts of the Green Loop. We will refer to these types of bike/pedestrian facilities as “advanced bike facilities” in the rest of this report.

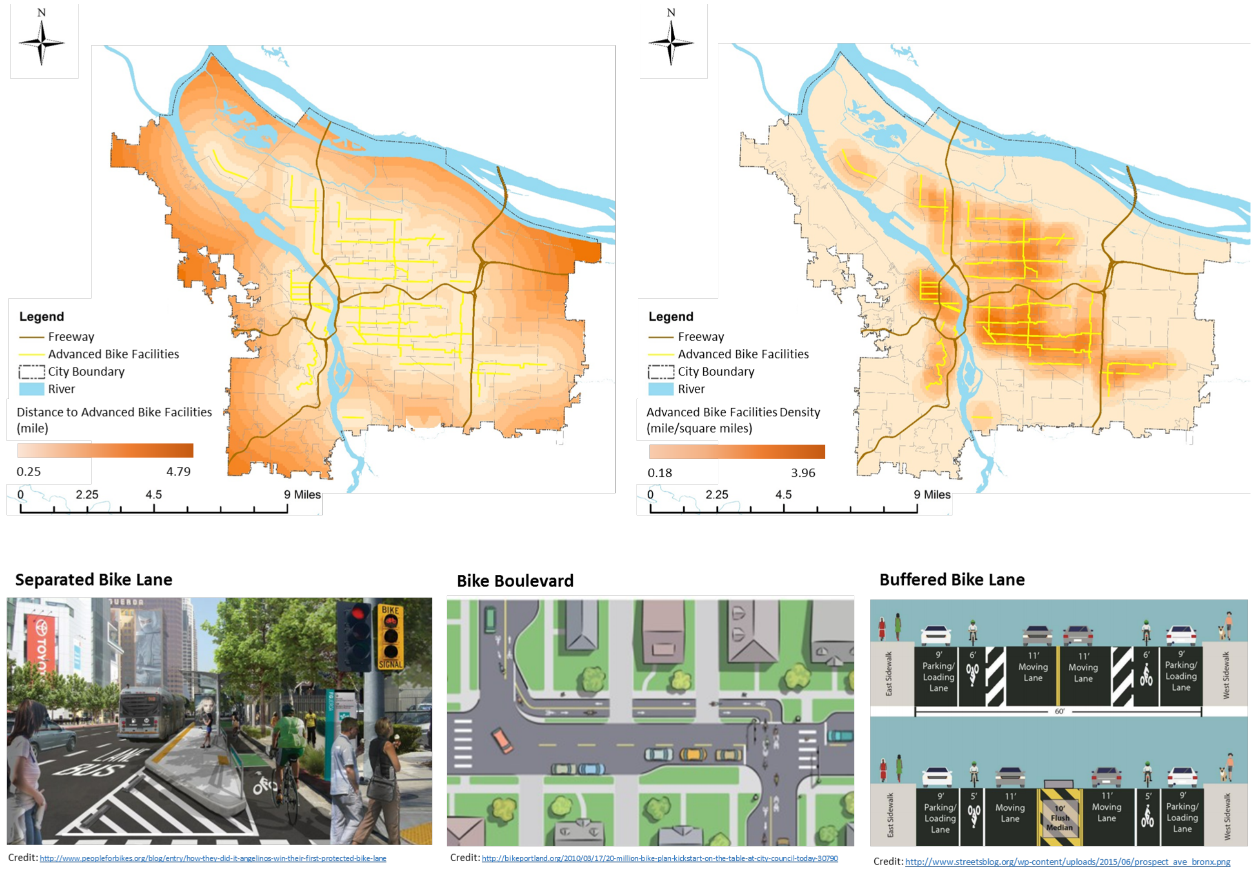


FIGURE X. Distribution (distance to nearest and density) of Advanced Bike Facilities in Portland

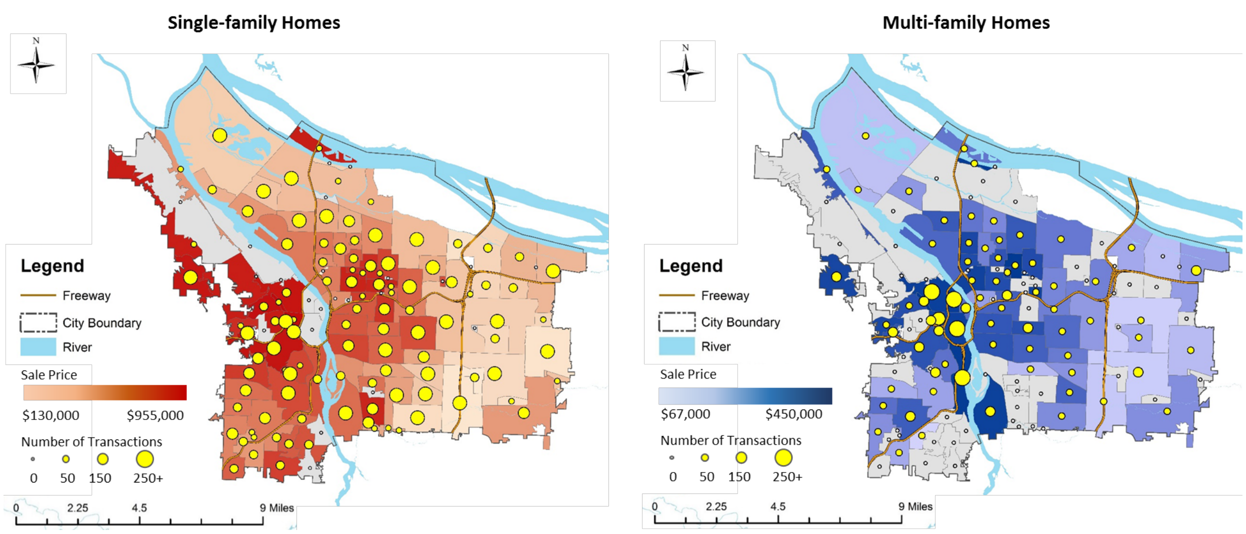


FIGURE X. Distribution and Values of Property Transactions by Neighborhoods (2010-2013)

Table 1. Variable Descriptive Statistics

Variables	Average (N=21100)	Single-family Home (N=17600)	Multi-family Home (N=3500)
Sale characteristics			
Sale price	$314,199	$316,573	$302,264
Property characteristics			
Age of property	59.55	65.46	29.85
Size of property (sqft)	1625	1721	1140
AV/RMV ratio	65.33	62.72	78.46
Neighborhood characteristics			
Reading score	75.34	73.31	85.52
Math score	67.93	65.73	78.99
Distance to CBD (mile)	4.15	4.45	2.63
Crime rate per 1000 residents	84.9	70.3	158.8
Population density (person/square mile)	7481	6835	10731
Bicycle facility characteristics			
Distance to nearest bike facility (feet)	3514	3723	2463
Bike facility density (feet in half-mile radius buffer zone)	4012	3693	5613

Table X above illustrates the descriptive statistics of our cleaned dataset of property sales between 2010 and 2013, including variables that describe property, neighborhood and bicycle facility characteristics. Overall, residential real estate in Portland sold at an average price of $314,199, with single family homes valued at approximately $316,573 and multi-family homes at $302,264, respectively. When compared to multi-family homes, single-family homes tend to be older (building age is 65 years on average compared to nearly 30 years), larger (1721 sq-ft compared to 1140 sq-ft) and have lower property tax liabilities as a percentage of their real market values (RMV). In addition, single-family houses are typically located in lower density area further away from the CBD. Multi-family homes are typically located in more central locations with better access to advanced on-street bike facilities, both in terms of distance to the nearest facility or availability of a denser network of bike facilities.

Regression Models – Ordinary Least Square (OLS)

We first estimated a pooled regression model with properties from both residential types, and found that the residential property type (single-family home or multi-family home) significantly influences property value. We then proceeded to estimate a restricted model to check for any structural change in the determinants of property values for the two different types of homes, and found evidence that supports structural change (Chow test - $F = 155$, $p<0.01$). This indicates that the determinants of property value may affect single-family homes and multi-family homes differently, which may be due to differences in consumers' preference for amenities and neighborhood characteristics when they are in the market for SFHs as opposed to MFHs. Therefore, we estimate two separate models – SFH Model (Model 1) and MFH Model (Model 2) – for the ordinary least squares (OLS) specification.

Table 2. OLS Regression Model Results

Variables	**SFH Model (Model 1)**	**MFH Model (Model 2)**
N	17600	3500
(Intercept)	50650 ***	-25750
	(9503)	(31210)
Property characteristics		
Age of property	310 ***	-887 ***
	(35.2)	(73.5)
Size of property	158 ***	322 ***
	(1.2)	(4.5)
AV/RMV ratio	-204 ***	-805 ***
	(72.6)	(188)
Neighborhood characteristics		
Reading score	904 ***	1704 **
	(193)	(681)
Math score	532 ***	-1026
	(161)	(656)
Distance to CBD	-22740 ***	-28930 ***
	(753)	(2399)
Crime rate per 1000	-226 ***	38**
	(20.2)	(16.3)
Population density	-1.18 ***	1.40 ***
	(0.37)	(0.23)
Bike facility characteristics		
Distance to nearest bike facility (feet)	-0.46	-2.63 ***
	(0.30)	(-0.85)
Bike facility density (feet in half-mile buffer zone)	2.39 ***	6.02 ***
	(0.25)	(0.55)
Sale year (Reference = 2010)		
2011	-15730 ***	-10420
	(2650)	(6548)
2012	-3499	14760 **
	(2538)	(6598)
2013	29320 ***	41310 ***
	(2470)	(6185)
Adjusted R^2	0.669	0.694
F statistics	2738	611
(p value)	(0.000)	(0.000)

Notes: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

For single-family homes, property values are positively related to the size of the property and age of the property, and estimated coefficients are statistically significant at the 1% level. Each additional square-feet contributed approximately $158 worth of marginal value, while building age contributed $310 for each additional year. This may be because older homes in Portland tend to have larger lots with bigger yards (which is not captured in other variables in our model), and historical construction and design may provide desirable attributes for home purchasers as well. In addition, a single family home with higher percentage of property real market value that is assessed property taxes (as indicated through the AV/RMV ratio) has a property value that is $204 lower for each percentage point, all else equal. As expected, neighborhood characteristics are significant determinants of property values for single family homes: homes located in school districts with better reading and math scores in elementary schools are more valuable; properties closer to CBD, with easier access to transit and public service, also have higher values; neighborhoods with higher population density and higher crime rates tended to have lower property values. Bicycle facility characteristic coefficients indicate positive and statistically significant effect of availability of advanced on-street bike facilities within a half-mile buffer zone – each additional foot increases property values by $2.39 and proximity to these bike facilities increases values by $0.46, after controlling for all other variables, after controlling for other determinants. These results, taken together, indicates that consumers who are in the market for SFHs prefer to be both closer to advanced bike facilities, and to have access to a dense network of bike facilities. An additional quarter mile[3] of bike facilities within a property's half-mile radius buffer zone is estimated to increase SFH property values by approximately $3,155 while being a quarter mile closer to the nearest bike facility increases these values by $607. Year of sale fixed effects estimates are generally statistically significant.

For multi-family homes, we found that coefficient estimates were similar to single-family homes for a few characteristics, but found that others did not match both in terms of sign (negative or positive) and magnitude. Each additional square-feet of space contributed $322 to multi-family home values, and each additional percentage point of its AV/RMV ratio negatively impacted values by $805. Multi-family home values are positively driven by population density and lower building age, indicating differing preferences for this population. It is reasonable to suspect that these properties are usually located in mixed-use zones (both commercial and residential) with convenient access to a varieties of activities, which is correlated with both higher densities and relatively higher crime rates. Both estimated bicycle facility characteristic coefficients are positive and statistically significant. Being an additional foot closer to advanced on-street bike facilities results in a $2.63 increase in MFH property values, and an additional feet of advanced bike facility density in a property's half-mile buffer zone translates to an increase of $6.02. This means that an additional quarter mile of bike facilities within a property's half-mile radius buffer zone is estimated to increase MFH property values by approximately $7,946, and being a quarter mile closer to the nearest bike facility increases these values by $3,472.

For both residential property types, increases in the provision of bike infrastructure in the form of advanced bike-priority facilities lead to significant increases in property values. However, this impact is of greater magnitude for multi-family homes than for single-family homes.

[3] Each mile is equivalent to 5280 feet. A quarter mile is equal to 1320 feet.

Regression Models – Spatial Autoregressive Model (SAR)

Homebuyers and realtors often assess a given property value by referring to prices of nearby sold or listed properties (using a comparable sales assessment approach), since properties that are more close by are better indicators of how much a property is truly worth (Cellmer, 2013; Conway, Li, Wolch, Kahle, & Jerrett, 2010). This is specified in the form of a spatial dependency effect (spatial autocorrelation) and can be included in the hedonic property value models in the form of property value correlations with property values of homes sold in close proximity. Ignoring this spatial autocorrelation may lead to inefficient coefficient estimations in the OLS specification (Conway et al., 2010). Therefore, in this section, we extend the OLS regression specification and utilize a spatial autoregressive model (SAR) to control for the spatial autocorrelation effect through spatial regression techniques.

There are two common used spatial models: the spatial lag model, and spatial error model. Spatial lag model interprets spatial dependence as consequence of omitted variables. The general spatial lag model form is:

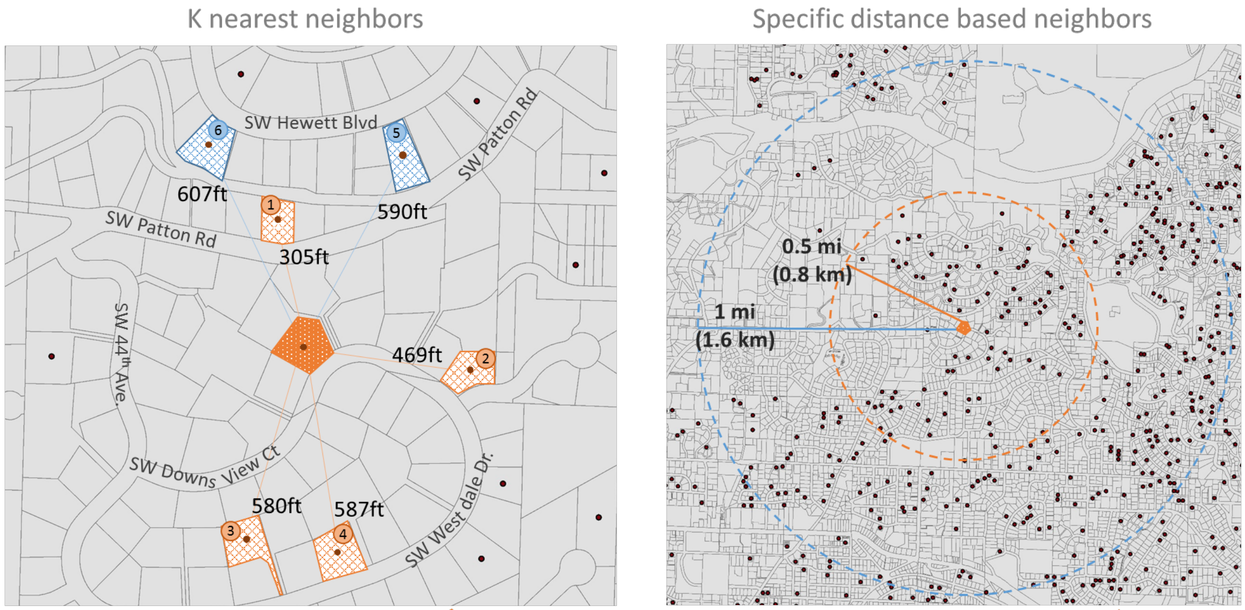
$$Y = \rho WY + X\beta + \varepsilon$$

where ρWY is a spatially lagged dependent variable to represent the omitted variable in regression. p is the spatial lag parameter, while W is the spatial weighting matrix representing interaction between different locations (Conway et al., 2010). On the other hand, the spatial error model interprets spatial dependence as model misspecifications. The general spatial error model form is:

$$Y = X\beta + \lambda W\varepsilon + v$$

where the original error term from OLS is modeled as an autoregressive error term $\varepsilon = \lambda W\varepsilon + v$. λ is the spatial error parameter, while $W\varepsilon$ is the spatial error, which should be interpreted as the mean error from neighboring locations, and v is the independent model error (Cellmer, 2013; Conway et al., 2010).

A spatial weighting matrix W is constructed using two specific neighboring methods commonly used in the literature: k nearest neighbors (4-nearest neighbors) and specific distance based neighbors (within one-mile). This spatial weighting matrix is a representation of which properties are hypothesized to have the most impact on the property values at hand: k-nearest neighbors will capture the k nearest properties sold while the specific distance based method captures all properties sold within a specified circumference. These methods are illustrated in the figure below. Furthermore, the weighting matrix is row-standardized for further testing and modeling.



