The Case for Crowdsourcing in Bicycle Planning: An Exploratory Study

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Jennifer Molina

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Adviser: Mary E. Davis
Reader: Mark Chase

Abstract

In an effort to make broader mode shifts by attracting users of all abilities to bike, research needs to focus on understanding cyclists' behaviors at the local level and collecting real time travel data. Crowdsourcing is an online problem solving and production model that presents great potential in the area of bicycle planning by tapping into the collective intelligence of networked communities to support local policies and programs, as well as improve community engagement. This model has benefited both the private and public sectors, but has yet to be fully realized as a method for improving bicycling planning. A mixed-methods approach was employed, using a literature review, document and media research, and interviews with a subset of program managers and software developers. Through this exploratory case study, existing practices and limitations of crowdsourcing for bicycle planning projects in various metropolitan communities are discussed. The document also provides planners with recommendations as they look to this data collection and public participation method for bicycle planning projects, specifically bicycle facility demand, network planning, suitability modeling, and route choice modeling.

Keywords: Crowdsourcing, Bicycle Planning, Web 2.0, Mobile, Public Participation, Civic Technology

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Table of Contents

Abstract **2**
Acknowledgements **3**
Chapter 1: Introduction **7**
Chapter 2: Literature Review 9
2.1 National Trends in the U.S. **11**
2.1.1 Bicycling Levels and Trip Purpose 11
2.1.2 Demographic/Socio-Economic Characteristics 13
2.1.3 Public Health, Safety, and Economic Benefits 15
2.1.4 Federal Policy/Funding 17
2.2.1 Bicycle Preference Surveys 21
2.3 A New Bicycle Planning Strategy: Crowdsourcing **29**
2.3.2 Challenges and Risks to Crowdsourcing 37
Chapter 3: Methodology 41
Chapter 4: Case Studies 47
4.1 Introduction **47**
4.2 Case Descriptions **48**
4.2.1 Bicyclist /Pedestrian Map Survey, Virginia Tech & City of Blacksburg, VA **48**
4.2.2 Boston Bike Network Plan Crowdsourced Mapping, City of Boston, MA 49
4.2.3 Chapel Hill Bike Master Plan, Wikimapping, Chapel Hill, North Carolina 49
4.2.4 Capital Bikeshare-Bike Arlington, Arlington, VA 50
4.2.5 Citi-Bank Bike Share, New York City, New York 50
4.2.6 Philly Bike to Transit Web Survey, Open Plans, Greater Philadelphia, PA 51
4.2.7 Crowdsourcing-Bikeability Scoring (BLOS), Mercer County, New Jersey 52
4.2.8 CycleTracks Smartphone Application, San Francisco County, California 53
4.2.9 Cyclopath, Twin Cities, Minnesota 54
4.2.10 Chicago Bicycle Crash Map, Chicago, Illinois 55
Chapter 5: Findings **56**
5.1 Crowdsourcing Objectives **56**
5.2 Application Development & Design **62**
5.3 Implementation **68**
5.4 Post-Implementation **71**
5.4.1 Key Impacts **72**
5.4.2 Reporting & Transparency **76**
5.4.3 Cost and Funding Sources **77**
Chapter 6: Discussion **82**
6.1.1 Public Planning Process 82
6.1.2 Street Level Data 83

6.1.3 Expansion through Technology ... 85
6.2 Challenges to Crowdsourcing ... 88
6.2.1 Transparency & Open Communication ... 88
6.2.2 Recruitment and Retention of Participants ... 90
6.2.4 Civic Innovation and Institutional Adoption ... 95
6.3 Future Direction of Crowdsourcing for Bicycle Planning ... 96
Chapter 7: Recommendations: Applying Crowdsourcing to Bicycle Planning ... 98
7.1 Planning Phase ... 99
7.2 Implementation Phase ... 102
7.3 Post-Implementation ... 108
Chapter 8: Conclusion ... 112
Appendices ... 127

Figures & Tables

Figure 1. Field Scan of Bicycle Planning Crowdsourced Projects and Types 2009-2014 ... 43
Figure 2. Screen shot from Citi-Bike, Facility Demand ... 60
Figure 3. Screen shot from Chapel Hill Bike Plan, Networking Planning ... 60
Figure 4. Screen shot from Cyclopath, Suitability Modeling ... 61
Figure 5. Screen shot from CycleTracks, Route Choice ... 61
Figure 6. Screen shot from Chicago Bicycle Crash Map, Bike Safety ... 62
Figure 7. Screen shot of Open Plans Bike-to-Transit interface ... 64
Figure 8. Screen shot of CBS voting feature ... 64
Figure 9. Screen shot of project administrator features, Wikimapping, Inc. ... 65
Figure 10. Screen shot of Cyclopath Android (Demo) & CycleTracks iPhone interface ... 67
Figure 11. Boston Bike Network-Route Tracking Visualization Maps, Toole, Inc. ... 71

Table 1. Common Bicycling Suitability Models 28
Table 2. Four Main Crowdsourcing Typologies and Common Examples 33
Table 3. List of organizations interviewed 45
Table 4. Five distinct crowdsourcing approaches in bicycle planning 58
Table 5. Cross Comparison of Cases 59
Table 6. Post Implementation Findings 80

List of Abbreviations

The following list includes various abbreviations and acronyms used throughout the thesis.

ACS: American Community Survey
API: Application Programming Interface
ArcGIS: Geographic Information System computer software
BCI: Bicycle Compatibility Index
BLOS: Bike Level of Service
BNAT: Bicycle Network Analysis Tool
BS: Broadcast Search
BSL: Bicycle Stress Level

CAPTCHA: Completely Automated Public Turing test to tell Computers and Humans Apart
CBS: Capital Bikeshare
CGIT: Virginia Tech's Center for Geospatial Information Technology
CPD: Chicago Police Department
DHIT: Distributed Human Intelligence Tasking
DOTs: Department of Transportation
DVRPC: Delaware Valley Regional Planning Commission
GIS: Geographic Information System
GPS: Geospatial position system
IDOT: Illinois Department of Transportation
IRB: Tufts Institutional Review Board
ISTEA: Intermodal Surface Transportation Efficiency Act of 1991
KDM: Knowledge Discovery and Management (KDM
LTS: Level of Traffic Stress
MAP-21: Moving Ahead for Progress in the 21st Century
MPOs: Metropolitan Planning Organizations
NHTS: National Household Travel Survey
NHTSA: National Highway Traffic Safety Administration
NPTS: National Personal Transportation Survey
NYDOT: New York Department of Transportation
PVCP: Peer -Vetted Creative Production
RP: Revealed Preference
RT: Recreational Trails
SAFETEA-LU: Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users
SF-CHAMP: San Francisco Chained Activity Modeling Process
SFCTA: San Francisco County Transportation Authority
SP: Stated Preference
SRTS: Safe Routes to School
TA: Transportation Alternatives
TE: Transportation Enhancements
TEA-21: Transportation Equity Act for the 21st Century

Chapter 1: Introduction

Over the past decade, a strong movement has developed across the country to increase bicycling as a means to improve health and activity, reduce vehicle miles travelled, improve air quality, and stimulate economic development. Growing evidence pointing to these benefits are driving more and more state and local agencies, non-profits, and public health organizations to advocate for more cycling. Numerous studies and policy briefs continue to cite that comprehensive strategies are crucial to affecting travel behaviors, including shifting automobile drivers to bicycle modes (Schneider, 2013; Pucher et al., 2010a; Maibach et al., 2009).

However, in spite of increased bicycling across the U.S, especially in metropolitan areas, encouraging bicycling for every day use still remains a challenge. At the federal level, a small percentage of transportation funds are allocated towards designing communities that encourage active transportation. This is a major impediment, as more and more state and local agencies are looking to bicycle travel, in addition to transit and walking, to address concerns about health, safety, and the environmental impact of automobiles. Secondly, understanding the varying behaviors and concerns of bicyclists who vary in experience and preferences are often not captured at the street level. Currently, most bicycle-use statistics are collected using the National Household Travel Survey (NHTS), U.S Census data, or through stated preference surveys and bike counts at the state and local government level. While these are necessary methods in providing planners with relevant bicycle trends and further analysis, there are evident limitations to these methods. In an effort to make broader transportation mode shifts by attracting users of varying abilities, research needs to focus on connecting with the public in order to understand bicyclists' real time traveling behaviors and street level barriers to bicycling. Therefore, it is an opportune time for planners to look for technological approaches to collect more robust local data, as well as capitalize on the ever-increasing digital era to engage citizens in new ways. This is where the application of crowdsourcing can prove beneficial.

Crowdsourcing can be defined loosely as a type of participative online problem-solving and production model in which an individual, institution, company, or non-profit organization leverages the collective intelligence of online communities ("crowds") by posing a voluntary task to the community (Brabham, 2013a; Estellés-Arolas & González-Ladrón-de-Guevara, 2012; Hudson-Smith et al., 2009; Howe, 2006). It is not solely top down or bottom up, but a shared process where both the organization and online community share control of problem solving (Brabham, 2013a). Proven to be successful as a collaborative method in the private sector (i.e. software development and design), this model may also prove to be a beneficial and cost-effective strategy in governance practices. Slowly, planners have started to gravitate towards the utilization of technology as a means engage the public in the planning process. This is particularly relevant considering the ever-increasing use of digital technologies over the past 20 years (Rainie et al., 2014). However, while many municipalities have entered the digital age for disseminating information and/or collecting general feedback, very few municipalities are embracing the use of web and mobile devices to effectively engage the public and collect demand data for bicycle specific planning projects.

This thesis' central aim is to contribute deeper insight to this emerging civic technology process in the bicycle-planning field. It provides the theoretical and evidentiary based framework necessary for understanding the relationship between bicycle planning and crowdsourcing, and investigates recent cases that have used online mapping platforms to crowdsource. While this study is exploratory in nature, its main objective is to present bicycle planners with the opportunities and risks inherent to applying crowdsourcing in the planning process. Due to the scarcity of studies evaluating the influence of crowdsourcing in bicycle planning, recommendations are provided to improve the development, implementation, and evaluation of such practices. In summary, this thesis seeks to explore four main questions:

1. What are the current challenges in supporting and advancing bicycle planning and policy?
2. Why and how is crowdsourcing currently being used to support and advance bicycle-planning projects?
3. What are the opportunities and challenges inherent in crowdsourcing?
4. How do several crowdsourcing cases in the field inform the future use of civic technology for engaging citizens and gaining knowledge for bicycle planning projects?

Chapter 2: Literature Review

The literature review provides the theoretical and evidentiary framework necessary for understanding the relationship between the process of crowdsourcing and bicycle planning. It reviews the current state of bicycle policy and planning in the U.S, explicitly focusing on the variety of established methods for building evidence for new or improved bicycle infrastructure, and the limitations inherent in these methods. It then explores crowdsourcing as a public engagement and data collection method in planning, focusing on how emerging online crowdsourcing techniques can contribute and enhance current bicycle planning efforts in metropolitan areas.

The U.S transportation system touches most aspects of daily life and, in turn, plays a vital role in the health, safety, and welfare of its users. In an effort to combat the negative consequences of motor vehicles, policymakers and transportation planners are seeking to promote built environments that encourage healthier, safer and more attractive modes of transportation including bicycling. Over the past decade, a strong movement has developed across the country to increase bicycling as a means to improve health and activity, reduce vehicle miles travelled, improve air quality, as well as stimulate economic development (Krizek 2007; Gotschi 2011; Dill & Carr 2003; Saelens et al 2003; Bassett et al 2008; Teschke et al 2012). The mounting body of evidence pointing to the benefits of active transportation has led state and local agencies, non-profits, and public health organizations to advocate for more bicycling.

One beneficial area of research in informing and encouraging bicycle policy and programs is the collection of more robust forms of bicycle data at the local level. Recently there has been an increase in the real world implementation of web and mobile applications to crowdsource public input and knowledge. Crowdsourcing is an online distributed problem-solving model that leverages the collective intelligence of the online community [crowds] to serve specific organizational goals (Brabham, 2012). Although crowdsourcing has benefited both the private and public sectors, it has yet to be fully realized as a method for improving bicycle planning. Crowdsourcing in bicycle planning provides an opportunity to collect both quantitative (e.g. GPS coordinates, recalled routes, facility demand) and qualitative data (barriers to biking, comfort/stress levels) to better understand user behavior and further prioritize where bicycle facilities should be built, as well as evaluate the long-term impact of such investments. Crowdsourcing can also provide planners with a new technique to engage the public beyond traditional forms of public participation.

2.1 National Trends in the U.S

2.1.1 Bicycling Levels and Trip Purpose

Nationwide, motor vehicles still dominate the U.S transportation system, making up 91.5% of the mode share overall and 77% in major U.S Cities (USDOT 2010a). However, levels of bicycling in the U.S have increased dramatically over the past 20 years, where individuals are not just riding for recreation and sport but also riding for utilitarian purposes (e.g. commuting, social, shopping).

According to the National Personal Transportation Survey (NPTS) of 1977-1995, and the NHTS (2001-2009), which report on bicycle travel for all trip purposes, the number of total trips has nearly tripled between 1977-2009 from 1 million to over 4 million annual bike trips and the bike share of total trips has nearly doubled from 0.6% to 1.0% (USDOC 1980–2000, 2009, 2010; USDOT, 2004, 2010). In addition to bicycle travel for all trip purposes, the U.S Census Bureau has been providing survey data on bicycling to work statistics since the early 1980's. From 1990-2012, the share of commuters bicycling to work increased from 0.4% to 0.6% (USDOC, 2010). The descriptive statistics from the NHTS regarding trip proposes over the past decade also shed light on the increasing trend in bicycling in the U.S. Between 2001 and 2009, there has been an increase in bicycling for utilitarian purposes, from 43% of all bicycling trips in 2001 to 52% of all bicycling trips in 2009 (USDOT, 2001-2009). Based on the share of all trips, NHTS reports increases in commuting from 8 to 12%, trips to and from transit stops from 1 to 3%, as well shopping and personal errands from15 to 18%. In addition to travel purpose, the distance of all trips is also telling. Nearly 60% of all trips are one mile or less, 78% are two miles or less, and 85% are three miles or less (USDOT, 2009). These short trip statistics present opportunities for municipalities looking to impact mode shift from cars to bicycles for shorter trips, especially in urban areas where 53% of all trips are three-miles or less (USDOT, 2009).

The fastest growth in bicycling is occurring in metropolitan areas, more than doubling in cities like Portland, Chicago, New York, and Minneapolis since the early 1990s (Puncher et al., 2011). The U.S Census' five year American Community Survey (ACS) reports that the percentage of workers commuting by bicycle is close to four times higher in urban areas (0.6 %) than in rural areas (0.16%) (USDOC, 2010) and NHTS reports that the share of all trips is higher in urban areas, 1.12% versus 0.78%. Recreational trips accounted for over 60% of all trips made in rural areas versus 47% in urban areas (USDOT, 2010).

Furthermore, collective survey data from the U.S Census' ACS (2012) showcases considerable growth in bicycling in large cities over the past 20 years. For instance, Portland currently has the highest bicycling rate of any large North American city. Between 1990 and 2012, commuting rates increased from 1.2% to 6.1%, almost a six-fold increase. Other cities like Chicago have made great strides in increasing bicycle mode share to work, quadrupling its rates between 1990 and 2012. Minneapolis and San Francisco are not far behind, close to tripling their bike share of work commuters over this same time period.

Despite considerable growth in bicycling over the past few decades, the U.S still lags behind other developed countries with respect to the total share of people travelling by bicycle (Pucher et al. 2003a; Pucher et al. 2003b; Pucher et al., 2006; ABW 2012;). By comparison, the Netherlands, Denmark, and Germany have bicycle trip shares between 10% and 26% (ABW 2012). However, the increase in bicycling levels seen in the U.S.

is encouraging and comparable to levels in Canada, Australia, and the UK (Puncher et al., 2011b).

2.1.2 Demographic/Socio-Economic Characteristics

Socio-economic and demographic characteristics, such as income, race, ethnicity, age, gender and general activity patterns help planners capture who in fact is bicycling. This is especially important when determining if bicycle policy and planning decisions are inclusive to all groups and users. As of 2009, data from NHTS showed that bicycle mode share was roughly distributed evenly across income classes (NHTS 2009). However, while there was little variation by income levels, surveys indicate that income most likely influences trip purpose: high-income persons bike more for recreation and sport, while low-income persons bike mainly for utilitarian purposes (Pucher et al., 2011; Heinen et al., 2010; NHTS 2009). Additionally, for households without a car, bicycles provide an essential means of transportation. Based on the NHTS survey, urban households without a car biked nearly 3.3 times more than households with one car (NHTS 2001, 2009).

Over the past two decades most of the growth in bicycling across the U.S has been by men. In 2009, women made up 24% of all bike trips, a 9% decrease from 2001. Meanwhile, during the same period the percentage of bike trips made by men increased from 67% to 76% (USDOT 2005, 2010a, NHTS 2009). These numbers are similar to bike to work statistics, where only 27% of bicycle commuters are women. The share of all bike trips has more than doubled for the age group 40-64 (from 10% to 21%), while only slightly increasing for seniors and the age group 16-39. Compared to increases in age groups 16 and up, the bike share of trips made by youth under the age of 16 has decreased by nearly 20%, from 56% to 39% (USDOT, 2004, 2010a).

When we look at the ethnicity breakdown in the U.S it is clear that non-Hispanic whites represent the highest bike mode share at 79% of all bike trips in the U.S. This is particularly high considering that non-Hispanic whites only account for 66% of the U.S population. However, there has been a recent surge in bicycling rates among African American, Hispanics/Latino, and Asian America from a 16% to a 21% share of total bike trips between 2001 and 2009 (Pucher, J., et al., 2011, USDOC, 2010a), rising faster than the rate among non-Hispanic whites.

Overall, the U.S Census (decennial and ACS) and NHTS provide important data examining travel behavior and socio-economic characteristics of bicyclists. However, there are limitations in these data. For example, Census data is only collected for commuting to work, not travel behavior associated with other purposes such as shopping or recreational trips. Moreover, the decennial Census by design is only taken once every ten years between the months of March and August, representing a snapshot in time as opposed to the ACS, which samples throughout the year. While the timeliness of the ACS may better reflect bike travel throughout the year, it presents higher sampling errors due to the survey's smaller sample size (3 million households compared to the Census' 18 million households). Sample error is also a concern with NHTS data, surveying about 150,000 households and 300,000 individuals - less than 3% of the Census (NHTS 2009). This does not permit reliable estimates for individual cities. Finally, as with any self-survey reporting, there may be additional non-sampling errors (i.e. mistakes in how data is reported, coded, interview bias) in respondents' answers, as well methodological shortcomings in survey design. These limitations must be kept in mind when drawing comparisons across travel behaviors for bicycle planning and policy purposes.

2.1.3 Public Health, Safety, and Economic Benefits

Public health, safety, and economic factors have also been brought into the conversation surrounding national trends in bicycling. There is growing evidence that links transportation-related physical activity and improved health outcomes. Increases in physical activity aid in alleviating the negative health outcomes associated with inactivity and obesity, including premature mortality, chronic diseases such as diabetes, obesity, hypertension, and poor psychological well being (Handy 2005). Generally, states with the highest levels of walking and bicycling have the lowest levels of obesity-related health problems (Pucher et al 2010, Gordon et al 2009, ABW 2012). A study of physical activity and Type 2 diabetes showed a 35% reduction in risk with at least 30 minutes per day of commuting by bike or on foot, a greater reduction than with physical activity during leisure time or at work (Hu et al., 2003). More research is needed to evaluate and distinguish between the health benefits of varying bicycle route types, uses, geographies, and socio-demographic differences.

Road safety is also crucial when promoting the benefits of active transportation. Between 1988 and 2008, the total number of bicyclist fatalities fell by 21%. During this same time period, there has also been a 31% decrease (as percent relative to 1988) in the number of serious bicycling injuries (USDOT, 2010b), and a 65% decrease in fatalities per ten million bike trips between 1977 and 2009 (Puncher et al., 2011b). While national data on injuries and fatalities have shown a decreasing trend since the 1980’s, bicyclists are still one of the most vulnerable types of road users with a higher risk of injury compared to motor vehicles users. Based on 2010 nationwide data from the National Highway Traffic Safety Administration (NHTSA), pedestrians and bicyclists accounted for nearly 15% of motor vehicle collision fatalities, with more than 122,000 individuals injured in 2010 (NHTSA, 2012a; NHTSA, 2012b). Vehicle speed is a key factor in pedestrian and bicyclist injuries. Most notably, Leaf & Preusser (1999) found that at 20 mph, 95% of pedestrians survive auto crashes, while at 40 mph the likelihood of surviving is only 20%. A more recent study looked specifically at bicycling safety and found that lower motor vehicle speeds (less than 20 mph) were associated with lower injury risks to bicyclists at intersections (Harris et al., 2013).

Promoting bike specific infrastructure with appropriate traffic calming elements is a promising intervention to reduce injuries and deaths. Contrary to previous research that shows an increased injury risk for separated facilities (Aultman-Hall & Hall 1999; Moritz, 1998; Tinsworth et al 1994), recent studies have found a decrease injury risks for bicycle lanes and cycle tracks (Reynolds et al., 2009; Lusk et al., 2011; Teschke et al., 2012). Reynolds et al. (2009) reviews studies looking at transportation infrastructure and the risk of injury to bicyclists, finding that the lowest risk for crashes and injury occurred among bicycle facilities (bike lanes, cycle tracks) and the largest risks were on sidewalks, multiuse paths, and major roads (Harris et al., 2013; Teschke et al., 2012; Minikel, 2012; Lusk et al., 2011). Lusk et al (2011) used ten years of emergency records in Montreal, Canada and compared them to average bicycle counts to estimate risk of injury on six cycle tracks. Overall, 2.5 times as many bicyclists used the cycle tracks and were associated with a 28% reduced risk of injury compared to control streets with no cycle track. Teschke et al. (2012) found that cycle tracks and bike lanes (with no parked cars), off street bike paths, and local streets had significantly lower injury risk. Similar findings came from a comparison study that found bicycle boulevards (bike routes on residential, low speed roadways) to be safer than parallel arterial routes (Minikel, 2012). Studies are still lacking in looking at the safety differences between one and two way cycle tracks, injury severity, and intersections along separated facilities.

Finally, investing in bicycling infrastructure and promoting bicycling can also provide economic benefits. An increasing number of studies consider bicycle infrastructure a valuable community asset that is likely to enhance real estate values; state and local business/tourism; and provide a cost effective approach to meeting other transportation, health, and job needs (Asabere &Huffman, 2009; CAP, 2009; Drennen, 2009; Krizek & Johnson, 2006; Nicholls & Crompton, 2005; Penna, 2006; Lindsey et al., 2004, 2006; Meisel, 2010; Przybylski & Lindsey 1998; WDOT, 2005). While some of these studies show promise in the economic benefits surrounding bicycling, they are preliminary and impacts have been studied minimally, particularly in areas with on-street bike infrastructure (i.e. bike lanes, cycle tracks, and bicycle boulevards). More research needs to look at actual pre and post differences when such infrastructure is built or improved, both quantitatively and qualitatively. While follow-up research is required, these findings provide planners and policymakers with additional talking points as municipalities re-evaluate how to incorporate bicycling into transportation policy goals and municipal programs.

2.1.4 Federal Policy/Funding

Both the increase in bicycling over the past decades and growing research supporting the benefits of mode shift have pushed more and more states and metropolitan areas towards transforming communities into healthier, safer, and more livable areas through biking. In order to make the shift to more sustainable modes of transportation such as biking, municipalities have implemented an array of bicycle friendly programs, policies and legislation that include things such as master planning and design, driver enforcement, mandatory helmet laws, and complete street and safe routes to school policies. The majority of funding to support bicycle friendly policy and programs has originated from the federal government through transportation legislation, including the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Transportation Equity Act for the 21st Century (TEA-21) of 1998, and the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) of 2005. SAFETEA-LU had three distinct programs, Transportation Enhancements (TE), Safe Routes to School (SRTS), and Recreational Trails (RT). Each program has its own method for distributing funds to state Departments of Transportation (DOTs). The SAFETEA-LU, along with smaller federal funding programs, have been viewed as key revenue streams for state and local programs to promote bicycling and walking via infrastructure, safety, and education projects (Clarke, 2003; USDOT, 2004b; Cradock et al., 2009; Pucher, J., Dill, J., Handy, S., 2010b).

