Bicycling and Transit

A Marriage Unrealized

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When effectively integrated with transit services, bicycling may achieve various environmental, health, and congestion-mitigation benefits for communities. A successful marriage between the two will most likely result in increasing (*a*) the catchment area and subsequent patronage of transit, (*b*) the efficiency of transit, and (*c*) the overall demand for cycling. A core problem, however, exists in that the predominant approach for integrating bicycling and transit vehicles frequently runs against capacity restraints. Effectively integrating bicycling and transit requires analysis of a broad range of alternatives that consider the travel patterns and needs of individuals and accompanying urban form characteristics. To fill a void in the literature concerning integrating bicycling and transit, this paper surveys existing knowledge about the two modes, describes three innovative initiatives that show promise in addressing capacity limitations, and sketches an analysis framework for communities and transit agencies to maximize the integration of bicycling and transit. A preliminary index is developed to predict cycling transit user (CTU) generation at transit stops. Factors identified in the literature as important in determining the share of CTUs (i.e., transit mode, location in the urban fabric, access and egress distance, and trip purpose) are nonuniform among communities, indicating that solutions must be tailored to fit local circumstances. Although the literature has traditionally focused on bicycles aboard transit, real gains will most likely be realized through initiatives such as bicycle stations and bicycles at egress locations for use with egress trips. Analysis relying on robust cost-effectiveness could help transit agencies with increased integration of bicycling and transit.

When effectively integrated with transit services, bicycling may achieve various environmental, health, and congestion-mitigation benefits for communities. A successful marriage between the two will likely result in increasing (*a*) the catchment area and subsequent patronage of transit, (*b*) the efficiency of transit by reducing the necessity of feeder bus services, and (*c*) the overall demand for cycling.

Bicycling and transit are receiving increasing attention in planning circles in their own right. Many countries are experiencing climbing levels of cycling (*1, 2*) and available reports of transit ridership suggest that in 2008, the United States had the highest transit patronage in 52 years in absolute terms despite falling gas prices (*3*). Several studies are suggesting that the growth in both modes may be in small part a result of the marriage between the two, although it is difficult to know (*4–6*). To date, there is a minimal but growing amount of published material that comprehensively documents knowledge of how bicycling can best be integrated with transit and methodologies for systematically approaching this marriage.

A core issue is that the predominant approach for integrating the two modes—bicycles aboard the transit vehicle—frequently runs up against capacity restraints (typically two or three bicycles for each bus on a front rack or three to four bicycles per light rail car). Although existing cycling–transit capacity could be adjusted at the margins by using these approaches (e.g., through incentives, exploiting technology to enhance communication between riders), the opportunity is ripe to consider broader solutions—solutions about which there is a dearth of information. Broadly speaking, effectively integrating bicycling and transit requires analysis of a broad range of alternatives; such alternatives would fully consider the travel patterns and needs of individuals and the accompanying urban form characteristics. In regard to a traveler's decision making, at least five broad possibilities are available options worthy of consideration:

1. Transporting the owner's bicycle aboard (inside or outside) the transit vehicle;
2. Using and parking the owner's bicycle at a transit access location;
3. Sharing a bicycle, which would be based primarily at the transit access point;
4. Using an owner's bicycle at the egress location; and
5. Sharing a bicycle, which would be based primarily at the transit egress point.

To fill a current void in the literature about integrating bicycling and transit, this paper fulfills three purposes. First, existing knowledge about the intersection of the two modes is thoroughly summarized and reviewed. To help describe how cycling transit users (CTUs) vary across modes, a table summarizing modes and issues peculiar to cycling and transit is offered. One issue that traverses most modes of transit (i.e., city bus, regional bus, subway, light rail) is capacity limitations; that is an issue that does not appear to be successfully or comprehensively addressed in most cases. Second, the paper describes three innovative initiatives that move beyond the traditional limitations of the bus and transit interface and proposes promising ways of thinking about capacity limitations and CTUs. Finally, the paper describes the types of information and details about a proposed analysis framework that communities and transit agencies could use to optimize the integration of bicycling and transit.

