

# Testing the Effectiveness of Bicycle and Pedestrian Access Improvements in Reducing Commute Vehicle Trips

Prepared by

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## **Abstract**

DKS Associates has led the development of the tool called the *TDM Effectiveness Evaluation Model* (TEEM) to help the Washington State Department of Transportation evaluate transportation demand management (TDM) strategies. DKS has included in TEEM a method for evaluating the effect of improving bicycle and pedestrian access to employment sites through physical improvements. The tool was based on research conducted by DKS and OTAK on the existing level of bicycle and pedestrian accessibility for all employers in King County that are participating in the State's Commute Trip Reduction program. The research team developed an index of accessibility for both bicycle access and pedestrian access based on the extent of physical infrastructure to accommodate commuting by the two modes. Data on commute mode to work for all of the employees in the CTR database for King County was then correlated with the index values to produce a functional relation between the two. Estimates were also developed for the costs per acre of raising an index value one unit for an area. With these research results, it is possible to estimate the change in walk and bicycle commute mode shares that would result from a specified percentage increase in the index values and the cost of doing that. The new tool has been used to test the cost-effectiveness of bicycle and pedestrian improvements relative to other TDM options in the I-405 corridor of the Central Puget Sound region.

## **Overview**

The Washington State Department of Transportation (WSDOT) sponsored research to construct a tool to evaluate the effectiveness of travel demand management and land-use strategies in reducing peak-period travel demand in heavily congested corridors. This paper reports on research performed by DKS Associates and Otak, Inc. on the effectiveness of physical infrastructure improvements for bicycle and pedestrian access in increasing bicycle and pedestrian commute travel. The research team

developed an index of accessibility for both bicycle access and pedestrian access based on the extent of physical infrastructure to accommodate commuting by the two modes and correlated the indices with observed commute mode shares for bicycle and walking for employers in the WSDOT Commute Trip Reduction database. The results have been incorporated in the model that was developed for WSDOT to predict the effects of corridor TDM and land use strategies. The model was developed as a screening-level tool to provide order-of-magnitude estimates of trip reduction potential and cost-effectiveness in reducing trips. The tool has been useful in helping decision makers decide which strategies are worth pursuing as cost-effective measures to reduce peak-period vehicle trips in heavily congested commute corridors.

In recent years, TDM and land use actions have played significant roles in Environmental Impact Statements (EISs) and corridor studies in the Puget Sound region. Because of physical constraints, excess travel demand that cannot be accommodated by highway expansion and a need to maximize highway efficiency at peak periods; TDM was widely supported by advisory committees, public officials and citizens involved in those corridor studies.

WSDOT initiated the Implementing Corridor TDM Programs project collaboratively in order to support the development of a TDM and land use implementation plan(s) and contractual agreements to implement TDM in the SR 520 and I-405 corridors (and likely others in the future). Funding to conduct this project was provided by a Transportation Community System Preservation (TCSP) grant from the Federal Transit Administration (FTA) in 2001 with local match provided by WSDOT, and from a second TCSP grant from the Federal Highway Administration (FHWA) in 2002.

The model that has resulted from the Implementing Corridor TDM Programs project, known as the TDM Effectiveness Estimation Methodology or TEEM, was developed to support the analysis for the corridor studies. The model was developed to allow testing of twenty different strategies:

**Mode Shift Support Strategies**

1. Vanpooling
2. Alternative Mode Subsidy
3. Universal Transit Pass
4. VanShare
5. Guaranteed Ride Home

**Parking Management Strategies**

6. Restricted Parking Supply
7. Parking Pricing at Employment Sites

**Alternative Work Schedules Strategies**

8. Telecommuting
9. Compressed Work Week

**Programmatic and Policy Support**

10. CTR-Type Programs for Smaller Employers
11. Multi-Employer Transportation Management Associations (TMAs)

**Marketing and Promotion**

12. Marketing and Promotion

**Bicycle and Pedestrian Facilities**

13. Improved Bicycle Access
14. Improved Pedestrian Access

**Non-Commute Strategies**

15. Shopping Trips
16. Special Event Travel

**Land Use Strategies**

17. Increased Density Near Transit Corridors
  18. Increased Mixed-Use Development
  19. Increased Infill & Densification
- Increased Transit Service**
20. Increased Transit Service<sup>1</sup>

Sixteen case studies were used to calibrate and test TEEM and to understand the potential for various TDM and land-use strategies in a variety of settings along the corridor. Documentation of the TEEM model and the project can be found in the final report (DKS Associates et al 2005).

### **Development of the Bicycle and Pedestrian Access Indices**

Before developing indices for bicycle and pedestrian access, the research team conducted a review of other similar efforts. In research for the Florida Department of Transportation, Landis et al (2001) developed a method to objectively quantify “pedestrians’ perception of safety and comfort in the roadside environment.” Their methodology used surveys from 75 people walking a roadway course to quantify how well a roadway accommodates pedestrian travel. Their *Pedestrian Level of Service* calculation includes consideration of sidewalk width, outside roadway lane width, and presence of on-street parking among other factors. While the methodology provided a reasonable method for assessing the desirability of a route for walking at a single point, it did not provide a method for assessing the desirability of an area.