Row-standardized weighting matrix for property

ID #	1	2	3	4	5	6
K=4	0.25	0.25	0.25	0.25	0	0
K=6	0.17	0.17	0.17	0.17	0.17	0.17

Row-standardized weighting matrix for property

ID #	1	2	3	....	85	...	372
D = 0.5 mi	0.012	0.012	0.012	0.012	0.012	0	0
D = 1 mi	0.003	0.003	0.003	0.003	0.003	0.003	0.003

• Properties sold between 2010-2013

Figure 2. Spatial weighting matrix diagrams for two neighboring methods

LM (Lagrange Multiplier) tests are conducted first to determine the existence of the above described spatial dependence in OLS property value model. The technical procedure is attached in Appendix A2. The results show significant autocorrelation in both the lag term and error term in both the SFH and MFH models. The lag term spatial autocorrelation was stronger in the SFH model (Model 1), while the error term spatial autocorrelation was stronger for the MFH model (Model 2). In order to avoid overestimation of coefficients within the OLS property value model due to spatial autocorrelation, we proceed with a spatial lag model for SFHs (Model 3) and a spatial error model for MFHs (Model 4) using the 4-nearest neighbors weighting matrix method.[4]

Compared with the OLS models, the coefficients from spatial autoregressive models are smaller in magnitude, following the hypothesis that the OLS property value models tend to produce overestimations in the effects of variables on property values. By introducing spatial autocorrelation terms, the new estimated coefficients from Models 3 and 4 are more reliable, and we observe improvements in overall model fit as well. Similar to the OLS specifications, we see positive impacts of property size on property values and negative (although smaller) impacts remained for AV/RMV ratios for both SFHs and MFHs. Single family home property values increased with age ($135 per year) while multi-family property values decreased with age ($582 per year). Neighborhood characteristics impact

[4] Statistical tests showed better results with the 4-nearest neighbors method compared to the within one-mile distance neighbors method.

property values in similar ways when compared to our previous models, although again with attenuated coefficient estimates.

In single family homes, the bicycle facility characteristic coefficient again indicates positive and statistically significant effect of availability of advanced on-street bike facilities within a half-mile buffer zone – each additional foot increases property values by $0.84, after controlling for all other variables. Proximity to these bike facilities also increases property values of single family homes by $1.53 for each feet. These results reinforce OLS model results that indicate SFH buyers prefer to be close to advanced bike facilities, and to have access to a dense network of bike facilities. An additional quarter mile of bike facilities within a property's half-mile radius buffer zone is estimated to increase SFH property values by approximately $1,109 while being a quarter mile closer to the nearest bike facility increases these values by $2,020.

For multi-family homes, only the estimated the density of bicycle facility coefficient remains positive and statistically significant while being an additional foot closer to advanced on-street bike facilities results in a $1.95 increase in MFH property values, although this result is not statistically significant. Increases in the density of advanced bike facilities within a MFH property's half-mile buffer zone translates to an increase of $5.46. This means that an additional quarter mile of bike facilities within a property's half-mile radius buffer zone is estimated to increase MFH property values by approximately $7,207.

Table 3. Spatial Autoregressive Model Results for Portland Property Sales Price during 2010-2013

Variables	**SFH Spatial Lag Model (Model 3)**		**MFH Spatial Error Model (Model 4)**	
(Intercept)	-5189 *** (1331)		-2351 (52549)	
Property characteristics				
Age of property	135 *** (28)		-582 *** (112)	
Size of property	124 *** (1.2)		322 *** (4.4)	
AV/RMV ratio	-300 *** (45)		-352* (193)	
Neighborhood characteristics				
Reading score	577 (-)		118 (1120)	
Math score	94 *** (13)		-76 (1059)	
Distance to CBD	-11448 *** (546)		-32864 *** (4342)	
Crime rate per 1000	-104 *** (16)		45 (34)	
Population density	0.36* (0.21)		1.5 *** (0.45)	
Bike facility characteristics				
Distance to nearest bike facility (feet)	-1.53 *** (0.21)		-1.95 (1.70)	
Bike facility density (feet in half-mile buffer zone)	0.84 *** (0.17)		5.46 *** (1.10)	
Sale year (Reference = 2010)				
2011	-14754 *** (1694)		-17680 *** (5051)	
2012	-1828 (-)		-743 (5335)	
2013	30173 *** (1475)		29775 *** (4910)	
	Log- Likelihood	-228040	**Log- Likelihood**	-45213
	AIC	456110	**AIC**	90458
	Rho	0.389	**Rho**	0.640
	LR test	3207.1 (0.000)	**LR test**	1412 (0.000)

Notes: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

Estimated Property Value Impacts of Green Loop

We estimate the overall impact on Portland property value as a result of proposed Green Loop infrastructure investments by applying coefficients from the above estimated models to properties across the city. The proposed Green Loop concept translates to additional advanced on-street bike facilities, decreasing the proximity of nearest bike facilities for many households and increasing the density of the bike facility network within each household's buffer zone. Multnomah County valid tax rolls for all residential properties in year XXXX were utilized, totaling 174,453 properties, including 156,052 single-family homes and 18,401 multi-family homes.

The addition of Green Loop bike infrastructure does not produce large changes in proximity to nearest advanced on-street bike facilities for most properties, but does significantly increase the density of bike facility length within a half-mile buffer zone of each property. In other words, we would expect more potential impacts to result from the increase in bike facility network density rather than from ease of access (distance to nearest facility).

Table 4. Descriptive Statistics for All Residential Properties

Variables	Average (N=174453)	Single-family Home Average (N=156052)	Multi-family Home Average (N=18401)
Property characteristics			
Age of property	61.95	65.64	30.67
Size of property (sqft)	1643	1704	1124
AV/RMV ratio	66.85	65.56	77.76
Neighborhood characteristics			
Reading score	73.81	72.72	83.13
Math score	66.28	65.09	76.35
Distance to CBD (mile)	4.43	4.60	2.97
Crime rate per 1000	82.4	73.16	160.8
Population density (person/square mile)	7230	6837	10409
Bicycle facility characteristics			
Distance to nearest bike facility (feet)			
Original	3663	3762	2822
Green Loop Scenario A	3644	3760	2662
Green Loop Scenario B	3643	3759	2656
Green Loop Scenario C	3644	3760	2666
Bike facility density (feet in half-mile buffer zone)			
Original	3751	3548	5135
Green Loop Scenario A	4130	3613	8510
Green Loop Scenario B	4199	3616	9140
Green Loop Scenario C	4112	3610	8373

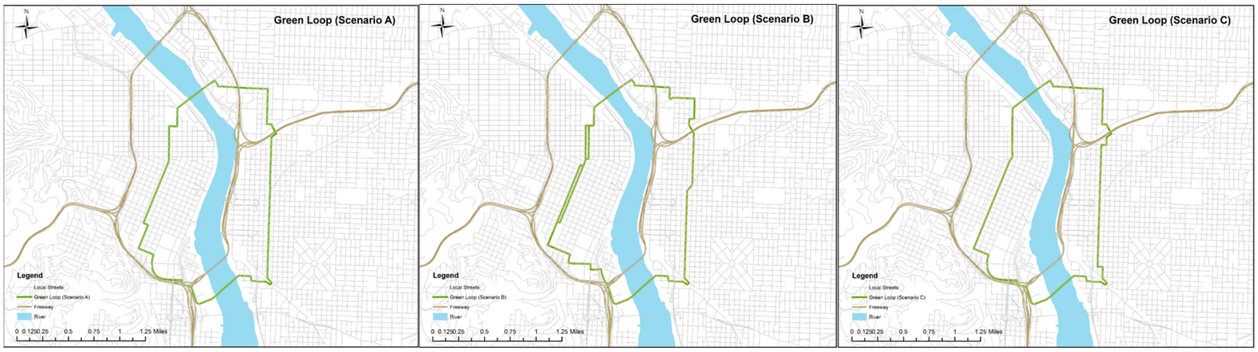


Figure 3. Green Loop Scenario A/B/C

We apply coefficient estimates from both the OLS and SAR model specifications for both single family and multi-family homes, and find that the introduction of Green Loop will generally increase property values. An average single-family home in Portland will have property values that increase from $333,135 to between $333,285 and $333,300 depending on the specific scenario (A,B or C), an average growth of around 0.05%. For multi-family homes, the average property value increases from $308,103 to between $327,999 and $332,642 depending on the specific routing scenario, an average increase of approximately 6.46% to 7.96%. Using coefficients from spatial autocorrelation models (which tend to be lower than OLS estimates), Green Loop infrastructure impacts on average property values still range from 5.88% to 7.26% for the various scenarios.

If we isolated only those properties where property values have been impacted, the effects are larger in magnitude. Table 5 illustrates property value changes for the properties affected (excluding all properties where property values are unchanged) by Green Loop infrastructure under the three routing scenarios. Because there are only very limited numbers of single family homes in close proximity to the Green Loop, we observe smaller property value impacts for these properties, averaging 1.45% using the OLS model and 0.82% using the SAR model. However, almost half of all multi-family properties benefit from higher values as a result of the proposed Green Loop concept, resulting in average increases of over 10% for all impacted multi-family homes.

Figure 4 below shows estimated aggregate changes of total property values in Portland. The total value increase exceeds $350 million for all three scenarios, with larger impacts concentrated in multi-family homes. This increase in property values could potentially cause positive impacts on Multnomah County's property tax base and resulting property tax revenue, although the interactions of assessed value, real market value and compression resulting from Measure 5 and Measure 50 will require additional analysis.

Table 5. Average Property Value Change in Impacted Properties by Scenario and Model

	Scenario	# of affected properties	OLS Model		SAR Model	
			Before	After	Before	After
Single-family home (SFH)	**A**	3527	$544,056	$552,075	$565,277	$569,945
			+1.47%		+0.83%	
	B	3740	$545,236	$553,350	$565,053	$569,770
			+1.49%		+0.84%	
	C	3533	$544,056	$551,647	$565,277	$569,699
			+1.40%		+0.78%	
Multi-family home (MFH)	**A**	8610	$375,817	$420,108	$373,489	$413,507
			+11.79%		+10.71%	
	B	8817	$374,059	$425,258	$371,637	$417,919
			+13.96%		+13.96%	
	C	8610	$375,817	$418,149	$373,498	$411,895
			+11.26%		+10.28%	

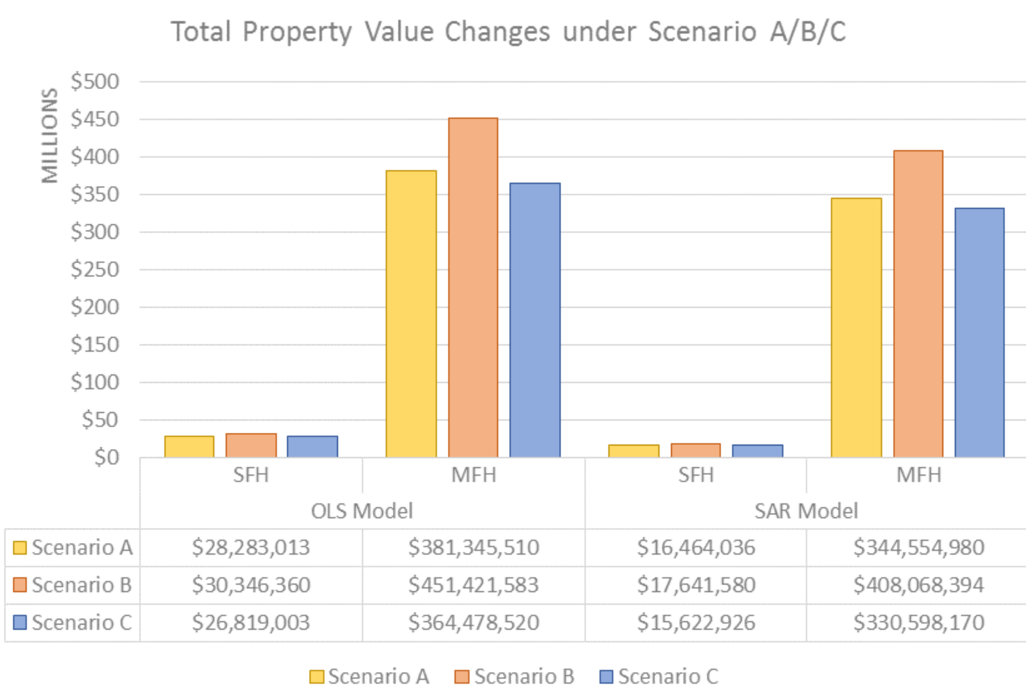


Figure 4. Total Property Value Impacts by Scenario and by Model

OLS Model SAR Model

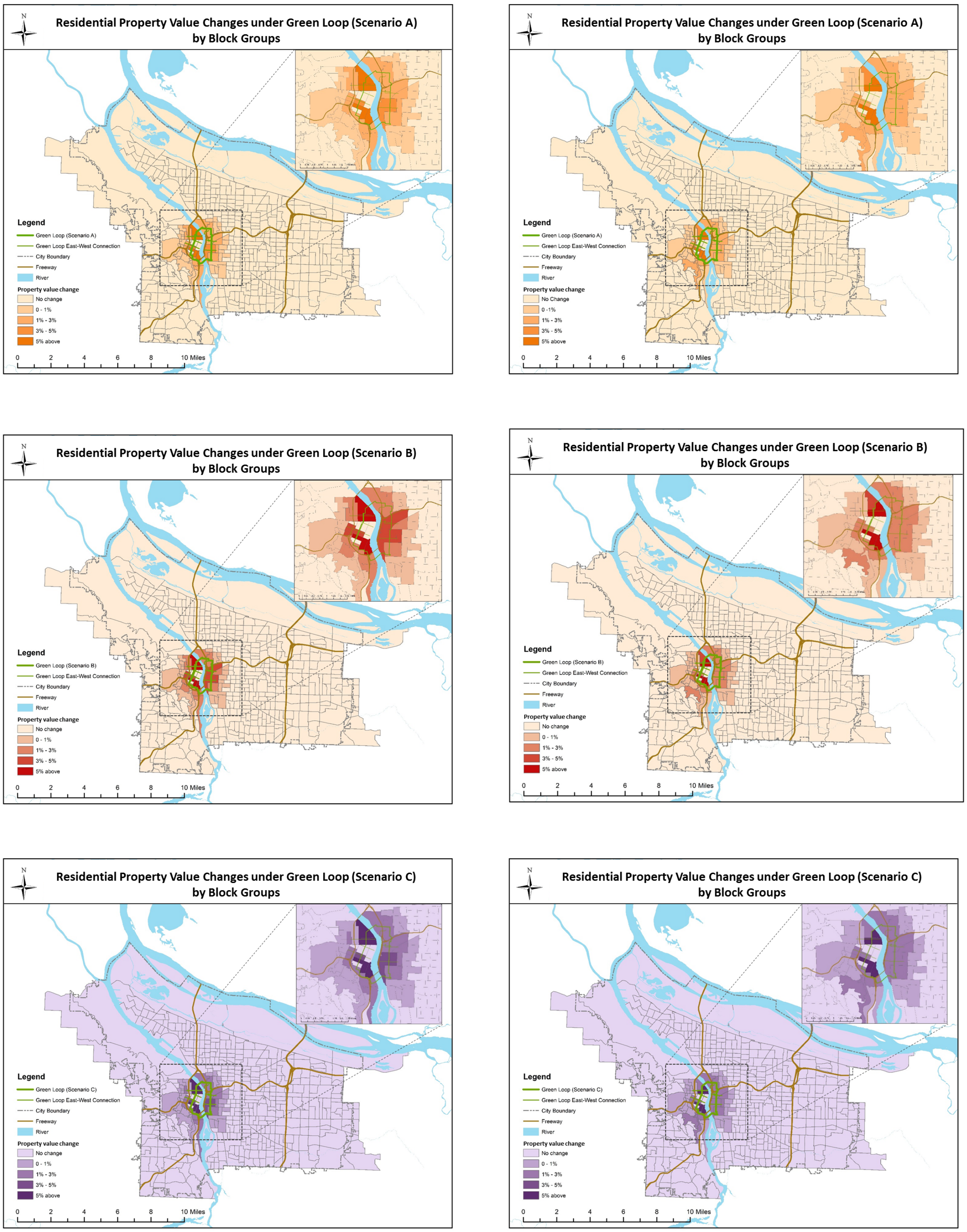


Figure 5. Geographical Distribution of Property Value Impacts by Scenario and by Model

Distribution of Property Value Impacts

Geographic Distributional Impacts

The above figures illustrate the geographic distribution of property value impacts across Census block groups, and find that properties with close proximity to the proposed Green Loop concept will see more property value impacts mainly due to higher density of advanced on-street bike facilities. We further parse property value changes in different geographic scales other to better understand how each sub-geography within central Portland neighborhoods or City Center sub-districts are affected by property value increases.

Since the proposed Green Loop concept is geographically located in the city center area, neighborhoods in central Portland are expected to see the most property value increases. Using the coefficients estimates from the SAR model, we estimate that 11 neighborhoods will observe property value changes, resulting in an overall property value increase of 5.27% and an average per unit increase of 0.98% for SFHs and 9.98% for MFHs. Among the impacted neighborhoods, the estimates show that the Old Down/Chinatown and Lloyd neighborhoods will benefit most from property value gains (Figure 6 & Table 6), possibly due to the greater prevalence of multi-family properties (as opposed to single-family homes or commercial properties) in these neighborhoods.

Using City Center sub-districts as geographic units and applying estimated coefficients from the SAR model, we find that 9 sub-districts will experience property value increases as a result of infrastructure investments from the Green Loop concept (with the exception of the Lower Albina sub-district). Total property values (and, thus, the property tax base) will experience growth of 10.95% in these sub-districts, with an average per unit increase of 2.13% for SFHs and 11.33% for MFHs. Similar to the central Portland neighborhood analysis, the Old Down/Chinatown and West End sub-districts benefit the most from property value gains (Figure 7 & Table 7).