STATE OF KNOWLEDGE

The existing knowledge base of cycling and transit is relatively thin and recent but it appears to be growing. In addition to a few write-ups from various agencies, at least two research reports (focused

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Transportation Research Record: Journal of the Transportation Research Board, No. 2144, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 161–167.
DOI: 10.3141/2144-18

primarily on U.S. practices) exist, as well as a handful of peer-reviewed publications based on research predominantly from the Netherlands as well as Germany, the United Kingdom, and Denmark. One document provides a thorough compendium of the practice of integrating bicycles and transit in the United States (*7*). A common goal in most of these studies is to describe issues, behaviors, and hurdles related to what is introduced as cycling transit users. A survey of the literature revealed four factors that affect the share of CTUs: (*a*) transport mode, (*b*) location in the urban fabric, (*c*) egress catchment area, and (*d*) trip purpose. Although other factors inform the literature on inducing bicycle mode share, this paper focuses on factors related specifically to CTUs.

Consistent with the prevailing knowledge of transit use, the literature on CTUs suggests that transit mode is significant in determining the ability to recruit a greater or lesser size of the access catchment area. Transit services that quickly transport users relatively long distances [i.e., 48 km (30 mi)] with relatively few stops (e.g., commuter rail or express buses) tend to draw a larger share of CTUs than slower and shorter-distance routes (*8, 9*). The larger share of CTUs associated with rail and higher speed routes may be explained by frequent transit users who seek out faster travel modes and are willing to accept a longer access trip in return for shorter overall commute time (*10*). Conversely, it is widely acknowledged that relatively shorter distances (i.e., less than 5 mi) can oftentimes be cycled more quickly than by local transit (*11*). A study of three European countries showed that most CTUs ride between 2 and 5 km (1.2 and 3.1 mi) to access faster modes of transit, whereas for slower modes of transit CTUs generally prefer not to ride more than 2 to 3 km (1.2 to 1.9 mi) (*8*). The National Center for Transit Research confirmed similar access catchment area sizes in a study of transit agencies in Florida and elsewhere in the United States (*12*).

Location in the urban fabric also affects the number of CTUs. Results of two European studies found that suburbs generate higher levels of CTUs than cities (*8*). In transit-rich, compact cities, transit and walking are attractive alternatives to the bicycle (*13*). Travel distances between common origins and destinations are relatively shorter in cities as compared with suburban locations, enabling greater pedestrian activity. Relatively higher densities in cities also support high-quality feeder bus service with short headways, making transit without bicycles more convenient. Access distance is relatively short in cities because local bus service is characterized by shorter distances, lower speeds, and more stops closer together. However, in suburbs with less-frequent transit service and greater access and egress distances, bicycles are a more efficient mode. The customer satisfaction survey of rail users by Brojns et al. (2009) revealed that improving transit access would increase ridership at the periphery of transit systems and be more cost-effective (*4, 14*). Correspondingly, in urban areas with well-established transit systems, increasing the level of service would be more likely to increase ridership.

Across all transit modes in the countries studied, egress distance from transit to activity end appears to be relatively consistent. Egress catchment area is small and most trips are less than 2 km (1.2 mi). Egress distances of up to 2.2 km (1.4 m) are dominated by walking, followed by additional transit trips and cycling. Distances farther than 2.2 km (1.4 mi) are dominated by transit and cycling (*15*). Although one's personal bicycle is usually available for the access trip from home, transit capacity limits the availability of bicycles at the activity end of the trip (*13, 15*). Even when CTUs travel with bicycles aboard transit, one study determined that 80% of egress distances were less than 1.6 km (1 mi) and almost 50% of survey respondents replied that their egress distance was less than 0.4 km (0.25 mi) (*13*). These findings suggest that transit ridership decreases with large egress distances. Another important pattern of CTUs is that most are combining bicycle and transit trips for work and education purposes (*12, 16, 17*)—not surprising considering that trips for work and education dominate most transit use. CTUs on work-related trips tend to prefer transit modes and routes that more quickly transport them long distances and involve more expensive modes than for CTUs on education-related trips. Because CTUs on work-related trips are more likely to have an automobile at their disposal, they seek out the fastest and most efficient routes, often bypassing inefficient feeder systems (*13, 18*). In contrast, CTUs on education-related trips tend to make shorter and less expensive trips and frequently do not have automobiles (*8*).