The transportation provisions over the past two decades reflect the federal government's growing commitment to encouraging non-motorized travel. Since 1988, annual federal funding for biking and walking has increased considerably from $5 million per year to close to $1 billion from 2006-2009 under TEA-21 (USDOT 2010c). Pucher et al. (2011b) summarized some of these city level policy trends in a review that looks at the U.S as a whole, as well as in nine large U.S cities. Currently, research shows that better policies for bicycling and walking has led to higher levels of bicycling and walking (Pucher and Buehler 2008, Pucher et al., 2010; Pucher et al., 2011a). Specifically, the review points to various infrastructure projects, policies, and programs that have been used in metropolitan areas to increase cycling rates and safety. As of 2012, of the 51 most populous cities in the U.S, 47 had set benchmarks to increase bicycling (ABW, 2012). Their analysis specifically points to integrated policies in Portland and Minneapolis as strong models that have succeeded in encouraging more bicycling citywide.

Nevertheless, the newest transportation legislation targeting non-automotive transportation is a major step back from the last three major federal transportation acts. This recent funding allocation, known as Moving Ahead for Progress in the 21st Century (MAP-21), was signed into legislation in June 2012. This law cut the annual walking and bicycling funding under the previous law (SAFETEA-LU) by 33%, from $1.2 billion to $800 million. Additionally, lawmakers consolidated programs into Transportation Alternatives (TA) and significantly changed how biking and walking funds are distributed to state and local projects. State DOTs or Metropolitan Planning Organizations (MPOs) distribute half of the TA funding based on the population and each state's proportionate share of funding from fiscal year 2009. Of the funds requested, the participating municipalities must match 20%. The other half can be redirected (any or all) from local control to highway programs, or distributed by the state DOT via a competitive grant program open to local governments, school districts, public lands, and tribal governments. While the 20% local match for TA funding is not any different from previous legislations, the ability for state DOTs to opt out or transfer funding by grants for highway projects is considered a major blow to making biking and walking safer and more convenient across the U.S. Also, while SRTS language is still in the bill, eligibility for education and safety activities were removed from the program. States can still choose to run a state SRTS program as-is, but the funding would need to come from overall transportation dollars allocated to the state (MAP-21 H.R.4348, 2012; American Bikes, 2012).

Although the U.S government has slowly incorporated funding for non-automotive needs over the past two decades, as of 2013, federal funding to increase the safety and convenience of biking and walking only represents close to 1.6% of the federal government's total budget for transportation (ABA, 2012). While some states utilize other sources of federal, state, and/or private funds to support state and local projects, many policymakers, researchers, and advocates continue to argue that this is not enough funding to make significant modal shifts.

2.2 Data Collection & Analysis in Bicycle Planning

Despite the aforementioned funding limitations, the trends and benefits associated with bicycling have encouraged more and more municipalities to support bicycling programs and provisions. The U.S has also taken notice to the major mode shifts in European cities, especially Amsterdam, Copenhagen, and Berlin. A 2009 international review compared bicycling funding and mode share and demonstrated that European cities that invested greater resources into infrastructure and programs per capita had higher levels of bicycling (Gotschi and Mills 2009). Given the rising interest in bicycling as a mode of transportation and successes seen abroad, planners are focusing energies in improving and expanding bicycle networks that meet the needs of various types of bicyclists. More specifically, numerous U.S metropolitan areas have committed time and available resources to implement programs and policies, such as education, enforcement, infrastructure, and traffic calming, to encourage and educate people about bicycling—some incrementally, some more aggressively. Municipalities that have experienced substantial increases in bicycling (e.g. Portland, Minneapolis) have implemented a wide range of programs and policies to promote and increase bicycling rates. Aggregated national and international research suggests that increases in bicycling require integrated and complementary interventions, including expanding and improving bike infrastructure, traffic calming, and training and educational programs (Pucher et al., 2011b; Pucher et al., 2009; Pucher & Buehler, 2008).

As a part of this integrated approach, infrastructure is vital to increasing bicycling.

Bicycle infrastructure and roadway design is still considered one of the major strategies in the transportation mode choice decision processes, especially in attracting people to bicycling (Schneider, 2013). Various surveying methods are being used to help planners build evidence for new or improved bike infrastructure, beyond the available census and national household data. The approaches frequently used to elicit local demand and individual bicyclists' behavior along routes includes stated preference (SP) and revealed preference (RP) surveys. SP surveys provide respondents with hypothetical choice situations and collect responses based on a rating, ranking, or stated choice using mail, phone interviews, personal interviews, focus groups, or online surveys. RP surveys rely on collecting data of actual preferences for recent trips via mail, interviews, focus groups, intercept surveys, bike counts, and more recently, through web surveys and the adoption of online mapping applications and global positioning system (GPS) devices. This section will review these surveying methods as they relate to informing bicycle network planning and the selection of facilities.

2.2.1 Bicycle Preference Surveys

Bicycle Counts

Municipalities have looked to bike counts or cyclist travel surveys to collect time and location data from predetermined areas. Counts have been shown to provide even greater evidence of local bicycling demand than reported by the U.S. census data. A Manhattan count survey (NYCDOT, 2011) showed a tripling of bike trips (220% increase) between 2000 and 2009, compared to the 51% increase reported by the US Census over that same time period. Some municipalities use bike counts on a seasonal basis to document bicycle usage and demand. Often these counts are focused on major bike routes and intersections at rush hour or peak periods. Counts can be conducted manually or using automatic count technologies (e.g. inductive loops, pneumatic tubes/hoses). They also can be used in estimating modal split within a municipality or region. Portland is an example of a municipality that uses both manual counts and more permanent count devices to support the city's bike policy and planning goals. Descriptive statistics from the Portland DOT 2012 Bicycle Count Report showed that since 2000-2001, the overall trend in bicycle traffic was up 211%. However, female ridership (31%) remains unchanged since 2000, corresponding closely to national and other metropolitan gender trends (PBOT, 2012).

Although bike count data is an important RP survey method of establishing baseline activity along certain routes/intersection and justifying expenditures for new or improved facilities, there are several inherent drawbacks. First, data alone cannot establish bicyclists' preferences along an entire bike network, understand barriers to biking, or determine whether the new infrastructure attracted new riders or that cyclists just changed their route. Researchers should be careful when comparing the differences reported by these data sources, as there are spatial and temporal variation in survey methodologies including timing of measurements, and the extent of the geographic area studied (Pucher et al., 2011b). Drawbacks to manual counts programs include significant municipal resources, human error, and inability to verify data. Automatic counters also present challenges and can be a difficult cost to bear for some municipalities and pose inherent error rates with the technology that would need to be compared to manual counts. . Estimated costs for count devices range from $2,000 to up to $25, 000 per counter, not including labor/ costs to install and maintain permanent counting devices (Benz et al., 2013; Proulx, 2013). For example, a counting program in Davis, California cost the municipality $74,000 for 10 automated counters

Route Choice Preferences

Factors that influence bicycling route choice are emerging in transportation literature. Studies have explored route choice from both an aggregated to local, individual level, pointing to an array of influential factors and preferences (e.g. facility type, route attributes, individual characteristics, and perceived safety). As a result there is growing amount of data from both SP and RP surveys of bicyclists, including newer types of datasets acquired via GPS units and smartphone applications.

Results from aggregate, cross-sectional studies indicate that there is a positive correlation between bicycling levels and the supply of both off-street bike paths and on-street bike lanes after controlling for other determinants (i.e. land use, climate, socioeconomics, gas prices, public transit supply, and cycling safety) (Cleveland & Douma 2009; Parkin et al., 2008; Dill & Carr, 2003; LeClerc 2002; Nelson & Allen 1997). Individual studies have been mixed--some finding a positive correlation and other less conclusive between bicycle preferences and bicycling route choice. Most of the evidence surrounding bicycle infrastructure and how bicyclists choose or value routes is based on SP surveying. SP studies have found that individuals prefer separated facilities (i.e. cycle tracks, paths, bike lanes) over no facilities or in some cases residential roads with traffic calming elements (Abraham et al., 2002; Antonakos, 1994; Emond et al., 2009; Landis et al., 1998; Madera, 2009; Parkin et al., 2007; Stinson and Bhat, 2003; Tilahun et al., 2007; Winters & Teschke, 2010). Some RP studies reveal that individuals value off-street bike paths or are willing to take longer routes to use bike paths (Broach et al., 2012; Dill & Gliebe, 2008; Howard & Burns, 2001, Krizek et al., 2007; Shafizadeh and Niemeier, 1997).

More recently some researchers have turned to GPS units to reveal preferences of bicyclists to estimate a bicycle route choice model (Broach et al., 2012; Menghini et al. 2010). The most recent RP study out of Portland suggests that bicyclists put a higher value on off-street bike paths, bikeways with traffic calming measures, and that bike lanes were no more attractive than basic low volume streets (Broach et al., 2012). However, findings are preliminary and will require a larger sample size that includes various types of cyclists, as well as surveying the preferences of non-cyclists. In addition, several RP surveys report inconclusive findings or zero effect between bicycling levels and bike facilities (Cervero et al., 2009, De Gues et al. 2008; Kriek & Johnston 2006).

Both SP and RP studies have also highlighted the importance of route attributes and individual characteristics. Most studies found that flat route topography positively correlated with bicycling levels, and that bicyclists chose routes that avoid steep hills (Hunt &Abraham, 2007; Menghini et al., 2010; Rietveld & Daniel, 2004; Timperio et al., 2006; Vandenbulcke et al., 2011). Studies have also pointed out strong preferences for paved surfaces, off-street parking, traffic calming elements, and the avoidance of signal controlled intersections (Menghini et al 2009; Winter et al 2010; Sener et al., 2009). There is mixed evidence that bike infrastructure preferences vary based on individual characteristics. SP surveys found that experienced cyclists preferred lanes or no facilities to bike paths (Hunt and Abraham, 2007; Sener et al., 2009; Stinson and Bhat, 2003; Taylor and Mahmassani, 1996; Tilahun et al., 2007).). Other SP studies find experienced cyclists have weak or no preference for lanes to separate paths (Senar et al., 2009, Taylor & Mahmassani, 1996). Age and gender did not have a statistically significant impact on facility use, challenging past research on personal characteristics and cycling (Dill and Glibe 2008).

Recently, given the prospects of GPS units in obtaining revealed preferences, interactive mapping application and smartphones provide additional tools to obtain various RP data from facility preferences and route attributes to individual characteristics. In response to the increasing rate of smartphone use in the US, smartphones are beginning to be used by transportation agencies to collect route choice data directly from users. For example, a smartphone application entitled CycleTracks was developed in 2009 as a way for planners to collect smartphone based GPS data. This data revealed second-by second information (e.g. location, speed distance) over the course of multiple days, along with a mobile interface designed to incorporate a level of surveying that ask users for voluntary demographic information (i.e. home/work zip code, cycling experience, trip purpose, email). This allows planners in municipalities including San Francisco, Austin, Atlanta, Reno and Charlottesville to identify potential patterns of route choice with other variables (i.e. weather, time, road characteristics, cycling experience) and rely less on SP surveys that are prone to survey biases and error (McDonald and Burns 2001). Second, smartphones are able to send data wirelessly to remote servers without planners having to retrieve data in the field, saving project teams time and money (Dorothy 2009, Carleton et al 2010). Beyond the technological advantages of retrieving GPS data to identify patterns of route choice with other variables, this mobile interface was designed to collect personal information, incorporate a level of surveying and provide reward schemes to attracts and retain users.

Finally, while biking has become safer in the U.S over the past 20 years, one of the major deterrents to bicycling is the perception of risk to injury. The role of perception is defined as how people will experience the same conditions in different ways depending on their personal needs as opposed to the objective measurements such as traffics volume or bike lane width (Alfonzo, 2005). In response to these safety concerns, researchers have looked beyond objective measurements of the built environment to evaluate individual perceptions on travel behavior and mode choice. Several SP and RP studies have found that sensitivity to unsafe road conditions and comfort levels along a route are frequently cited reasons that deterred individuals from bicycling (Dill et al., 2011; Duncan et al 2005, Ogilvie et al 2004, Carver et al 2005, Winter and Teschke 2009, Monsere et al 2012). This was most significant for women, who were more likely than men to feel like new bicycle facilities (i.e. cycle track and buffered bike lanes) improved their safety over alternative routes and other facility types (Dill et al., 2011).

These surveying efforts present planners with evidence quantifying local demand and relationships between route preferences and bicycle levels. Still, findings are mixed and it remains unclear which factors influence bicycling levels and route choice across a network. Much of the evidence correlating route preferences to the likehood to bicycle are limited to aggregate or local SP studies. However, these hypothetical findings are based on small sample sizes and do not capture the realities of how cyclists are behaving along a network, but merely test features that may or not be applicable to the current bike network. RP studies prove useful in capturing bicyclist's preferences along local bicycling routes in some cases. There are still limitations to this data elicitation method, including selection and recall bias and sample size issues. It is also unknown whether recalling routes affect the accuracy of the actual routes taken, especially for routes not regularly used. GPS technology addresses these biases, but findings are preliminary in how best to use this emerging technology. Finally, these surveying methods collecting small sample sizes have been found to be costly on a per-record basis and prone to human error during the data collection and analysis (Carlton et al., 2010; McDonald & Burns, 2001; Schneider et al 2005).

Bicycle Suitability Mapping

In addition to preference surveys informing planners during network planning and facility selection**,** researchers have also developed various models looking at the level of service of road segments and networks for bicyclists. Most of the models for assessing bicycle networks and travel have been focused on suitability, an objective measurement of perceived comfort and safety of shared use paths and roadways of an entire network where bicycle travel is permitted. The models for 'scoring' suitability date back to the late 1980's and are outlined Table 1. Most of the models are primarily based on roadway characteristics (e.g. traffic volume, speed), and driven by "experts" who develop the qualitative weighting for segment attributes to help decipher which types of roadways are attractive to bicyclists. Some also tie in small samples of SP data via interviews and video surveying to account for the growing evidence of varying levels of tolerance for traffic comfort based on individual preferences and roadway characteristics. These assessment methods calculate a score by summing points with various physical characteristics of a linear section of a road, path, or way designated for bicycle travel in order to provide estimates of existing conditions. These scores or ratings are then further analyzed and/or communicated using mapping software, such as ArcGIS.

Table 1. Common Bicycling Suitability Models

Name of Model	Acronym	Reference	Developed
Bicycle Safety Index Rating	BSIR	Davis	1987
Roadway Condition Index	RCI	Epperson	1994
Bicycle Stress Level	BSL*	Sortan and Walsh	1994
Bicycle Level of Service	BLOS	Botma	1995
Bicycle Level of Service	BLOS	Landis	1997
Bicycle Compatibility Index	BCI*	Harkey et al	1998
Bicycle Suitability Assessment	BSA	Emery and Crump	2003
Bicycle Level of Service	BLOS	Zolnik and Cromley	2007
Bicycle Level of Service	BLOS	Petricitch et al.	2007
Bicycle Intersection Safety Index	ISE	Carter et al.	2007
Bicycle Network Analysis Tool	BNAT*	Klobucar and Fricker	2007
Bicycle Level of Service	BLOS*	Highway Capacity Manuel	2011
Level of Traffic Stress	LTS	Maaza et al.	2012

Note: *Incorporated limited stated preference surveying

There are numerous models used to assess bicycling networks across the U.S in order to help prioritize projects or to communicate the benefits of bike infrastructure. These models vary in methodology (e.g. point systems, road characteristics) and are dependent on data and resource availability. While these suitability models can be used as various scales from cities to regional bicycle networks, they use objective measurements such as pavement conditions, vehicle traffic volumes, and width of bike lanes, while rarely incorporating bicyclists' revealed preferences, experience, perceived safety, gender, and age. BSL, BCI, BNAT, and BLOS include limited SP surveying from video surveys, but the sample sizes are small and mostly targeted the intermediate or experienced adult riders. Experienced riders' sensitivity to road conditions and comfort levels has been found to vary from those who are interested, but concerned with safety or non-bicyclists (Geller, 2009; Dill & McNeil, 2012). It is also unclear how transferable these models are to varying regions of the U.S. A more recent suitability method, Level of Traffic Stress (LTS), challenges these models by including user tolerance and experience in the scoring scheme based on four levels of traffic stress that corresponds to Geller (2009) four classes of cyclists (Maaza et al, 2012). This model allows both experts (e.g. engineers, planners) and non-experts (advocates, residents) better identify with a more simplified classification scheme, as opposed to BLOS which grades streets A through F. Still, similar to previous models, the LTS model does not incorporate surveyed preferences of bicyclists of varying experience and non-bicyclists into their traffic stress criteria.

2.3 A New Bicycle Planning Strategy: Crowdsourcing

Public engagement is considered a crucial process in most, if not all urban planning policies and projects. Since the early 1970's, improvements have been made to the participation process due to the continuing efforts of advocates, researchers, and everyday citizens that pushed for inclusion in the planning process, particularly in marginalized communities (Arnstein 1967,1969; Evans-Cowley & Hollander, 2010). These processes occur in a collaborative format between participants in the planning process (e.g. citizen, planners, developers) in which the planner takes on a facilitator role in making sure the discourse is non-hostile and there is a two-way exchange of knowledge and input during the entire planning process (Healy 2003, 2006, Selzer and Mahmoudi 2012, Innes & Booher 2010).

Notably, there is a significant amount of literature that cites the benefits associated with citizen engagement. In addition to typical evening town/city meetings, municipalities have implemented various methods in order to enhance and improve the participation process; including forums, charettes, and visioning workshops and less formal methods such as one-on one interviews, and small group discussions. These methods can help to increase participation by not only generating ideas, but also building relationships and trust, offering participants flexibility, kick starting longer-term commitments to participation, and overall, creating better policies (Berry et al., 1993; Potapchuck 1996; Potapchuck & Crocker, 1999; Burby, 2003; Brody et al., 2003; Perry, 2009). Beyond enhancements to the democratic process, researchers have also pointed to the value of non-experts bringing new knowledge and perspectives to the planning process (Hanna, 2000; Corburn, 2003; Van Herzele, 2004; Brabham, 2009).

However extensive these improvements, decision makers still lead one-way forms of communication, where citizens have the opportunity to hear and be heard, but rarely influence the final decisions. Therefore, planners are continually challenged to find the best approach to involve the public in the planning process that is inclusive and effective in steering policy and planning decisions. Many of the cited challenges are not whether citizens participate in the planning process, but who should participate, which methods should be used, what type of knowledge is needed, and how municipalities can efficiently and effectively integrate this information in the planning process. The main barriers to public participation pointed out in the literature include the dynamic nature of face to face politics, one-way communication format, failure to effectively engage citizens of all socio-economic levels, language barriers, transportation, social ease, municipal resources, and lastly, inability to provide creative solutions (Arnstein, 1969; Inness and Booher, 2000; King et al, 1998; Evans-Cowley & Hollander 2010; Hou, 2009). In some cases the systematic and institutionalization of participatory methods at the local, regional, and state level have led decision makers to “public participation” as a box to be checked, where time is limited for citizens to learn about the issues and/or provide input. These challenges provide an opportunity for planners to seek out newer participatory methods such as crowdsourcing. While not a method that is foreseen to replace other participatory methods, crowdsourcing has the potential to aid in the problem solving process through data collection, as well as involve citizens through nontraditional ways.

2.3.1 History and Role of Crowdsourcing

The concept behind crowdsourcing dates back to the Internet boom of the mid-1990s. During this time, the introduction of the Web allowed businesses to attract customers based on certain needs and/or tastes. The growth of the Internet allowed researchers and businesses to explore the logic behind harnessing knowledge (also known as collective intelligence) through the adoption of technology to address global communication and problem solving (Levy, 1995; Ignatius, 2001; Masum & Tovey, 2006). Consequently, this notion of crowd wisdom can be initiated through the act of crowdsourcing. The term crowdsourcing was first coined in a 2006 article entitled "The Rise of Crowdsourcing" by journalist, Jeff Howe. Defined as a web based business model that gathered the creative solutions from a network of individuals, Howe described it as:"… The act of a company or institution taking a function once performed by employees and outsourcing it to an undefined (and generally large) network of people in the form of an open call . . . (Howe 2006)

Since Howe's 2006 commentary, most researchers have looked to both the sciences and popular literature to create commonality across varying definitions (Seltzer & Mahmoudi 2013; Arolas & Guevara 2012; Bott and Young 2012; Hudson et al 2009; Howe 2006). Proven to be successful as a collaborative method in the private sector (i.e. software development, design) this model may also prove beneficial in governance as a public participation and data collection method. Presently, most governance and planning literature look to crowdsourcing scholar David Brabham's definition. He defines crowdsourcing as an “online, distributed problem solving and production model that leverages the collective intelligence of the online community [crowds] to serve specific organizational goals” (Brabham, 2012). Brabham also makes the distinction of crowdsourcing with other creative online processes. Crowdsourcing is considered to occur strictly between an organization and the public where both entities partake in the process together. It is not solely a top down or bottom up approach. Examples of user information produced and organized from the online community include Wikipedia and YouTube. Traditional top down management in online participatory activities often consists of managing online voting campaigns (Brabham, 2013a).

Moreover, Brabham (2009) posits that crowdsourcing is a viable alternative to the traditional forms of public participation in the governance process. Based on the principal of universal participation, the use of online applications in the planning field provides an opportunity for experts and non-experts to interact, share information, and collaborate with each other often using digital technologies such as websites, wikis, blogs, mapping software, and mobile applications. This technique differs greatly from some public meeting formats or even static websites. This broad, but pivotal definition showcases crowdsourcing as a participatory data collection tool that has great potential to better understanding the needs of citizens, as well as to collect data for the decision making process

In response to the lack of guiding documents for practitioners in the public sphere, Bramburn recently presented a framework for assessing the appropriateness of using crowdsourcing as a tool in government. Here he introduced four problem based crowdsourcing approaches that could be transferred to solving governance problems (Table 2). This guiding document also provides best practices and key considerations based on lessons learned from previous crowdsourcing projects when planning, implementing, and assessing projects. Some of the key best practices outlined in the document include; the importance of determining the organization's level of commitment to the outcomes; understanding the motivations of an online community; investing in a usable- well designed platform; and lastly, making sure the organizations follow through on updating users on the outcomes of the projects and potential next steps (Branham, 2013).

Table 2. Four Main Crowdsourcing Typologies and Common Examples

Typology	Definition	Best Use	Commonly Cited Examples
Knowledge Discovery and Management (KDM)	Crowd is tasked with finding and collecting information into a common location	Information gathering, organization, identifying/reporting problems	• SeeClickFix • Peer-to-Patent
Distributed Human Intelligence Tasking (DHIT)	Crowd is tasked with analyzing large amounts of information	Large scale data analysis where human intelligence is efficient or effective over computers	• Amazon Mechanical Turk • CrowdFlower
Broadcast Search (BS)	Crowd tasked with solving empirical problems	Ideation problems that can be proved empirically	• InnoCentive • White House SAVE Award
Peer -Vetted Creative Production (PVCP)	Crowd tasked with creating and selecting creative ideas	Ideation problems where solutions are driven by market support, such as design, aesthetics, or technology solutions	• Threadless • 99design

Note: Adapted from Brabham, Using Crowdsourcing in Government, IBM Center, 2013

The potential of crowdsourcing in the public sphere is due in part to the advancement and increasing use of online technologies over the past 14 years. The adoption of the internet and mobile device access has dramatically increased, where 87% of American adults used the internet, 90% owned a cell phone of some kind, with 58% of adults owning smartphones in 2014. Major demographic groups (except among seniors 65 and older) experienced growth in both Internet adoption and smartphone ownership between 2012-2014. Smartphone ownership is similar across race/ethnicity, with Hispanics having the highest ownership across this group, with African Americans and whites not far behind.

As society continues to move towards an increasingly networked society, there has also been an institutional shift in how government looks to technology. In 2009, President Barack Obama’s administration pushed for the use civic technology for improving government transparency, accountability, and civic engagement and data analysis to inform federal, state, and local decision-making. The Knight Foundation recently released report that examines the current trends of civic tech in government. While researchers are still unsure how many municipalities and states across the U.S are embracing civic technology, this reports reveals that from 2008 to 2012 the civic tech companies grew at an annual rate of 23% (Patel et al., 2013).

The continued growth of civic technology is shifting how online tools are being viewed and used by government agencies. The City of Boston is an example of local government embracing crowdsourcing to improve both municipal services and promote citizen involvement. In 2009, a free municipal mobile application called *Citizen Connect* was developed by the Mayor’s Office of New Urban Mechanics for users to report service issues (e.g. potholes, graffiti, damaged signs) and check on the status of those requests. It provides users with the ability to share reports (request, GPS tagged photo, text) if desired and allows the opportunity to view requests submitted by other users. Anecdotally, the City of Boston has received positive feedback through the application implementation process. Project managers found that users of the application felt like they were “helping” versus just “complaining”. Today, over 20% of requests come from

Citizen Connect, resulting in over 35,000 individual improvements in Boston neighborhoods. The mobile application now reaches over 138 municipalities across Massachusetts (City of Boston 2012; City Lab 2013).