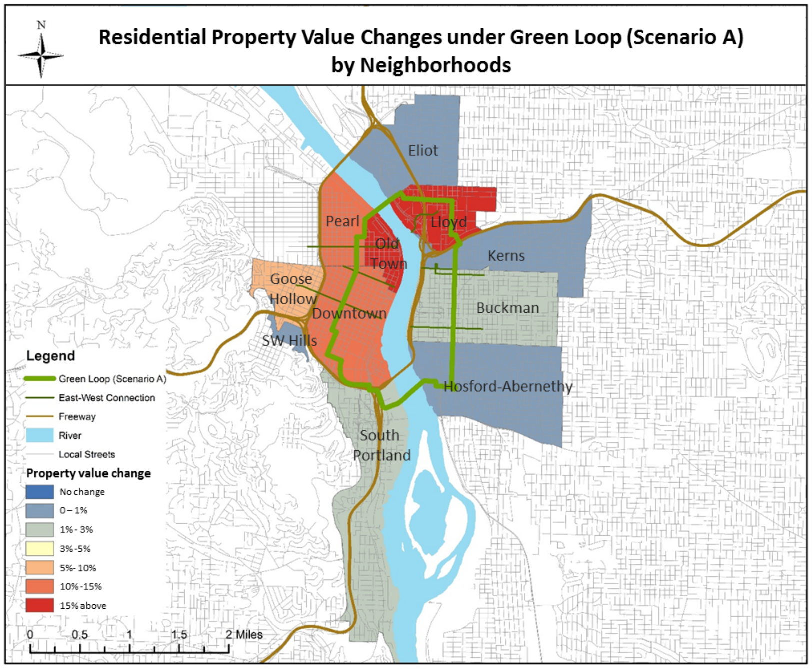


Figure 6. Property Value Changes by Neighborhoods under Scenario A

Table 6. Residential Property Value Changes by Central Portland Neighborhoods

Neighborhoods	SFH			MFH			Total	
	#	Avg. Value	%	#	Avg. Value	%	Value	%
Eliot	770	+$1,408	+0.37%	98	+$5,987	+1.41%	$1,670,886	+0.50%
Lloyd	8	+$8,868	+1.80%	87	+$46,212	+20.34%	$4,091,388	+17.26
Kerns	837	+$410	+0.09%	154	+$117	+0.05%	$361,188	+0.09%
Buckman	1185	+$3,037	+0.63%	118	+$25,963	+7.52%	$6,602,479	+1.08%
Hosford-Abernethy	2248	+$1,590	+0.33%	116	+$5,557	+1.62%	$4,218,932	+0.38%
Old Town/Chinatown	0	--	--	361	+$70,803	+24.40%	$25,559,883	+24.40%
Pearl	28	+$14,876	+2.98%	3033	+$51,903	+12.69%	$157,838,327	+12.59%
Downtown	8	+$9,513	+1.27%	1947	+$52,658	+13.16%	$102,601,230	+13.06%
Goose Hollow	194	+$4,861	+0.70%	954	+$20,171	+5.96%	$20,186,168	+4.41%
SW Hills	123	+$4,692	+0.71%	127	+$21,891	+7.36%	$3,357,273	+2.81%
South Portland	1348	+$1,231	+0.28%	1538	+$7,007	+1.77%	$12,436,154	+1.02%
Total	**6749**	**+$1,828**	**+0.39%**	**8533**	**+$38,280**	**+9.98%**	**$338,923,908**	**+5.27%**

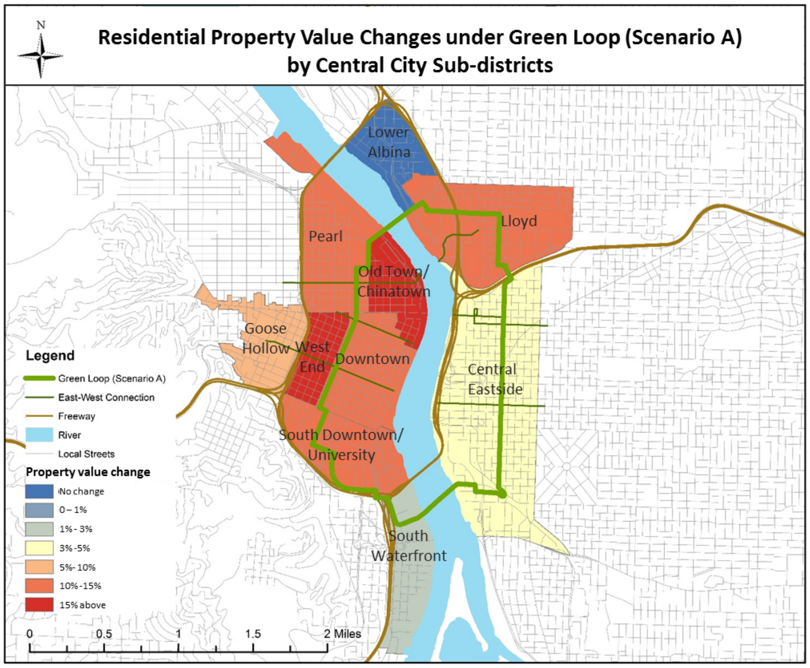


Figure 7. Property Value Changes by City Center Sub-districts under Scenario A

Table 7. Residential Property Value Changes by Central Portland Sub-districts

Sub-districts	**SFH**			**MFH**			**Total**	
	#	Avg. Value	%	#	Avg. Value	%	#	Avg. Value
Lower Albina	1	0	0	0	--	--	0	0
Lloyd	18	+$4,691	+0.79%	140	+$33,667	+13.97%	$4,797,818	+10.82%
Central Eastside	123	+$12,033	+2.76%	11	+$50,334	+18.15%	$2,033,733	+3.59%
Old Town/Chinatown	0	--	--	361	+$70,803	+24.40%	$25,559,883	+24.40%
Pearl	28	+$14,876	+2.98%	3211	+$49,026	+11.88%	$157,839,014	+11.78%
Downtown	0	--	--	377	+$59,541	+14.88%	$22,446,957	+14.88%
West End	1	+$15,173	+1.86%	481	+$59,933	+15.19%	$28,842,946	+15.14%
Goose Hollow	71	+$7,855	+1.45%	860	+$25,782	+8.03%	$22,730,225	+7.22%
South Downtown	7	+$8,705	+1.19%	1089	+$47,062	+11.68%	$51,311,453	+11.56%
South Waterfront	1	0	0	766	+$11,804	+2.84%	$9,041,864	+2.84%
Total	**250**	**+$10,459**	**+2.13%**	**7296**	**+$44,132**	**+11.33%**	**$324,603,893**	**+10.95%**

Further Distributional Impacts

Our estimations show that over 10,000 properties are positively impacted by infrastructure investments or improvements from the Green Loop concept. However, since the Green Loop concept is geographically located in central areas of Portland and bike facility impacts deteriorate as we move further away, most positive property impacts are estimated to be spatially concentrated in close-in areas. The following analysis examines the demographic characteristics of Census block groups where positive property values are expected from the Green Loop, and compares to overall demographic characteristics of Portland.

With respect to race and ethnicity, Portland's 442 block groups are on average 79.01% white while the 52 Green Loop impacted block groups have an average of 83.55% white. Our tests indicate that the racial and ethnic compositions are statistically significantly different between these geographic areas. Within these impacted block groups, only 16 of them have lower percentages of white population when compared Portland's median. In other words, the positive property value impacts from the Green Loop concept may disproportionately benefit Portland areas with higher proportions of white residents. However, the Green Loop may benefit a wider range of the population who hold jobs or go to school or engage in recreational activities in central Portland, but are not captured in the property value impact analysis.

The impacted block groups hold significant larger young populations as well as more educated populations (with education attainment of college or higher). It makes intuitive sense that Green Loop impact properties tend to be dominated by multi-family properties, which tend to attract a younger demographic. On the other hand, within the impacted block groups, we observe a higher than average percentage of populations living below 200% of the poverty line. More than half of the Green Loop impacted block groups have an average poverty level above Portland as a whole.

The proposed Green Loop concept is spatially concentrated in Portland's city center, which results in disproportionate distributions in property value impacts amongst different demographic groups. The impacted population tends to be white, young and well-educated but with lower-than-average income levels. These demographic characteristics generally mirror those of Portland city center residents where many young professionals or students reside in multi-family residences.

Table 6. Demographic Characteristics (City of Portland and Green Loop Impacted Block Groups)

Category	**Indicators**	**Portland Overall (N=442)**		**Green Loop Impacted Block Groups (N=52, Scenario B)**		**Difference**
		Median	Mean	Median	Mean	t statistics
Ethnicity	% white	80.98%	79.01%	85.62%	83.55%	- 3.37 ***
Age	% young adults (18-34)	26.57%	28.05%	41.98%	43.60%	- 6.32 ***
Education	% college or higher	79.56%	75.66%	90.54%	88.46%	- 9.37 ***
Poverty	% below 2 times poverty line	34.43%	35.17%	39.10%	39.98%	-1.83 *
Income	Household annual income	67980	78690	61580	74710	0.61
Notes: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.						

IV-2. Economic Impacts

This section describes the economic impact analysis conducted to characterize Green Loop infrastructure investment scenarios to the regional and state-level economy. This analysis provides a quantitative benchmark measure of the scope and scale of the investment in terms of its economic contributions and activities (i.e., employment and wages) and fiscal (i.e., taxes) contributions at the local, regional, and state levels. Since the Portland Green Loop is still in its conceptual stage of development, we assume that funding for the Green Loop concept infrastructure investments come from an external source (e.g., Federal grants or philanthropy).

Economic Impact Analysis - Description of IMPLAN

Northwest Economic Research Center (NERC) used the data on employment and output changes as inputs for IMPLAN, an input-output (I/O) based economic model that estimates the total macroeconomic impacts resulting from changes at a detailed geographic and economic level. A portion of the new wages paid to the firm's employees will be spent on the output of other firms. Likewise, a portion of the new intermediate materials purchased by the expanding business will increase the sales of other firms, which will hire additional workers, who will spend some of their additional income, and so on. The direct impacts estimated through BPS and PBOT's infrastructure investment scenario development process are NERC's primary inputs to IMPLAN.

IMPLAN models a region's economy as a highly interconnected network of firms and households spread across the state. It is constructed from Social Accounting Matrices (SAMs), which are based on the input-output tables of purchases and sales across industries available from the Bureau of Economic Analysis (BEA) and supplementary data from other publicly available sources. IMPLAN's matrices reflect the actual industry interactions

IMPLAN Impacts

The impact summary results are given in terms of employment, labor income, total value added, and output:

Employment represents the number of annual, 1.0 FTE jobs. These job estimates are derived from industry wage averages.

Labor Income is made up of total employee compensation (wages and benefits) as well as proprietor income. Proprietor income is profits earned by self-employed individuals.

Total Value Added is made up of labor income, property type income, and indirect business taxes collected on behalf of local government. This measure is comparable to familiar net measurements of output like gross domestic product.

Output is a gross measure of production. It includes the value of both intermediate and final goods. Because of this, some double counting will occur. Output is presented as a gross measure because IMPLAN is capable of analyzing custom economic zones. Producers may be creating goods that would be considered intermediate from the perspective of the greater national economy, but may leave the custom economic zone, making them a local final good.

within and between regions, and include the government sector which is often omitted from this type of analysis. Put simply, they present a map of the economy that illustrates the flow of money, resources, and employment through the sectors of a geographic area. IMPLAN thus simulates the wave of spending and hiring spurred by changes in one or more industries. In addition to results in the private sector, the model estimates impacts to disposable income and tax revenue.

The magnitude of these simulated changes relies on estimations of the historical relationships between households, industries, and the government sector. In the model, a production function for each industry describes the numerous resources from other industries and households each industry requires to produce its output. When the industry's sales increase, the specific number of additional employees it will hire and the amount of additional material inputs it purchases in IMPLAN's simulations are based on the past hiring and purchasing activity in that industry and region.

Ultimately, IMPLAN's analysis produces results of three types: direct, indirect, and induced.

- **Direct Impacts**: These are defined by the model and placed in the appropriate industry. They are not subject to multipliers. In this case, revenue and employment were aggregated from BPS and PBOT infrastructure investment scenarios and allocated to the appropriate industries.
- **Indirect Impacts**: These impacts are estimated based on national purchasing and sales data that model the interactions between industries. This category reflects the economic activity necessary to support the direct impacts of other firms in the supply chain – the "ripples" in the economy resulting from an initial direct impact.
- **Induced Impacts**: These impacts are created by the change in wages and employee compensation. Employees change purchasing decisions based on changes in their income and wealth.

Economic Impact Analysis – Results

Working with a few conservative estimates of potential investment scenarios, we find that even a relatively low-level of infrastructure investment may yield high economic impacts. General infrastructure investments for the Green Loop concept include striping, stormwater drainage, bollards, art boxes, planters, trees, paving, lighting, seating, etc. A **Low Investment** test scenario is estimated at $10,427,929 with 2% going towards public art installations. An alternative **High Investment** test scenario identifies seven sites where potential signature park investments may be made, and is estimated at $67,973,039. Note that these are hypothetical scenarios meant to illustrate the range of economic impacts associated with different levels of infrastructure investments.

Employment impacts from the low and high investment scenarios are presented in Table 1. Direct impacts In the **Low Investment** scenario are a total of 156 full-time equivalent jobs: 92 in industries directly involved in the project, 22 in industries that interact with those directly involved, and 42 induced by changes in compensation and spending behavior. In the **High Investment** scenario, the effects are more than quadrupled—462 jobs are directly created, another 111 emerge in related industries, and 210 are induced by increased wages, for a total of 783 new full-time jobs.

Figure 2 describes the industries that these new positions would emerge in—the blue chart shows the **Low Investment** scenario, and the green chart shows the **High Investment** scenario. As would be expected, construction is the sector with the largest increase, where the majority of direct employment occurs. The next greatest sector of increase is architecture, engineering, and related services, where direct employment also occurs, and the remainder of employment occurs across a variety of industries. The differences in facility provision between scenarios are visible—note the presence of ornamental and architectural metal products and greenhouse, nursery and floriculture provision in the **High Investment** scenario, which incorporates more signature park and public art investments than the **Low Investment** scenario. The remaining sectors are largely those expected to experience increases in employment with increases in income—health services, retail, and real estate.

The other employment impacts—labor income, total value added, and output—follow directly from the increase in jobs, and thus proportionately mirror them (some variation occurs due to the types of emergent jobs). In the **Low Investment** scenario, new workers earn over $11 million while adding $13.5 million in value and producing $22.5 million in output. In the **High Investment** scenario, those numbers are, again, more than quadrupled, with workers earning $54.9 million, adding $67.6 million in value, and producing $114.2 million in output.

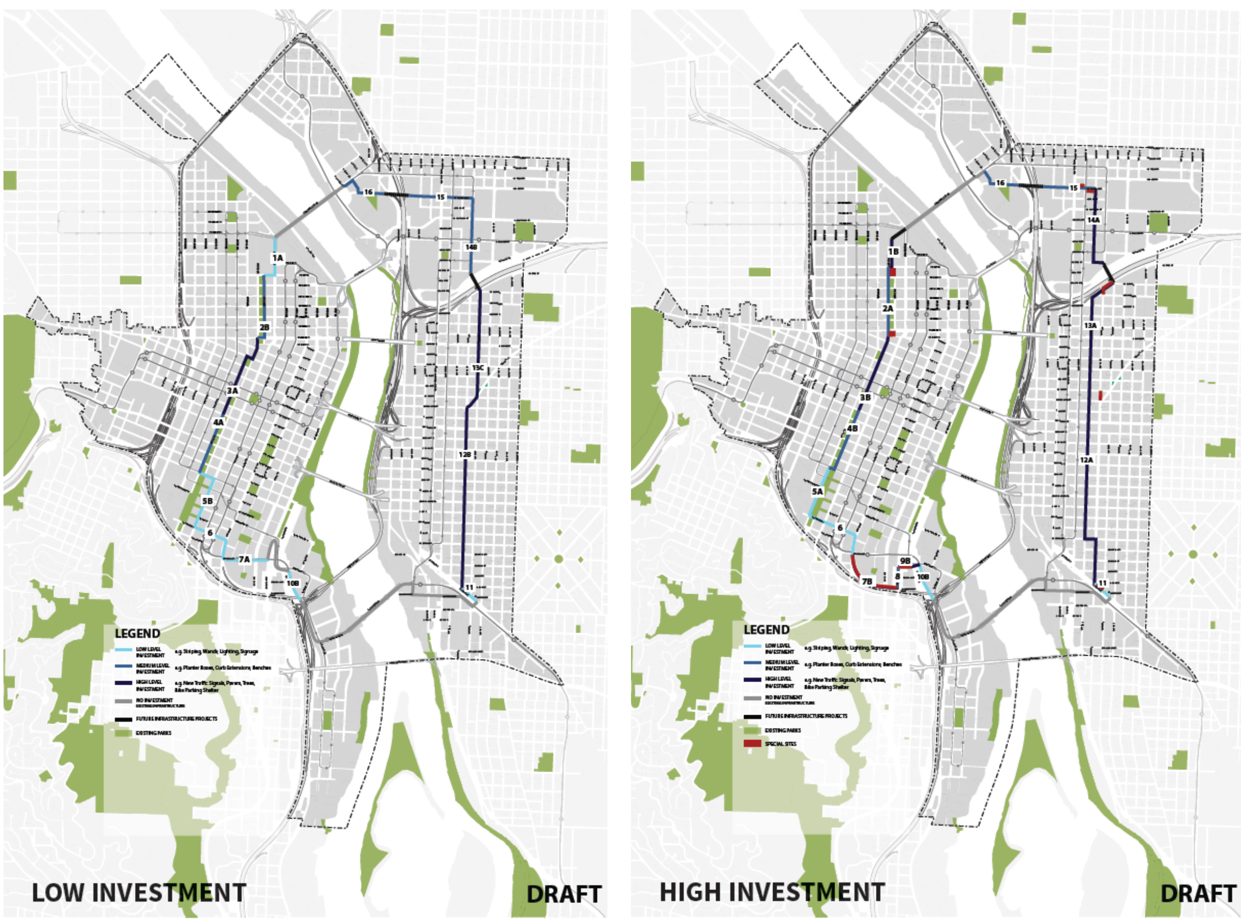


Figure 1 – Low and High Investment Scenarios

Table 1 – Green Loop Economic Impact Summary by Investment Scenario

	Impact Type	Employment	Labor Income	Total Value Added	Output
LOW INVESTMENT	Direct Effect	92	$7,637,933	$8,115,530	$13,205,929
	Indirect Effect	22	$1,404,599	$1,980,569	$3,406,832
	Induced Effect	42	$2,036,227	$3,436,662	$5,887,918
	Total Effect	**156**	**$11,078,759**	**$13,532,761**	**$22,500,678**
HIGH INVESTMENT	**Impact Type**	**Employment**	**Labor Income**	**Total Value Added**	**Output**
	Direct Effect	462	$37,657,391	$40,385,368	$67,289,278
	Indirect Effect	111	$7,180,266	$10,181,050	$17,765,643
	Induced Effect	210	$10,092,591	$17,033,768	$29,183,320
	Total Effect	**783**	**$54,930,248**	**$67,600,186**	**$114,238,241**