Although the four factors above summarize key aspects of bicycling and transit integration, existing research on CTUs is minimal and spotty. Because some central issues related to CTUs vary dramatically by transit mode, key differences are summarized between six different modes on the basis of the current state of knowledge (see Table 1). Although within each measure there may exist con-

TABLE 1 Bicycle and Transit Integration Considerations

	City Bus	Rapid Transit (underground rail–metro)	Light Rail	Regional Bus	Commuter Rail	Ferry
Access catchment area (*8, 20*)	Small	Small	Medium	Large	Large	Medium
Return on investment	Low	Low	Medium	High	High	High
Bicycle facility improvements	Racks	Racks and lockers	Racks and lockers	Racks and lockers	Racks, lockers, bicycle stations	Racks, lockers
Issues affecting widespread adoption (*12*)	CTUs likely to substitute bus trip with bicycle trip or walking	Grade separation may present large obstacle for CTUs and safety hazard	Limited bicycle capacity, possible grade separation challenges	Limited bicycle capacity, although undercarriage storage may be available	Grade separation may present difficulty for bicycle loading and unloading	Few
Bicycle capacity (*7, 19*)	Two to three bicycles per bus	Two to four bicycles per car	Two to four bicycles per car	Two to three bicycles per car, some buses have luggage bins (six-plus bicycles)	20–40 bicycle capacity (*19*)	Often no limit

siderable variability due in part to differences in bicycle culture and the level of bicycle-friendly infrastructure, future research may be able to better provide more precise estimations of the potential for capturing CTUs on the basis of a number of local variables.

As described above, the access catchment area increases from slower modes with more stops to faster modes with fewer stops (moving across the table from left to right). The return on investment (ROI) measure compares the potential for capturing CTUs on particular transit modes on the basis of improving bicycle parking and bicycle infrastructure (i.e., bicycle lanes, paths). It is proposed that with scarce funding typical of transit agencies, infrastructure investments of bicycle parking facilities (i.e., racks, lockers, and bicycle stations) should be targeted at commuter rail and express buses on longer-distance routes. Research findings support these ideas because CTUs are likely to substitute slower local bus service with walking and cycling (*9*). Recent findings from a national rail customer satisfaction survey in the Netherlands suggest that guarded bicycle parking (i.e., lockers and bicycle stations) are not preferred by regular CTUs (*14*). Upgrading to guarded bicycle parking frequently increased the distance to the station because of the locker's larger space requirements. Respondents reported that investing in better unguarded bicycle parking facilities, improving connections, and higher-capacity park and rides would do more to increase ridership. Finally, bicycle capacity generally is limited with all types of transit. Several studies highlighted successful programs that allowed additional bicycles on buses, either inside or in the undercarriage of the bus (where available), dedicated more bicycle capacity on trains, or converted car spaces on ferries to bicycle parking without substantial problems and were likely to increase transit ridership (*7, 12, 19*). Some transit agencies even allow an additional 10 bicycles aboard buses in the priority seating for elderly and disabled when available (*12*).

INNOVATIVE INITIATIVES TO ADDRESS CAPACITY LIMITATIONS

Most of the existing literature assumes that bicycles are transported along with the CTUs either inside or outside the transit vehicle. Alternative options have not been experimented with in a widespread manner and therefore have not been sufficiently researched. Nonetheless, the variety of ways in which some limitations of existing bicycle and transit barriers have been overcome are informative. All communities and settings have peculiar challenges that in many instances are best addressed through very specific circumstances. Because the state of the knowledge is limited in these respects, a glimpse into some innovative practices can be helpful. Three innovative initiatives were chosen to highlight practical solutions that move beyond the simple limitations of fixed bicycle capacity on transit vehicles. One initiative suggests that it is possible to transcend some of the traditional limitations of bicycles on rail, resulting in increased ridership and a more seamless integration of bicycles on transit.