Beyond general city governance tools such as *Citizen Connect*, the use of crowdsourcing applications as a method of civic technology have also expanded to urban planning practices. Over the past ten years, planners have started to gravitate towards the utilization of technology as a means to engage the public in the planning process and to gather various forms of data. This shift in how technology is viewed provides online alternatives to overcome the challenges of traditional planning processes while influencing planning and policy decisions. Evans-Cowley and Hollander (2010, pg. 397) reviewed this shift and determined that crowdsourcing technologies have the potential in planning practices to “elevate public discourse in an unprecedented manner while providing an interactive, networked environment for decision making.” In addition, online applications have the capability to reach out to a broader group of citizens and boost satisfaction and participation in the planning process (Brabham, 2013; Conroy & Gordon Hollander & Evans, 2010; Cooper, 2007; Mandarano et al., 2010; Snyder 2012).

Mandarano et al. (2010) and Zhan and Zhu (2012) extensive review of crowdsourcing in planning found that the literature raises more questions than answers. This is mostly due to the scarcity of studies evaluating the influence of these activities in planning practices. There are only a few examples that highlight how crowdsourcing can be used in tackling urban planning questions and problems. For example in 2010, planners in Canela, Brazil explored the development of online tools to develop alternative ways to promote public participation in the planning process. Canela developed an online mapping application to solicit comments regarding their updated land use plan. Results from the Canela web based GIS prototype study showed great potential as a participatory tool, with satisfaction from participants and city officials from an ease of use, communication and engagement perspective (Bugs et al 2010).

Nash (2009) is one of the first scholars to introduce the potential of web applications to improve transportation systems. His review provides multimodal examples, but with little to no evaluation. There are also only a few emerging examples in the literature that highlight how the practice of crowdsourcing is applied to transportation planning questions and problems. The *Next Stop Design* project in Salt Lake City, UT is currently the strongest crowdsourcing application to date that explored the development of a web application to promote public participation in the transit planning process. Funded as part of the Public Transportation Participation Pilot Program, the main goal was to test this strategy in a transit oriented public participation process by asking the online community to design bus stop shelters for the Utah Transit Authority and submit it via an online web application. There were three winning designs at the end of the competition. Overall, of the 3,187 registered participants, two thirds shared that it was their first time partaking in a public process and users perceived the project to be accessible, informed, and inclusive (Brabham, 2012a). Moreover, there was no monetary incentive provided for participating. Researchers found that the motivation of participants included a mix of both extrinsic and intrinsic factors, including career advancement, peer recognition, contribution to supporting government, application usability, and learning new skills (Brabham, 2012b). These findings support other empirical studies looking at the motivational influences of crowdsourcing (Brabham, 2008b; Lakhani et al., 2007; Leimeister et al., 2009; Zheng et al., 2011). Nevertheless, research also suggests that projects such as these are far from perfect, highlighting the need to look at online projects as a process to improve and refine participation tools rather looking at these online tools as a one-time, end all be all project (Brabham, 2012b).

2.3.2 Challenges and Risks to Crowdsourcing

There are significant challenges and risks that transportation planners must closely consider when looking to use online technology to crowdsource. First and foremost, there is a scarcity of research evaluating the influence of crowdsourcing in planning and public participation practices. Most of the studies connecting crowdsourcing to planning studies focus on theory, and raise questions regarding the relationship between its use and overall impact on a project or initiative. Systematic reviews of the literature to date stress that evidence surrounding the impacts and reach of crowdsourcing in planning practices is only preliminary (Seltzer and Mahmoudi 2013; Zhao and Zhu 2012; Mandarano et al 2010).

There are also major risks highlighted in the literature that predominately focus on the development and implementation of crowdsourcing platforms. The most common risks associated with the public participation process (e.g. crowdsourcing), include participation inequalities (e.g. the digital divide, barriers to technology adoption), input bias, demographic bias, quality control and assessment of data, as well as challenges associated with the motivation, recruitment and retention of participants (Seltzer and Mahmoudi 2013; Bott and Young, 2012; Evans-Cowley and Conroy 2010; Eagle 2010; Sharma 2009; Krykewycz et al 2011).

Using the Internet and mobile devices to reach out to the public will systematically miss certain demographic groups due to the persistent digital divide. As of January 2014, 13% of American adults do not use the internet. This is most striking among adults age 65 and older, with 44% saying they do not use the internet or email. Pew Research (2014) reveals that the primary reason why older adults do not use the internet is usability (e.g. internet is too difficult, don't know how, physically unable). There is also a divide among race/ethnicity and education levels. African Americans continue to be less likely than whites and Hispanics to use the internet, as well as those with a high school diplomas or less than those with some college or more. In addition to internet use, smart phone adoption varies significantly by age groups, household income, except for among younger adults (18-34). Seniors continue to exhibit low adoption rates of smartphones, where 19% of American age 65 and older owns a smartphone. For older adults, smartphones use is most prevalent in the upper end of income distribution of $75K plus (Rainie et al., 2014). It is clear that internet and smartphone ownership is still not ubiquitous and digital divisions persist in across some demographics groups and technology platforms.

Recently both OpenPlans and Place Matter, non-profits for civic engagement in urban planning, have distributed emerging guidelines that present various factors that are critical for using technology tools for engaging underrepresented groups. From a development perspective, they recommend that municipalities connect and work with community groups and well respected/trusted advocates in neighborhoods when considering using online tools to engage target groups. These reports also stress involving underrepresented communities in the tool development process. These initial strategies can be a crucial step in making sure the online tool will be accessible and used by a targeted group. This process should include community members providing input on application design and functionality that meets the needs of people with varying language and educational backgrounds. Finally, from an evaluation perspective, collecting demographic information (e.g. zip code, age) when implementing crowdsourcing can aid planners in deciphering gaps in citywide participation. This data can help municipalities focus time and limited resources in targeted areas to better understand how neighborhoods prefer to engage with city services (Place Matters, 2014; Open Plans and Living Cities, 2012).

In regards to municipal crowdsourcing and motivation of participants, research is still limited. Municipalities should closely consider the various techniques when developing and recruiting participants for a public crowdsourcing project. While findings point strongly to intrinsic motivators behind participation, municipalities should consider local circumstances when deciding on whether and what types of incentives might be used during the recruitment phase of a project. Understanding motivations and usability experience of individual applications should be evaluated to better understand how to best capture a representative sample of users.

Finally, while the literature acknowledges the potential in crowdsourcing for both data collection and citizen participation, it should be stressed that it is not being considered as a means to replace traditional forms of participation and communication, but as a complementary technique. The use of web tools can enhance the tools available to planning practitioners and be combined with low-tech, face-to-face engagements techniques. Mandarano el al. (2010) mentions the need to incorporate mixed methods (web based and other traditional forms) to investigate the link between participation and development of social capital. Also, similar research should be conducted to compare responses from varying engagement and survey methods. Different demographic groups and users may or may not show variations in response by engagement strategies and survey types.

The crowdsourcing model has benefited the private sector, but has yet to be fully realized as a method for improving bicycling planning process. There is great potential in using web and mobile technology in bicycle planning, but currently very few state and local transportation agencies are actively using this strategy to engage and seek non-expert support from the public. Many planners rely on national travel data, or time and staff intensive mail or manual SP and RP surveying to support projects or justify funding requests. Learning more about the attributes of bicycle networks using web and mobile applications can further inform sustainable transportation decision making at the city and regional level. These attributes may include street level data on travel routes and purpose, accident data (movement preceding collision, location of collision) to measure crash rates at street and bike network levels, and changing conditions with infrastructure and policy developments. It also presents a case for engaging citizens to take a proactive role in improving the built environment. In addition to these opportunities, crowdsourcing also presents planners with the ability to reach large groups without the costs in time and resources that other data and participatory methods can present in the field. This is important to consider as municipalities are challenged with limited funding for bicycling at all levels of government.

The current rise in projects focusing on surveying the online community using web and mobile mapping highlights a promising new direction for bicycle planning. Generally, these applications have the capability to reach out to a broader group of citizens and engage the public in a collaborative process to improve planning projects. The remaining sections will discuss the research methodology of this research project and then apply the theory and evidence explored in the literature review to ten bicycle planning crowdsourcing case studies. This will extend the crowdsourcing discussion to the bicycle planning field, including what is being done currently and future recommendations to municipalities and practitioners as research develops over the coming years.

Chapter 3: Methodology

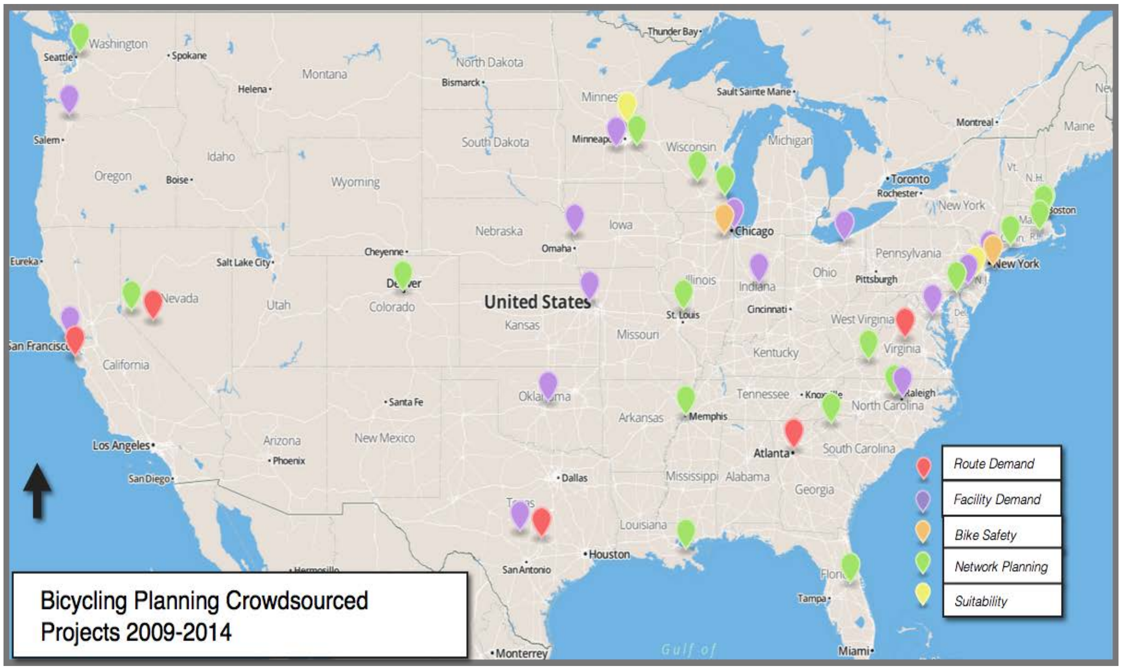
The purpose of this study is to investigate current crowdsourcing practices in the bicycle planning field in regards to the planning and development process behind the project, as well as the associated drivers and challenges to this civic technology process. The purpose of this chapter is to describe the research methodology of this study, explain the case study sample selection, describe the techniques used in the collection of the data, and provide an explanation of the procedures used to analyze the data and limitations to the research design.

A qualitative research methodology was used for this study of crowdsourcing initiatives using both interviews and available documentation and public reports. This study was exploratory in nature as a way to provide details into the crowdsourcing process within the context of bicycle planning in the US. An exploratory case study is carried out when considerable uncertainty exists about an area of study or when there are few or no earlier studies to refer to for this subject matter (Baxter & Jack, 2008; Yin 2003). The main focus is to gain insight into the opportunities and limitations crowdsourcing presents and questions for future inquiry. This case study research is situational to the bicycle planning field, and not necessarily generalizable to other crowdsourcing situations.

3.1 Case Sample Selection

A list of U.S projects that leveraged crowdsourcing as a means to improve bicycling in metropolitan areas was compiled through in-depth research of websites, social media and online reports/documents. As of December 2013, a total of 33 U.S states were found to have used or were currently using crowdsourcing as a strategy to improve various bicycle planning activities. This field scan indicated that managers of these initiatives include State DOT’s, MPO’s, local municipalities, non-profit organizations, and private firms. This preliminary research also presented five main project types in which crowdsourcing was applied including facility demand, network planning, bike safety, suitability, and route demand modeling (Figure 1). Ten cases were selected from the larger sample based on two main criteria, (1) cases selected were representative of the five project types, and (2) cases had documentation and reporting available in print or online. This purposeful sampling limited the selection process greatly. Moreover, not all potential participants agreed to participate, leaving an even smaller pool of cases to choose from for this study.

Figure 1. Field Scan of Bicycle Planning Crowdsourced Projects and Types 2009-2014



Note: This map presents state-by-state examples of where bike planning and crowdsourcing have converged. While not a comprehensive map, it showcases his emerging practice for improving and expanding bike networks around the U.S.

3. 2 Data Collection & Analysis

Research method procedures included structured interviews and the examination of available public documents, reports, and news sources. Semi-structured interviews were administered to a selected sample of cases chosen during the case sample selection phase. The semi-structured nature of the interviews allowed for some divergence, allowing for new ideas or comments to be brought up by the interviewee. This qualitative method was used to investigate the planning and development process behind crowdsourcing projects, as well as the associated opportunities and challenges.

The questions used in the interview process were submitted to the Tufts Institutional Review Board (IRB) and approved in May 2013 (see Appendix A). Questions fit into four main categories; project development, implementation, post-analysis, and challenges/opportunities. Once IRB approval was confirmed, interviewees were contacted to schedule interviews. Interviews were not conducted for all 10 cases due to unavailability of interviewees during the project timeline. A total of nine interviews were conducted in person or over the phone and lasted no more than 45 minutes. All interviewees' responses and comments were manually transcribed during the interview with the permission of the individuals being interviewed. Of the projects interviewed, interviewees consisted of the lead project managers and in some cases a second participant, including a software developer or non-profit administrator involved in the planning and implementation of the project (Table 3).

Table 3. List of organizations interviewed

Organization Interviewed	Job Titles of Interviewees	Location	Crowdsourcing Project
Delaware Valley Regional Planning Commission	Transportation Planner	Philadelphia, PA	Mercer County BLOS Philly Bike-to-Transit
Toole Design Inc.	Transportation Planners (2)	Chapel Hill, NC Boston, MA	Chapel Hill Bike Plan Boston Network Crowdsourcing Map
Wikimapping	Software Developer	Chapel Hill, NC	Chapel Hill Bike Plan
Capital Bike Share/Bike Arlington	Program Manager	Washington, D.C.	Capital Bike Share
Mobility Lab	Software Developer	Washington, D.C.	Capital Bike Share
Bicycle Coalition of Greater Philadelphia	Policy Director	Philadelphia, PA	Philly Bike-to-Transit
Open Plans	Executive Director	New York, NY	Philly Bike-Transit Crowdsourced Map NYC BikeShare
Virginia Tech & City of Blacksburg	GIS Analyst/Software Developer	Blacksburg, VA	Bike/Ped Survey Map

Once interviews were completed, a qualitative content analysis approach was used to analyze text data from interview transcripts. Research using content analysis focuses on the characteristics of languages as communication with attention to the content or contextual meaning of the text with the goal of providing " knowledge and understanding of the phenomenon under study." (McTavish & Pirro, 1990; Downe-Wamboldt, 1992; Hsieh & Shannon, 2005). This research method was carried out by re-reading transcripts and coding text into prevalent themes or categories to be used in the research study (Creswell, 2008, chp.9). Coded data included repeated processes, statements, words, or phrases that were grounded within the four main categories of the interview questions; project development, implementation, post-analysis, and challenges/opportunities. These codes were used to uncover relevant pattern across interviews and combined to create major themes evident across the life cycle of the cases explored. Moreover, public documents were also reviewed to supplement this interview data analysis with additional case study details.

3.3 Limitations in Methodology

This research project was exploratory in nature in order to bring new insights to the use of crowdsourcing within the context of the bicycling planning field. It merely probes for a deeper understating of this process. While the discovery and process of crowdsourcing is not new to the private sector, very little research has been done to evaluate such practices in the civic realm, including bicycle-planning practices. Planning practitioners must look to this study as a guiding document to further study and evaluate such practices in the field—whether it means rigorously studying one project from start to finish or designing a cumulative research study.

There are various limitations of this study’s qualitative methodology that can be identified. While the sampling technique was purposeful based on established criteria, it was clear that most projects had little documentation and in most cases, potential participants with the most information-rich projects were not interested in being interviewed at the time. This left the study with a fairly biased sample of projects reviewed. Second, a limited sample of individuals involved with the development and implementation of these projects were interviewed (i.e. planners, software developers, nonprofit members). There was a missed opportunity to select actual users of the mapping application that may have proved useful in the analysis and recommendation section.

This study also presents the limitations to it validity, particularly external validity. External validity refers to the degree to which the results of an empirical investigation can be generalized to and across individuals, settings, and times. We cannot fully generalize the findings to other crowdsourcing cases in the field due to the small sample size of cases reviewed. The more representative the cases the more confident the study could generalize from the sample to the use of crowdsourcing in bicycling planning. Finally, instead of using a single method approach (content analysis), using a multiple methods approach could prove beneficial in increasing validity to the study. This study could have complemented the interviews with stakeholder focus groups for each case and/or surveys that looked to the public's experience with the mapping platforms.

Chapter 4: Case Studies

4.1 Introduction

In an effort to help planners and other groups improve and expand bicycling, researchers and municipalities around the U.S and beyond have looked to Web 2.0 crowdsourcing tools to better plan for bicycle networks. These crowdsourcing tools have started to emerge over the past five years at the neighborhood, municipal and regional levels by allowing groups of people to become part of the actual planning and administrative process. These mapping tools have been used in collecting real time travel data and bicyclists' preferences, as well as trying new ways to engage the public in planning processes. More recently, these tools are being used to confront the challenges associated with bicycle suitability and overall network planning.

The use of crowdsourcing will be demonstrated through ten case studies that highlight crowdsourcing in the bicycle planning field. For a list of selected cases, see Table 2. This section provides background information on each case study collected from both interviews and available documentation, followed by results and a cumulative analysis that will point out various key themes, including motivation behind such projects, the development and implementation process, and limitations for using crowdsourcing tools in the context of bicycle planning. Project screenshots from the case studies are available in Appendix B.

4.2 Case Descriptions

4.2.1 Bicyclist /Pedestrian Map Survey, Virginia Tech & City of Blacksburg, VA

In an effort to make Blacksburg a more appealing town in which to bike and walk, Virginia Tech's Center for Geospatial Information Technology (CGIT) and the City of Blacksburg partnered in 2009 to create an online tool to garner public input that could inform pedestrian and bicycle planning decisions. This project mostly acted as a way to increase community awareness of biking/walking issues and show city officials the potential of interactive mapping as a non-traditional public engagement tool. Data from surveys, while limited, were aggregated and used in the production of maps and graphs, which were presented to the Town of Blacksburg. The web survey was complemented with non-electronic methods of participation and printed maps that were made available at local bike businesses for people to draw routes or pinpoint problematic areas.

This web platform allowed users to provide input on routes taken by bike or foot. The three-step interactive mapping survey first asked respondents to select the most common bicycle and/or pedestrian routes they have followed in the past month using editing tools to the left of the map interface. Then users were asked to use the point feature tool located to the left of the map to identify a location of concern for pedestrians or bicyclists.

Respondents then filled out a short motivation and demographics assessment (reasons for trip, bike experience, and age), as well passing a security test (i.e. CAPTCHA to decipher users from spambots.

4.2.2 Boston Bike Network Plan Crowdsourced Mapping, City of Boston, MA

From 2010 through 2012, the City of Boston and Toole Design Group ("Toole") worked to update and improve Boston's Bicycle Network Plan to meet the increasing demand for better bicycle infrastructure and facilities. During the earlier phases of the Boston Bike Network Plan, Toole used an online interactive mapping tool to collect popular/most used bike routes.

This project was structured around free Google mapping software (Google Maps/Engine Light) that allowed project administrators to create and share maps, which Boston Bikes and Toole used to collect demand data on bicycling routes. This mapping tool also has data analysis capabilities, including the ability to connect features drawn on the map with a data spreadsheet, geocode line or point features, and upload them into more advanced mapping software such as ArcGIS. Data collected during this project was exported to ArcGIS to create a Route Tracking Map.

4.2.3 Chapel Hill Bike Master Plan, Wikimapping, Chapel Hill, North Carolina

The Town of Chapel Hill, NC, along with community stakeholders and neighboring communities, is currently in the process of developing a bicycle network master plan from 2012-2013. The project team main goal was to use Wikimapping, an interactive mapping application, to identify places where people bike, where they want better facilities, and where they would like to bike if they felt safer or more comfortable.

This Wikimapping is a web and mobile platform that allows users to create, visualize and share stories on a map. After users registered with an email address (not shown publicly), users can login at any time to add points or lines that identify high or low stress routes, problem intersections, bike parking needs, and popular destinations respondents bike to and from (e.g. parks, shops, restaurants). Users also have an option to upload photos and to read other anonymous comments and agree with them by clicking on a “like” sign above the comments.

4.2.4 Capital Bikeshare-Bike Arlington, Arlington, VA

After Washington D.C’s successful 2010 launch of one of the largest bikeshare programs in the U.S., Capital Bikeshare (CBS) looked to expand its bikeshare services to Arlington, VA, with the main goal of creating a dense network of stations that meet the needs of citizens. As part of their five year strategic expansion plan, CBS decided to build off of the traditional public meeting format and incorporate an online tool that had the potential to reach a larger audience, while still providing a sense of ownership in the public process

This crowdsourcing map allowed users to suggest station locations by dropping a pin on the map interface, offering comments on their suggestion, and liking or disliking suggested stations. Users also had the ability to share the tool with other people via social media outlets, such as Twitter and Facebook.

4.2.5 Citi-Bank Bike Share, New York City, New York

Between September 2011 and April 2012, NYDOT carried out a lengthy public process to introduce the bikeshare concept to New York City residents. This process included 33 open houses, 54 extensive public meetings with Community Boards, 14 community workshops, 115 meetings with business owners and other stakeholders (NYDOT 2012). In addition to face-to-face communication, NYDOT built from their current online presence by providing a crowdsourcing mapping software (Shareabouts). This software was developed by Open Plans, a non-profit with a mission to improve government functions via technology. This map's main objective was to complement more traditional forms of public participation. NYC's bike share program started in May of 2013 and continues to work with communities to locate and expand stations throughout the five boroughs.

This crowdsourcing tool provided New Yorkers an opportunity to suggest bikeshare locations, explain their choices, and vote on other users' suggestions. It also allowed users to share locations with friends and family via Facebook, Twitter, or email. GIS demand modeling considered these comments/preferences in addition to an array of other determining factors -- land use, populations, transit access, access/proximity to bikes lanes, station design criteria—to develop a final site plan for NYC's first fleet of bikeshare stations. Opens Plans has recently expanded the Shareabouts software to a mobile-friendly platform.

4.2.6 Philly Bike to Transit Web Survey, Open Plans, Greater Philadelphia, PA

Between September and December 2012, "Philly Bike to Transit Crowdsourcing Survey" was made available to the public to reveal the potential obstacles that prevent and/or deter cyclists from using their bikes to get to and from transit stops. This public process was a preliminary effort to pilot an online participatory tool, as well as inform a regional transit study to be released by Delaware Valley Regional Planning Commission (DVRPC) in early 2014.

This crowdsourcing tool provided transit users of varying bicycling experience an opportunity to choose a station they bike to, or would bike to, if improvements were made to the transit stops. More specifically, the four survey questions for each station looked to reveal the demand for better bike parking, how often the respondent bikes there, quality of transit station parking, if improvements would impact their likelihood to bike there, as well as provide additional comments. Anonymous answers were counted and made available each time a respondent clicked on a transit station. It also allowed users to share locations with friends/family via Facebook, Twitter, or email.

4.2.7 Crowdsourcing-Bikeability Scoring (BLOS), Mercer County, New Jersey

In 2009, the Delaware Valley Regional Planning Commission (DVRPC), which serves 9 counties in Delaware and New Jersey, generated an interactive bicycle level of service (BLOS) map for roadways in Mercer County, NJ. The map was intended to prioritize the development of Mercer County's bike master plan by incorporating GIS data and crowd wisdom. The application was designed with two main goals in mind--gather input to improve the quality of the BLOS dataset, and explore a non-traditional way to interact with stakeholders, advocacy groups, and residents through web-based outreach.