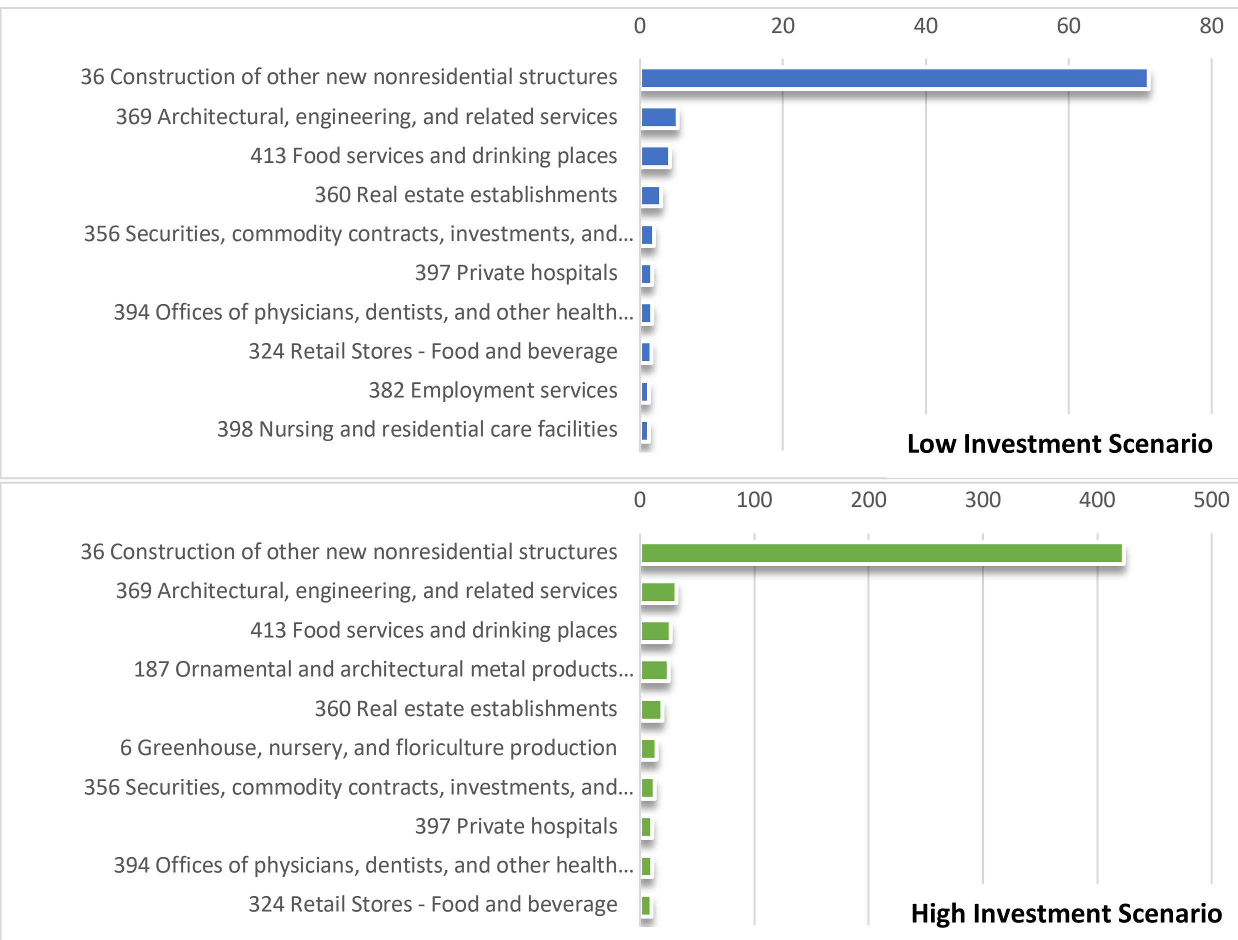


Figure 2 – Top 10 Industries by Employment Impact

IV-3. Business Impacts

Research has shown that active transportation infrastructure has potentially positive impacts on business activities and economic vitality in a region (Drennen, 2003; Flusche, 2012). Several case studies examine Northern American and European cities to compare business activities (sales) and consumer expenditures before and after the construction or improvements of bike facilities, and they have generally shown that an increase in cyclists and pedestrians enhances the level of retail activity in shopping districts that support regional businesses (Flusche, 2012; Jaffe, 2015). Jaffe (2015) summarizes 12 international case studies where street parking lanes have been converted to bike lanes, and finds that little to no impacts (and positive impacts in a few cases) of such conversions on local business activities.

Clifton et al. (2012) examine how travel modes may be related to consumer expenditure behaviors through surveys and analysis of consumers at 78 businesses in the Portland metropolitan area. The authors found that people who bike or walk tend to spend on average similar amounts or more than their driving counterparts, attributed to higher frequency of visits by non-drivers when compared with drivers. A survey of East Village, New York, found that cyclists spend about $163 per week on average compared to $143 among drivers (Jaffe, 2015). The specific type of retail businesses also matters – the Portland study found that while cyclists spend less on grocery trips, they typically spend more at restaurants, bars, and convenience stores (Clifton et al., 2012). The below tables summarize research literature that examine the business impacts of lane removal/conversions and the relationship between transportation mode and consumer spending.

Table 2 - Business impacts of lane removal in selected cases

City	Actions	Outcomes
City of Vancouver[5]	Install protected bike lanes by removing 172 parking spots, restricting turns in five locations and altering loading zones	Revenue and shopping frequency decreased range from 3%to 11%
Toronto – Bloor St.[6]	Remove parking to bike lane	Merchant: 75% think a bike lane or widened sidewalk would improve or no effect on business; Visitors: - Mode share: 46% walk, 12% bike, 32% public transit, and 10% car; - Spending: in category, walkers spend most; - 62% of responses want bike lane & less parking
Seattle – 65th St.[7]	Remove 12 parking spots and striped a bike lane	Sale index exploded 400 percent compared with surrounding neighborhoods

[5] Stantec. (2010). Vancouver Separated Bicycle Lanes Business Impact Study. Retrieved from http://www.peoplepoweredmovement.org/site/images/uploads/penv3-BusinessImpactStudyReportDowntownSeparatedBicycleLanes-StantecReport.pdf

[6] Sztabinski. (2009). Bike Lane, On-Street Parking and Business. Retrieved from http://www.bikeleague.org/sites/default/files/bikeleague/bikeleague.org/programs/bicyclefriendlyamerica/bicyclefriendlybusiness/pdfs/toronto_study_bike_lanes_parking.pdf

[7] Jaffe. (2013). No, Bike Lanes Don’t Hurt Retail Business. Retrieved from http://www.citylab.com/work/2013/09/no-bike-lanes-dont-hurt-retail-business/6833/

Seattle – Greenwood	Remove a traffic lane and parking to bike lanes	No negative compared with surrounding neighborhoods			
NYC - Vanderbilt Ave.[8]	Remove two traffic lane, add one median center lane and two bike lanes		1st year	2nd year	3rd year
		V Ave.	39%	56%	102%
		comparisons	19%	46%	64%
NYC – Ninth Ave.	Remove parking, add one bike lane		1st year	2nd year	3rd year
		Ninth Ave.	17%	47%	49%
		comparisons	25%	27%	26%

Table 2. Mode share and shopping frequency/spending

City	**Method**	**Results**
San Francisco (Bent & Snga, 2009)	Survey on 1187 people to examine the spending patterns of travelling to downtown SF	Driver 16%, $88/visit, 4 days/m, $259; Transit 60%, $40/visit, 7 days/m, $274; Walker 21%, $47/visit, 8 days/m, $291.
Davis (Popovich & Handy, 2014)	Two cross-sectional online surveys, use binomial regression model for estimate frequency of downtown shopping, and linear regression to estimate spending in downtown	Shoppers who enjoy biking statistically more frequent (0.185) shopping in downtown than car uses Shoppers who bike to downtown spent slightly more than car uses range from $7 to $12 per time, however not statistically significant
Portland (Clifton et al., 2012)	Survey from customers at restaurants, drinking places, convenience stores and supermarket patrons	Average month spending: Supermarket: car $440, bike $338, walk $386; Convenience stores: car $69, bike $82, walk $65; Drinking places: car $41, bike $82, walk $64; Restaurants: car $41, bike $48, walk $32.
NY East Village – 1st and 2nd Ave[9]	Install protected bike lane	Bike and pedestrian spend are $163, $158 per week, while drives are$143

Estimated Business Impacts

In order to understand the local business activity impacts of the proposed Green Loop, we utilize estimates from Clifton et al. (2012) in a preliminary benefits transfer analysis. We focus on establishments within a half-mile buffer around the Green Loop, estimate their retail sales before and after Green Loop infrastructure upgrades based on Scenario A for illustration.

We retrieve all Portland area business establishment data from the Reference USA database, which includes geographical location, business types, number of employees and retail sales. The distribution of businesses by industry sector within a half-mile buffer around the Green Loop (establishments with no NAICS Code or retail sales were dropped) are shown in Table 1. Following Clifton et al. (2012), Table 2 isolates the retail and food related businesses in the buffer zone, and Table 3 below summarizes their findings regarding the relationship between mode share and monthly spending for four categories of

[8] NYCDOT. (2012). The Economic Benefits of Sustainable Streets. Retrieved from http://www.nyc.gov/html/dot/downloads/pdf/dot-economic-benefits-of-sustainable-streets.pdf

[9] Transportation Alternatives. East Village Shoppers Study. Retrieved from https://www.transalt.org/sites/default/files/news/reports/2012/EV_Shopper_Study.pdf

businesses: supermarkets, convenience stores, drinking places and restaurants. Businesses along the Green Loop which fall into one of these categories are summarized in Table 4.

Table 1. Business Types in City Center affected by Green Loop

Sectors	Store Number		Total Employees		Annual Sales	
	Stores	%	Person	%	Sale Value	%
Manufacturing	753	6.6%	7,483	7.0%	$2,452,442,000	9.0%
Wholesale	319	2.8%	4,143	3.9%	$7,624,122,000	27.9%
Retail	1,316	11.5%	13,928	13.0%	$3,229,534,000	11.8%
Information, & Tech Service	3,615	31.7%	26,377	24.6%	$4,132,903,000	15.1%
Finance & Insurance	597	5.2%	7,890	7.4%	$3,177,691,000	11.6%
Real Estate	556	4.9%	4,913	4.6%	$1,161,933,000	4.3%
Health Care & Social Assistance	1,924	16.8%	12,460	11.6%	$1,876,049,000	6.9%
Arts, Entertainment & Recreation	147	1.3%	1,469	1.4%	$98,123,000	0.4%
Accommodation & Food Service	954	8.4%	16,705	15.6%	$1,011,247,000	3.7%
Other	1,239	10.8%	11,781	11.0%	$2,526,427,000	9.2%
Total	**11,420**	100%	**107,149**	100%	**$27,290,471,000**	100%

Table 2. Retail, Accommodation and Food Services in City Center affected by Green Loop

Sectors	Store Number		Total Employees		Annual Sales	
	Stores	%	Person	%	Sale Value	%
Bulk Products & Appliances	414	18.2%	4,496	14.7%	$1,472,776,000	34.7%
Food and Beverage Stores	125	5.5%	1,065	3.5%	$246,276,000	5.8%
Health and Personal Care	67	3.0%	388	1.3%	$94,663,000	2.2%
Clothing and Accessories	265	11.7%	2,564	8.4%	$400,606,000	9.4%
Musical Instrument, Book Stores	96	4.2%	862	2.8%	$137,077,000	3.2%
General Merchandise Stores	32	1.4%	1,302	4.3%	$280,037,000	6.6%
Others	317	14.0%	3,251	10.7%	$598,099,000	14.1%
Accommodation	76	3.3%	4,288	14.0%	$379,886,000	9.0%
Food Services and Drinking Place	878	38.7%	12,417	40.5%	$631,361,000	14.9%
Total	**2,270**	100%	**30,633**	100%	**$4,240,781,000**	100%

Table 3. Survey Result of Mode Choice and Average Monthly Spending in Portland

	Automobiles		Transit		Bike		Walk	
	Mode share	Monthly Spending	Mode share	Monthly Spending	Mode share	Monthly Spending	Mode share	Monthly Spending
Supermarket	86%	$440	9%	$301	4%	$338	1%	$386
Convenience Store	59%	$69	28%	$60	7%	$82	6%	$65
Drinking Places	43%	$41	27%	$36	22%	$82	7%	$64
Restaurant	64%	$41	22%	$49	8%	$48	6%	$32

Source: Clifton et.al (2012)

Table 4. Selected Business Types around Green Loop

Sector	Number of Stores	Total Employees	Total Sales
Supermarket	40	496	$125,114,000
Convenience Store	26	139	$35,054,000
Drinking Place	75	723	$41,109,000
Restaurant	771	11,346	$569,687,000
Total	**912**	**12,704**	**$770,964,000**

Studies found that higher levels of bicycle infrastructure are positively related to higher shares of bicycle commuting in US cities, although a causal relationship has not been confirmed (Dill & Carr, 2003; Nelson & Allen, 1997). Following Dill and Carr (2003), their regression result indicates that each additional mile of on-street bike lane per square mile in the city is significantly associated with a 1% increase in bicycle commuting mode share. Given that the Green Loop approximately 6.36 miles in length, and the Portland city center area is approximately 4.65 square miles, back-of-the-envelope calculations indicate that the Green Loop may introduce a 1.4% increase in bicycle mode share.[10]

If we assume that the total number of consumers and the average spending patterns within each travel mode are constant, the only changes to retail sales result from shifts in modal shares. We will further assume (for simplicity) that all of the increase in bicycle mode share is directly transferred from automobile users.

$$\text{Original Annual Sale}=12 * \sum_{modei=1}^{4}(\text{total\_customer} * mode\_split_{modei} * monthly\_spending_{modei})$$

$$\text{New Annual Sale} = 12*\sum_{modei=1}^{4}(\text{total\_customer} * new\_mode\_split_{modei} * monthly\_spending_{modei})$$

where modes 1-4 represent driving, transit, bike and walk.

Therefore, new estimated annual sales for each business category (supermarket, convenience store, drinking places, restaurants) can be calculated as

$$\text{Original annual sale} /\sum_{modei=1}^{4}(mode\_split_{modei} * monthly\_spending_{modei}) * \sum_{modei=1}^{4}(\text{new}\_mode\_split_{modei} * monthly\_spending_{modei})$$

The new estimated annual sales due to bicycle mode share increase (from the construction of the Green Loop) is $722,382,869, representing an increase of 0.18% compare with original sales numbers. However, to be more accurate, we expect that impacts of the Green Loop should be most significant and likely to occur in those businesses directly adjacent to users of the Green Loop infrastructure, particularly due to higher visibility and exposure to users. If we narrow our analysis to consider only business establishments directly along the Green Loop, we find a total of 106 establishments, of which 39 are retail and food related businesses (summarized in Table 6). Similar to the above procedure for

[10] Note that this rough calculation of increased mode share represents an increase in commuting mode share (Dill & Carr, 2003), and may or may not apply to recreational or shopping trips.

predicting new annual sales, new annual sale of the directly adjacent businesses on the Green Loop due to bicycle mode share increase is estimated to be $11,167,908, an increase of 0.20%.

If we consider establishments directly along Green Loop and also include businesses on intersecting streets within 100 feet (of the intersection) to capture some spillover effects, there are 276 total business establishments, of which 85 are retail and food related businesses (summarized in Table 8). We estimate that the additional annual sales revenue of these businesses along the Green Loop due to bicycle mode share increase to be approximately $18,167,221, representing a 0.21% increase.