Bicycles Aboard Caltrain

The 80-km (50-mi) Caltrain route from San Francisco to San Jose, California, serves as an example of how a transit agency and bicycle advocacy group have mutually benefited from addressing bicycle capacity limitations. The program began in 1992 to increase ridership and satisfy CTU demand. As many of the egress distances to employment centers along the route are greater than a comfortable walking distance, the efficiency and speed of bicycles were seen as a way to attract the ridership of those who would not otherwise consider Caltrain. According to a Caltrain survey, 40% of trips from home or work to a Caltrain station are less than 10 min by bicycle, and 80% are less than 20 min (*19*). In addition to allowing bicycles aboard, Caltrain has also established shuttle buses to access major employment centers. The program proved to be so successful that the demand for space quickly outpaced the available bicycle parking on the train. Since 1992, bicycle capacity has steadily increased to accommodate up to 24 or 40 bicycles on two different train car models, and 34 of the 90 daily trains include two bicycle cars per train with a capacity of 48 bicycles.

Over the years, Caltrain and the San Francisco Bicycle Coalition (SFBC), a local bicycle advocacy group, have taken steps to improve the efficiency of bicycles aboard Caltrain. SFBC has set up a Twitter message board for regular Caltrain users to share real-time information on the availability of bicycle parking on particular trains. During a recent 1-month period, 135 messages were counted on Twitter (*20*). To supplement the limited data collected by Caltrain, SFBC has also set up a protocol for regular commuters to count bicycles on trains, as well as to report when a bicycle was bumped because of lack of capacity. Another initiative to increase bicycle capacity focuses on folding bicycles because these do not require special bicycle parking on the train. The Caltrain Bicycle Park and Access Plan has recommended providing a $200 subsidy to commuters toward the purchase of a folding bicycle.

At the current level of ridership and train car configuration, increasing bicycle capacity will come at the price of increased dwell times, thereby diminishing the train's express appeal (C. Dunn, personal communication, March 9, 2010). As Caltrain considers a forecast 100% increase in ridership by 2030, it initiated a comprehensive plan in March 2010 to study access capacity. Caltrain realizes the need to maximize access capacity by increasing walking, riding transit, and biking to improve service and to be able to handle the expected increased ridership.

Boulder County Final Mile Initiative

A second innovative program to increase CTUs comes under the banner of the Final Mile Initiative of Boulder County in Colorado, where planning efforts are aimed at reducing traffic congestion along a highly congested state highway. Highway 119, linking the towns of Boulder and Longmont, Colorado, located approximately 24 km (15 mi) apart, reportedly experiences the highest number of hours of congestion in Boulder County. Traffic forecasts for this corridor show expected traffic volume growth of 23% to 56% by 2020. The Boulder–Longmont corridor is a practical location for a bike–bus initiative because it links several thousand employment sites, all within a few miles of the targeted routes.

The Final Mile Initiative is a bicycle adoption program that provides commuters with a loaned bicycle and bicycle locker at their egress location. Funds from the grant will purchase up to 200 bicycles, bicycle corrals, and lockers that will be placed at busy egress areas in the city of Boulder along two longer-distance 35- and 42-km (22- and 26-mi) regional bus routes with 15-min peak-commute-hour headways. Bicycle service will be available at a locally contracted bicycle shop.

In addition to addressing issues surrounding vehicle miles traveled (VMT), congestion, and air quality, ancillary goals of this project are to find alternatives to the traditional bicycles-on-bus model that is limited by low bicycle capacity, increased dwell time associated with undercarriage storage, and weak feeder bus services typical of U.S. residential development. By reducing the number of bicycle boardings and alightings and the associated dwell time, this project also hopes to improve bus service. The Denver, Colorado, Regional Transportation District service planners have noted increased delays of up to 2 min per bicycle on regional routes as a result of bicycle storage in luggage bins on the undercarriage and on the front bicycle racks. Through mitigating inefficient transfers, travel time may be decreased and bus frequency increased, improving service to low-density residential areas and potentially making the transit trip more attractive.

Although the project is still in the early stages of implementation, the aim is to evaluate it on the basis of its ability to reduce trips and VMT, as well as its cost-effectiveness. Participants will also be surveyed on three occasions to track initial travel behavior, usage after 1 year, and final usage after a second year.