Moudon et al (2001) developed a GIS based methodology to identify the potential latent demand for pedestrian trips within an activity area. The methodology relies primarily on identification of land uses that are functionally complementary for pedestrian travel and spatially close enough for pedestrian activity. Their methodology provides a useful way to assess the potential for pedestrian travel but focuses primarily on non-work travel and on the land uses rather than the physical facilities.

Dill (2004) produced a review of a range of measures of connectivity for bicycling and walking. In her research, she reviewed measures of existing characteristics and their correlation with observed bicycle and pedestrian activity. She identified street network density, connected node ratio, intersection density and link-node ration as the most promising measures. She then demonstrated how these would be calculated for a study area in Portland, Oregon. While these factors clearly had high explanatory power for predicting bicycle and pedestrian travel, they did not capture the types of improvements that are likely to be made to improve access for these modes in already-developed areas. Most of the factors that Dill identified are correlated with the area types that our research team used to stratify the employers and employment areas in our analysis.

The research team developed an index of accessibility for both bicycle access and pedestrian access based on the extent of physical infrastructure to accommodate commuting by the two modes. The details of the research conducted can be found in Roberts (2004). The team used aerial photos and GIS data on sidewalk networks and bicycle routes and trails to classify each zone according to the indices. A sample of the GIS data used is illustrated in Figure 1. Data on commute mode to work for all of the employees in the Commute Trip Reduction (CTR) Program database for King County was then correlated with the index values to produce a functional relation between the two. Employers of 100 or more in Washington are required by state law to develop a program for trip reduction designed

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<sup>1</sup> TEEM was not designed to be a tool for testing significant changes in transit service. Other tools are better suited for this purpose. TEEM can be used to test how changes in transit frequency can affect the vehicle trip rate over time.

to achieve area goals for trip reduction. As part of the program, the employers are required to survey their employees on bi-annual basis to determine commute mode shares by all modes including walk and bicycle. For the four-county Puget Sound Region, 876 employment sites were included in the database. The employee surveys for these sites were used as the sources of bicycle and walk commute mode share for analysis zones in the study area. Although the CTR data did not provide before-and-after data on how non-motorized mode share changed in response to physical improvements, the data set did provide evidence of how the mode share varied by the physical characteristics of the surrounding area. One draw back of the use of the CTR database is that it only represents employees working for large employers (100 or more employees). Additional research might be appropriate to determine if the same mode shares and sensitivities applied to employees of smaller employers.

Estimates were also developed for the costs per acre<sup>2</sup> of raising an index value one unit for an area. With these research results, it was possible to estimate the change in walk and bicycle commute mode shares that could result from a specified percentage increase in the index values and the cost of doing that.

For bicycle travel potential, the presence of the following facilities was considered:

- Bicycle system (on street lanes and routes) completeness within 6 miles of the TAZ boundaries
- Multi-use pathways in existence within 6 miles of the TAZ boundaries
- Where known, the presence of bicycle facilities such as bike storage lockers, racks, showers, etc. and the presence of bicycle friendly programs and outreach efforts contribute to the conduciveness of the setting to bicycle travel

For pedestrian travel potential, the presence of the following facilities was considered:

- Sidewalk system completeness
- Signalized intersections with crosswalks and pedestrian improvements at intersections
- Transit stops in the vicinity
- The setting's general conduciveness to pedestrian travel (i.e. area is an attractive place to walk, street trees exist, driveway cuts are minimized, buildings are oriented to the street, etc.)

The resulting indices were as follows:

#### Bicycle Index Description

##### *Level 6 (Highest Level of Completeness of Facilities Exists)*

- Bicycle lanes are striped and present on 90 percent of the major roads (arterial and collector streets) in the study area
- Multi-use trail facilities are available within the study area or within proximity and there are connections between the trail and CTR sites
- Bicycling facilities are available such as lockers, showers, etc. (where known)
- Setting characteristics and conditions are "excellent" for bicycle travel

##### *Level 5 (High Level of Existing Facilities)*

- Bicycle system appears to be 70 to 90 percent complete.
- Trails exist in the vicinity and appear to be actively used for commuting purposes
- Bicycle support facilities may exist
- The general setting exhibits "good" to "excellent" conditions and characteristics conducive to bicycling.

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<sup>2</sup> Cost were developed on a per-acre basis rather than a per-mile-of-facility basis because changes are tested in the model for an entire TAZ and not for a particular project.

*Level 4 (Medium Level of Existing)*

- Bicycle system appears to be 50 to 70 percent complete.
- Trails exist in the vicinity
- Bicycle support facilities may exist
- The general setting exhibits "moderate" to "good" conditions and characteristics conducive to bicycle travel.