Overall, our preliminary analysis of retail business activities related to the Green Loop concept shows small increases of 0.18% to 0.20% in annual sales based on Portland-specific research (Dill and Carr, 2003; Clifton et al., 2012). Further research that specifically examines changes in both bicycle and pedestrian mode share in conjunction with business activity impacts before and after street infrastructure improvements or conversions will be necessary to characterize how active transportation infrastructure affects businesses and economic development.

Table 5. Annual Retail Sales Changes before and after Green Loop installation

Sectors	Original Annual Sales	New Annual Sales	Percent change
Supermarket	$125,114,000	$124,651,078	-0.37%
Convenience Store	$35,054,000	$35,148,646	+0.27
Drinking Places	$41,209,000	$41,585,864	+1.16%
Restaurants	$569,687,000	$570,997,280	+0.23%
Total	**$770,964,000**	**$772,382,869**	**+0.18%**

Table 6. Selected Business Types along Green Loop

Sector	Number of Stores	Total Employees	Total Sales
Supermarket	1	4	$1,009,000
Convenience Store	1	3	$756,000
Drinking Place	1	4	$227,000
Restaurant	19	182	$9,154,000
Total	**22**	**193**	**$11,146,000**

Table 7. Annual Retail Changes before and after Green Loop installation

Sectors	Original Annual Sales	New Annual Sales	Percent change
Supermarket	$1,009,000	$1,005,255	-0.37%
Convenience Store	$756,000	$758,049	+0.27
Drinking Places	$227,000	$229,634	+1.16%
Restaurants	$9,154,000	$9,174,970	+0.23%
Total	**$11,146,000**	**$11,167,908**	**+0.20%**

Table 8. Selected Business Types along Green Loop (plus establishments on crossing streets within 100 feet to Green Loop)

Sector	Number of Stores	Total Employees	Total Sales
Supermarket	1	4	$1,009,000
Convenience Store	2	6	$1,512,000
Drinking Place	1	4	$227,000
Restaurant	31	306	$15,381,000
Total	**35**	**320**	**$18,129,000**

Table 9. Annual Retail Changes before and after Green Loop installation

Sectors	Original Annual Sales	New Annual Sales	Percent change
Supermarket	$1,009,000	$1,005,255	-0.37%
Convenience Store	$1,512,000	$1,516,098	+0.27
Drinking Places	$227,000	$229,634	+1.16%
Restaurants	$15,381,000	$15,416,234	+0.23%
Total	**$18,129,000**	**$18,167,221**	**+0.21%**

V. Conclusions and Further Research

As many cities are investing and committing significant resources to enhance bicycle and pedestrian mobility and to promote active transportation through infrastructure upgrades and improvements, it has become crucial for practitioners, planners and other stakeholders to understand the impacts of such policies and resource allocation decisions. In this study, we integrate analysis of case studies from active transportation infrastructure investments in numerous cities and state-of-the-art research methodologies in this field to characterize, quantify and estimate the potential property value impacts, the economic (input-output) impacts, preliminary business/retail activity impacts, distributional impacts and additional sustainability impacts of the Portland "Green Loop" concept.

We find that significant public outreach, often to underserved areas, is highlighted as key to both development and success of the infrastructure investments. By integrating new infrastructure improvements with preexisting networks, these cities both reduced the cost of improving active transport and arguably smoothed adoption by users. Interviewees cite performance and outcome measurements as key to assessing and understanding the effectiveness, efficiency and equity of these programs and investments.

In terms of economic (input-output) impact, we estimate that investments into Green Loop infrastructure will generate approximately $22 to $114 million in economic output, with 156 to 783 full-time equivalent jobs, depending on the particular test scenario estimated. In addition, we find that introducing advanced bicycle and pedestrian infrastructure such as those envisioned as part of the Green Loop concept provides positive amenity values for nearby residential properties, even after controlling for other factors that influence property values. We estimate that average property values will increase by approximately 0.05% for single-family homes, and between 6.46% and 7.96% for multi-family homes. The most significant impacts will be concentrated in neighborhoods that are located closest to the Green Loop, allowing for easier access to the amenity.

Many other social and environmental benefits such as greenhouse gas emissions savings from modal shifts, congestion time savings, public health benefits from increases in physical activities, social benefits of green spaces in urban environments or changes in ecosystem services that may be provided through enhanced natural environmental features along the Green Loop are additional considerations that will require further research. Additionally, we find that the following future research directions will greatly enrich the understanding of the linkages and interactions between active transportation infrastructure and economic outcomes going forward:

1. Given the significant economic impacts of the central city Green Loop estimated in this study, it is intuitive to expand our analysis framework to understand the economic impacts of a citywide bike facility network. It would be essential to characterize the bike network in a larger *network* context rather than the typical segmental approach in order to examine how the "citywide" network of bike facilities connects to the urban transportation system and contributes to the economy.
2. As cities are investing in different types and levels of active transportation infrastructure with varying objectives and outcomes, we find that it is critical to understand the differences in the impacts of different types of infrastructure investments (e.g. Are cycle tracks preferred to bike lanes without any separation from vehicular traffic? If so, how much and in what types of neighborhoods?). This type of research will greatly aid in policy and resource allocation decisions to place the most effective and efficient types of infrastructure within different neighborhood and policy contexts.

3. Although this report presents preliminary estimations of the business/retail and economic development impacts of active transportation infrastructure, further research is needed to accurately characterize these impacts. Research efforts utilizing more rigorous econometric methodologies to examine business/retail changes before and after street infrastructure improvements will provide much needed economic evidence for cities and neighborhoods looking to expand or improve their active transportation infrastructure.

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A1. Appendix – Case Studies

Austin, TX

Austin released its bicycle plan in 2014 highlighting three best practices: implementing protected bicycle lanes, capturing short trips, and building a complete bicycle network. This plan proposes a connected and protected active transportation network system, which provides people of all ages and abilities a safe and convenient transportation option. Austin utilizes ridership, safety, connectivity, equity, and city image measures to evaluate its bicycle programs. The plan also incorporates multidimensional benefits of the bicycle network system, such as its potential for reducing motor vehicle trips, increasing regional mobility and congestion management, boosting affordability (as a low-cost transportation option), public health improvement and environmental benefits.

Background

Prior to April 2014, the Austin region had 288 miles of active transportation facilities in total, including 57.6 miles of urban trails (shared-use paths), 2.6 miles of protected bicycle lanes, 17.8 miles of buffered bicycle lanes and 210 miles of bicycle lanes. Austin's bike lane network grew from 126 miles in 2009 to 210 miles in 2014, accompanied by a citywide bicycle mode share[11] increase to 2 percent in 2011, nearly doubling rates from 2009. In a 32 square miles region surrounding central Austin, the reported bicycle mode share ranged from 5.5 percent to 13 percent from different sources, which significantly relief the congested traffic in Central Austin ("2014 Austin Bicycle Master Plan," 2014). Since 2009, the city completed numerous new projects and removed barriers to cycling, including the creation of new bicycle lanes, and the widening or buffering of existing lanes. For other projects, appropriate measures are taken to increase efficiency: for example, projects in construction and in design, and restriping projects are often coordinated with scheduled street resurfacing or other street maintenance ("2014 Austin Bicycle Master Plan," 2014).

Active Transportation Plans and Implementation

Austin's most recent Bicycle Master Plan identifies "five elements of a strong, comprehensive bicycle system":

1. Create an all ages and abilities bicycle network;
2. Provide comprehensive end-of-trip facilities;
3. Fully integrate cycling with transit service;
4. Maintain and expand the bike share system;
5. Provide superior bicycle facility maintenance.

("2014 Austin Bicycle Master Plan," 2014, p. 40-41)

Planned bicycle facilities include protected bicycle lanes, urban trails and dedicated bikeways, quiet streets, intersection treatments, bike lanes, buffered bike lanes, and shoulder and traffic calming ("2014 Austin Bicycle Master Plan," 2014). According to the plan, the selection of on-street bicycle facility for a given street depends on overall traffic speed and volume (see Table 1).

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[11] "Mode share" describes the percent of commuters who choose a certain mode of transport at least three days per week.

Table 1 Austin bicycle facilities selection criteria

		Average Annual Daily Traffic (vehicle per day)		
		Less than 3,000	3,000-9,999	10,000+
85th Percentile Speed (MPH) Meaured or Projected	< or =30	Shared*	Bike Lane	Buffered
	31-40	Bike Lane	Buffered	Protected
	41-50	Buffered	Protected	Protected
	> 50	Protected	Protected	Protected

Source: City of Austin, 2014, 2014 Austin Bicycle Plan, p. 59.

Three issues thought to influence bicycle mode share have recently come to the fore, and subsequently are highlighted in Austin's plan. (2014):

First, the largest group, and those most likely to switch their transport mode, are those termed "interested but concerned:" individuals who are intrigued by the idea of a bike commute, but are afraid for their personal safety (Dill & McNeil, 2012). To induce such individuals to take up cycling, it may be necessary to provide protected bicycle lanes. Austin was selected as one of six US cities to participate in the Green Lane Project, an effort by the national organization PeopleForBikes to catalyze the implementation of protected bicycle lanes similar to those found in many bike-friendly European countries. During its two-year participation (2012-2014), the city increased the number of buffered or protected bicycle lanes from 5 miles to 20 miles ("2014 Austin Bicycle Master Plan," 2014). The 2014 plan highlights further expansion of such lanes.

Second, the Plan emphasized that short trips are those most easily converted into bike trips. Austin estimates that a protected bike lane network would make bikes the vehicle of choice for 15 percent of trips under three miles and 7 percent of 3-9 mile trips, resulting in a total reduction of 7 percent from automotive trips to the so-called "ring of congestion" located around the central city ("2014 Austin Bicycle Master Plan," 2014). According to the two above principles, the implementation of protected bicycle lanes should focus where short trips most frequently occur, including the central city, major transit stations, schools, and parks. Additionally, it is possible to convert longer trips to a series of short trips by incorporating public transit so that short bicycle trips can be combined with longer transit trips. This is best facilitated by the creation of protected bicycle lanes on streets surrounding major transit stations, coupled with the provision of secure bicycle parking at the station and bike share system facilities. When bicycle travel is incorporated into public transit in this way, the transit catchment area grows by a factor of 16, expanding from a quarter-mile radius to a two-mile radius ("2014 Austin Bicycle Master Plan," 2014).

Third, Austin identified the importance of building a "complete" bicycle network, defined as one that serves all ages and abilities (See Figure 1). The complete bicycle network is an incentive for people more likely to use bicycles. Focus on this particular attribute resulted in the highly successful plan implemented in Seville, Spain, where 87 miles of protected bicycle lanes were installed, and bicycle mode share increased from 0.5 to 7 percent over a period of three years ("2014 Austin Bicycle Master Plan," 2014).

Figure 1. Austin all ages and abilities network

Source: City of Austin, 2014 Bike Plan Update, p. 25.

In order to achieve the goals of increase bicycle usage and safer streets, appropriate programs are integrated into the implementation of the plan, including bicycling and safety education, encouragement and promotion, equity and access, bicycle laws and enforcement, and evaluation ("2014 Austin Bicycle Master Plan," 2014).

Evaluation

In accordance with the above three principles, periodic goals and corresponding benchmarks are set for measuring the success of the bicycle programs. Measured attributes include ridership, safety, connectivity, equity, and overall support for the multiple goals delineated in Imagine Austin, a comprehensive city plan ("2014 Austin Bicycle Master Plan," 2014).

The plan also includes a multidimensional analysis of expected benefits. Data from other cities that have completed all ages and abilities bicycle network is examined, and benefits are calculated by forecasting the increase of bicycle use and associated decrease in motor vehicle use. Such benefits include the reduction of citywide motor vehicle trips to downtown, regional mobility and congestion management advantages, boosted affordability (as a low-cost transport option), public health benefits, and environmental benefits ("2014 Austin Bicycle Master Plan," 2014).

Chicago, IL

Chicago released the Chicago Streets for Cycling Plan 2020, an updated bicycle and pedestrian plan, in 2012. The plan identifies a 645-mile network of on-street bikeways that provide a bicycle accommodation within a half-mile of every Chicagoan. The plan proposed ambitious goals, including constructing a large number of protected bike lanes. Currently, the city is wrapping up the first phase of the plan, which includes the construction of approximately 100 miles of protected bike lanes.

Background

Chicago has installed over 200 miles of on-street bike facilities, including 40 miles of marked shared lanes (cars and bicycles share the same lane, but a cautionary marking indicated bike traffic), 18 miles of buffer protected bike lanes, and 12 miles are barrier protected bike lanes prior to 2012 ("Chicago Streets for Cycling 2020 Plan," 2012). Between 2000 and 2010, Chicago constructed many new and innovative bicycling facilities, and witnessed the bicycle mode share increased from 0.5% to 1.3%. Although Chicago bicycling ridership increased at a rate higher than almost every major city in the US, the rate of crashes increased at much lower rate during the same time period ("Chicago Streets for Cycling 2020 Plan," 2012).

Aiming to offer safer active transportation infrastructures and help with the improvement of quality of life and economic growth, the City of Chicago issued the Chicago Streets for Cycling 2020 Plan and Chicago Pedestrian Plan in 2012.

Active Transportation Plans and Implementation

Both the Cycling Plan and the Pedestrian Plan were developed through a public engagement process. In terms of the Cycling Plan, large public meetings were led by Chicago Department of Transportation (CDOT) to engage Chicagoans in facilities destination and alignment decision-making, and new facility promotion through a robust outreach process; meanwhile, neighborhood meetings, organized by the public, were held to reach more residents ("Chicago Streets for Cycling 2020 Plan," 2012). A similar process was undertaken in the development of the Pedestrian Plan. Various approaches, including public meetings, opportunities for comment on the project website, an interactive on-line meeting, mail-in comment cards, and a final downtown walking workshop were provided to residents to enable them to engage in the plan development process ("Chicago Pedestrian Plan," 2012).

Chicago Streets for Cycling 2020 Plan

Three key principles of the Cycling Plan:

1. Provide a bicycle accommodation within ½ mile of every Chicagoan.
2. Provide a greater number of bikeways where more people live.
3. Increase the amount of infrastructure where ridership is high, while establishing a strong backbone of infrastructure where ridership is currently lower.
   ("Chicago Streets for Cycling 2020 Plan," 2012)

The Cycling Plan identifies a 645-mile network of on-street bikeways that enable residents feel safe and comfortable to ride through Chicago neighborhoods. The bikeways system is composed of three smaller route classifications: Neighborhood Bike Routes, which utilize residential streets; Crosstown Bike Routes, which use collector and arterial roadways; and Spoke Routes, which connect all corners of the city to downtown ("Chicago Streets for Cycling 2020 Plan," 2012). According to the Plan, by 2020, the system will consist of 310 miles of neighborhood bike routes, 275 miles of crosstown bike routes, and 60 miles of spoke routes. Altogether, the Plan aims to build more protected bike lanes than any other city in the country.

Figure 2. Chicago crosstown bike routes and spoke routes rendering

Source: Chicago Department of Transportation, 2012, Chicago Streets for Cycling 2020 Plan, p. 26, 28

There are three implementation phases of the bikeway network:

1. Build 100 miles of protected bike lanes, as well as the first 10 miles of neighborhood greenways, by 2015.
2. Construct the remainder of the network through 2020, including an additional 50 miles of protected bike lanes. Strong focus is placed on the neighborhood bike routes, and proposed additions include 30 miles of neighborhood greenways and 40 miles of bike lanes. Additional improvements include measures to make intersections safer and the improvement of bicycle accommodations along existing barriers to cyclist travel, such as bridges and viaducts.
3. Fill gaps in the network and expand the number of bikeways in neighborhoods with little cycling activity currently. In 2018, details of this phase will be updated in accordance with progress on implementation of the previous two phases and the impacts of all the new facilities installed. (“Chicago Streets for Cycling 2020 Plan,” 2012):

In accordance with the first phase, CDOT installed 51.25 miles of new and restriped bikeways in 2014, including 36.5 miles of barrier and buffer-protected bike lanes. Altogether, 85.5 miles of protected bike lanes have been constructed since 2011 (“2014 Bikeways - Year in Review,” 2015). Additional improvements include the expanded use of bike boxes, green pavement markings and intersection markings.

The Chicago Pedestrian Plan

In addition to the Chicago Streets for Cycling Plan 2020, the city introduced the Chicago Pedestrian Plan in 2012. This separate plan provides guides, tools, policies and programs to improve all aspects of the street environment, with the goal of eliminating pedestrian fatalities over the next ten years. Through these tools and actions, the city hopes to achieve maximal safety, connectivity, livability and health, which in turn will have a positive economic impact (“Chicago Pedestrian Plan,” 2012). This plan lists sixteen tools and strategies for safer streets, including “marked crosswalks, in-road State Law Stop for Pedestrians signs, pedestrian refuge islands, signals and beacons, accessible pedestrian signals, pedestrian countdown timers, leading pedestrian intervals, lagging left turns, road diet, speed feedback signs, roundabouts, chicanes, vertical traffic calming, skinny streets, bump-outs, and neighborhood traffic circle” (“Chicago Pedestrian Plan,” 2012, p. 16).

Evaluation

The bicycle crash analysis report, also released in 2012, identifies all of the factors that contribute to bicycle crashes in Chicago between 2005 and 2010 by laying out various types of crash data and information, and then sets goals for improvement. The report includes detailed descriptions the crashes involving pedestrian injuries and fatalities in the city over the described time period, previous recommendations include changes to roadway design, education and marketing, and data and reporting (“City of Chicago 2012 Bicycle Crash Analysis,” 2012).