Puget Sound Bicycle Station Demand Methodology

A third innovative initiative designed to determine appropriate locations and levels of bicycle infrastructure was commissioned by the Puget Sound Regional Council (PSRC) in Washington in 2002 (*21*). The multifaceted program was designed to achieve a more efficient transportation system that encouraged increased shares of bicycle commuting and public transit. The initiative included developing a methodology to estimate bicycle parking demand, a feasibility study for constructing four pilot bicycle stations, design guidelines for a variety of controlled access bicycle parking, and a regional marketing plan. Of relevance to this research is the bicycle station demand methodology that was developed by a consulting firm for PSRC. The demand methodology was intended to help transit agencies make more informed decisions on accommodating bicycles at transit stations and park and rides.

The methodology calculates the total number of potential users of a bicycle station from the following user groups: (*a*) bicycle commuters who work within a quarter mile of the bicycle station, (*b*) CTUs who park their bicycles at transit stations, and (*c*) CTUs who travel with their bicycles. The methodology calculates baseline and worst- and best-case scenarios requiring the following data: (*a*) employment data, (*b*) number of transit trips, (*c*) bicycle commuting mode share within 3 mi of a proposed bicycle station, and (*d*) number of bicycle commuters to within a quarter mile of the bicycle station. The methodology was validated on two existing bicycle stations with usage data, and the predicted bicycle demand was reasonably accurate when compared with actual bicycle station use.

At this time it is unclear how useful this tool has been in guiding the placement of bicycle stations and protected parking; however, it demonstrates a clear understanding on the part of PSRC of the importance of considering the dimensions of bicycles, transit, and work locations for determining bicycle facilities.

FRAMEWORK TO ANALYZE CTU POTENTIAL

Effectively integrating bicycling and transit requires analysis of a broad range of alternatives that fully consider the travel patterns and needs of individuals but also key characteristics of the built environment (e.g., density, bicycle facilities). Typical transit trips rely on trunk lines. Access and egress to main trunk lines come in a variety of forms: walking, driving, feeder bus systems, or cycling. Cycling is a top contender as a mode to enhance such access (and egress) to trunk lines; a national survey suggests that almost one-half of Americans live within 0.4 km (0.25 mi) of a transit stop (*2*). But an outstanding question in any initiative is, given a variety of urban form contexts, what are the costs of feasible alternatives (e.g., transporting a bike, using a bike at access location, sharing a bike at egress location) and which alternative provides the most effective solution?

Each alternative carries considerably different costs, convenience, infrastructure, and benefits to consider. These considerations, however, are complicated by the variety of types of users, their frequency, and the variety of urban form characteristics. Evaluation studies are useful in such circumstances because typically they boil the myriad factors into a common framework. For example, benefit–cost analysis weighs the total expected costs of any alternatives against the total expected benefits of one or more actions—placing both in consistent monetary terms—to choose the best or most profitable option. Optimization studies obtain “best available” values of some prescribed objective function given a defined set of conditions. Arguably the most applicable evaluation for the applications described here, cost-effectiveness, considers a microview of a particular program’s activities, outputs, or outcomes and informs the degree to which competing programs maximize said effectiveness versus costs.

There are various frameworks for cost-effectiveness analysis (evaluation) but typically they require considering four broad factors: (*a*) the costs of different alternatives, (*b*) likely effectiveness of each alternative [a measure of the degree to which a common aim is reached (e.g., number of CTUs at the access or egress location)], (*c*) potential externalities (positive or negative), and (*d*) degree to which the above three considerations are weighted (e.g., possibly by different perspectives or interest groups). Each factor could be assessed in monetary terms or through a variety of indices; when considering relatively intangible phenomena, analysts find the latter more useful. Any such research that captures these dimensions will provide much needed and necessary inputs to inform necessary parameters. The aim is to evaluate different programs and inform alternatives that contribute maximally to goal attainment within the various constraints of reality (i.e., costs and other). In the following subsections alternatives are prescribed for the way various CTU planning issues might best be addressed and analyzed under such a framework.

Costs

Gathering data on costs is relatively straightforward and could be measured in per unit terms (dollars per expected CTU) for various alternatives; cost estimates would be gathered via a variety of means. For example, pricing from industry representatives could be gathered for bicycles aboard transit; bicycle parking alternatives would be priced by using industry standards and interviewing representatives. Values for inputs other than costs mentioned above can be arrived at by using several methods; triangulating among varying approaches will help arrive at consistent values. Given the dearth of available data on the subject, such estimates could be gathered from interviews with focus groups to better understand how different groups prefer various alternatives (thereby affecting the overall effectiveness), how they weight different factors (costs, effectiveness, externalities), and other relevant information (additional information on focus groups provided below). For example, cost estimates for specific bicycle racks across the five major brands yielded an interesting result. Although most of the companies carried a similar model of a multiple bike hanging loop rack, one company suggested that they are easy to vandalize because of the nature of the welds from a larger diameter pipe to a smaller diameter pipe.