The ArcGIS map interface platform was set up with a pop up window in order to introduce users to the project background (i.e. what is bikability, purpose), the map's legend, and how to use the interface. The BLOS index was simplified for the application in order to make it more palatable for non-planning professionals. Therefore, "BLOS" was replaced by "Bikability", and the six letter grades for BLOS were combined into three categories, excellent (A, B), fair (C, D), and unfavorable (E, F). Users were allowed to re-rate bikability scores for road segments as lower or higher, identify “problem spots”, and identify priority bike routes and bicycling destinations. Users were able to provide comments on their own routes and other users’ suggested routes.

4.2.8 CycleTracks Smartphone Application, San Francisco County, California

In 2009, San Francisco County Transportation Authority (SFCTA) developed a smartphone application called CycleTracks. This approach takes advantage of the public’s increasing use of personal smartphones, allowing for researchers to increase distribution and sampling. CycleTracks is a free, quick to download application for the Apple iPhone and Google Android. Once downloaded, users can log their bike routes from start and end. Not only does this application collect route choice data (GPS enabled), but also collects trip purpose and demographics data from cyclists in San Francisco to better understand cyclists’ travel preferences. Personal data (i.e. age, sex, frequency of cycling, ZIP code, email) was optional, and not required to use the application. Users also had the ability to view their recorded trips and the distance, time, and average speed of each trip logged using the application.

The main goal behind this smartphone application was to collect route choice data (GPS enabled) and demographic data from cyclists in San Francisco to better understand cyclists’ travel preferences. The initial data collection phase occurred between Fall 2009 and Spring 2010. Analysis included data cleaning and GPS post processing to screen for non-Bay area users (application was open to anyone) and remove false paths/non-bicycle trips. After post-processing data, a total of 366 individual users were identified, providing over 3,000 usable bike routes. Data analysis to identify characteristics of bike routes and participants who used the routes was based on this post-processed data. Of the users who provided demographics information, the mean age was 34, 79% of bicyclists were male, and 60% of total respondents reported bicycling daily (Charlton et al., 2011). Data analysis of the bike trips also showed statistically significant demand trends. Routes indicated that infrequent cyclists preferred streets with bike lanes twice as much as frequent bicyclists. In addition, the likelihood that commuters avoided hilly routes was three times higher than that of non-commuters and non-commuters are willing to bike out of their way one mile for every 100 feet hill rise (Hood et al., 2011, Charlton et al., 2011).

As one of the first models to forecast travel behavior and the effects of bicycle infrastructure investment (i.e. congestions, green house emissions), it will enhance the ability of transportation planners to respond to the needs of bicyclists, including opportunities to research the effects of pre and post infrastructure projects on bicycle trip making and facility use. Improvement to the model is needed, including increasing the response rate and sample size in future data collections to make sure the model is more representative of the bicycling population. SFCTA completed analysis of phase one of this projects in 2010 and will continue to collect bicycle route choice data starting in 2013/2014. The longer-term objective of using this modeling data will be to inform sustainable transportation investments at the city and regional level (Zorn et al., 2012).

4.2.9 Cyclopath, Twin Cities, Minnesota

Cyclopath is a bike route-planning online tool that covers Twin Cities' metro region. It was developed in 2008 by GroupLens Research, a computing research group at the University of Minnesota, with the objective of using crowdsource wisdom to build a comprehensive, up to date resource for bicyclists with varying preferences. In 2011, the City of Minneapolis included Cyclopath in their Bike Master Plan as a moderate/high cost non-infrastructure project that would likely help the municipality increase bicycle mode share and safety (City of Minneapolis, 2011).

The main functions of Cyclopath allowed users to search for routes, rate road segments, and share information on an editable map (geowiki), such as tagging roads under construction or a city landmark not currently on the map. Routes provided to individual users are based on users' personal distance preference and bikability rating. These ratings are based on a five-point scale; excellent, good, fair, poor, impassable. This allows the tool to find the best route for the rider, while also improving the bikability scores for the entire bicycling community. This is captured through a sophisticated algorithm that applies users' ratings to improve route recommendations for all users. As of December 2013, Cyclopath had developed an Android mobile application to support and expand their user base. The application provides less editable functions than the web application, but allows users to find routes tailored to distance and bikability, browse routes, rate road segments and record GPS tracks.

4.2.10 Chicago Bicycle Crash Map, Chicago, Illinois

Two independent web developers first conceptualized Chicago's Bicycle Crash Map. They combined 2005-2012 data from the Illinois Department of Transportation (IDOT) and the Chicago Police Department (CPD). These data were made available on a searchable online map for the public use. Willen Law Firm built from these open source platforms and launched a web application in 2013that is free and works on most Internet browsers. Chicago's Bike Crash Application allows users to search for crashes based on location/zip-code, weather conditions, date range, and injury severity. It also allows bicyclists the opportunity to self-report close calls and bicycle accidents. Name and contact information is optional, but users must provide the address and identify collision type, weather, and surface conditions. They also have the option to be contacted by a Willens attorney for legal advice regarding their accident. All self-reported submissions are made available in real time on the online map and can be used by city or advocacy agencies to complement IDOT and CPD crash reports.

Chapter 5: Findings

This section summarizes the findings surrounding the development and implementation of crowdsourcing projects across ten different communities based on the exploratory case study approach described previously in the methods. The major findings will then be highlighted within the context of the existing literature, with applications to the burgeoning use of crowdsourcing in the bicycle-planning field.

5.1 Crowdsourcing Objectives

The ten crowdsourcing cases presented in this study showcase how various agencies are using crowdsourcing via interactive online mapping applications to help improve bicycling infrastructure and safety at a municipality or regional level. All of the online mapping applications sought to acquire knowledge from the public to meet various bicycle planning and safety needs. Major project leaders of these initiatives varied from state DOTs, MPO's, and local municipalities, to non-profits, and private businesses. Early in the research process, five distinct approaches were identified. These include: bicycle facility demand, network planning, bike safety, suitability, and route choice modeling (Table 4).

In general, bicycle facility demand and network planning were used in a larger planning process that included more traditional forms of public engagement (i.e. public meetings, community workshops) and field analysis from project team members. Conversely, bicycle safety and route choice applications are more empirically focused with the primary intent of looking to the wisdom of a crowd with the intention of capturing larger datasets over time to improve regional demand modeling and bike crash data. While public participation was key to collecting the data, it wasn’t the main driver in developing these tools. CycleTracks is presented as a data collection application to serve a region’s needs for better data at the street level. Chicago’s Bike Crash application is not a municipal driven tool per se, but presented as a tool that could provide local municipalities with helpful data. This web application presents an online alternative for bicyclists to provide information on crash hotspots or near misses that are not included in police or emergency response data. This application’s self-reported data is available to the public, but there is no evidence of local advocacy groups or government agencies taking advantage of such data. Chicago’s transportation officials point to the limitations of collecting self-reported data, such as selection bias. The city is not looking to use the method at this time to complement annual crash data (Bauer, 2013).

The suitability crowdsourcing projects presented are distinct in their own right. Mercer County’s BLOS project was part of a larger planning process looking to update a regional master plan. The interactive bikability map was used early in the project phase to gather public input on BLOS scores and identify priority routes along the network. Cyclopath is promoted as a personal route-planning tool that incorporates users’ feedback into a suitability algorithm in order to provide the best routes based on riders preferences and abilities. Although the emphasis is promoting it as a personal tool, the goal is to use the community to improve route planning. The city of Minneapolis includes this tool as an educational resource for residents (Minneapolis Bike Master Plan, 2011). Both suitability projects were presented as tools to learn how various types of bicyclists ride across the current network and potential areas for improvements and/or expansion.

Table 4. Five distinct crowdsourcing approaches in bicycle planning

Crowdsourcing Approach	Background
Bicycle facility demand	Bicycle facility demand mapping applications help planners identify demand for bicycle facilities. They are designed to collect public input on suitable locations for bikeshare station and better bike parking access at transit stations. They also provide users the ability to comment on suggestions and support existing suggestions (Figure 2).
Network planning	Network planning application support the bike master planning process. This process usually involves a municipality presenting the community with both short and long-term planning and policy goals to improve bicycling mobility and safety. This planning process requires significant public input and fieldwork before recommendations can be made. With crowdsourcing, interactive online maps are used to gather input through the collection of users' preferences and opinions regarding a municipality or region's bike network—from entire routes to locations along routes (Figure 3).
Suitability/Bikability	Municipalities interested in assessing bicycle networks and ease of travel usually focuses on suitability, an objective measurement of perceived comfort, and the safety of shared used paths and roadways. The suitability crowdsourced applications look to improve suitability ratings by surveying bicyclists' actual preferences at the street level (Figure 4).
Route choice modeling	The route choice modeling approach requires users to download a mobile application onto a smartphone device. Once downloaded, users can record a new trip from start to finish. Each logged trip collects users' GPS coordinates, trip purpose and personal data (zip, age, gender). Planners have the ability to see the actual travel behaviors of users and aggregate trends into travel demand models when predicating mode share. It has great potential in aiding decision-makers in reworking travel demand models and in turn prioritizing infrastructure projects (Figure 5).
Bike Safety	Bike safety mapping applications have two man functions; provide government bike crash data to the public in a user friendly way and allow users to self-report bike crashes or near misses. This approach is not commonly used, only appearing in a few large U.S cities (i.e. Chicago, NYC). There is also the opportunity to use these platforms in providing options for the public to share knowledge regarding bike crashes, near misses, & problematic areas (Figure 6).

Table 5. Cross Comparison of Cases

Case Study	Year	Main Objective	Platform	Mapping Software	Beta Testing	Registration	Data Collected	Project Demand	Estimated Cost	Estimated cost/respondent	Funding Source
Facility Demand											
Capital Bike Share/Bike Arlington	2011 (ongoing)	Public Participation,	Web (Custom, open source)	Google Maps API	No	Yes, email/login	Locations, Votes	Moderate	N/A	N/A	Nonprofit (Mobility Lab)
NY City Bike Share	2011	Public Participation, Data Collection	Web (Shareabouts)	OpenStreet Maps (open source)	No	No	Locations, Votes	Moderate	$4,000	0.40 cents	Government (NYDOT)
Philly Bike to Transit	2012	Public Participation, Data Collection	Web (Shareabouts, open source)	OpenStreet Maps (open source)	No	No	Locations, Votes	Moderate	$4,000	$8.65	Nonprofit (Open Plans)
Network Planning											
Blacksburg Bike/Ped Map Survey	2009	Public Participation, Data Collection	Web (Custom)	Google Maps API	No	No	Locations, Routes, Bicyclists Type/Freq	Moderate	N/A	N/A	Nonprofit (Virginina Tech)
Boston Network Plan	2011	Data Collection	Web (Google Engine Maps)	Google Maps Engine	No	No	Routes	Low	N/A	N/A	N/A
Chapel Hill Wikimapping	2013	Public Participation, Data Collection	Web (Wikimapping)	Google Maps API, Leaflet API	No	Yes, email/login required	Locations, Routes, Votes, Bicyclists Type/Freq	Moderate	$349	$2.00	Government (City Chapel Hill)
Suitability/Bikeability											
Mercer County BLOS Map	2010	Public Participation, Data Collection	Web (Custom)	ESRI's ARCGIS API	Yes (external stakehold	Yes, email/login required	Locations, Routes, Bicyclists Type, Demographics	High	$75,000	$68.36	Government (DVRPC-MPO)
Cyclopath	2009 (ongoing)	Data Collection	Web, Mobile (Custom, open	Custom (open source)	Yes (internal)	Yes, email/login	Locations, Routes	High	$100,000/year	$66.66	Private Funding
Route Demand Modeling											
CycleTracks	2009 (ongoing)	Data Collection	Mobile (Custom, open source)	Tom Tom Map API	Yes (internal)	No, email optional	GPS routes, Cyclists Type/Freq, Demographics	High	$20,000	$14.28	Government (SFCTA)
Bike Safety											
Chicago Bike Crash Map	2013 (ongoing)	Data Collection	Web (Custom)	Google Map API	N/A	No	Locations, Crash Conditions, contact info (optional)	Moderate	N/A	N/A	Private Funding

Figure 2. Screen shot from Citi-Bike, Facility Demand

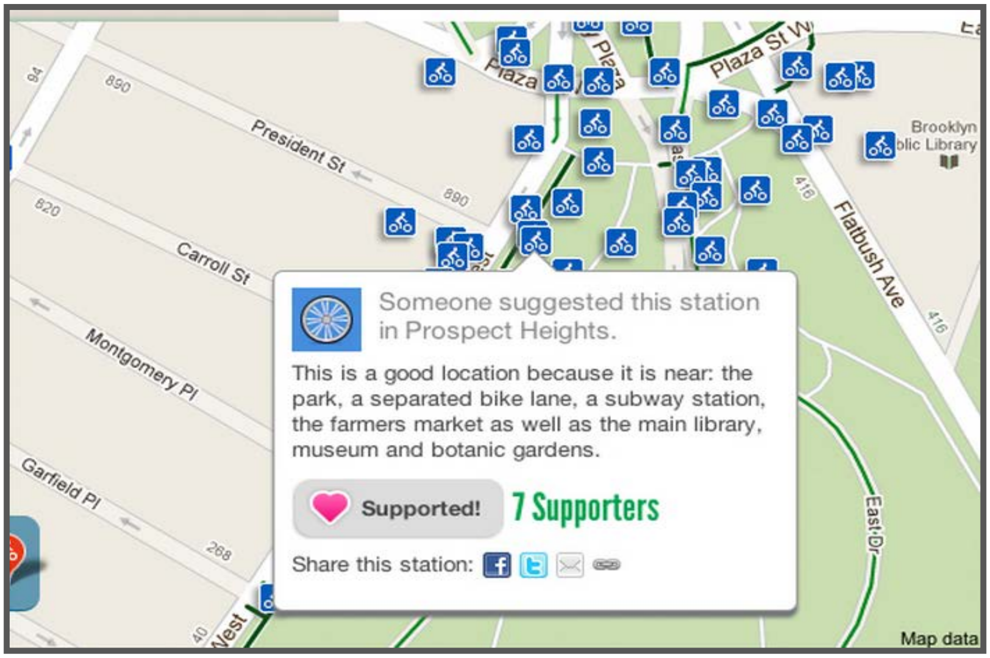


Figure 3. Screen shot from Chapel Hill Bike Plan, Networking Planning

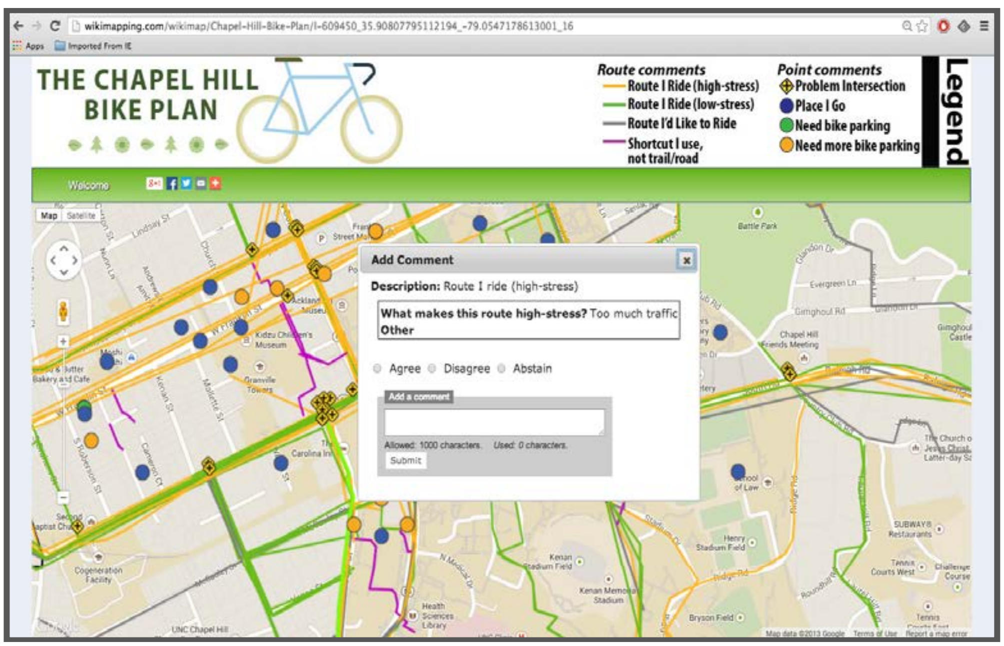


Figure 4. Screen shot from Cyclopath, Suitability Modeling

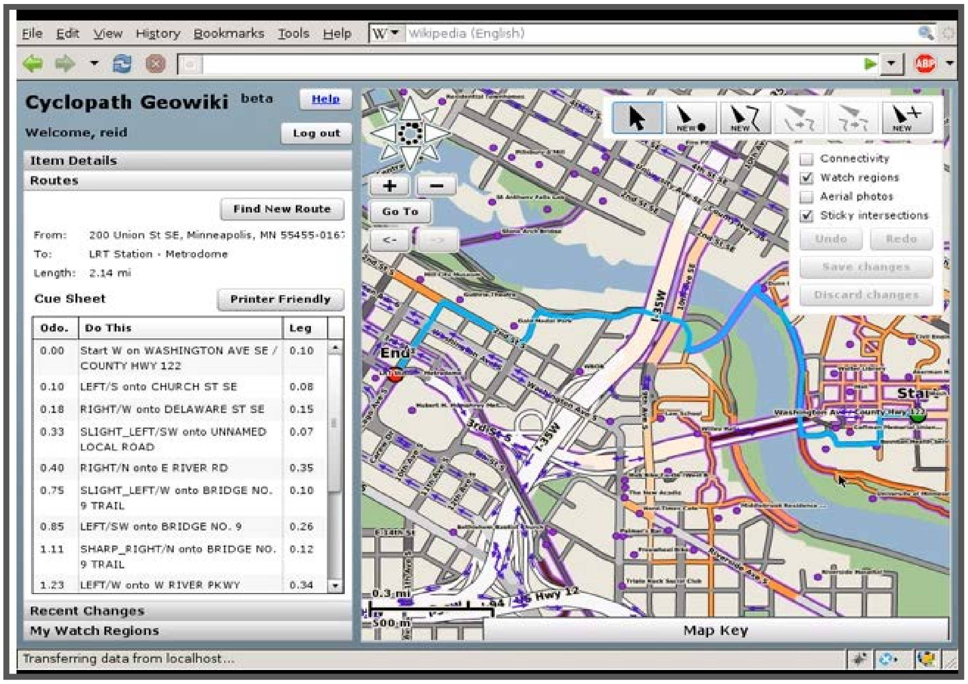


Figure 5. Screen shot from CycleTracks, Route Choice

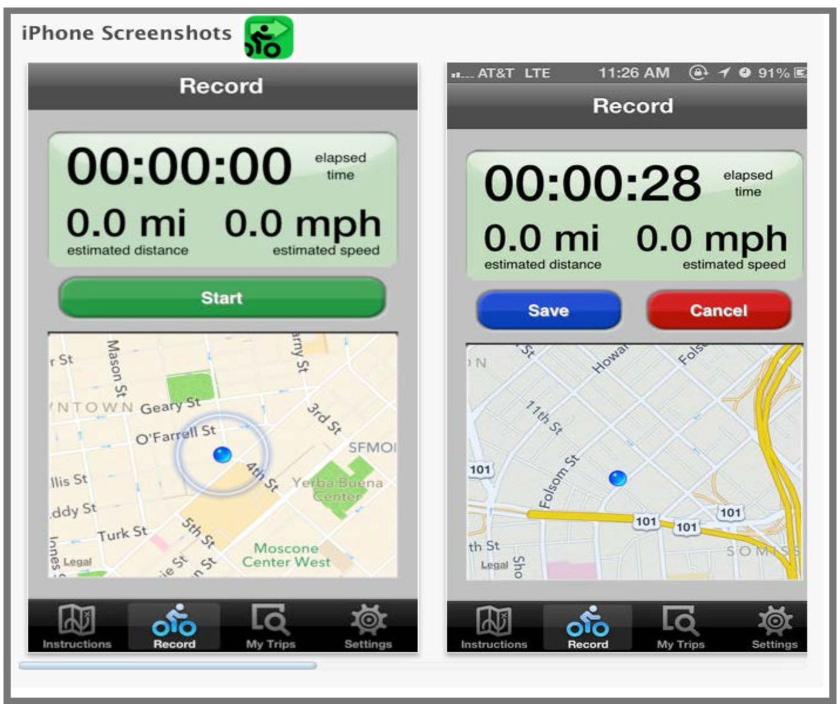
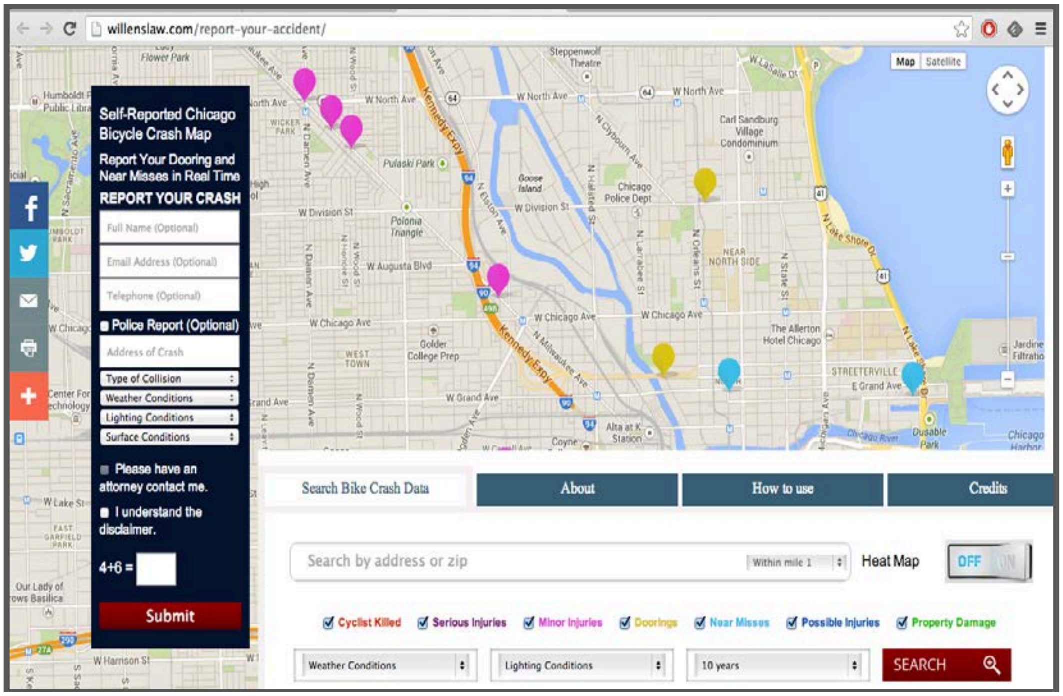


Figure 6. Screen shot from Chicago Bicycle Crash Map, Bike Safety



5.2 Application Development & Design

The web applications reviewed were developed to run on various browsers, including Chrome, Firefox, Internet Explorer, Safari, and mobile operating systems, iOS and Android. This allowed applications to be directly assessed through a user's desktop or mobile browser. They were coded with various supported programming languages, including PHP, MySQL, Ruby on Rails (RoR) and /or JavaScript (Java).

Mapping software interfaces (Application Programming Interface-APIs) varied across all of the applications. The applications were embedded with various mapping APIs ranging from Google Engine Map and Tom Tom commercial APIs that charge for mapping services to more flexible open source alternatives such as OpenStreetMaps (Table 5). Open source mapping software is free, works more efficiently across major desktop and mobile platforms, as well as allows software developers to access and develop a wider range of tools and customizable features not permitted when using commercial APIs (Table 5). This open source freedom presents opportunities for innovation and collaborative development not seen in commercial products.

In general, most of the application interfaces provided a prominent navigation bar at the top of the page for users to easily access background on the project, FAQ's in using the application, disclaimers (if any), and project administrator contact information (Figure 7). Boston's Google Engine Map lacked a navigation bar and provided background and directions for how to use the interactive map via a separate PDF document. The presence of privacy/security policies or general disclaimers also varied across web applications. Most provided a general disclaimer indicating how data collected will or will not be used, and a statement of the application hosts' limitation of liability. There was no evidence that CBS, Chapel Hill and Boston provided such information that was easily accessible to users before using the application. Also all crowdsourcing application platforms were only available in English.

All of the web applications asked users to place a "pin" and/or identify a route using their cursor on the map interface. When a location or route was selected, a pop out box or side box usually appeared prompting users to answer survey questions and/or provide open-ended feedback (Figure 7).