Denver, CO

Denver, CO, initiated its non-motorized transportation system plan, Denver Moves, in 2011. It planned to add 270 miles of multi-use facilities to the existing 172 miles (as of 2011), with 80% of the final network composed of moderate to high ease-of-use facilities. There are 3 phases of implementation, with Phase I concentrating on near-term projects to achieve connectivity and equity goals in the downtown area. In 2014, the city created an additional plan, Denver Moves: Enhanced Bikeways, which focuses on downtown on-street bicycle facilities to supplement Denver Moves.

Background

The city of Denver has over 100 miles of multi-use trail, 100 miles of bike lanes, 39 miles of sharrows (defined below), and nearly 400 miles of signed bike routes as of 2014.[12]

Aiming to expand transportation and recreation system in Denver, the city initiated Denver Moves, the most recent comprehensive active transportation action-oriented plan, in 2011. The plan describes a toolbox of multi-use and bicycle facility types and networks, accompanied with implementation strategies for the future. In addition, the city created an additional plan, Denver Moves: Enhanced Bikeways in 2014, which focuses on downtown on-street bicycle facilities to supplement Denver Moves.

Active Transportation Plans and Implementation

An interactive and transparent public involvement process was undertaken to integrate with Denver Moves network and facility types for final decision-making. Public involvement opportunities include: citizens taskforce, which involves citizens participate in plan draft review and workshops; providing interactive project website, which enables residents identify desired routes and facilities, and comment; large-scale aerial image tour stops to enable residents experience the potential facilities; and draft plan workshop to gain feedback on proposed network and facility types ("Denver Moves," 2011).

Building upon the existing active transport facilities, the main goals of this plan are:

1. A biking and walking network where every household is within a quarter mile (5-minute walk or 2-minute bicycle ride) of a high ease of use facility.
2. Achieve a 15% bicycling and walking commute mode share by 2020.
   ("Denver Moves," 2011, p. 4)

The final Denver Moves network is identified through five procedures:

1. Mapping previous existing and planned facilities as potential network choice;
2. Multiple approaches of public involvement;
3. Field feasibility evaluation by transportation planner and engineer;
4. City staff review the network draft to ensure the consistency with other plans;
5. Final feasibility analysis incorporated with public review workshop.
   ("Denver Moves," 2011)

Finally, a total 442 miles of non-motorized facilities were proposed (see Table 2).

[12] Biking on Denver's Streets and Trails, access on October, 2015 from https://www.denvergov.org/content/denvergov/en/bicycling-in-denver/streets-and-trails.html

Table 2. Propose non-motorized facility types in Denver Moves

Facility Type	Existing miles	Miles added with Denver Moves	Total network miles	Percentage of system
Multi-use (trails, on sidewalk)	107	24	131	30%
Separated in-roadway (cycle track, bike lanes—regular, buffered, climbing)	51	121	172	39%
Enhanced shared roadway (sharrow, party parking, pave shoulder)	14	63	77	17%
Bike Boulevards	0	62	62	14%
TOTAL	172	270	442	100%

Source: City of Denver, 2011, Denver Moves, p. 5

Proposed facilities types include the following: (“Denver Moves,” 2011)

a. Bike Boulevards: streets, typically low-volume, that are re-designed to ease non-motorized transport and provide connectivity between neighborhoods and common destinations (Figure 3).

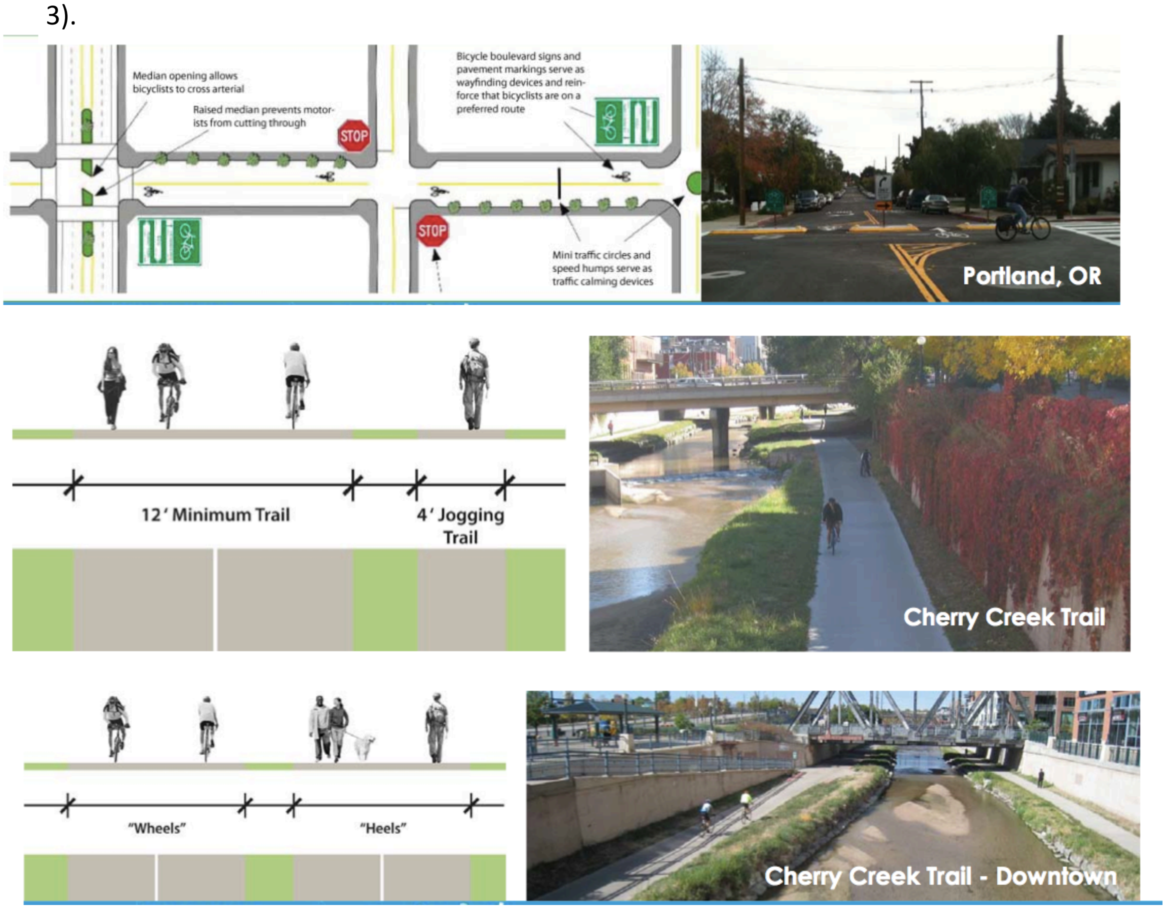


Figure 3. Rendering of Bike Boulevards, Regional Trails and Heels & Wheels Trails

Source: City of Denver, 2011, Denver Moves, p. 16-18

b. Regional Trails: off-street facilities for shared non-motorized use. Such trails provide both recreational opportunities and eased active transport (Figure 3).
c. Heels & Wheels Trails: trails that ease the mix of different types of active transport by adding a parallel trail to the current trail, thus minimizing conflicts between users of different speeds in highly-trafficked segments of trail (Figure 3).
d. Minor Trail: off-street facilities designed for shared non-motorized use, typically in a park, open space, or near a low volume roadway (Figure 4).
e. Cycle Tracks: exclusive bikeways separated from motor vehicle and pedestrian traffic by a median planter strip, parking lane, or both, typically installed on streets with higher traffic volume/speed with long blocks and few intersections (Figure 4).
f. Shared Use Sidewalk: sidewalks designed for bicycle usage to avoid conflicts with motor vehicle traffic. (Figure 4).

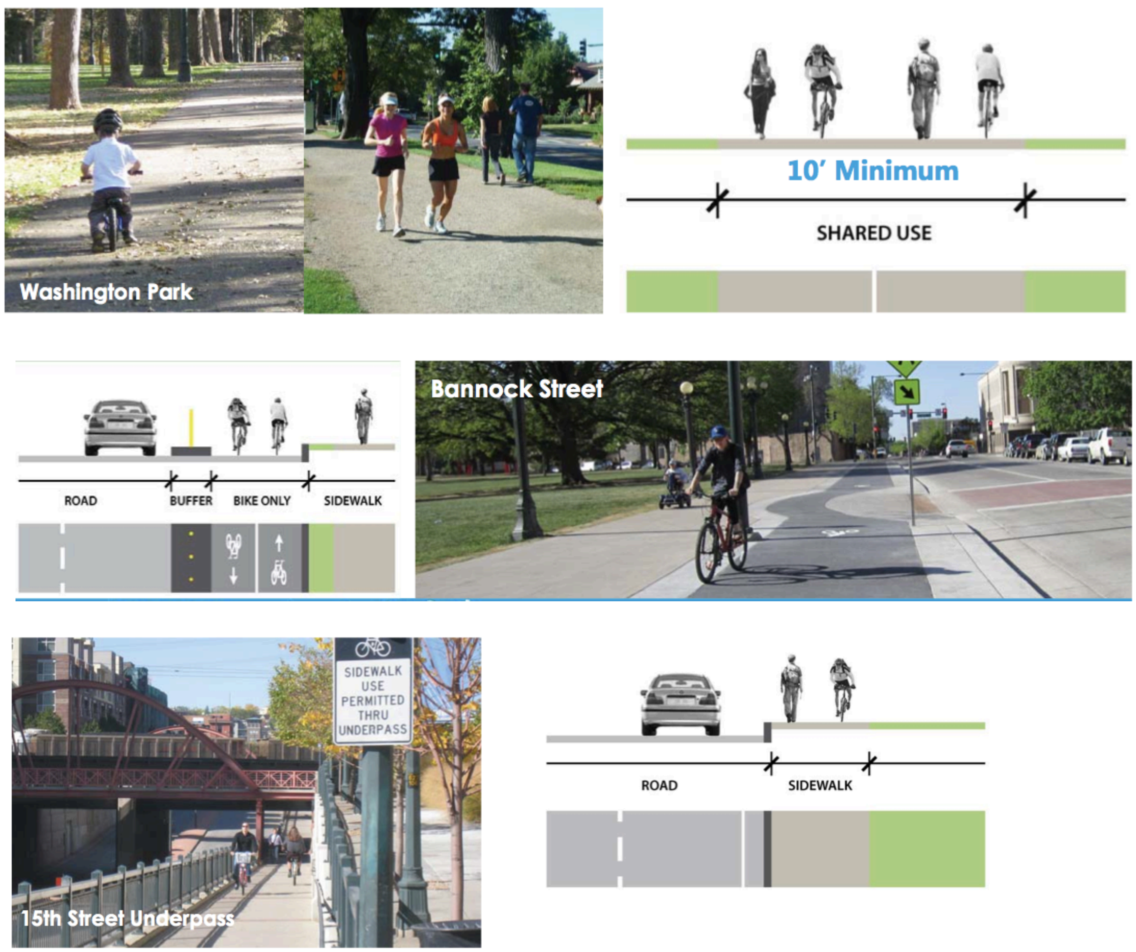
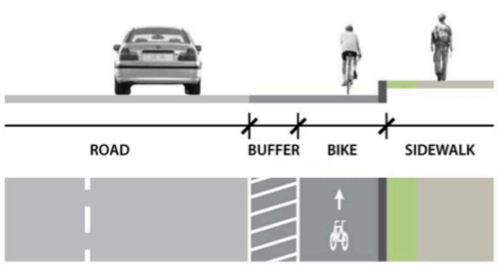
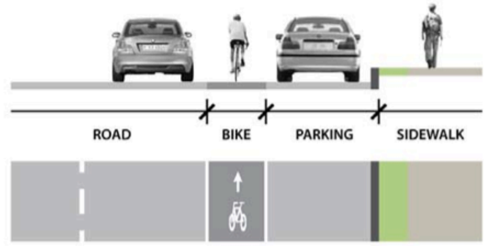


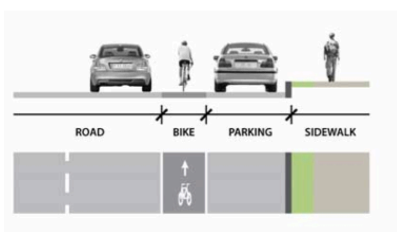
Figure 4. Rendering of Minor Trails, Cycle Tracks, and Shared Use Sidewalk

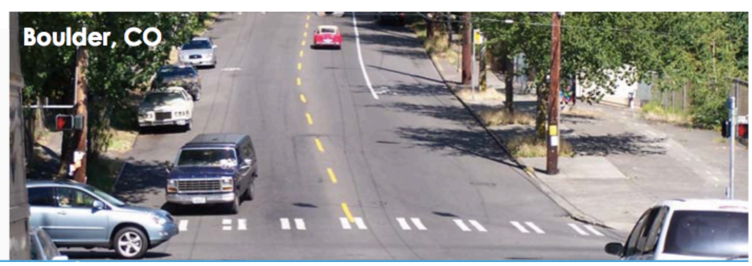
Source: City of Denver, 2011, Denver Moves, p. 19-21

g. Buffered Bike Lane: bike lanes buffered by a demarcated zone between the bike lane and adjacent travel or parking lane to prevent bicyclists from travelling close to the parking lane, subsequently reducing “dooring” accidents. (Figure 5).
h. Bicycle Lanes: the minimum standard for separate on-street bicycle accommodation. These are a good option for roads of the collector and arterial type because they improve rider comfort and safety when traffic volume and speed are higher at minimal cost (Figure 5).
i. Climbing Lane: hybrid bicycle facilities on roadways with steep grades. In order to account for speed differentials, bicycle lanes are marked in the uphill direction while shared-lane markings suffice in the downhill direction (Figure 5).
j. Shared Roadway/Signed Routes: while this type of roadway includes no specific bicycle design, measures like appropriate signage, good pavement quality, and possibly speed reduction techniques can make them safer for cyclists (Figure 5).









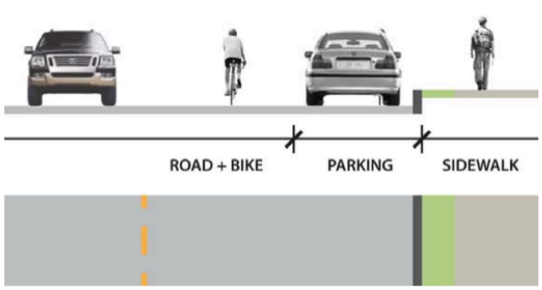


Figure 5. Rendering of Buffered Bike Lane, Bike Lanes, Climbing Lane, and Shared Roadway/Signed Routes

Source: City of Denver, 2011, Denver Moves, 22-25

k. Party Parking Lane: in areas with a low rate of weekday use, marked parking lanes can also operate as bicycle lanes. "Low rate" is defined as 5-10% use of block length for parking during off peak times (Figure 6).
l. Sharrows: also named shared lane marking, are road markings that provide guidance in situations where space is too narrow for a motor vehicle and a bicycle to travel side by side (Figure 6).
m. Paved Shoulder: areas where there is additional space between the outer travel lanes and the edge of the right of way. This space is typically marked off with a solid white line (Figure 6).

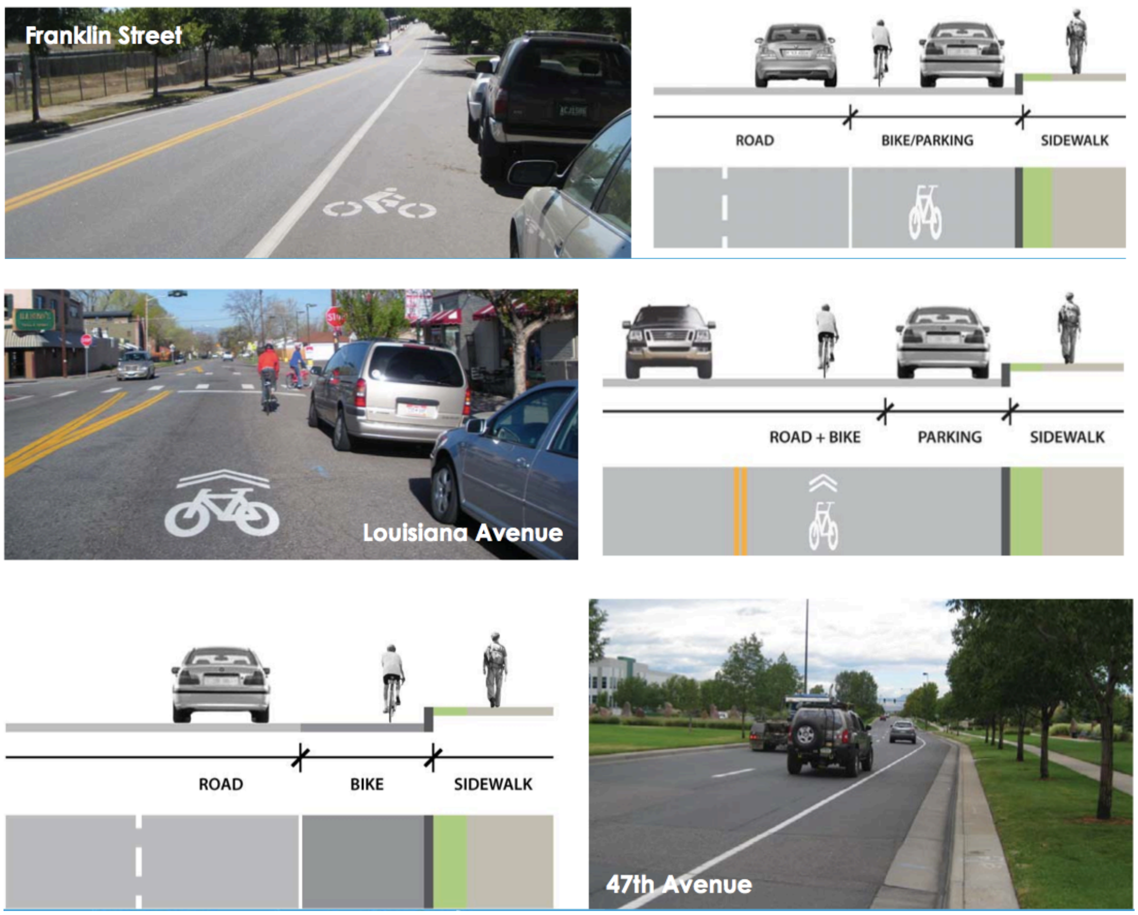


Figure 6. Rendering of Party Parking Lane, Sharrows, and Paved Shoulder

Source: City of Denver, 2011, Denver Moves, p. 26-28

Implementation of the proposed network and facilities includes 3 phases, with priority based on a system of proximity and feasibility criteria (See Table 3). Phase I focuses on connectivity by closing gaps in the existing system, providing active transport geographic equity, and construction of on-street facilities that link regional parks and trails. At the time of the plan's release, progress on Phase I was already underway: measures had been taken to create a cohesive active transport network in the downtown area, and new facility types were being tested. Phases II and III expand changes to cover a larger area and increase the density of the network. The timeline for these phases is left open, so that goals can be adjusted in accordance with available funding.