Effectiveness

A logical measure of effectiveness that could be used is the number of CTUs that could be expected to or from the trunk transit service. Several approaches could provide such information, primary among them is an exploratory analysis of transit stops vis-à-vis the built environment. High or low amounts of CTU activity could be predicted as a function of independent variables such as demographics, supply of transportation services, urban form characteristics (employment or residential density), and geography. For example, a network area of 2 mi—often considered the cyclist's "sweet spot"—around transit stops could be used as an example unit of analysis. Thresholds could then be used to inform station-specific estimates on the likelihood of attracting a high, medium, or low number of CTUs, given various sources of information. These estimates could then feed measures of effectiveness and costs for different alternatives.

As a preliminary proof of concept, an index is proposed to predict CTU levels along the regional bus route from the Boulder County Final Mile project described above. The CTU index incorporates available data about sociodemographics from the U.S. census, bicycling facilities, and transit use. A buffer is calculated around all 70 transit stops by using a network structure analysis that determines the area served within 2 mi of a particular point or facility (i.e., the stop). Network buffers provide a more accurate depiction of the true area serviced by a facility when compared with a "crow-flies" distance-based buffer. Existing theory suggests that several factors would lead to higher CTU potential; these measures include (*a*) median household income, (*b*) percent population between the ages of 20 and 39, (*c*) average net density as measured by number of dwelling units per acre in each network buffer, (*d*) percent who commute by transit at least 3 days per week, (*e*) percent who commute by bicycle at least 3 days per week, and (*f*) kilometers of bicycle lanes. After measuring these attributes for each of 70 stops along the route in each buffer area, a factor analysis was done by using Statistical Package for the Social Sciences 18.0 to arrive at a standardized score for each stop. Results of the factor loadings are presented in Table 2, with a single factor (eigenvalue of greater than 4.5) explaining more than 75% of the variance across all six measures; all six measures load heavily on the first unrotated factor.

TABLE 2 Factor Analysis of CTU

Variable	Factor Loadings
Median household income	–0.640
Percent population (age 20–39)	0.931
Density (dwelling units/acre)	0.797
Percent transit (commuting three times or more per week)	0.912
Percent bicycle (commuting three times or more per week)	0.945
Bicycle facilities (kilometers of bicycle routes)	0.947

NOTE: Extraction method, principal component analysis; rotation method, Varimax with Kaiser normalization.

Factor scores were output and used as the CTU index in this case, and Figure 1 displays the BOLT (Boulder to Longmont) Route with the calculated CTU index shown for each stop. Table 3 highlights seven transit stops with the highest, lowest, and median values on the CTU index. For example, transit stops that ranked highest by the CTU index are (*a*) Canyon Boulevard and 28th Street and (*b*) Walnut Street and 14th Street—areas that rank relatively high in regard to kilometers of bicycle routes, percent that commute by bicycle, and density. Such calculations represent an analytical approach to identifying transit stops particularly worthy of further consideration in regard to future CTU planning activities. The lowest rank stops are (*a*) Oxford Road and Highway 119 and (*b*) Niwot Road and Highway 119 where the buffers consist of lower densities, fewer bicycle facilities, and subsequently fewer commuters using principally transit and bicycle.

Externalities

Finally, any analyzed alternative needs to take into account any externalities that may be imposed on other populations. For example, a relaxed policy about bringing bicycles aboard light rail cars may affect other users; during rush hours, it may even decrease capacity. Or CTUs who have to wait because capacity has already been reached would need to be considered. Externalities would be difficult to quantify but it is envisioned that reliable values for such factors could be arrived at via surveys or focus groups.