Figure 7. Screen shot of Open Plans Bike-to-Transit interface

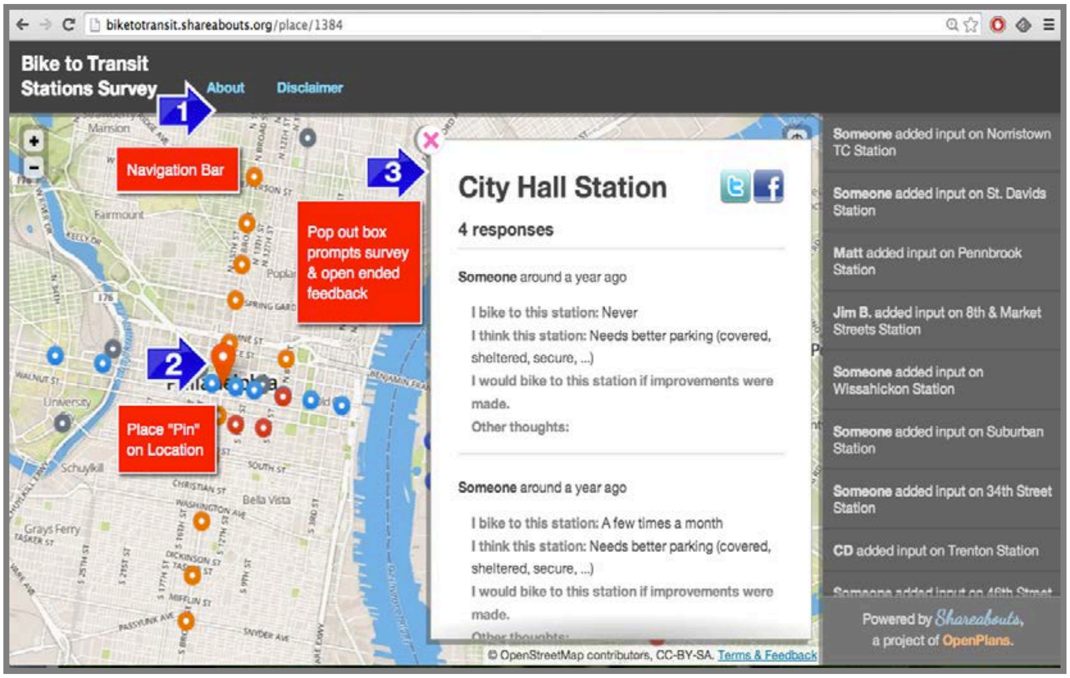
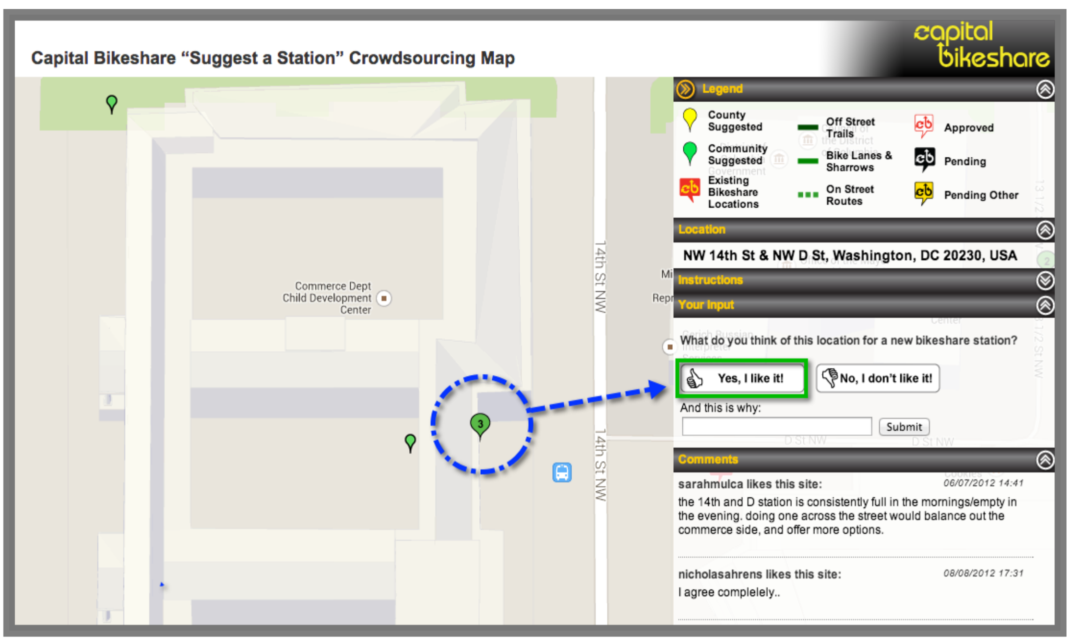


Figure 8. Screen shot of CBS voting feature



In addition to surveying, CBS, NYC BikeShare, and Chapel Hill's platforms provided an option for users to vote (like/dislike) other users' suggestions and provide additional comments regarding their vote (Figure 8). The premise was to use votes to measure further demand for particular locations and was used for both Citi and CBC Bikeshare projects.

Some of the web applications entailed more custom coding than others. For example, Boston used a basic, Google Map Maker (now called Google Map Engine) application to loosely crowdsource route data without additional development or coding from project team members. Google Maps Engine presents managers with data limitations, as well as the inability to add features that go beyond what is provided. Other platforms reviewed were customized web applications allowing for more flexibility to individual projects. Wikimapping and Open Plan interactive mapping platforms include querying and surveying tools, and importing/exporting data functions for project administrators (Figure 9). These platforms are examples of third party crowdsourcing service providers that specialize in interactive mapping for urban planning processes, specifically for bike and pedestrian projects and initiatives. They are currently being used by state and local planning agencies and nonprofits.

Figure 9. Screen shot of project administrator features, Wikimapping, Inc.

More empirically focused applications, such as Cyclopath, entailed a custom bikability algorithm (Figure 10). Cyclopath allows users to not only find a bike route that best suited their travel plans, but also allowed bicyclists to rate road segments, identify problematic spots, and share notes about locations (e.g. potholes). Only Cyclopath, CBS, and Open Plan web applications provided open source code for users to have the freedom to run, copy, distribute, study, change and improve the software (Table 5).

The only mobile application examined in this study was CycleTracks (Figure 10). This application required complex, customized coding and development, and involved installing an application on a personal smartphone device and opting into a geo-location function. The primary goal of the CycleTracks application was to collect real time user data, specifically routes traveled. Survey questions or personal information were optional and requested before and after logging a trip. This mobile application was coded in varying programming languages, including Java, C+, Cocoa, and/or Objective C. Code for CycleTracks is also open source, providing access to the code for use and improvement openly across the web (Table 5).

Figure 10. Screen shot of Cyclopath Android (Demo) & CycleTracks iPhone interface

An important phase of development process is beta testing, which involves testing the application's usability with a small groups of selected users. This is typically the final phase prior to the implementation of a web or mobile application. There were three projects that underwent some form of beta testing before launching the project in the respective communities: Cycle Tracks, Cyclopath, and Mercer County (Table 2). Based on feedback, program managers were able to make improvements to the platforms prior to formal deployments. For example, Mercer County tested their platform with a small group of community stakeholders. The test suggested making changes to the interface, including providing descriptive text when users hovered over legend items and the addition of a "how to" site tab to guide users on using the interactive mapping platform (Krykewycz et al., 2011). CycleTracks beta testing period enabled the research group to correct for battery issues that correlated with heavy GPS usage. Modifications were made to avoid draining the battery by having the app make a "bicycle bell" ring and vibrate to remind users after the initial 15 minutes that they were collecting data and every five minutes thereafter (Charlton et al., 2011). The Chapel Hill project didn't test the platform among local stakeholders or residents, but did test an earlier version of the platform in Howard County, MD to affirm the value of crowdsourcing public input for bicycle master planning (S. Spindler, personal communication, August 2013).

5.3 Implementation

Execution of projects occurred across various timelines, ranging from three to 12 months to ongoing. The implementation phase of the crowdsourcing process involves the promotion/recruitment of users, use of host/user security, monitoring contributions, and processing data for public viewing and post-analysis.

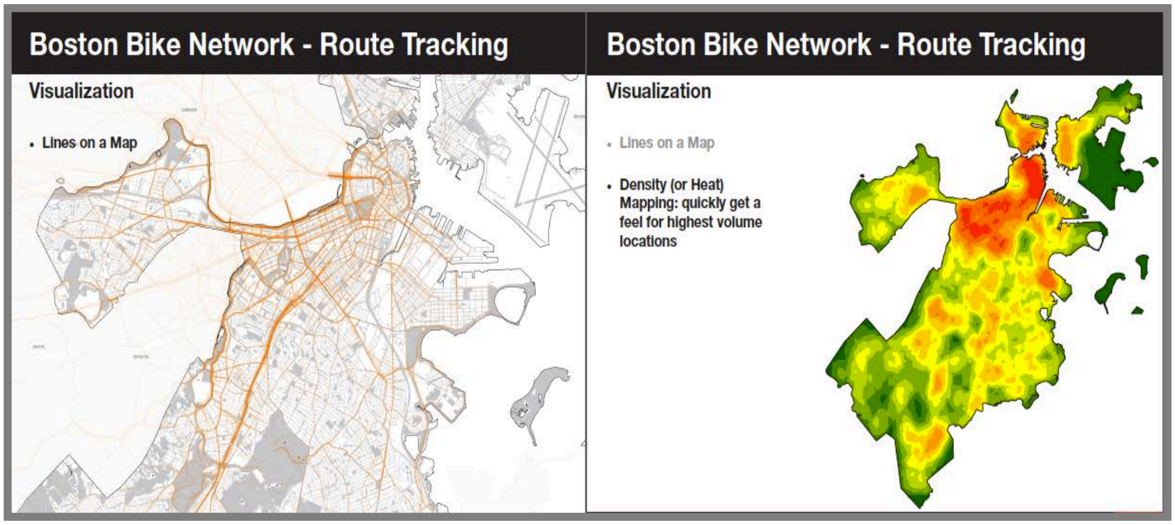
The overall recruitment and retention of users through the various timelines was also challenging. A majority of cases attracted a small number of responses, likely raising sampling error and biases. Most cases used similar promotional methods to garner support and traffic to the web or mobile applications. Project teams reached out to communities via email list-serves (e.g. universities, bicycle coalitions, community groups). Others took advantage of postcard mailings and/or social media outlets (e.g. Facebook, Twitter). Only a few projects provided users the option to share the application via email or popular social media sites (i.e. Cycle Tracks, Open Plans, and CBS). Beyond these basic promotional methods, incentives were also used as a means to attract users to a few applications. Incentives included material goods such as raffled items (e.g. CycleTracks), and more self-serving items associated with the application itself, such as ride statistics (CycleTracks) and bike route planning (Cyclopath).

Some cases loosely looked at promotional activities and user behavior. CycleTracks' project managers found that the number of newly registered users directly correlated with the inception of publicity strategies that introduced the mobile application (Sall, 2013). Using Google Analytics, Mercer County was able to collection a geographic distribution of all users where roughly 25% of unique site visitors accessed the site from within Mercer County. They also were able to assess how the various promotional methods correlated with online traffic levels over the three-month survey period using Google Analytics. However, all of the cases reviewed were not able to determine which means of promotional methods (if any) attracted the most visits and user comments over the project timelines. Finally, none of the cases carried out evaluations to better understand users' motivations to participating and overall experience with the web and mobile applications.

Managing security and accountability for comments differed across applications. Some cases required mandatory registration (email/login names) to authenticate users' registration and comments, and CAPTCHA (i.e. Blacksburg, CBS) to help prevent spam. Other applications were less demanding from a security and comment accountability standpoint. Some applications chose to keep the applications open to all users without requiring registration and personal email (Table 2). These platforms included, Open Plan's Philly to Transit and NYC BikeShare, Chicago's Bike Crash Map, Boston's Crowdsource Map, and CycleTracks. Privacy policies and/or disclaimers were also provided by most projects to indicate how information would or would not be used. Boston and CBS were the only cases that lacked a visible privacy policy.

The extent to which each project administrator could view, monitor, collect, and export data for analysis varied. The third party platforms provided access to personal dashboards that allowed project administrators with little to no software development expertise to view comments, edit categories, and create/update surveys. These functions were exclusively available for projects that used third party platforms, including Open Plans and Wikimapping project administrators. These dashboards are customized for each project's specific needs. Many cases collected and exported crowdsourced data (i.e. point, line, demographics, and other survey data) to various visualization and analysis tools depending on the quantity and quality of the data collected (Table 5). Export tools for additional analysis included Google Fusions, Microsoft Excel, and visualization and analytical tools such as Adobe Illustrator/MA Publisher, Google Earth and ArcGIS. Figure 11 below shows how Boston's consultant team used the route tracking data obtained from the Google Map engine application to visualize routes and highest volume locations (Robie, 2013).

Figure 11. Boston Bike Network-Route Tracking Visualization Maps, Toole, Inc.



Finally, projects required an investment in the maintenance of their applications. The requirements varied based on application complexity. There was a higher maintenance demand on the project teams for applications with mature, sophisticated software from a time and skill perspective (Table 5). For example, since CycleTracks' inception in 2009, their development team has had to maintain multiple versions of the same information on two different platforms, iPhone and Android. Any changes made, whether it is additional functionality or debugging efforts, had to be re-packaged in a newer version of the application before making it available as an update in the platform's application store. Conversely, Boston's projects required much less skill due to Google's basic mapping application functions and features.

5.4 Post-Implementation

The post-implementation phase of the crowdsourcing process involves the overall impacts the projects had on the bicycle planning process, including data analysis and application evaluation. The projects reveal the potential in which crowdsourcing can be used by organizations committed to improving bicycling infrastructure and safety. Most of reported impacts across cases were based primarily on anecdotal and descriptive data as opposed to scientific evidence (Table 6). There were also varying costs associated with the cases presented, including how projects were funded. These cost estimates provide a rough financial snapshot to practitioners who are considering developing and implementing crowdsourcing projects in the near future.

5.4.1 Key Impacts

CycleTracks' route choice application introduced the capabilities behind GPS enabled smartphones to understand the needs of bicyclists. Currently, most travel demand models that model non-motorized trips assume bicyclist choose the shortest-distance route, ignoring characteristics and revealed preferences along the path of travel. The application distributed tasks to the public via a mobile application to better understand where bicyclists ride, and how personal, network, and trip-based factors affect those route choices. The most significant trends indicated that infrequent bicyclists preferred streets with bike lanes twice as much as frequent cyclists, bicyclists not commuting were willing to bike one mile away from the most direct route for every 100 ft. of slope increase, and the likelihood that commuters will try to avoid hilly routes was three times higher than that of non-commuters (Table 6, Hood et al., 2011). A newly estimated bike route-choice model using the CycleTracks data was developed based on the revealed attributes most likely to affect route choice; bicycle facilities, travel distance, slope, and number of turns. This data was then used to develop a bike route choice model with two main objectives in mind; one, to create a quantitative way to understand the tradeoffs bicyclists make while riding, and two, to incorporate validation into SFCTA regional travel model (SF-CHAMP). This model presently allows travel forecasts in San Francisco County to quantify the benefits of bike infrastructure on mode share, active travel, and congestion.

In addition to the strong prospects of crowdsourcing for revealing preferences with GPS enabled smartphones, facility demand projects showcased how crowdsourcing can complement an agency's existing public participation process. This was evident with both NYC's and CBS's bike share planning process (Table 6) where NYDOT used the web platform to interact with stakeholders, advocacy groups, and residents. NYDOT received the most individual responses across all the 10 cases reviewed, with over 60,000 support votes for the 10,000 individual station location suggestions (Table 6, NYDOT, 2013). These suggestions, along with input from several community workshops and stakeholder meetings, complemented the final bikeshare demand analysis. CBS collected fewer total suggestions, with a confirmed 1,692 individual users making over 2,000 location suggestions (some for the same locations). They received close to 6,700 voting responses for the suggested locations. Project managers provided anecdotal evidence to how the crowdsourcing map was most influential during the public outreach process, especially in confirming Columbia Pike's station (Table 6). Although the permit process for the location was a major deterrent to the planning team, the preference data gathered via crowdsourcing and public meetings was paramount in siting this station (C. Eatough, personal communication, April 2013). Philly's Bike To Transit crowdsourced map was the first step in learning how transit stations can better accommodate bicyclists. Of the 457 participants, most had some level of interest in bicycling and transit, where at least three quarters of those surveyed biked monthly, weekly or daily to transit stations. Aggregated responses suggested that stations with a high level of usage had a relatively high demand for improvements. DVRCP plans to use this demand data for better bike access and parking as part of a larger, primarily web-based project, and to inform several local station area access studies (DVRPC, 2013; Boyle, 2013; G. Krykewycz, personal communication, May 2013; S. Stuart, personal communication, May 2013).

The network planning cases also present the power of these interactive mapping tools in the master planning process. The use of these platforms complemented technical fieldwork, community surveys, as well as expertise from committee working groups (Table 6). Although Virginia Tech's basic Bike/Ped mapping survey attracted minimal response from users, it introduced municipal decision makers to the capabilities of online mapping tools (T. Dickerson, personal communication, April 2013). Virginia Tech and the city of Blacksburg are currently considering building off the web survey by developing a mobile application in the near future. Boston used Google Map Engine to track users' most used routes between 2011-2012. Though this crowdsourcing exercise wasn't aimed directly at influencing the network plan, it proved to be influential in the planning process after the fact (P. Robie, personal communication, October 2013). The map collected over 1,600 routes, which were used to visualize and confirm popular primary routes shared at public meetings and charettes. Beyond confirming these routes, the crowdsourced data also visually informed design teams of the need for better connectivity along heavily used, highly multimodal locations, especially Boston Public Garden (Robie, 2013). Chapel Hill experienced similar project results. Respondents using the online platform identified similar high-stress routes that were also acknowledged in public and stakeholder meetings considered vital for creating a more complete bike network (Table 6, J. Zdeb, personal communication, November 2013).

Also, similar to CycleTracks data driven project, the two suitability cases relied on the assumption that the applications would attract a sufficient amount of aggregated preferences to improve suitability ratings along a bike network. Mercer Country's BLOS project is one of the first cited examples of a regional agency using web-based crowdsourcing to interact with the pubic in the early phase of updating a master plan. Beyond the novelty associated with the project's objective, it had minimal impact on improving the quality of the BLOS dataset. Of the 3,000 road segments across Mercer County, only 235 comments were received (most intermediate to expert bicyclists) in the context of bikability ratings. Nearly all of the road segments scored were changed based on a time-consuming, subjective review process by DVRPC staff. Moreover, the Mercer County platform presented site visitors with several ways of using the county wide interactive map, from rating routes, to identifying roadway or intersection “problem spots”, and priority bike routes and destinations. While users were not required to provide information for each request, the platform demanded time from users that went beyond placing a “pin” on a location. There is no evidence to indicate whether this survey approach was flawed by excessive demand on users. However, asking users to provide detailed information could impact accuracy. It is crucial to gather only as much information that you need and that a crowd is willing to provide. The scale of the project also raises potential issues with survey design. Mercer County’s land area is 229 sq. miles (593.1 km²) with thousands of road segments. Having local planning agencies and/or community groups present the project at the municipality level may prove more effective in garnering interest and users than countywide email blasts and blog postings.

Twin Cities’ Cyclopath application presents a more sustainable strategy in using crowdsourcing to improve bikability ratings based on personal preferences. The application is presented as a personal route-planning tool that looks to the wisdom of the Twin Cities’ community to improve the application over time. Bicyclists’ preferences are incorporated into a route-planning algorithm that weighs personal bikability preferences against other attributes to provide the best route for individual riders. As of December 2013, they have over 1,500 registered users. Also, there is a great opportunity for higher institution and planning agency partnerships. The University of Minnesota (creators of

Cyclopath) can support municipalities that are interested understanding how various types of bicyclists ride and areas in need of potential improvements.

However, beyond these anecdotal impressions portrayed by the cases, there is little quantitative evidence to show how crowdsourcing is influencing the bicycling planning process, from participation to improved data sets to improved decisions making. CycleTracks is the only application reviewed that carried out a quantitative analysis, which proved statistically valid. Still, these findings are preliminary and don't describe how the tool impacts planning and longer-term policy decisions. With the exception of CycleTracks, the remainder of the cases reviewed were not scientific studies. Bike to Transit's crowdsourcing project did present survey results online, although there was no analysis of the sample beyond the descriptive statistics attached to the survey questions. Inferential statistical analysis was not performed to test whether the samples were representative of the population being surveyed, including potential sampling error and biases in the sampling process.

5.4.2 Reporting & Transparency

A limited number of cases did provide brief summary reports, whether in paper form or on the agency's websites. CycleTracks, Philly Bike to Transit, and NYDOT Bikeshare provided summary reports to the general public on agency websites. CycleTracks was the most transparent in providing documentation, which included web links to numerous PowerPoint presentations, reports, and peer reviewed articles. In addition to a lack of analysis and application evaluation, there was also a lack of reporting to the public after projects were completed.

Crowdsourcing projects also leave a tremendous amount of responsibility on the organization to be transparent in how information will be collected, controlled for quality, and used in further analysis. For example, it was unknown to the public how crowdsourced suggestions and votes in CBS and NYDOT's bike share projects were weighted (if in fact they were) in the site analysis process. Also demographic information attached to individual responses (zip code, age, gender, etc.) was rarely made public after projects were completed. Only CycleTracks disclosed this information in online and printed reports. Finally, there was no evidence of cases evaluating impact and users' overall experience with the platform. This presents a lost opportunity to organizations and software developers who will not benefit from best practices exposed through evaluations.

This lack of disclosure, information sharing, and evaluation may create or further exacerbate mistrust in the government's planning process, especially if municipalities decide to push similar types of projects in the future.

5.4.3 Cost and Funding Sources

The crowdsourcing application project costs ranged from a few hundred dollars to $100,000 (Table 5). Costs were obtained via interviews/email correspondence and public documentation. Close to half of the applications that disclosed costs were under $4,000, including Open Plan's Philly and NYC projects, and Wikimapping's Chapel Hill project. It should be carefully noted that the costs were estimated by program managers or provided by documentation and do not reflect the total resources (e.g. staff time) needed to complete the projects. For example, while Boston's crowdsourcing approach used a free third party mapping platform, this low-cost platform does not reflect the consultant fees for data collection and mapping analysis. Blacksburg, Chicago Bike Crash, and CBS were the applications that did not disclose development costs of the project.

Projects costing more than $4,000 included CycleTracks ($20,000), Mercer County ($75,000) and Cyclopath ($100,000 per year). These projects were all developed internally and costs were associated with upfront development and maintenance. Both Cyclopath and Cycle Tracks are ongoing, long-term projects that are looking to aggregate preferences overtime. CycleTracks' project team considered CycleTracks a cost-effectiveness way of crowdsourcing preferences in lieu of traditional, often time-consuming preference surveys (Zorn, L et al., 2012).

Estimated costs per respondent were calculated to provide some insight into how estimated cost could differ across projects, which can be greatly influenced by response rates (Table 5). Open Plan's Bikeshare applications provided the greatest insight into how response rate impact an application's total costs. For example, the NYC Bikeshare project with over 10,000 users was estimated to cost $0.40 per user. The same platform was used in the Philly to Transit project with less than 500 users and was estimated at $8.65 per user.

Finally, while cost estimates cannot be compared across all cases, it is clear that funding for the development of applications differed—ranging from internal agency resources to pro-bono efforts. Cyclopath's GroupLens Research (University of Minnesota), Mercer BLOS project and CycleTracks were also internally funded and developed in-house. Both OpenPlans' NYDOT and Wikimapping projects provided software and tech support for a fee for service. A consultant firm used Wikimapping software to support Chapel Hill's Bike Master Planning process. The cost of these tools to the firm is reflected in the consulting time for implementation/support and paid by the municipality. OpenPlans' projects typically cost between $4,000 and $10,000, depending on the complexity and level of customization needed. These fees for service costs are typically used to subsidize project partners with limited resources. This was the case with Greater Philadelphia's

Bike-to-Transit project (F.Hebbert, personal communication, November 2013). This pro-bono service was similar for CBS, where Mobility Labs (a nonprofit dedicated to the use of civic technology in transportation) provided the development and implementation services.