Table 3. Denver Moves scoring criteria for project phasing prioritization

Proximity Criteria	Scoring
Mitigates pedestrian/bicycle/vehicle conflicts	*High=2 Medium=1 Low=0*
Connects off-street to on-street bike facilities or sidewalks (500' buffer around trail)	*Yes= 1 No=0*
Directly adjacent to a school (500' buffer around school)	*Yes= 1 No=0*
Within a ¼ mile of a park recreation center, or library	*Yes= 1 No=0*
Within a ¼ mile of a Living Street or Enhanced Transit Corridor	*Yes= 1 No=0*
Within a ¼ mile of a neighborhood destination	*Yes= 1 No=0*
Within 1/2 mile of a Denver TOD	*Yes= 1 No=0*
Fulfills recommendations in Bicycle Master Plan	*Yes= 1 No=0*
Fulfills recommendations in the Pedestrian Master Plan	*Yes= 1 No=0*
Fulfills recommendations in the Gulch Master Plan	*Yes= 1 No=0*
Implementation Feasibility	
Community support	*High= 2 Low=1 None=0*
Action (trade-off)*	*None=2 Medium=1 High=0*
Cost**	*Low=2 Medium=1 High=0*
Opportunity driven	*Yes= 1 No=0*

*High=Parking Impacts, Medium=Road Diet, Low= Lane narrowing (lane diet) No action needed, add striping/marking
**High=construct future facility, Medium= in-street improvement, pave existing shoulder, Low = add signage/striping

Source: City of Denver, 2011, Denver Moves, p. 39

The plan estimates the total cost of all identified improvements at $119 million (2010 dollars; $66 million in linear projects and $54 in crossing improvements) (Figure 16).

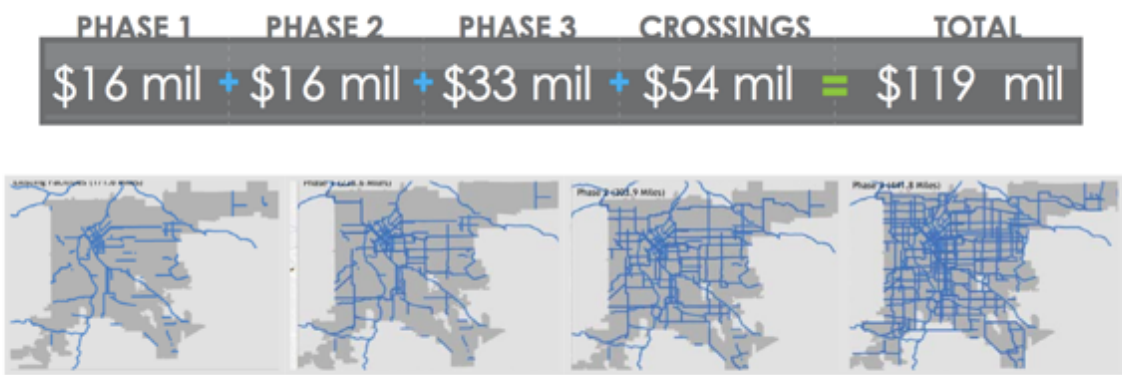


Figure 7. Denver Moves phasing and cost estimation

Source: City of Denver, 2011, Denver Moves, p. 5

In 2014, the enhanced bikeways plan was initiated, with the aim of developing a detailed plan for the network of enhanced on-street bicycle facilities (e.g., cycle-tracks, protected or buffered lanes, signalized or marked intersections) in downtown, with linkages from adjacent neighborhoods to either downtown or off-street facilities, enhancing attractiveness to cyclists of average ability[13]. The recommended network of enhanced on-street bicycle facilities will incorporate the Denver Moves plan.

[13] Denver Moves: Enhanced Bikeways (2014), from https://www.denvergov.org/content/denvergov/en/bicycling-in-denver/streets-and-trails/planning.html

Indianapolis, IN

Indianapolis, IN released the most recent version of their updated its bicycle and pedestrian plan, named "Indy Greenways Full Circle Master Plan," in 2014. This plan describes 250 miles of greenway, including a 64-mile circle that connects the region, major neighborhoods, and city green spaces. Economic impacts of the greenway system are evaluated in the plan in terms of property value, property tax, job creation, economic potential and retail sales. The cultural trail in downtown Indianapolis (launched in 2013) acts as an "engine" of the greenway system, connecting existing regional greenways. Studies show that the place-making and ecological design of the system facilitate recreational riding and spur economic activity and tourism for the city.

Background

The state of Indiana released the Indiana State Trails, Greenways & Bikeways Plan in 2006, with the goal of providing trail access within 7.5 miles or 15 minutes for all residents by 2016. As of 2014, they have met this criterion for 98.2 percent of the city ("Hoosiers on the Move, the Indiana State Trails, Greenways & Bikeways Plan - Progress Report January 2015," 2015). The city of Indianapolis greenways system plan was first drafted in 1994, and then updated in 2002 to identify 14 greenway corridors that would serve as the basis for greenways system improvement.

In 2014, Indianapolis adopted the Indy Greenways Full Circle Master Plan, and identified 9 new greenway corridors in addition to those already described in previous plans. The Plan outlines the comprehensive vision of the greenways development in Indianapolis.

Plans and Implementation

Indy Greenways Master Plan

For the Indy Greenways Master Plan, the city laid out an extensive public-driven planning process starting in 2013. First, potential new routes were developed based on a process of identification and assessment of inventory and existing greenway system, and followed by a series of public engagement events. A second round of public meetings and an economic impact review contributed to the route prioritization for implementation recommendation across the Indy Greenways System. Due to the scale of the master plan and levels of community investment, multiple methods of public engagement were involved, including public meetings, promotion of the process through public information handouts, online public surveys, a project website, social media, and the creation of a project office and consistent office hours, among others. ("Indy Greenways Full Circle 2014-2024 Master Plan," 2014).

Multi-dimensional goals and objectives were designed for guiding the development of the Greenways System:

1. Recreation: Provide opportunities for recreation throughout the city;
2. Access: Identify, promote and increase access to the greenways by residents;
3. Connectivity: Provide connections to neighborhoods, commercial centers, parks, pedestrian and bicycle facilities, and public transportation;
4. Transportation: Provide routes that can be used for alternative transportation;
5. Economics: Provide a positive economic benefit to the community and foster the growth of existing and emerging commercial districts;
6. Environment: Promote responsible and sustainable stewardship of greenway corridors and their resources;

7. Inter-agency coordination: Identify appropriate oversight and coordination with related agencies overseeing similar bicycle and pedestrian functions in the City;
8. World-class: Promote the continued recognition of Indy Greenways as one of the nation's world-class greenways systems.
   ("Indy Greenways Full Circle 2014-2024 Master Plan," 2014, p. 58)

The Plan delineates 250 miles of greenways throughout the City of Indianapolis by 2024 ("Indy Greenways Full Circle 2014-2024 Master Plan," 2014). These greenways provide a 64-mile circle around the city and offer multi-modal connections (bikers, walkers and other users) between four flagship parks in the city.

Indianapolis Cultural Trail

Constructed between 2007 and 2013, the Indianapolis Cultural Trail in downtown Indianapolis acts as a "hub," connecting many greenway trails ("Indy Greenways Full Circle 2014-2024 Master Plan," 2014).

Figure 8. Indianapolis Cultural Trial map, facility examples, and place-making

Sources: Map – Indianapolis Cultural Trial[14], Pedestrian and cycling trail, Indianapolis Cultural Trail[15], Cycling in the United States[16], and Home of Indy 500 embraces bicyclists and pedestrians[17].

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[14] Map-Indianapolis Cultural Trial, from http://indyculturaltrail.org/map/
[15] Indianapolis Cultural Trail, from http://altonrdcoalition.org/wp/category/pedestrians/;
[16] Cycling in the United States, from http://www.skyscrapercity.com/showthread.php?t=519960&page=7.
[17] Home of Indy 500 embraces bicyclists and pedestrians, from https://www.transportation.gov/fastlane/home-indy-500-embraces-bicycle-pedestrian-transportation.

The 8-mile cultural trail was opened in 2013, with the goal of connecting neighborhoods, cultural districts and entertainment amenities. It is also connected to 40 miles of the Indianapolis Parks Greenway Trail System. The total cost is $63 million, composed of $27.5 million private funding and $35.5 million federal transportation funding ($20.5 million of which is from a TIGER grant). No local tax money was used during this process. It estimates $864.5 million in economic impact, including the creation of 11,372 jobs. It has 5 acres of new landscaping, 11.25 acres of paved trails, 8065 cubic yards of topsoil and 25,400 square feet of storm-water planters[18]. In addition, a bike-sharing program with 26 stations and 250 bicycles is available along the trail[19].

Evaluation

The Greenways Full Circle Master Plan includes an economic impact analysis of the proposed greenway system, covering the topics of property value, property tax, job creation, economic potential, and retail sales. They summarized:

- There is 6,371 acres of land with development potential in the ½ mile surrounding the five highest priority future trails.
- After all mixed-use trails are constructed, $39.7 million in new property taxes may be generated by increases in property value. The result is a return of $0.90 on each construction dollar spent on mixed-use trails currently estimated at $44.2 million in total construction costs.
- The construction of 183.3 miles of new mixed-use and residential trails in the county at a construction cost of $183.2 million will create $73.3 million in labor costs creating 1,102 jobs in the process.
- Based on annual trail user counts, the expected retail sales generated by future trails range from $2.7 to $5.7 million supporting 11 to 23 retail employees.
  (“Indy Greenways Full Circle 2014-2024 Master Plan,” 2014)

Wang & Hji-Avgoustis (2011) conducted a cost-benefit analysis of the Indy Cultural trail. Construction and maintenance costs, and benefits of expenditures of residents, job creation and tourism growth were taken into account in the analysis. Additional benefits include urban revitalization, property value increase, recreation and health and reduction of travel cost. The results indicated that without counting tourism benefits, the benefits would not exceed the costs. They emphasize the importance of tourism strategies of the cultural trail.

Further Information

There are four research papers regarding the impact of greenways using the Indianapolis case, in terms of trail usage, property value, recreation, and equity of access. Some studies found neighborhood characteristics, including urban forms and social-demographic characteristics, influence the greenway usage in Indianapolis (Lindsey, Han, Wilson, & Yang, 2006; Ottensmann & Lindsey, 2008). By using data from Indianapolis Greenways, another study shows that some but not all greenways have a positive, significant effect on property value and the recreational value exceed the cost of constructions (Lindsey, Man, Payton, & Dickson, 2004b). In addition, the greenway access for diverse groups should be considered in the planning and implementation process (Lindsey et al., 2001).

[18] Fun Trail Facts - Indianapolis Cultural Trial, from http://indyculturaltrail.org/alongthetrail/facts-and-figures/

[19] Bikeshare – Indianapolis Cultural Trial, from http://indyculturaltrail.org/bikeshare/.

Minneapolis, MN

Minneapolis, MN updated its bicycle plan in 2011. In their plan, they emphasize multiple strategies to strengthen the bicycle network including education, encouragement, enforcement, engineering, equity and evaluation. The city updated their protected bikeway plan for near-term implementation of protected bikeways.

Background

Prior to the end of 2009, there were several types of bikeways throughout Minneapolis: 44 miles of on-street bike lanes, bicycle boulevards, on-street greenways, signed bike lanes, and shared use pavement markings (sharrows), and 84 miles of off-street trails[20]. As of 2014, on-street bikeways has increased to 118 miles, and off-street bikeways to 92 miles[21].

The most recent Minneapolis Bicycle Master Plan was adopted in 2011, with the aim of improving safety and mobility for bicyclists around the city. This plan provides a comprehensive framework for projects and initiative for future active transportation development in Minneapolis. In addition, an updated protected bikeway plan was proposed for near term protected bikeway implementation in 2015.

Plans and Implementation

Minneapolis Bicycle Master Plan

The city took over one year to prepare the plan. A public meeting was held in June 2008 where over 150 people attended. Five additional public meetings were held in 2010 to receive public comments on the draft plan (Pflaum, 2011).

The main guiding principles of the Minneapolis Bicycle Master Plan (2011) are improving safety and mobility, increasing numbers of bicyclists and mode share, and ensuring community support and wise investments. In this plan, they proposed to add 183 miles of bikeways at a cost of $270 million, over the course the next 30 years. The stated goal is to ensure that all residents are within 1 mile of a trail, ½ mile of a bike lane, or ¼ mile of a signed bike route by 2020 (Pflaum, 2011).

The plan poses a need analysis for the “Six E’s”: education, encouragement, enforcement, engineering, equity and evaluation. Addressing these needs will help them to achieve the goal of increasing bicycle mode share, safety and comfort, and accessibility. Under each goal, the six E’s are illustrated by setting initiatives, benchmarks, performance measures and responsible parties. The research team evaluated the bicycle system in terms of bicycle counts, crash and injury reduction, and miles of bikeways, with a final goal of zero deaths (Pflaum, 2011).

Protected Bikeway Update

In 2015, Minneapolis updated the plan to include more protected bikeways in the near-term. Protected bikeways may be one-way or two-way facilities. In street corridors, they may be at street-level or at sidewalk level.(“Protected Bikeway Update to the Minneapolis Bicycle Master Plan,” 2015)

Table 4. Minneapolis bikeway network development

[20] “Improvements making Minneapolis a better biking city”, from http://www.ci.minneapolis.mn.us/news/news_20100105betterbikingcity
[21] “Bicycling in Minneapolis”, from http://www.ci.minneapolis.mn.us/bicycles/

Minneapolis Bikeway Network Development

Bikeway Type	Centerline Miles by Year 1997	2010	2014	This Plan	Long-Term*
Protected Bikeways	62	89	96	144	174
Bike Lanes	19	44	82	50	104
Shared Lanes	1	5	15	11	74
Bike Boulevards			20	20	44
To Be Determined				6	6
Total	**82**	**138**	**213**	**232**	**403**

** Based on existing network, this plan, 2011 Bicycle Master Plan, and other recent planning activities.*

Source: City of Minneapolis, 2015, Protected Bikeway Update to the Minneapolis Bicycle Master Plan, p.1

Midtown Greenway, Minneapolis

Loring Bikeway, Minneapolis

Figure 9. Examples of protected bikeways in Minneapolis

Source: City of Minneapolis, 2015, Protected Bikeway Update to the Minneapolis Bicycle Master Plan, p.2

The implementation of protected bike lanes also involve in an evaluation and engagement process around the city for master plan amendment. The process is:

1. Identify the location of the proposed protected bikeway, considering high bicycle demand, high traffic conflict, good network integration, and public input;
2. Confirm location for further evaluation, and evaluate design and implementation feasibility;
3. Draft recommended protected bikeway corridors and plan document of feasibility analysis results and already-programmed projects;
4. Public review and input;
5. Final draft of bicycle master plan amendment.
   (“Protected Bikeway Update to the Minneapolis Bicycle Master Plan,” 2015)

New York, NY

New York, NY created its Bicycle Master Plan in 1997 and released its strategic plan, Sustainable Streets, in 2008. The city aimed to double bicycle commuting between 2007 and 2012 (the goal was reached early in 2011) and to triple it by 2017. With its expansion of bicycle/pedestrian facilities, bicycle safety has improved significantly, even after accounting for the growing number of bicycle commuters in recent years. New York utilizes multidimensional evaluation metrics to study key street redesign treatments. They also evaluate the economic impact of street redesigns by using retail sales as their key indicator of local economic opportunities and vitality.

Background

New York issued the Bicycle Master Plan in 1997. There is no more recent updated bicycle master plan, besides Sustainable Streets, the agency's comprehensive transportation strategic plan, which launched in 2008. The strategy plan laid out the vision of improving safety and mobility for residents, and achieving the final goal of "world-class quality of life" ("Sustainable Streets - Strategic Plan for the New York City Department of Transportation 2008 and Beyond," 2008).