In sum, such a framework centers on the following steps:

1. Identify characteristics for transit station areas with high potential CTUs.
2. For ranges of select urban form characteristics, estimate bounds for potential number of CTUs per day (being sure to calibrate on the basis of existing measures of use and aiming to better understand a possible latent demand for CTUs).
3. On the basis of analyzed or uncovered parameters, estimate costs, effectiveness, and indices for other calculations.
4. Perform cost-effectiveness analysis to help prioritize alternative.

FUTURE DIRECTIONS AND CONCLUSIONS

As municipalities and transit agencies aim to increase CTUs, there appears to be room for the synergy between the two modes to be better exploited. A limiting factor, however, lies in the relatively small capacity for bicycles to be transported aboard transit vehicles. Discussion and practice to date have seemingly embraced an alternative that seeks to maximize the degree to which bicycles can be transported aboard transit; with small adaptations, this has been the status quo for bicycle–transit integration. Given that markedly increasing the capacity of bicycles aboard transit is often a prohibitive alternative (because of costs, logistics, etc.), it is prudent for municipalities to better understand conditions in which other alternatives (e.g., bicycle stations, bicycle sharing) could be aggressively pursued.

Existing knowledge of bicycling and transit integration is still limited, but quickly growing. Work thus far has identified several factors affecting the share of CTUs: (*a*) transport mode, (*b*) location in the urban fabric, (*c*) egress catchment area, and (*d*) trip purpose. Understanding these factors is critical for allocating scarce resources, increasing ridership, and improving the efficiency of the total transit journey. One challenge, however, is moving from a

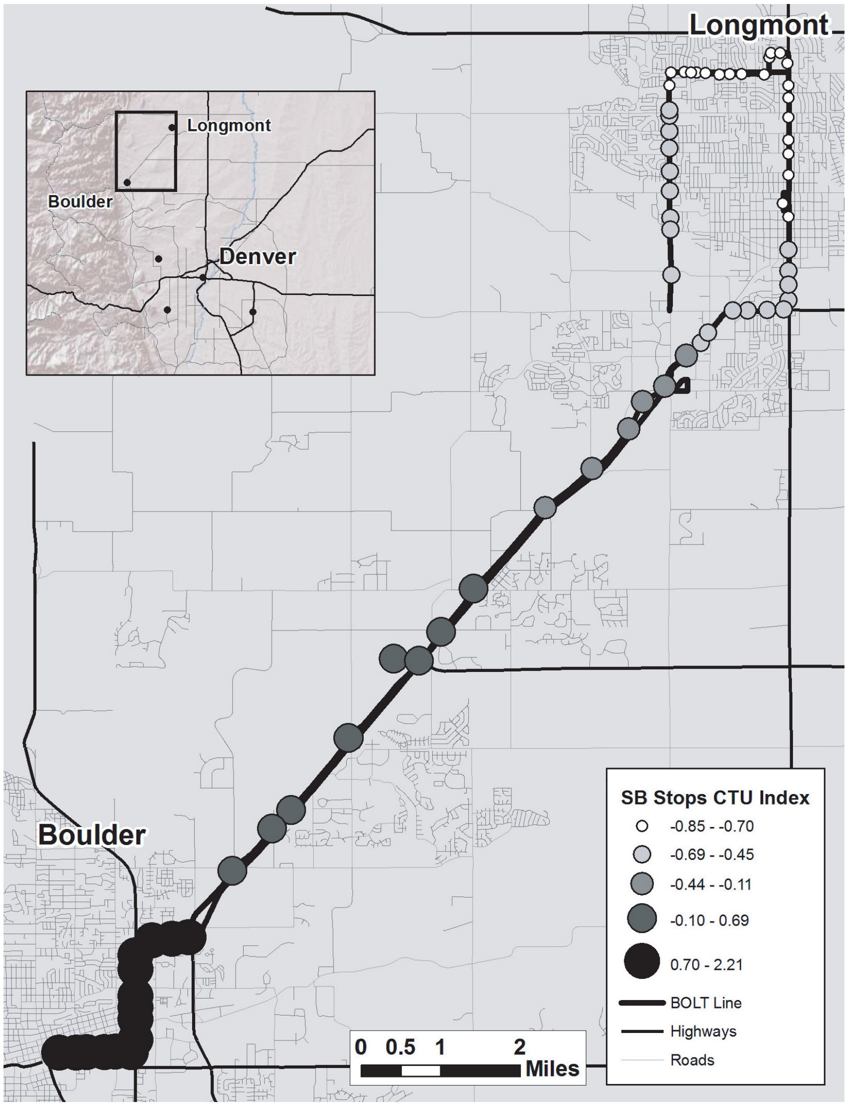

FIGURE 1 BOLT regional route.