Table 6. Post Implementation Findings

Case Study	Total Individual Respondents	Key Impacts	Evidence	Sources	Project Status	Project Evaluation
FACILITY DEMAND						
Capital Bike Share/Bike Arlington "Suggest a Station"	1,692	Crowdsource data incorporated into Bikeshare Demand analysis for station expansion into Arlington County, MD	CBC's bike expansion plan called for 20 more bike sharing stations to be installed by Fall 2013. The online map collected input from over 1,600 individual users, making over 2180 location suggestions (suggestion may include same location) Input was especially influential in confirming Columbia Pike's station. The permit process for the location was challenging, but public demand via the crowdsourcing and public meetings was paramount in this station location.	Reports, phone interviews, email correspondences	**Ongoing**	No
NYC Citi Bike Share	10,000*	Crowdsource data incorporated into Bikeshare Demand analysis for NYC	Close to 10,000 individual station location suggestions and more than 60,000 support votes on map. Comments were included in the demand analysis that informed the bikeshare plan.	Case report, interviews, online documentation	**Closed**	No
Philly Bike to Transit Crowdsourcing Map	462	Bike Parking Demand and improved facilities	Of the 462 people who responded, 87 percent want more or better bicycle parking at transit stations throughout the region. 30th streets station and Girard El Station received the most feedback for better bike parking facilities, including more parking and better quality facilities (e.g. shelters, bike garages)	Case Report, interviews, online documentation, email correspondences	**Closed**	No
NETWORK PLANNING						
Bicycle and Pedestrian Map-Based Survey	140	Heighted awareness, confirmed high usage routes	Introduced non-traditional methods of data collection and public participation to community and city officials. Albeit a small survey sample, the relative rankings of web survey route counts at intersections were consistent with traffic count data.	Phone interviews, reports, email correspondences	**Closed**	No
Boston Network Plan Crowdsource Map	1600*	Reaffirmed public comments and informed planners of connectivity opportunities	Route-tracking map of 1600 routes collected to visualize and confirm popular primary routes shared at public meetings and charettes. From design perspective, data informed team need for better connectivity along heavily used, highly multimodal locations (e.g. Boston Public Garden)	Report, documentation, interviews, email correspondences	**Closed**	No

Chapel Hill -- Wikimapping	300	Reveled problematic routes and locations along the city's current bike network	Of the total registered users, 117 added point, line, or comments to map. This info reinforced responses and input from the steering committee, survey, and public meetings about what roads in town are most important for integration into the bike network. The "high-stress" and "route I'd like to ride" categories coincided with the routes expresses at both stakeholder and public meetings	Online documentation, phone interview, email correspondences	**Closed**	No
SUITABILITY						
Mercer County BLOS Crowdsourcing	1,097 unique site visitors, 59 registered users	Minimally influenced bikability data set and countywide Bike Master Plan	Upon reviewing the 200 plus comments, 110 road segments had their bikability scores raised, and 110 roads had their scores lowered.	Case Study, white paper, interviews	**Closed**	Limited (Transportation Research Board 2011 Annual Mtg. paper)
Cyclopath	1,500+	Provides routes for varying types bicyclists (based on distance and comfort level)	Over 366 registered users. Application will improve as more people use it and the more roads are rated by bicyclists with varying riding preferences.	Online documentation	**Ongoing**	No
ROUTE CHOICE						
CycleTracks (SF)	366	Data uncovered bicyclist's preferences and used to create an estimated bike route choice model. Open source code being used across U.S.	Over 1400 routes collected by 366 individual users in Phase 1. Statistically significant demand trends; infrequent cyclists preferred streets with bike lanes twice as much as frequent cyclists. Cyclists not commuting willing to bike one mile away from the most direct route for every 100 ft. of slope increase. Likelihood that commuters will try to avoid hilly routes was three times higher than that of non-commuters.	Online documentation, whitepapers, journal articles	**Ongoing**	Yes (multiple agency reports & peer reviewed articles)
BIKE SAFETY						
Chicago's Bike Crash Map	140	Open data tool for bicyclists and non-bicyclist, alike	Data combined from IDOT and reports from Chicago's Police Department and made searchable via an online mapping application. Provide users with the ability to search past crashes & self-report bike crashes or near misses, and request legal advice.	Online documentation, email correspondences	**Ongoing**	No

Note: ***** Number of suggested stations or routes, not individual respondents

Chapter 6: Discussion

The most prevalent crowdsourcing practice specific to bicycle planning is the use of interactive mapping platforms to provide new data to support and inform planning efforts. As indicated by this study, there are various crowdsourcing platforms accessible to planning organizations looking to build a more robust tool kit when working with communities and stakeholder groups. This study broadly identifies the extent that crowdsourcing is currently being adopted by planners in the bicycle planning field; each of the ten cases reviewed present distinct uses, yet similar motivations to leverage crowdsourcing. Most cases looked to this process to enhance the public engagement process and fill in local data gaps to help push bicycle planning decisions. While the use of civic technologies in governance is not widespread, there is great optimism in the bicycling planning field given the increasing access and use of digital technology for everyday purposes.

6.1.1 Public Planning Process

These cases highlight a new method for bicycle planners to gain insightful knowledge from the public and help prioritize planning needs complementary to more traditional methods of participation and communication. The most compelling evidence was apparent in the bicycle facility demand and network planning projects, especially bikeshare projects. The information gathered was used to guide the siting analysis process prior to finalizing the bikeshare plans. The notion that crowdsourcing works best as a complementary tool is not a new concept and has been readily cited in planning literature (Leighhninger 2012, Bramburn 2012, 2009, Messina, 2012; Takemoto, 2010).

These cases reflect how crowdsourcing can be an influential tactic for collecting and prioritizing public needs when used with other engagements tactics (e.g. public meetings, community workshops, and stakeholder sessions).

6.1.2 Street Level Data

Planners are continually hindered by the lack of local bicycle data, especially at the street level. The available data are based on small sample sizes and do not always permit reliable estimates for individual municipalities. Robust count programs and preference surveying can prove useful, but are also limiting due to time and resource constraints. The crowdsourcing platforms allow planners to reach participants digitally without the need to provide additional time or staff to survey in the field or set up volunteer led count programs. Moreover, it allows planners to gain knowledge across a network, not just select road segments or popular intersections within a bike network. This can prove useful to planners when looking to improve or expand bike infrastructure to attract users of varying abilities and preferences. For example, Chapel Hill's master planning process revealed various low stress routes that were confirmed by both crowdsourcing and public meetings—further informing planners on infrastructure and connectivity improvements needed to attract more bicyclists (J. Zebb, personal communication, June 2013).

In addition to collecting facility and route preferences, crowdsourcing introduces a novel way for planners to conduct more complex analysis, e.g. comprehensive suitability mapping, travel demand modeling, and pre/post studies on bike infrastructure projects. Crowdsourcing has the capability to improve or even replace standardized suitability indices. Currently, suitability indices are heavily reliant on the physical design of streets and assumptions of how bicyclists identify with roadways and traffic. The latter can be inherently misguided. Based on such shortcomings, planners have recently looked to online mapping applications as a way to capture revealed comfort at the street level. Mercer County BLOS, and Cyclopath web applications combine RP data along with characteristics of a road segment to help decipher which types of roadways or routes are attractive to varying types of bicyclists—from experienced, fearless riders to those who have an interest, but are looking for less stressful ways of getting around.

Even though it is unknown what factors motivate users to use these applications, previous literature has pointed to various intrinsic and extrinsic factors that motivate participation. Future research should delve into bicycle specific applications and evaluate the application user’s experience and reasons for participation. For example, is Cyclopath’s focus on providing a route planning tool a better way to attract and retain users than an application that focuses on users’ altruistic reasoning to improve a regional bike master plan? Questions also remain about whether pairing the web application with a mobile application version will work best to attract users over the long term to provide personal preferences.

There are also opportunities for mobile/smartphone technology to advance route choice modeling, origin-destination, and travel time data at the municipal and regional level. Mobile applications have great potential to fill in major revealed preference data gaps based on the convenience of utilizing GPS on personal smartphone devices, as showcased by CycleTracks. With the increased adoption of smartphone technology over the past few years, more planning agencies and cities are starting to look at the benefits of mobile technologies to collect more robust data and engage the public in non-traditional ways. This was evident when interviewing planning practitioners and developers using web applications. Most were interested or already planning to use a mobile interface to improve their reach and take advantage of the GPS capabilities (i.e. Cyclopath, Wikimapping, Open Plans).

CycleTracks presented the most promising crowdsourcing tactics looking to collect robust RP data at city or regional scales. This crowdsourcing approach takes advantage of the public's increased use of personal smartphones and cost-effectiveness of distributing an application in lieu of traditional, often time-consuming preference surveys. Unlike the cases reviewed that use the crowdsourcing strategy as a means to engage the public in the planning process, this case primarily focuses more on collecting data. CycleTracks' ability to collect real time preferences along a bicycle network, as well as trip purpose and personal data, currently cannot be met by other data collection methods such as SP surveys, bike counts, and census data. Although real time user behavior provides numerous opportunities for incorporating bicycle demand data into a regional travel demand model, findings are preliminary. Once a larger sample size of preferences are collected, bicycle planners will have the opportunity to use demand modeling to target bicycle infrastructure investments and improvements, as well as quantify benefits from new or improved infrastructure.

6.1.3 Expansion through Technology

Civic technology tools are increasingly being used across the U.S., including the use of web and mobile crowdsourcing applications. These applications are being implemented in an effort to increase government transparency and efficiency, collect untapped knowledge, as well as spur much needed innovation. Currently the most prevalent crowdsourcing practice in the bicycle-planning field is the use of interactive mapping platforms for information gathering. In recent years, with technological advancement and increased accessibility, platforms such as Google Maps Engine (GME), Open Plans, Wikimapping, among others, are being utilized to support and enhance bicycle specific initiatives and projects. These examples demonstrate the emergence of lower-cost platforms that are increasingly accessible to planning organizations looking to build a more robust tool kit when working with communities and stakeholder groups.

Of the seven platforms that gave cost estimates for each project, close to half of these were not considered expensive expenditures by interviewees. Google's cloud based platform, GME, provides planners with a free mapping platform for collecting input data, such as points routes, shapes, and photos. Planners can import their own data layer (CSV, KML, Spreadsheet, images, shapefile) and export data for further analysis. The map can be shared via a public link for the public to view and/or edit. Beyond these mapping functions, Google's proprietary nature and licensing leaves very little room for project managers to add customization or improve the application design and capabilities. There are also some data usage limits that prompt monthly or annuals fees for platform upgrades. There is an option for users to provide contact details (emails, name, zip, etc.) in the description box, but this may pose privacy issues if the map is made public.

There are also platforms that are designed with both the user and planners in mind. These platforms come from third party organizations that provide customizable platforms and tech support throughout the project process. Shareabouts is open source software developed by Open Plans, a non-profit based in NYC that bridges technology with the planning process. Open access to software allows users to run, copy, study, change and improve the software. Shareabouts crowdsourcing platform was created with public needs in mind, allowing public agencies and non-profits to gather public input, ask survey questions, and upload photos. The Shareabout fee for service ranges from $4,000 to $10,000, allowing OpenPlans to subsidize projects if a public agency is unable to pay for the service. A major limitation is that users can only provide points, not routes.

Additionally, there is no log in required, but you can ask users to provide a zip code, email, etc. in the survey interface. Wikimapping also has a very strong mapping interface (web and mobile) for planners to gather input--from points, road segments, and routes, to open-ended commentary. They also have surveying and voting functions. Wikimapping charges a $349 fee per project/per year as of March 2014, with an option to renew before the project expires. The platform's interface is clean and simple, and provides project administrative controls, security settings (e.g. log in), as well as additional technical support if needed.

In addition to low to mid-cost options for planners, this study also showcases the option for planning agencies to develop platforms internally by staff with mapping/software development skills. This was the case for CycleTracks, Cyclopath, and Mercer Country's BLOS map. Although up-front costs were higher, the platforms can be reworked or improved for future projects without having to pay a third party per project or yearly fee. This may not be a viable or cost-effective option for all types of projects. Moreover, in the spirit of free and open source software, SFCTA openly shares the software and source code to encourage public agencies and developers to improve the design of the software (Sall, 2013; Sall, personal communication, May 2013). Providing the open source code gives users the freedom to use, run, copy, distribute, study, change and improve CycleTracks (GNU, 2013). Currently the application or derivatives of the application are being used in 15 other U.S municipalities with little to no upfront development costs (Sall, 2013; SFCTA, 2014).

Overall, these varying examples illustrate how technology and online mapping tools continue to rapidly make advancements in interface design, available tools, and capability across web and mobile platforms. The newer third party platforms present an opportunity for planning agencies to put less time and resources into developing in house crowdsourcing platforms and focus more on community outreach, implementation and post processing of data.

6.2 Challenges to Crowdsourcing

Practitioners interviewed believed the crowdsourcing strategy presented new opportunities to the bicycle planning field as a complementary tool to other more traditional types of outreach and analysis tools used in the planning process. The cases reviewed were not ad hoc in nature, but part of a larger planning process with long-term goals to capture empirical data. However, there are few peer-reviewed crowdsourcing studies or guidelines available to practitioners interested in recreating or building from these cases. Regardless of the identified advantages presented, there are also significant challenges and risks that planners must closely consider when exploring the use of interactive platforms. These identified challenges build off the issues presented in literature and include organizational transparency, recruitment of users, resource constraints, and institutional adoption of civic technology.

6.2.1 Transparency & Open Communication

Crowdsourcing is seen as an emerging approach to increase transparency and overall efficiencies of government processes. Yet, like many other methods of engagement, transparency and communication throughout the process is crucial to managing a crowdsourcing project, from attracting a broad group of participants to setting expectations for involvement (both for organizations and users). Planners must be clear in how input will be collected and reflected in decision-making processes.

This starts with an organization being open to public involvement and input in the problems that they are trying to solve. From a community planning standpoint, communications must start with introducing the community, along with trusted community leaders, to the concept of crowdsourcing and how it fits into the larger planning process of improving bicycling in a given municipality. This was not a large focus in many of the cases presented in this study. NYCDOT did incorporate *Shareabouts* in the larger planning process, but missed an opportunity to involve the public in the customization of the tool in the earlier planning phase. There was also no clear sense of how the input gathered was reflected in the outcomes of the bike share plan. Even a small case report would show community members how NYDOT used the comments collected during the outreach process to balance the needs of communities and siting protocols.

Crowdsourcing projects also leave a tremendous amount of responsibility on the organization to be transparent in how information will be collected, controlled for quality, and used in further analysis. For example, a breakdown of “Yes” versus “No” votes for suggested bikeshare locations or what stations received the most votes were not made available by to the public by both the Citi Bike and CBC projects team. Furthermore, it was unknown to the public how crowdsourced suggestions and votes in these bike share projects were weighted (if in fact they were) in the site analysis process. Also demographic information attached to individual responses (zip code, age, gender, etc.) was rarely made public after projects were completed. Only CycleTracks disclosed this information in online and printed reports. Finally, there was no evidence of projects evaluating users experience with the platform. This lack of disclosure, information sharing, and evaluation may create or further exacerbate mistrust in the government’s planning process, especially if municipalities decide to push similar types of projects in the future.

6.2.2 Recruitment and Retention of Participants

As with other survey methods and public participation programs, crowdsourcing applications also present challenges in attracting and retaining a broad group of users due to various participation inequalities (e.g. the digital divide, barriers to technology adoption), survey biases, and shortcomings in promotional efforts. Crowdsourcing may systematically exclude certain demographic groups in an area due to one's access to technology and comfort level using digital applications. Recent trends challenge these participation inequalities by pointing to the closing gap in internet and mobile access across socio-economics groups. However, there can be a major distinction in looking at information online versus filling out a survey and mapping a route on a map interface. Trends that support the closing digital divide do not present data on users' knowledge and/or ability to use various types of technologies, such as interactive online mapping platforms.

Beyond the exclusion of individuals due to the barriers to entry, these crowdsourcing platforms also present various survey biases. Selection bias is most likely a factor due to low response rates across a majority of the cases. This was evident in cases that collected demographic data (e.g. zip code, sex, age, frequency of bicycling). Chapel Hill, Mercer, and CycleTracks used this information to communicate the limits of each project. For instance, the data collected by CycleTracks was found to bias toward frequent cyclists and male bicyclists (Hood et al 2011). This is important for researchers and planners, as the cycling preferences of frequent cyclists could quite conceivably be different from those of infrequent cyclists. With San Francisco's overarching goal to increase the usage of bicycling across all abilities, knowing the preferences of infrequent cyclists is essential.

Other cases did not collect demographic data to show the type of users who participated in the projects. Projects using OpenPlans' *Shareabout* crowdsourcing platform did not require registration or ask users for personal information. This was based on the assumption that registration or providing personal information would ward off users by creating a barrier to entry (F. Hebert, personal communication, April 2013). While this provides users an opportunity to participate without disclosing personal information, this can be problematic, as it allows for potential abuses by participants. For instance, a few individuals can manipulate the projects by voting exclusively for a bike facility or route without being identified as the same user. Currently there are no case specific evaluations or comparative studies that support or refute this strategy, but nonetheless, it raises valid concerns regarding participation abuses and the overall quality of responses collected.

An important driver in attracting more representative crowds is to understand the motivations behind participation. All of the cases presented challenges with growing an online community that remained active throughout the project's timeline. Most cases reviewed lacked a promotional plan to attract and sustain an online community of users, and were uncertain of the best strategies for motivating and retaining participants. Promotional plans are usually short to long term plans that involve strategy in attracting participants, as well as an analytics component to better understand which outreach tactic(s) work best in a given projects' life cycle. These plans are most common in the private sector to help position a product or service to customers, stakeholders and the broader public. To date very little strides have been made in crowdsourcing projects to attract motivated crowds representative of the community's larger population. *Next Stop Design* is the only transportation crowdsourcing project to date that has evaluated participants' motivations. This project's evaluation supports previous research on engaging the public with a diverse pool of motivators when using online platforms. The motivational categories (both extrinsic and intrinsic) that served as strong indicators of whether users participate in application programs include peer recognition, gaining new skills and knowledge, contribution to collaborative efforts, having fun, and design and usability principles of applications (Brabham 2012b). However, it should be noted that this project's public reach was narrow. The project required participants to have at least basic knowledge in design and transportation—eliminating a large subset of people in the municipality.

Understanding motivations and usability experience of applications should be evaluated to better understand how to capture a representative sample of users. For instance, understanding motivation behind using civic tools and how varying demographics interact with online information can help researchers design applications that appeal to broad range of users or fit the needs of a particular community or target population. A recent report on the general best practices in the use of technology to engage underrepresented groups suggests designing applications that have strong visual communication strategies, such as short videos, images and graphics. These tactics were found to be most effective when communicating with individuals with varying educational backgrounds, language, and computer skills (Place Matters, 2014).

Although these challenges cannot be completely removed, further empirical research must be a priority when trying to better understand motivations that are representative of the community's larger population. This evidence could present planners, developers, and scholars an opportunity to rethink how applications should be built and promoted to citizens to improve bicycling. This may stimulate the creation and adoption of more socially centric applications that are designed with the users' needs in mind to stimulate more robust participation.

For instance, the inclusion of “gamification” in the private sector could be transferred to bicycle specific projects. Applications can use gamification to encourage users to travel by bike or foot, where points are given to top contributors and redeemed for local discounts and/or rewards. Underneath these applications are surveys and user authorized GPS tracking that can be used. Recently, Nash (2014) introduced the various ways gamification is being used for transportation planning and made general recommendations for agencies looking to make greater use of this approach. Nash’s exploratory study evaluated a bicycling planning gamification prototype called *Grr-Grr-Bike* that targeted ages 12-29 years old. This smartphone game was designed with two main objectives, encouraging people to get involved in local bike planning and advocacy, and second, teaching people about bike safety. The customization of this platform also presents agencies the ability to change the focus of the game or add additional features such as survey questions and voting capabilities. These features could help agencies gather crowd wisdom surrounding proposed bike infrastructure projects or high stress routes. Caveats to this approach are that money is needed to invest in the development and overall management of these platforms. Also, organizations will need to develop terms for sharing/using data while maintaining data privacy and sound security standards whether working with a third party developer or developing the application internally (Palmer et al 2012). Nevertheless, this gaming approach may serve a locality better as opposed to a static mapping application, and could encourage users to become more involved in bicycling planning or advocacy.

6.2.3 Scarcity of Resources

Several of the cases reviewed provided cost estimates associated with technical tool development and implementation. This study showed that the number of affordable options is increasing with advancement in technology, open source software, and strategic partnerships. However, others required significant investment for development and project management (i.e. Cyclopath, Mercer County). Resources associated with these projects include money to develop the applications, as well as skilled staff to act as online community managers. These estimates can be very cost-prohibitive for many local agencies under tight fiscal constraints and will require agencies to be creative in seeking outside funding for developments and/or resources to support implementation and evaluation. Collaborative partnerships between municipalities and outside firms were critical in some of the cases presented. While some involved private entities that were fee for service, cases such as Bike-to-Transit, Capital Bikeshare and City of Blacksburg involved non-profit agencies with the technical expertise at subsidized or pro-bono rates. While these opportunities are not always available, strategic partnerships such as these can allow municipalities to focus their efforts on the outreach and management process and less on the actual development and tech support surrounding crowdsourcing projects. These partnerships can counter some of the current federal and state funding constraints for active transportation projects that state agencies and municipalities are experiencing. Consequently, agencies should look to partnership opportunities with companies and nonprofits (e.g. Code for America, OpenPlans, SeeClickFix), higher education institutions, and private foundations (e.g. Knight Foundation) that are dedicated to improving government services through civic technology.

6.2.4 Civic Innovation and Institutional Adoption

Bicycle planners, advocates, and software developers interviewed for this study see great potential in crowdsourcing. But, they also spoke to its infancy in the public sector and how its application in government is not widely recognized or used at the state or local level. Several reasons for this were pointed out during the interviews. First, the concept behind crowdsourcing as a civic tool may not be considered a valuable or politically feasible method in the planning practice. Second, planners and agencies who are open to its application may not know where to start in developing and implementing technical tools into current planning processes. One of the overarching barriers made apparent during this study is the willingness and commitment of public agencies to embrace crowdsourcing as a civic tool to improve public participation, while also valuing non-experts' input in the decision making process. Interviewees provide varying opinions for the use of crowdsourcing in pursuit of solutions in bicycling planning and policy fields. They were unclear when and how such tools could be integrated into the planning process and the level of resources needed.

As technology advances and more and more government agencies look to civic technology to improve municipal services, there will be a much greater need for cross-sector innovation, development and support. Interviewees mentioned the need for more information sharing between agencies, software developers, and communities using various platforms to tackle transportation-planning issues. These cross-sector networking efforts must leverage available resources by bringing together experts and practitioners from various fields, such as software development, transportation, and public policy committed to developing civic tools that address transportation problems affecting municipalities, including bicycling.

This commitment will also require communities to collect data to evaluate its reach, effectiveness, and overall cost-benefit to crowdsourcing efforts in comparison with other engagements methods. This can be approached in pilot formats and supported by leveraging local or national partnerships that are dedicated to these innovative efforts. In the end, tools driven by results (both quantitative and qualitative) will be key to demonstrating the value of civic technology to decision makers, community leaders, and residents. These results will contribute to the development of best practices to guide project managers when considering the use of civic technology to gather crowd knowledge. This will require leadership from private and public institutions, as well as trusted community groups interested in systematically bridging technology and civic engagement over time.

6.3 Future Direction of Crowdsourcing for Bicycle Planning

Overall, the planners interviewed were optimistic about the direction of crowdsourcing in their field. Based on the cross-section of cases reviewed, there are various approaches to using this strategy to enhance and further improve bicycling planning practices (e.g. bike facility demand, master planning, suitability mapping, and route choice modeling). While these cases were exploratory in nature, they were valued as projects that increased the visibility of civic technology and crowdsourcing, and in some cases, acted as a complementary method in enhancing the larger planning process.

There are also a handful of recently published reports that provide guidelines for planners interested in using civic tech tools to inform the decision making process (IBM Center for The Business of Government 2011, 2013, Brabham 2013; Place Matters, 2013; Open Plans & Livable Cities, 2012; NCDD, 2010). These guiding documents provide various case examples and lay some of the groundwork for further research, but lack evidence-based findings. Of the limited research highlighting the use of crowdsourcing in the general planning field, many of the studies focused on public participation theory and broadly identified its use as a complementary tool in the public participation process. However, crowdsourcing projects in the public sector are rarely evaluated for reach and efficacy. There is less focus in the literature on what has been achieved thus far, how it addresses public participation objectives and goals, and its overall effectiveness on short and long term policy and planning decisions. Also the scarcity of case studies and peer-reviewed research provide little guidance and direction in how bicycle planners can take advantage of the crowdsourcing strategies to influence future planning and policy decisions. These challenges are also reflected in this exploratory study. While crowdsourcing presented some form of value to each case, most of the evidence gathered for this study was anecdotal and projects lacked strong data driven research and evaluation.