As of 2014, New York had 431.5 miles of on-street bicycle facilities in total, indicating rapid growth compared with the level of 2007 (See Table 5). Over half of the facilities constructed in this time period are exclusive bicycle lanes, but over the last three years, more shared bicycle lanes have been constructed.

Table 5. New York bicycle network expansion from 2007-2014

Miles by Type	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	Total	% of Total
Protected Bicycle Path	0.0	0.8	4.1	9.9	6.1	4.7	5.4	8.9	**39.9**	**9%**
Exclusive Bicycle Lane	35.8	54.4	60.2	16.2	18.3	8.1	18.4	17.3	**228.8**	**53%**
Shared Bicycle Lane	6.2	18.9	24.4	24.4	8.7	13.2	28.6	38.5	**162.9**	**38%**
Total	**42.0**	**74.1**	**88.7**	**50.5**	**33.1**	**26.0**	**52.3**	**64.7**	**431.5**	

Miles by Boro	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	Total	% of Total
Bronx	9.0	14.1	15.8	11.1	6.5	2.2	6.4	18.5	**83.6**	**19%**
Brooklyn	9.1	20.2	31.0	29.0	13.6	8.2	16.2	20.6	**147.8**	**34%**
Manhattan	13.1	10.4	12.8	4.4	5.7	11.4	25.9	10.9	**94.7**	**22%**
Queens	10.8	22.9	19.0	6.1	7.3	3.3	3.9	14.7	**87.9**	**20%**
Staten Island	0.0	6.5	10.1	0.0	0.0	0.9	0.0	0.0	**17.5**	**4%**
Total	**42.0**	**74.1**	**88.7**	**50.5**	**33.1**	**26.0**	**52.3**	**64.7**	**431.5**	

Source: New York City Bicycle Network Expansion[22]

Plans and Implementation

In order to implement and maintain city bicycle network and provide safer bicycle facilities, the 1997 Bicycle Master Plan proposed 909 miles of citywide bicycle network, designed guidelines for implementation of projects and initiatives ("New York City Bicycle Master Plan," 1997).

[22] New York City Bicycle Network Expansion, from http://www.nyc.gov/html/dot/downloads/pdf/bikeroutedetailsfy07-fy14.pdf

In 2008, Sustainable Streets, a transportation strategic plan, were released. It described a comprehensive framework of policies and actions toward goals of safety, mobility, customer service, greening, world-class streets, and global leadership ("Sustainable Streets - Strategic Plan for the New York City Department of Transportation 2008 and Beyond," 2008). Bicycle and pedestrian facilities and initiatives are important components in this plan to help to achieve the goals.

Evaluation

Comprehensive metrics

Using a cross-section of recent street design projects, NYCDOT evaluates the street project toward safe, sustainable, livable and economically competitive streets ("Measuring the Street: New Metrics for 21st Century Streets," 2012). The comprehensive metrics include multiple aspects: crashes and injuries, traffic volume, traffic speed, economic vitality, user satisfaction, environmental and public health benefits. This report lists several street design projects, and describes changes after specific treatments in terms of designing safer streets, building great public spaces, improving bus service, reducing delay and speeding, and increasing efficiency in parking and loading. The street redesign treatment inventory are listed below (See Table 6):

Table 6. Street redesign inventory

Strategies	Key treatments	Key Metrics
Designing safer streets	• Simplified intersections • Dedicated left, right, and through lanes • Pedestrian safety islands • Protected bike lanes • Leading pedestrian intervals and split phasing	• Crashes and injuries to motorists and other vehicle occupants, pedestrians, cyclists, and motorcyclists • Vehicle speeds
Building great public spaces	• Create new pedestrian plazas – first using temporary materials, later as capital projects • Street furniture • Seasonal seating platform in curbside lane • Striping and planters • Maintenance agreements with local organizations • Programmed events	• Economic vitality (sales tax receipts, commercial vacancies, number of visitors) • User satisfaction, revealed through surveys • Number of users
Improving bus service	• Offset bus lanes • Transit Signal Priority • Bus bulbs • Bus lane enforcement cameras	• Bus ridership • Bus travel speeds • Economic vitality (sales tax receipts, commercial vacancies, number of visitors)

Reducing delay and speeding	• Adaptive signal control • Signal optimization • Dedicated left, right, and through lanes • Simplified intersections • Neighborhood Slow Zones	• Travel speeds and times • Traffic volumes • Crashes and injuries to motorists and other vehicle occupants, pedestrians, cyclists, and motorcyclists
Efficiency in parking and loading	• PARK Smart • Commercial Paid Parking • Delivery Windows • Muni meters	• Vehicle travel speeds and volumes • Double parking • Parking duration • Number of unique visitors

Source: New York City Department of Transportation, 2012, Measuring the Street: New Metrics for 21st Century Streets, summarized by author

Economic Impact Study

A further economic impact study, the Economic Benefits of Sustainable Streets (2012), follows up to evaluate the improvements on neighborhood economies. The basic hypothesis is that changes in street environment, travel patterns, spending patterns and neighborhood characteristics can directly affect retail sales, and will further influence office and commercial rents, and finally impact businesses' and property owners' bottom lines (New York City Department of Transportation, 2012). They evaluate many potential measures of local economic vitality and found retail sales – specifically by using sales tax data of street-level retail and restaurants and food service businesses – can provide a robust measure of the health of local businesses. The sales comparison between changes in locally based businesses before and after project implementation, and changes in comparison sites over the same time period show that improved accessibility and a more desirable street environment due to the street design projects generate increases in retail sales in the project areas, and have positive impacts on local businesses (New York City Department of Transportation, 2012).

Bicycle Counts and Evaluation

New York City Department of Transportation (NYCDOT) has been tracking long-term trends in New York City cycling using the In-Season Cycling Indicator since 1984. In 2008, DOT began counting cyclists in winter months, and found that off-season cycling has grown significantly. More and more New Yorkers are cycling year round as part of their transportation option[23].

The Transportation Division of the New York City Department of City Planning conducted annual counts on bicycle lanes and paths in Manhattan from 2001-2008. The major findings can be summarized as follows:

1. Both on-street bicycle lanes and off-street path have witnessed a 26 to 30 percent increase during this time period.

[23] NYC DOT – Bicyclist –Bicycle Counts, from http://www.nyc.gov/html/dot/html/bicyclists/bike-counts.shtml

2. Cyclists would like to use bike facilities when they are available, especially on heavy vehicular traffic.
3. The number of female cyclists is increasing faster than their male counterparts, and they are more likely to use greenway rather than on-street facilities.
4. More and more people are using helmets.[24]

[24] NYC DOT – Bicyclists –Network and Statistics, from http://www.nyc.gov/html/dot/html/bicyclists/bikestats.shtml

Vancouver, BC

Vancouver, BC approved its Greenways Plan in July 1995 and updated it most recently in 2010. The city has set a goal of ensuring that a city greenway is located no more than a 25-minute walk or a 10-minute bike ride from every residence in the city, planning 17 routes totaling 140km in length. The city greenway system is supplemented by resident-initiated neighborhood greenways. Vancouver has conducted pedestrian and cycling safety studies that empirically analyze safety issues, strategies and treatments. In addition, the city conducted a business impact study of separated bike lanes in 2010 that examined the impacts of bike facilities on local businesses.

Background

The Vancouver Greenways Plan was approved in July 1995. In the updated 2010 version, the city is working toward the goal of a city greenway system, totalling 140km (87.5 miles) long with 17 routes, which will ensure that every resident can reach a greenway with no more than a 25-minute walk or a 10-minute bike ride[25].

Additionally, there are neighborhood greenways, acting as complement of city greenways, which initiated by local residents to promote partnerships between the City and communities. With the assistance with the design, development and construction process from the city, the community takes the lead to development and maintain the space once completed.[26] There are nine identified neighborhood greenway as of 2015.

Figure 10. Vancouver neighborhood greenways map.

Source: City of Vancouver, Vancouver neighborhood greenways[27]

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[25] City greenway network, from http://vancouver.ca/streets-transportation/city-greenways.aspx
[26] Neighborhood greenways, from http://vancouver.ca/streets-transportation/neighbourhood-greenways.aspx
[27] Vancouver neighborhood greenways, from http://vancouver.ca/images/cov/content/neighbourhood-greenways-2.JPG

Plans and Implementation

Vancouver Transportation 2040, adopted 2012, includes visions to “make walking safe, convenient, comfortable, and delightful”; and “make cycling safe, convenient, comfortable, and fun for people of all ages and abilities”, which calls for a low-stress, high quality bike routes system (“Transportation 2040,” 2012).

In the plan, the policies and strategies related to bicycle faculties include:

1. Cycling Network
    a. Build cycling routes that feel comfortable for people of all ages and abilities.
    b. Upgrade and expand the cycling network to efficiently connect people to destinations
    c. Maintain bikeways in a state of good repair
    d. Make the cycling network easy to navigate
2. Parking and End-of-Trip Facilities
    a. Provide abundant and convenient bicycle parking and end-of-trip facilities
3. Multi-Modal Integration
    a. Make it easy to combine cycling with other forms of transportation
    b. Provide a public bicycle system
    (“Transportation 2040,” 2012, p. 26-30)

Evaluation

Vancouver Separated Bike Lane Business Impact Study

Vancouver Separated Bike Lane Business Impact Study was conducted in 2011 to determine the impact of two separated bike lanes constructed in the downtown area. They surveyed stakeholders including business owners, customers, and employees on both separated bike lane corridors and adjacent corridors to distinguish the impact merely from the impacts of separated bike lanes installation. It is a short-term (one year) business impact study, which indicates negative impacts of separated bike lanes including reductions of sales and profit, due to the effects from the following factors: “loss of parking, reduced visibility; restrictions in turning at specific intersections; reduced access to loading zones and more difficult pedestrian access” (*Vancouver Separated Bicycle Lanes Business Impact Study*, 2011, p. v). This study reminds other cities which conduct similar projects to consider the concerns describing above, at least during the construction periods.

Pedestrian and Cycling Safety Studies

Vancouver also conducted two safety studies, the Pedestrian Safety Study in 2012 and Cycling Safety Study in 2015, which together provide a comprehensive and objective review of the safety of pedestrians and cyclists in the city and an action plan to address each of the identified safety issues. Even though Vancouver has one of the lowest cycling fatality rates when compared to other peer cities in Canada, the United States, and internationally, the study still identified twelve key cycling safety issues include: dooring, conflict zones, right hooks, left crosses, sidewalk cycling, two way stops, non-motor vehicle collisions, high collision corridors, high collision locations, designated bikeways, PM peak, adverse weather and low light (Cycling Safety Report, 2015). A combination of engineering, education, and enforcement measures are proposed to address each of the twelve cycling safety issues, including treatments such as "protected bicycle lanes, buffered bicycle lanes, colored conflict zone markings, and protected bicycle signal phases among others" (Cycling Safety Report, 2015, p. es-vi).

In terms of pedestrian safety issues, the report summarizes the cost effectiveness of various pedestrian treatments according to five peer cities in Canada and the Pacific Northwest (Calgary, Toronto, Seattle, Portland, and San Francisco) as shown in Table 7 (Pedestrian Safety Study, 2012):

Table 7. Cost and effectiveness of pedestrian treatments

Treatment	Relative Cost	Relative Effectiveness
Pedestrian Activated Signals	High	High
Corner Bulges	Moderate	Moderate
Speed Reader Boards	Moderate	Moderate-Low
Pedestrian Countdown Timers	Moderate-Low	Moderate
Crosswalks	Moderate-Low	Low
Pedestrian Scrambles	Moderate-High	High
Audible Pedestrian Signals	Moderate-Low	Moderate-Low
Leading Pedestrian Intervals	Low	Moderate
Left Turn Bays	Varies	Varies
Greenways	Varies	Varies
Crossing Guards	Moderate-Low	Moderate-Low
Yield to Pedestrian Signs	Low	Low
Raised Intersections	Moderate-High	Moderate-Low
Midblock Crossings	Varies	Varies
Raised Crosswalks	Moderate-High	Moderate
Separated vs Mixed Modes	Low	Moderate
New/Upgraded Intersection Lighting	Moderate	High

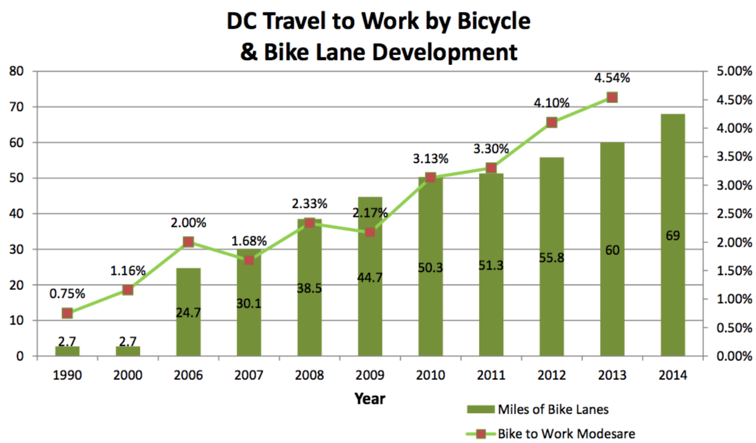
Source: City of Vancouver, 2012, p. e-10

Washington, DC

Washington, DC created its Bicycle Master Plan in 2005 and initiated an innovative bike lane pilot project in 2010. Bicycle commute mode share has increased in the city with 56 miles of trails, 69 miles of bike lanes and 6 miles of cycle tracks as of 2014. The bike lane pilot project initiated in 2010 was designed to evaluate different facility treatments in terms of facility use, operation efficiency, convenience, comfort and safety. They found that bicycle treatments improved cycling conditions without negatively impacting other modes in the vicinity of the investment.

Background

Washington DC adopted the bicycle master plan in 2005 with no updates since then. At the end of 2014, there were 56 miles of trails, 69 miles of bike lanes and 6 miles of cycle tracks in total in Washington DC, 2600 bike racks installed since 2001, 2000 capital bike share bikes, 202 capital bike share stations, and 85 miles of signed bike routes[28]. With the trend of increase of bike facilities, the bike share for commuting is increasing and the vehicle trip share is decreasing at the same time (Figure 11).



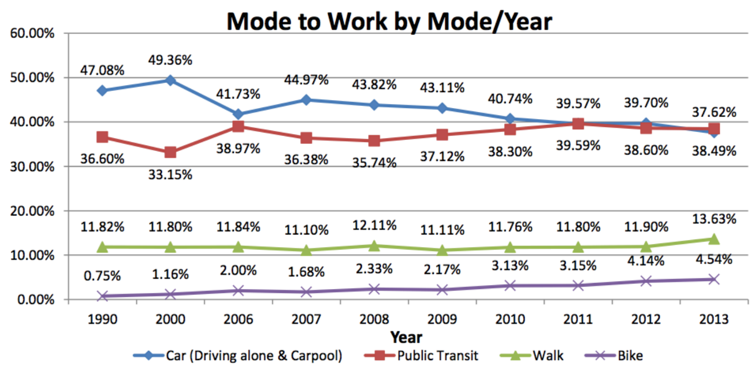


Figure 12. Trends of Bicycle facilities development and mode to work in Washington, DC

Source: 2014 Bike Program Fact Sheet – DDOT

[28] 2014 Bike Program Fact Sheet – DDOT, from http://ddot.dc.gov/publication/2014-bike-program-fact-sheet

Plans and Implementation

The 2005 Master Bicycle Plan presented fourteen core and supporting recommendations in three categories to improve bicycle transportation in DC, including "more and better bicycle facilities, more bicycle-friendly policies and more bicycle–related education, promotion and enforcement" ("District of Columbia Bicycle Master Plan," 2005).

In 2010, the downtown bike lane pilot project was initiated to improve bicycle safety and access in downtown. The city lists several separated bicycle facilities as pilot projects, and monitors the success of these facilities.[29] The results can be used to make improvements and help with the design of other similar projects.

Evaluation

DDOT has conducted evaluations of three innovative bicycle facilities installed in 2010("Downtown Bike Lane Pilot Project - DDOT," 2010):

1. 15th Street – two way cycle tracks
2. Pennsylvania Avenue – center median bicycle lanes
3. Intersection at 16th/U/New Hampshire – intersection treatments (bike box, bike signal, contra-flow bicycle lane).

After these treatments were installed, DDOT evaluated the before and after conditions along the following dimensions: facility use (bicyclist and motor vehicle volumes), efficient operations (LOS), convenience (travel time by bicyclists and motor vehicles), comfort, and safety. Overall, the analysis found that the bicycle treatments improved the conditions for cycling without negatively impacting other modes in the vicinity of the investment. Due to the unique and independent conditions at each facility, key findings are provided separately:

1. 15th St: more bicycle volumes, motor vehicle LOS remains similar, bicycle LOS increases, bicycle crashes remain similar, safer and easier perception from bicyclists, positive attitudes favorable toward cycle tracks.
2. Pennsylvania Ave: bicycle volumes increase by 200%, motor vehicle volumes decrease, arterial LOS remain similar, signal timing for bicyclists varies in different intersections, frequency of bicycle crashes increase, bicyclists know the rules but not obey, safer and easier perception from bicyclists, few bicyclists riding on sidewalks.
3. 16th/U/New Hampshire: bicycle volumes increase, motor vehicle volume/LOS remained constant, few cyclists use bike box, more bicycle crashes, positive perception of the facility.

[29] Downtown bike lane pilot project – DDOT, from http://ddot.dc.gov/publication/downtown-bike-lane-pilot-project-ddot-letter-tpb-may-2010