TABLE 3 CTU Index Analysis

Route	Median Household Income ($)	Percent Population Age 20–39	Density (gross dwelling units per acre)	Percent of Workers Who Commute by Transit (3 or more days per week)	Percent of Workers Who Commute by Bicycle (3 or more days per week)	Bicycle Routes (km)	CTU Index Score
Oxford Rd. and Hwy. 119	79,087	24	0.32	2	1	2.29	−1.14
Niwot Rd. and Hwy. 119	82,712	24	0.28	3	2	14.48	−1.02
Hover St. and Mtn.View Rd.	56,776	28	2.23	2	1	46.91	−0.35
Main St. and 6th St.	46,774	31	2.21	2	1	62.20	−0.15
Iris Ave. and 28th St.	52,251	42	3.92	7	6	73.53	1.26
Walnut St. and 14th St.	48,926	39	3.27	6	7	84.95	1.78
Canyon Blvd. and 28th St.	37,413	50	3.87	8	8	67.19	2.55

general understanding to the particular issues and concerns of a particular community. By exploring three innovative approaches to some of these issues, it is possible to see how communities have moved the dialogue beyond the traditional limitations of the bus and transit interface and proposed promising new ways of thinking about capacity limitations and CTUs. The three initiatives highlighted here are (*a*) explore increased bicycle capacity that mutually benefits transit agencies seeking increased ridership and cyclists seeking the efficiencies in pairing the two modes, (*b*) address inefficiencies in transit resulting from typical residential land use patterns by providing loaned bicycles and safe storage at egresses, and (*c*) develop a methodology for evaluating the need for bicycle infrastructure, such as parking and stations, that allows CTUs to leave their bicycles at transit access and egress points. Likewise, there is promising growth in the area of vehicle sharing programs such as zip cars, electric bicycles, segways, and increased use of folding bicycles. These are other approaches to solving the Final Mile problem.

Despite the knowledge gained from past research and experience, important unknowns remain. For example, how is user satisfaction and/or growth in use enhanced as a response to upgraded parking facilities at transit stations? Do documented procedures exist for marrying transit stops with public bicycle sharing, a rapidly emerging concept in cities? Does the availability of free parking at key transit stops perhaps serve as a mild impediment toward promoting cycling?

After reviewing the state of the knowledge and some innovative initiatives, this paper offers a strategy based on a cost-effectiveness framework that cities could adopt to better understand when, where, and how to promote bicycle–transit integration. For example, under what circumstances should communities consider bicycle-on-transit instead of bicycling-to-transit? Alternatively, where and how should bicycling be promoted as a single mode (possibly not involving transit)? Unfortunately, a reliable and empirical framework to reliably advise such does not exist.

Further research into various solutions will benefit those seeking guidance on cost-effective strategies to maximize bicycling–transit integration—guidance that will most likely reject a "one-size-fits-all" approach. Users will be expected to know key characteristics of the station area and/or route under question such as (*a*) transit headways and capacity, (*b*) key demographic inputs within a 2-mi radius of the station area, and (*c*) other relevant and important information that may inform externalities. This input information, combined with the researched information, can then be used in a framework of cost-effectiveness analysis to inform a preferred solution. The ultimate goal is research that will result in "better than back of the envelope data" and that can be used in a relatively robust framework to advise advocacy organizations, municipalities, and/or transit agencies about the merits and costs of differing alternatives.

Most important, information that builds on the foundations presented here will help transit agencies with more informed planning strategies about how they can maintain and improve the return on their investments by overcoming rack capacity limitations and more effectively integrating bicycling and transit.

ACKNOWLEDGMENTS

This research is funded in part by financial support enabled by the Mineta Transportation Institute. The authors thank Seth Tribbey for his assistance with the geographic information system analysis and the valuable comments from the reviewers who helped clarify and solidify the exposition of this manuscript.

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The Intermodal Transfer Facilities Committee peer-reviewed this paper.