Despite crowdsourcing's brief history in the public sector and the challenges associated with its use, improving public participation via online tools is becoming a more visible and recognized government strategy to improve service delivery, increase accountability and improve the quality of life for its residents. Planners are increasingly distributing information and engaging with the public using technology driven tools, whether by email, blogs, websites, wikis, and/or mapping tools. As more municipalities turn to web and mobile-based technologies to communicate and engage with the public, there is greater opportunity for planners to explore and test crowdsourcing as a public engagement and information-gathering tool. Finally, these challenges should also remind planners that while crowdsourcing may prove helpful in solving urban problems, it not being suggested that it be the single approach to the planning process. Guides and studies continue to state that the most accepted planning practice in working with communities is face-face-relationship building (People Matter, 2014, NCDD, 2010). The next chapter provides recommendations to government agencies, local municipalities and/or advocacy group looking to integrate crowdsourcing into bicycle planning projects.

Chapter 7: Recommendations: Applying Crowdsourcing to Bicycle Planning

It is an opportune time for planners to embrace the crowdsourcing model within the bicycle planning field considering the increasing ubiquity of digital technology and online mapping. Strides must be made in both the research and practice to better understand the process and its overall impacts (both short and long term) on participation rates and overall planning and policy decisions. Based on the literature review and case studies, there were common opportunities and challenges that emerged from applying crowdsourcing to the planning field. Given these findings, it is recommended that planners design crowdsourcing projects with agency goals, audience, and available resources in mind.

Below is a summary of guidelines that can help bicycle planners from an organizational perspective in determining if the crowdsourcing strategy is appropriate for meeting agency and project objectives and if so, how to establish a crowdsourcing process that is mutually beneficial for those managing the project and the “crowd” involved in the process. These guidelines are framed within a process familiar to planners and project managers—planning, implementation, and post-implementation.

7.1 Planning Phase

Commitment to Civic Technology & Innovation

Before planners decide to use crowdsourcing for related bicycle planning issues or barriers, it is vital to first decide whether crowdsourcing fits within the underlying values and mission of the agencies leading the efforts. The use of civic technology tools across all municipal projects, plans and policies is not endemic by any means, but is gaining ground as decision makers look to more non-traditional outreach methods to deepen the decision making processes. Making sure there are internal civic technology policies or guidelines in place to support project mangers are needed when looking to integrate this process into bicycle project plans.

Further efforts should be put into better understanding how a technology driven process like crowdsourcing meets larger public engagement objectives such as a shared vision for city improvements, data transparency and accountability, and the inclusion of underrepresented communities (e.g. low-income, youth, the elderly). Agencies open to its use and prepared to test and evaluate the process within the context of their agency's mission will prove useful in the long term. These larger commitments to using technology in the planning process will allow agencies to decide where this approach works best and where it may not be appropriate.

Skill & Knowledgeable Resources

Assuming there is institutional support or a willingness to incorporate this process into bicycle planning projects, project managers are still left with the decision of whether crowdsourcing would add value to a project. Most of the participants interviewed valued the theory and potential of crowdsourcing as a complementary approach, but spoke to the lack of professional development opportunities for transportation planners and advocates interested in using civic technology tools. Mangers were uncertain how crowdsourcing could be further applied to their profession and the available tools and technology tools available to carry out such processes. Therefore, having the knowledge and/or access to those who can support the required technology is key to deciding whether crowdsourcing could be a beneficial to the project or larger policy effort. It can prove helpful to review the types of questions an agency is looking to solve and whether civic technology processes can help them reach specific objectives and goals. For example, some communities may have robust bike network data, but could improve their engagement strategies. Other communities may be challenged by both demand data limitations and low public participation rates. Whatever the needs, agencies must decide how online tools can enhance or improve this process.

Preliminary work can also focus on scanning the various civic technology tools available and how other municipalities and agencies are using them in the field. It also may include organizing internal resources (e.g. IT personnel, GIS analysts, community planners) and leveraging outside partners in both the private and public sectors working in the area of civic technology who may be interested in municipal partnerships. This could involve providing pro-bono services (e.g. tool development, technical assistance) or long-term partnerships where experts take on advisory roles in helping agencies develop a framework for creating and/or implementing civic technology.

Available Funding

Initiating crowdsourcing requires resources throughout a project’s lifecycle, from pre-planning and development to evaluation. There are various low to mid- cost options highlighted in this study for crowdsourcing applications, depending on planners’ short and long term needs, internal staff skills, and financial resources. Understanding a project's overall objective is pertinent to discovering what resources are needed to execute a project. The upfront costs for projects are mainly associated with quality and capabilities of applications, as well as access to professionals with the appropriate technical skills. However, as technology continues to advance there are low cost crowdsourcing platforms such as GME API, Wikimapping, and OpenPlans that can support projects without the necessary cost of developing an application from scratch. For example, Mercer Country's BLOS project may have benefited from a Wikimapping platform that is customizable at a much lower price tag than $75,000. The creation of an internal platform presents organizations with a potentially cost effective application in the longer term. This allows an organization to use internal IT/tech staff without paying a third party and the potential to use the platform for future projects. The challenge to this approach is that many local, regional, and state agencies currently lack the resources necessary to carry out these projects internally or hire a third party group. This may be further exacerbated by the cuts in federal funding to alternative modes of transportation. If resources (e.g. monetary and human capital) are limited for developing in-house applications, there are various third party organizations (non-profit and private) that provide platforms that cater to crowdsourcing project needs. Some platforms' code is accessible as open source, allowing those municipalities that have personnel (or even a pro-bono professional) with software development experience to use and improve upon the code for their own public crowdsourcing projects. This saves local municipalities the time for development efforts, as well as provides opportunities to improve an existing application for other potential users to benefits from in the future.

Organizational Commitment to Crowdsourcing Process

Another key consideration in the planning phase is clearly outlining the organization's commitment to the crowdsourcing process. This includes a clear definition of the problem, how potential users can contribute and communicate, and how responses will be used in the overarching planning process—whether there is a commitment to use all comments as submitted or if results will be translated through a more consultative approach. Will the organization commit to following through on all outcomes or is it part of a shared process that includes other planning strategies such as community meetings, analysis, and cost-benefit studies? How organizations plan to use outcomes should be described early in the process. It must be noted that, while there are no right or wrong strategies in communicating the problem and the organization's commitment to process outcomes, it is pertinent that the process is transparent and organizations are held accountable for the commitments made before implementation.

7.2 Implementation Phase

Strategic Planning

Creating a strategic management plan for crowdsourcing projects is suggested for both short and long term projects. This plan should involve project team members and community stakeholders that can provide different perspectives on the issue or problem that is being discussed. Planners must be sensitive to the preferred methods of engagement in the communities they are serving and make sure they are designing projects that incorporate both low tech (e.g. community meetings, charettes, focus groups) and high tech tactics. As pointed out previously, crowdsourcing can be one of the many strategies to informing larger projects or policy plans. A multi-methods approach to the bicycle planning process will help deepen participation in the decision making process and demonstrate a more transparent process from development to evaluation. Discussions can lead to more established project goals that include the application of choice (wiki, website, mobile app, etc.), recruitment and retention strategies, and user experience. Whatever type of strategic plan is created, it is recommended that the components outlined in the below section are included in the implementation the phase.

Alpha-Testing

There is an opportunity for groups to pilot a crowdsourcing project to receive feedback on feasibility before developing or customizing a tool. This can be done in the form of Alpha-Testing, a conceptual process in which an idea is presented for feedback before an organization invests time and money in development. In this phase, project members can discuss and suggest how a crowdsourcing platform can be used to help solve the problem(s) an agency or group of partners are trying to solve or gain a deeper understanding. Alpha testing will hopefully lead the group towards the crowdsourcing platform that would best serve the project's intended outcome. Project teams must also rely on face-to-face relationship building and outreach with the communities they are serving. This may include working with trusted community groups in the development of a platform that builds upon the existing engagement strategies in communities. This provides planners with an opportunity to understand how communities are using digital technology on a daily basis or if there are apparent barriers or concerns to accessing technology (e.g. language, education, internet access).

Projects that extend beyond city or metro boundaries should also consider the challenges in attracting users from various municipalities, especially when projects could entail collecting preferences for thousands of road segments. Also, the scope of user submitted data in crowdsourcing projects must be carefully defined. Asking too many questions or having to many application functions has the potential to deter participation (e.g. Mercer County). In contrast, not asking enough from participants could leave organizations with data that is incomplete such as zip code, age, purpose of trip, etc. (e.g. Boston's

Crowdsourcing Map). This descriptive data is important to reaffirm the project's reach, as well as learn more about participants and their reasons for travel.

It is recommended that agencies look to systematically Alpha-test a crowdsourcing idea before resorting to a project that is complex or requires significant resources to develop and implement. This conceptual testing allow for organizations to collect feedback to improve applications and in turn, to address a problem most effectively.

Communication of Project Goals & Level of Commitment

The project goals and level of commitment established in the planning phase should be clearly and transparently communicated to the public via community meetings, worships, social media, mail, etc., during the implementation phase. Crowdsourcing is not a term that is used universally across municipalities. Managers must be cognizant that there is an education component to introducing this public process technique to communities. This includes reviewing the tactics, providing examples, as well as explaining how the information gathered will be used in improving bicycle planning and policy. Adherence to intended commitments and consistent use of the two-way process with the online community develops trust in the process and impacts how communities respond to future crowdsourcing projects. Finally, stating the organization's privacy policy prior to users engaging in the project is crucial. This policy must outline how the organization will use the data, and how it will maintain the security of the data and the identity of users. This, in essence, is what crowdsourcing is meant to create—a shared and trusted dialogue between an organization and the online community.

Choice of Crowdsourcing Application

Choosing an application type to carry out crowdsourcing is largely based on the problem to be solved, as well as project duration. Most of the bicycle planning cases used web applications (wikis, websites, social media platforms), but some used mobile or a mix of both (i.e. CycleTracks, Cyclopath). It is recommended that the project team should come to the table with an idea of what path to take based on Alpha-Testing, but open to altering the approach if it isn't relevant before deciding on an application type. This is particularly important when the defined problems require a specific type of data. These needs can dictate the features and design of an application. For example, if a project team is looking to survey bicyclists on RP, as well as collect demographic information, a mobile or web application with mapping capabilities would take precedence over social networking sites or simple online surveys. Nevertheless, social media should be a component in any crowdsourcing project, as this enables agencies to reach users through different mediums and allows users to forward the project website via social and professional networks.

Additionally, project teams may require a registration process on the website or mobile device for security and accountability measures. It enables teams to capture more personal demographic data (age, gender, zip code) to discover who was using the tool and what new voices (if any) they were able to bring to the conversation. To risk the chance of turning off users from a length registration process, collecting personal information can be collected intermittently. For example, as users use the platform more or be based on specific tasked the users undertake. Conversely, some of the cases in this study believed a registration and surveying process created more barriers to participation, although this is anecdotal evidence as there are no studies at this time that confirm this notion.

Not surprisingly, most if not all of the cases that used web applications were interested in exploring or developing mobile applications due to the potential for a larger reach and access to a variety of data—from demographic information to RP (via GPS). Mobile applications present the ability to expand an organization's reach, but must be met with caution. Time, cost, expertise, and maintenance demands can hinder some organizations. Also, many applications are specific to Android or iOS platforms, limiting their user base. However, technology is changing constantly and huge strides have been made with web applications. For example, HTML5 web applications present developers with emerging opportunities to build applications that can work similarly to a mobile application (geolocation support, user interfaces) with more reasonable development costs and the ability to work across all mobile operating systems and browsers (Business Insider, 2013).

Organizations can even go a step further and provide both web and mobile applications for data collection. Organizations looking to expand their reach and/or build a strong online community could apply a mix of approaches, where a web application is the base communication platform, but a mobile application is also available for download on the website (e.g. CycleTracks). This approach has the potential to increase data collection by meeting various users' needs and interests.

Application Design and Usability

Well-designed web and mobile applications that are easy to access and use have been found to be an influential motivator for attracting participants in public crowdsourcing projects (Brabham, 2012). Program managers and developers interviewed felt that it was important to present applications that are intuitive and appealing for users. While a well-designed application is a driving force in attracting users and collecting quality data, there are more stripped down versions that are low cost, but have the capabilities of collecting basic RP and background information. Examples to date are free mapping API, including Google Engine Light and MapQuest. These applications can collect basic user information and route preferences. It could also be a good way for an organization to test crowdsourcing capabilities before moving into more advanced, and aesthetically pleasing mapping applications that have the capabilities of collecting input and preference data.

Unlike Alpha-testing that takes into account conceptual ideas, beta-testing is a common practice in the private sector and should be used more widely in the public sector to test the design and usability of potential crowdsourcing applications. This is where user experience, performance testing and potential bug fixing comes into play. Here a focus group can log into a demonstration system and use the application to see if it accomplished what the agency and partners set out to do. This includes providing feedback on the technical components, as well as the user experience (ease of use/performance). This phase allows managers not only to change the look and design of the application prior to deployment (e.g. adding social media icons, changing visuals, adding a comment feature), but it also gives them the opportunity to get a sense of the user experience. This includes making sure the tool will be accessible and used by underrepresented communities. For example, making sure the application is available in multiple languages and intuitive to users with varying education backgrounds and technical skills. Additionally this testing phase can help create buzz for the application and drive recruitments and adoption.

Recruitment and Retention

There are evident challenges associated with the recruitment and retention of participants when leveraging crowdsourcing. A strong, inclusive promotional plan is needed to make sure this approach appeals to various groups and retains users for productive and sustained knowledge sharing. A plan should outline how the project will target the community, including an evaluation plan to assess the success of the strategies put in place. Planners must acknowledge the risks of disproportionately serving the most advantaged populations when using civic technology tools. Creating a promotional plan that complements high tech, with more traditional face-to-face recruitment strategies can help create a more inclusive strategy when working with the public. This is especially important for community groups with limited digital access, who may not have internet access or own a smartphone.

Promotional plans should incorporate incentives to participate. Incentives are an important implementation component of successful crowdsourcing projects. While some crowdsourcing projects can be efficient and attract motivated users, others involve a slower process of discovery and relationship building. A recruitment and retention plan should outline how the project will target the community, including an evaluation plan to assess the success of the plan put in place. Monetary incentives can be part of recruiting users, and can be as simple as gift cards or participation "points" that can be used towards community discounts. Non-monetary incentives can include free access to basic information, such as route output data created by the applications, or even social media recognition. In addition to incentives, applications that look to intrinsic motivators such as route planning tools, social networking, gamification, etc. may also prove useful in recruiting and retaining users.

7.3 Post-Implementation

Maintenance Tactics

Once an application is deployed for users, there is a degree of maintenance on the organization's part that includes monitoring comments, responding to concerns or questions from users regarding the project, troubleshooting performance issues, and organizing the data for visualization using various analysis tools such as ArcGIS and MAPublisher for Adobe Illustrator. Organizations must be aware of the level of skill needed to carry out these various tasks. Third party partners may prove fruitful to deal with technical and troubleshooting aspects of a project. For instance, Opens Plans and Wikimapping provide customizable crowdsourcing platforms, as well as the technical support services at minimal to moderate prices. These projects were met with positive reviews by managers and were part of a larger planning process that included face-face interactions with stakeholders, community groups, and the general public.

Project Assessments and System Research

Evaluating the success of this type of project is twofold. Planners must look at how the input was used in the larger decision making process and investigate users' experience throughout the project lifecycle. Additionally, research is needed to demonstrate how bicycle planners can take advantage of the crowdsourcing model as an additional tool for public engagement and gathering user behavior data. Data collected over a longer term can be used to encourage decision makers in the prioritization of long term capital investments, to inform them as to where capital investments are needed most (e.g. bikeshare station, cycle tracks, bike signaling, etc.) and whether such investments impacted bicycling levels post-implementation. This data includes RP, voting up/down comments, and demographics data. Many of the cases exported user data to basic tracking, analysis, and visualization tools, including Google Analytics, Excel, ArcGIS, and MAPublisher. Third party partners, such as Wikimapping, provided project managers with a customized analytic tool integrated within the platform to track comments and application traffic. These tools can also monitor and measure promotional performance over time. Metrics include total site visitors, total registered users, and source of users' access to the site (social media, community website, etc.).

If time and resources are a concern to organizations, the analysis step can in turn be crowdsourced. For example, de-identified data can be made public and curated by tech savvy individuals. In 2012, Boston's Hubway Bikeshare program released trip history data of more than a half a million bike trips to the public. This open data challenge produced powerful visualizations, animations, maps, and info graphics highlighting Hubway's reach across Boston and beyond.

Beyond impact, data visualization, and user analytics, organizations need to take a more proactive approach to understanding motivations and the cost-benefit to using an application. Evaluating the user experience may point to certain motivators and the incentives best suited for crowdsourcing applications, especially in attracting potential users that are hardest to reach. A higher response rate and sample size can be used as a performance measurement evaluating the effectiveness of the tool and team's recruitment method. For instance, low sample sizes can very well be attributed to promotional strategies that do not consider the motivators (whether intrinsic or altruistic, or both) to attracting online users. This data-driven research is needed to inform organizations and developers not only about how to attract various online communities, but to sustain them for the project's timeline. Project managers can assess users' overall experience via focus groups, web and mail surveys, and/or phone interviews. In addition to examining recruitment and retention, a cost-benefit analysis of a crowdsourcing project could allow agencies to evaluate whether the benefits outweigh the cost to carry out these projects. These costs of these online/mobile applications can also be compared to other forms of engagement and data collection methods.

This gained knowledge can inform both the development of the application and promotional plan for future projects. These assessment tactics can be implemented as early as the planning phase, or after the project is finalized. These evaluation steps are part of the feedback loop of crowdsourcing in which lessons learned and impacts are used to influence the problem to be solved for future crowdsourcing projects. Additionally, they can help establish concrete guidelines and best practices to help guide project managers when considering the use of civic technology.

Continued Communication with Stakeholders & Online Community

Sharing project outcomes and actions in a timely and open manner is pertinent once the response period has been closed to the public. Making sure gathered input is reflected in the decision making process, whether small (e.g. re-location of a bike share station) or large (e.g. city-wide bicycle master plan), demonstrates the effectiveness of the process and responsiveness of government to community input. If the project's impact is minimal this should be forthcoming in the communication with stakeholders. These actions or outcomes can be communicated through face-to-face interactions and through online mediums. For example, directing the public to the agency's website may be helpful in providing project overviews, action steps, updates, and documents once available. This continued communication should also include acknowledgements all of those involved with the project from community stakeholders, non-profit organizations, and the online community. Maintaining transparency and accountability is essential to demonstrating the value of civic technology, as well as strengthening connections between municipal professionals and communities they serve.

Chapter 8: Conclusion

It is an opportune time for planners to embrace crowdsourcing within the bicycle field. With the increase and evident benefits associated with bicycling across the U.S, more and more municipalities are promoting policy and plans to support making bicycling an easier and safer transportation option for the general public. While many municipalities have entered the digital age for disseminating information, very few are embracing the use of web and mobile applications to effectively engage the public to improve planning practices. Considering the data, public participation, and funding challenges faced by municipalities, the participatory technique of crowdsourcing has the potential to greatly benefit bicycle planning by tapping into the collective intelligence of communities to collect much needed street level data, as well as increase communication and public engagement. The cases discussed in this thesis represent the burgeoning interest from municipalities to incorporate crowdsourcing into research and project development given the increased access and use of digital technologies. They provide an opportunity for bicycle planners to improve upon the traditional public engagement process and collect user behavior data that has historically been more challenging to obtain.

This study adds to the scholarly work supporting crowdsourcing as a technology driven alternative to more traditional forms of public participation in planning projects with the capability to reach out to a broader group of citizens. This study's goal was not to evaluate each case at length, but to showcase some of the initial influences crowdsourcing has had on the bicycle planning process using both anecdotal and descriptive evidence from interviews and available documentation. Planners interviewed saw value in the crowdsourcing process, especially as a corresponding tool to other engagement strategies. There was also evidence that this digital strategy enhanced the bicycle planning process particularly for bikesharing projects, where input was used to prioritize station locations. This study also demonstrated the increasing use and benefits of moving to mobile platforms to collect user behavior data at the street level. Not only does this method reveal user behaviors that are often difficult to collect through other surveying methods, it can also be integrated into algorithms to provide advanced suitability and route choice demand modeling. There are great opportunities in taking bicycle specific web and mobile applications in new directions to attract and sustain online communities, including gamification, social networking platforms, and community vetted design competitions.

Nevertheless, it is still unclear the extent to which crowdsourcing can aid planners and decision makers in better understanding the behavior and concerns of bicyclists of various abilities. Planners are unsure of the scenarios that work best for crowdsourcing, the management resources needed, and how to recruit and sustain users who are diverse in interests and experiences. There is even greater ambiguity in how planners can maximize the benefits of revealed data to support longer-term bicycle planning projects given the resource challenges facing many municipalities. While research stemming from the computer science and business fields is helpful in establishing theory and context, industry specific analysis is crucial in understanding the conditions, barriers, and outcomes specific to the field. Based on the evident research gaps in the planning disciplines, this study calls on transportation scholars, developers, and practitioners to add to the data-driven research on the crowdsourcing model. Specifically, planning scholars should focus on in-depth inventory, evaluating the motivations of participants, especially underrepresented communities across varying types of bicycling projects, and assessing the performance of the crowdsourcing process from planning to post-implementation.

It is clear that crowdsourcing will continue to be explored in the bicycle planning field. The ubiquity of online mapping, open source platforms, and increasing access to digital technology presents practitioners an opportunity to engage the public in new ways and accumulate untapped behavior data in the process. By practitioners and scholars committing to the potential this process presents, what is currently considered a new, untested approach to solving urban problems will become one of the many services and tools that planners can rely on in attending to the increasing challenges facing our metropolitan areas. Using technology to create a more responsive government and engaged citizenry will ultimately lead to an improved quality of life for bicyclists.

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Appendices

Appendix A: Interview Question Format

Introduction

Hi, thanks for agreeing to speak with me today for this research project on crowdsourcing and bicycle planning. By way of introduction, you're on the phone with _______; I'll be asking the interview questions and taking notes on my computer. Before we get started, we just want to review what we've explained in emails/over the phone:

- Your responses will be kept anonymous in the final report, unless I ask and receive permission to quote you directly;
- And participation in the interview is voluntary; so if you don't want to answer any questions, or wish to end the interview at any time, just let me know.

B. Defining Crowdsourcing & Roles

1. To start I want to get a sense of how people define crowdsourcing. How would you define/describe it?
2. How long have you been involved with crowdsourcing using interactive mapping tools?

C. Planning/Implementation of Crowdsourcing Projects

3. Tell me a bit about the "______" crowdsourcing projects
4. How did this project get off the ground?
5. What were the initial goals and/or reasons for [insert name]?
6. Are these projects/initiatives integrated within other municipal polices and plans?
7. If yes, how so?
8. Did you or [name of organization] involve community members/residents in the planning, testing, and implementation of the project? In what ways?
9. [If yes] How effective do you think the process was?
   [If no] Do you think the project could have benefited from a community process? In what ways?

D. Resources, Expertise

10. What kind of support was made available in the planning/development and implementation stages of this crowdsourcing project? (i.e. technical expertise, funding, partnerships)

E. Post-Implementation: Monitoring, Evaluation,

11. What metrics were used (or being used) to measure success?
12. If metrics were collected, can you provide any indication to the overall impact the projects had on the bicycle planning process your organization was involved with?
13. If you haven't gathered metrics yet, do you intend to monitor/evaluate this crowdsourcing project?

F. Challenges and Opportunities

14. Did you or (name of organization) run into any challenges in the implementation of your crowdsourcing project/initiative?
15. If so, what were they? Were you able to overcome them?
16. In your experience with crowdsourcing initiatives, what kinds of information or resources were the most difficult to obtain for this project?
17. On a broader level, what are some of the barriers that impede municipalities/organizations from using civic technology applications for bicycle planning?

18. In your opinion, what do you see as the key opportunities in crowdsourcing application now and in the future?

G. Reflection

19. Can you tell us about any long-range plans and commitments to civic technology your organization or city may have?
20. What have you learned from your experience with this project/initiative?
21. When you think about crowdsourcing, are there things that you would like to know, data you wish you had, or research that would help address issues pertaining to crowdsourcing and bicycle planning?

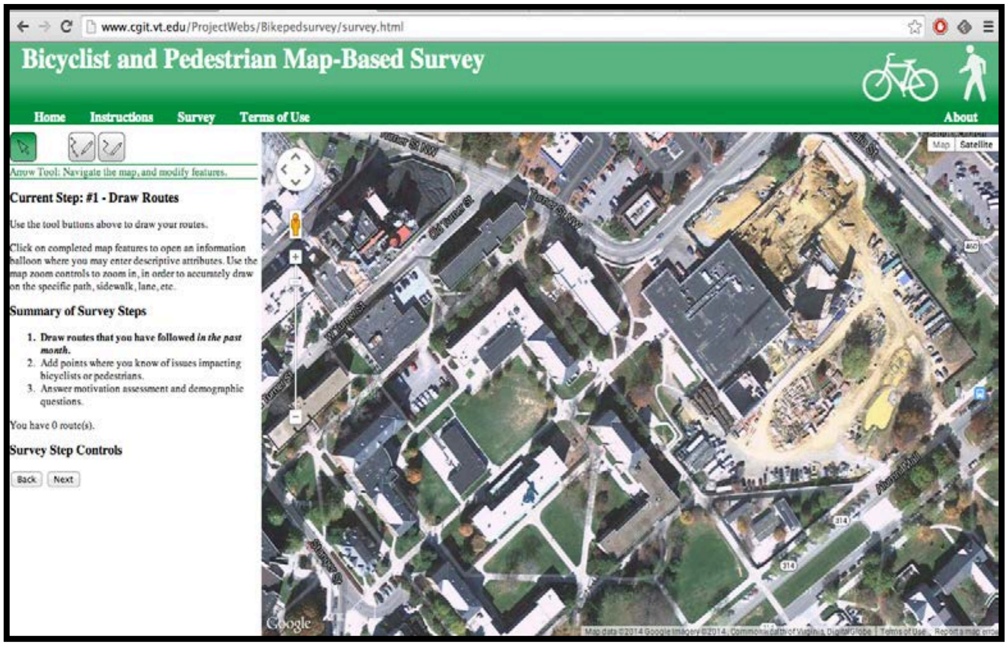
H. Closing

22. As we continue our interviews, we'd love your feedback on other players in your networks/municipality we should we be talking to. Could you recommend a few people that may be interested in talking with us regarding this project?
23. Is there anything else you'd like to add?
24. Do you any questions for me?

Thank you for your time!

Appendix B: Screen Shots of Crowdsourcing Applications

Bicyclist and Pedestrian Map-Based Survey, 2009
Virginia Tech and City of Blacksburg, Virginia

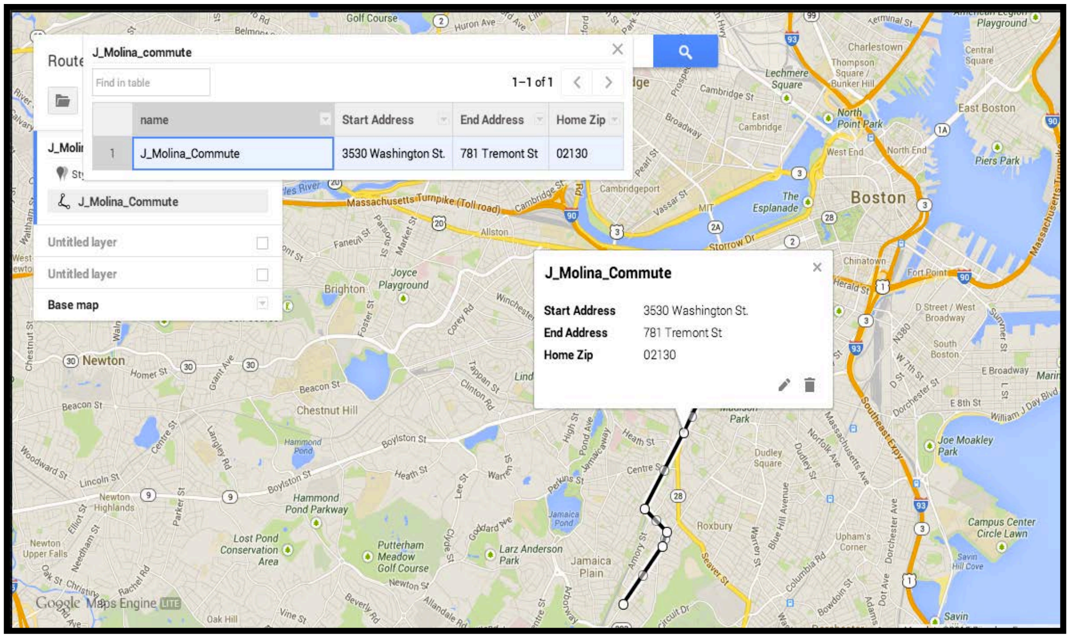


Screenshot, VT/Blacksburg's' Web Survey Application

<u>CASE AT A GLANCE</u>

Development Agency
City of Blacksburg, Virginia Tech Geospatial Lab
Civic Function
Transportation-Bicycle Network Planning
Software Type
Public Participation, Collective Intelligence
Technical Requirements
JavaScript, Google Maps API, ArcGIS

Boston Bike Network Plan Crowdsourced Mapping Project
City of Boston, Massachusetts

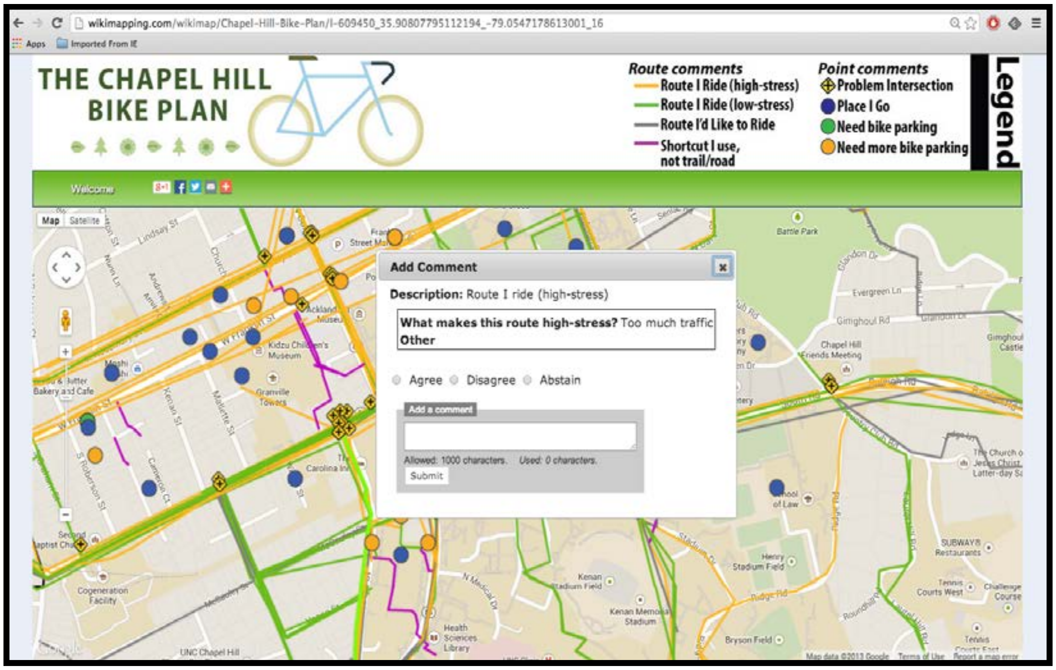


Screen Shot of Boston Crowdsourcing Map, Google Map Engine. 2012

CASE AT A GLANCE

Development Agency
City of Boston, Toole Design Inc.
Civic Function
Transportation- Bicycle Network Planning
Software Type
Public Participation, Collective Intelligence
Technical Requirements
JavaScript, Google Maps API, ArcGIS, Google Analytics

Chapel Hill Bike Master Plan, Wikimapping
Chapel Hill, North Carolina

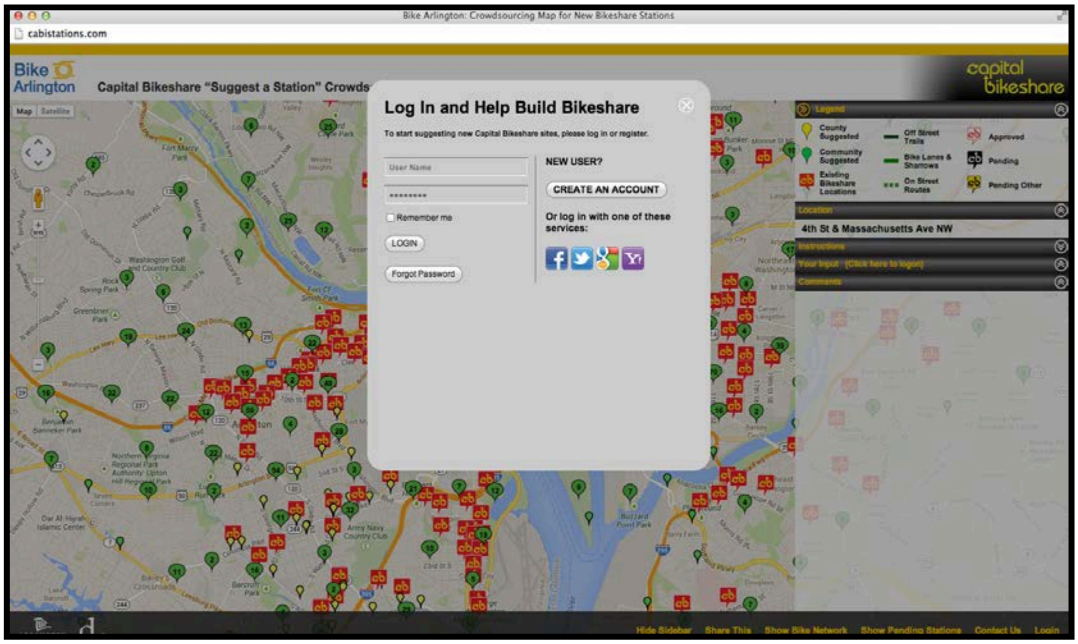


Screen shot of Wikimapping's Chapel Hill Bike Plan Map

CASE AT A GLANCE

Development Agency
City of Chapel Hill, Toole Design Inc., Wikimapping
Civic Function
Transportation-Bicycle Network Planning
Software Type
Public Participation, Collective Intelligence
Technical Requirements
JavaScript, XML, ajQuery, PHP. Google Maps API works off JavaScript

Capital Bikeshare Bike Arlington
Washington, D.C. / Arlington, Virginia

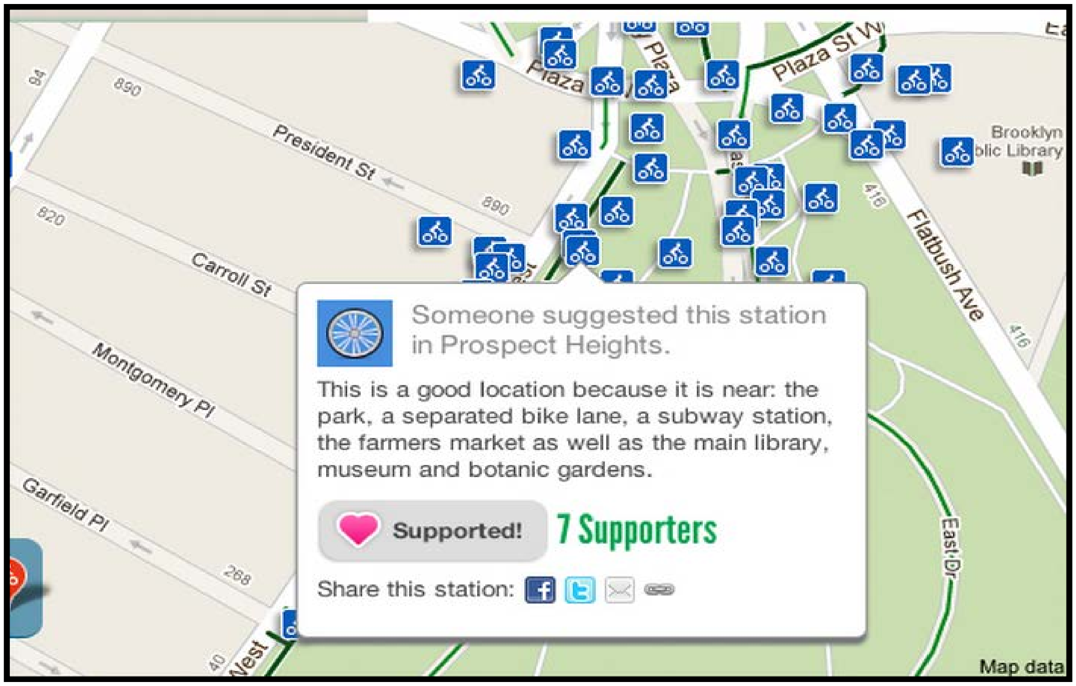


Screen shot of Capital Bikeshare Crowdsourcing Map

<u>CASE AT A GLANCE</u>

Development Agency
[Capital Bike Share, Mobility Lab, Arlington County]
Civic Function
[Transportation-Facility Demand, Bikeshare Planning and Expansion]
Software Type
[Public Participation, Collective Intelligence]
Technical Requirements
[JavaScript, XML, ajQuery, PHP. The Google Maps API works off of JavaScript]

Citi-Bike Share
New York City, New York

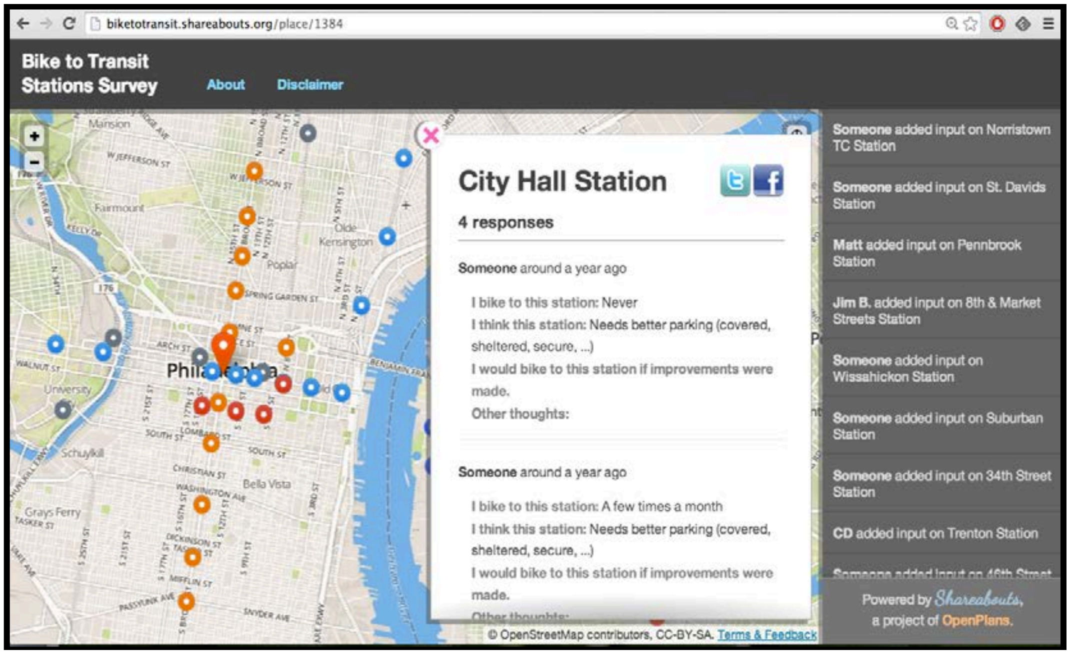


Screen shot of Open Plan's NYC Bike Share Map

CASE AT A GLANCE

Agencies
Open Plans, NYDOT
Civic Function
Transportation-Facility Demand, Bikeshare Planning and Expansion
Software Type
Crowdsourcing, Public Engagement, Open Source
Technical Requirements
JavaScript, Ruby Rails, Google API, Word Press

Philly Bike to Transit Stations Web Based Survey, Open Plans
Greater Philadelphia, Pennsylvania

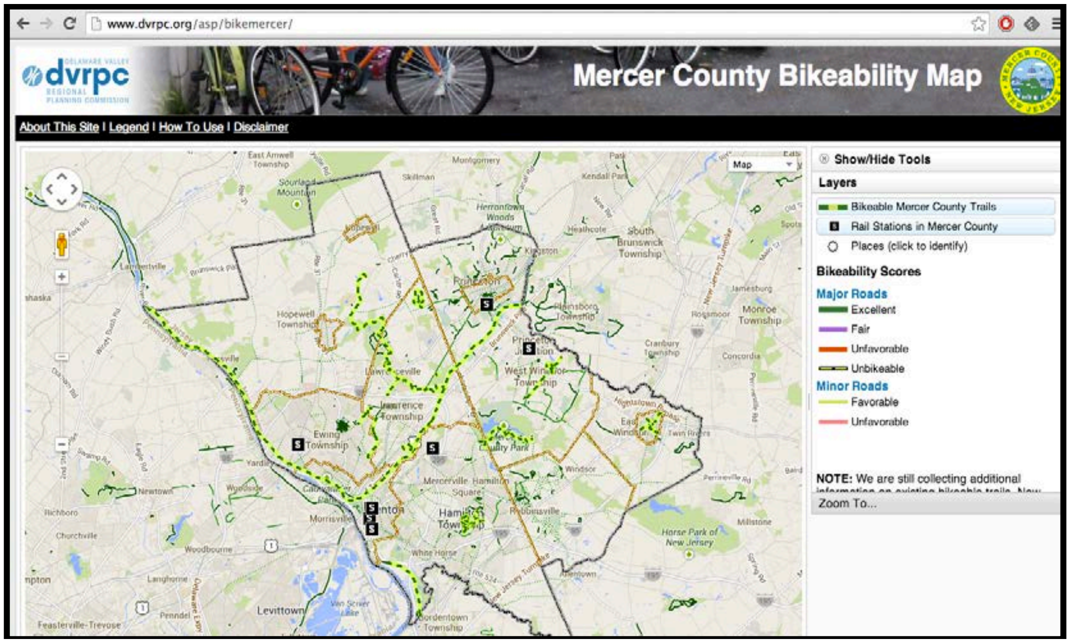


Screen shot of Philadelphia's Bike To Transit Crowdsourced Map

<u>CASE AT A GLANCE</u>

Agencies
Open Plans, Philadelphia Bicycle Coalition, DVRCP
Civic Function
Transportation-Facility Demand, Bike Parking
Software Type
Crowdsourcing, Public Engagement, Open Source
Technical Requirements
JavaScript, Ruby Rails

Web-based Crowdsourcing-Bikability Scoring (BLOS)
Mercer County, New Jersey

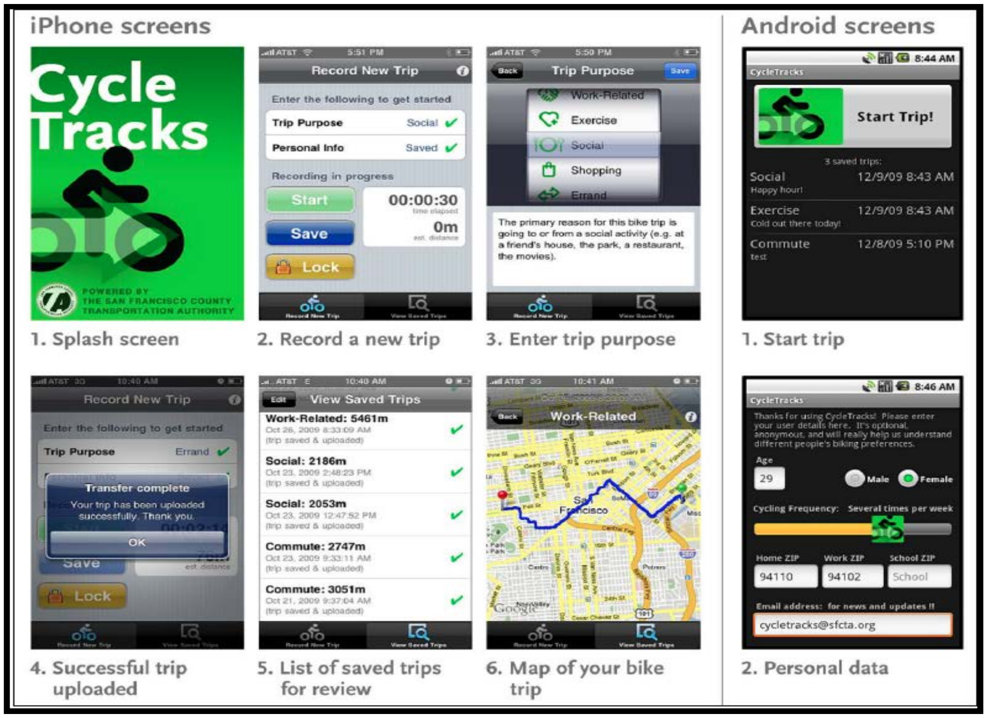


Screen shot of Mercer County's Bikability Map

CASE AT A GLANCE

Agencies
[DVRCP]
Civic Function
Transportation- Bicycle Network Planning, Suitability
Software Type
Public Engagement, Collective Intelligence
Technical Requirements
JavaScript, ArcGIS Map Server/API

CycleTracks Smartphone Application
San Francisco County, California

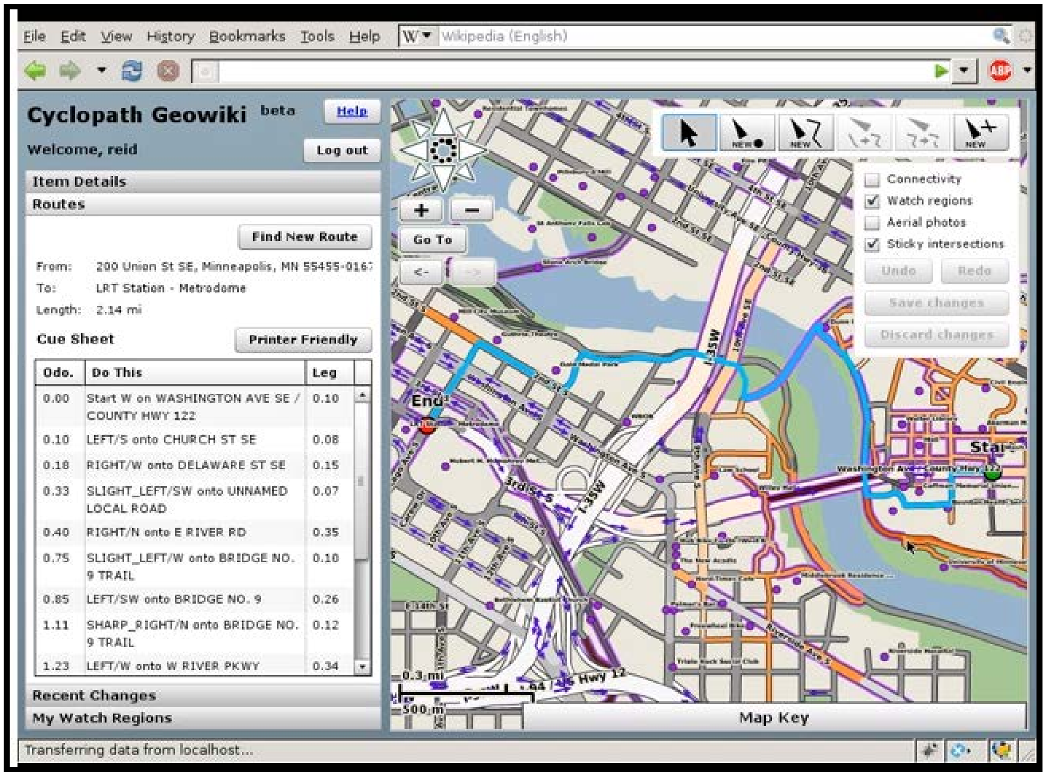


Screen shot of CycleTracks Mobile Platform

<u>CASE AT A GLANCE</u>

Agencies
[San Francisco County Transportation Authority (SFCTA)]
Civic Function
[Transportation-Route Demand Modeling]
Software Type
[Public Engagement, Collective Intelligence, Data Mining, Open Source]
Technical Requirements
[Java Script, Python, ArcGIS]

Cyclopath
Twin Cities, Minnesota



Screen shot of Cyclopath's Route Planning/Bikability Web Application

CASE AT A GLANCE

Agencies
University of Minnesota (GroupLens Research Lab), City of Minneapolis,
Civic Function
Transportation-Route Planning, Suitability
Software Type
Collective Intelligence, Data Mining, Open Source
Technical Requirements
GIS, UNIX/Linux, Apache, PostgreSQL/PostGIS