*Level 3 (Medium Level of Existing Facilities)*

- Bicycle system appears to be 30 to 50 percent complete.
- Some trails exist in the vicinity
- Bicycle support facilities may or may not exist
- The general setting exhibits "moderate" to "lacking" conditions and characteristics conducive to bicycle travel.

*Level 2 (Low Level of Existing Facilities)*

- Bicycle system appears to be 10 percent to 30 percent complete.
- Minimal trails in the vicinity (but may be in surrounding TAZs).
- Bicycle support facilities are minimal or nonexistent.
- The general setting exhibits "lacking" to "insufficient" conditions and characteristics for bicycle travel (and in some cases, conditions may not be conducive to bicycle travel).

*Level 1 (Lowest Level of Existing Facilities Present)*

- Bicycle system appears to be 10 percent or less, or in many cases nonexistent.
- No trails exist in the vicinity.
- Bicycle support facilities do not exist.
- The general setting exhibits "insufficient" conditions and characteristics for bicycle travel (and in most cases, conditions are not conducive to bicycle travel).

Pedestrian Index Description

*Level 6 (Highest Level of Facilities Exists)*

- Sidewalk system appears to be fully complete (90 percent or more of the streets have sidewalks) in the TAZ (or study area) and connections between CTR sites and adjacent sidewalks in the street rights-of-way are clear and convenient.
- Signalized intersections and/or mid-block crossings with pedestrian improvements (crosswalks, refuge islands, etc.) are present at 90 percent or more a majority of intersections in the TAZ.
- Bus stops and transit facilities exist most frequently.
- The general setting and character of streets appear to provide an "excellent" environment conducive to pedestrian travel (wide sidewalks and/or separation from vehicles, street trees, landscaping, buildings to the street, minimal driveway conflicts, etc.).

*Level 5 (High Level of Facilities Exists)*

- Sidewalk system appears to be 70 to 90 percent complete.
- Signalized intersections and pedestrian improvements at intersections appear to be 70 to 90 percent available.
- Bus stops/transit facilities exist more frequently than in levels 1-4.
- The general setting exhibits "good" to "excellent" conditions and characteristics conducive to pedestrian travel.

*Level 4 (Medium Level of Facilities Exists)*

- Sidewalk system appears to be 50 to 70 percent complete.

- Signalized intersections and pedestrian improvements at intersections appear to be 50 to 70 percent available.
- Bus stops/transit facilities exist more frequently than in levels 1-3
- The general setting exhibits "moderate" to "good" conditions and characteristics conducive to pedestrian travel.

*Level 3 (Medium to Low Level of Facilities Exists)*

- Sidewalk system appears to be 30 to 50 percent complete.
- Signalized intersections and pedestrian improvements at intersections appear to be 30 to 50 percent available.
- Bus stops/transit facilities exist more frequently than in levels 1-2
- The general setting exhibits "moderate" to "lacking" conditions and characteristics conducive to pedestrian travel.

*Level 2 (Low Level of Facilities Exists)*

- Sidewalk system appears to be 10 percent to 30 percent complete.
- Signalized intersections and pedestrian improvements at intersections appear to be 10 to 30 percent available.
- Bus stops and transit facilities are very minimal (or in adjacent TAZs).
- The general setting exhibits "lacking" to "insufficient" conditions and characteristics for pedestrian travel (and in some cases, conditions may not be conducive to pedestrian travel).

*Level 1 (Lowest Level of Facilities Exists)*

- Sidewalk system appears to be 10 percent or less, or in many cases nonexistent.
- Signalized intersections and pedestrian improvements at intersections appear to be less than 10 percent available or non-existent.
- Bus stops and transit facilities are non-existent.
- The general setting exhibits "insufficient" conditions and characteristics for pedestrian travel (and in most cases, conditions are not conducive to pedestrian travel).

An example of an area with a Pedestrian index value of 4 (Medium Level of Facilities Exists) is provided in Figure 2. Final assessments of the index value for each zone were made by members of the team and often required considerable judgment. The criteria in each point level above were used as guidance for the team, but did not always provide an exact match across all criteria for a zone being analyzed.

## **Development of Effectiveness Factors for Bicycle and Pedestrian Improvements**

The relationships between the index values and the commute mode share for each mode are illustrated in Tables 1 and 2. Index values of "6" were only found in downtown Seattle and there are special circumstances there that cannot be achieved in other parts of the region. These include the density of development, the proximity of high-density residential neighborhoods and the density of the street and sidewalk network. In recognition of this uniqueness, the values for "6" were not entered into the table and TEEM will not allow the analyst to change the value for a zone to 6. Mode shares were available for downtown Seattle, and index values could be incorporated in the model if another geographic area begins to take on the characteristics of downtown Seattle in the future.

## **Cost Analysis**

The project team estimated the costs of achieving an increase in an activity area's pedestrian accessibility index and bicycle accessibility index by one level of the index (i.e. areas classified at

Level 1 can be reclassified as Level 2; areas classified as Level 2 can be reclassified as Level 3; etc.) The cost investment would cover the capital cost of adding the following physical features to an area to increase pedestrian and bicycle mobility. (Estimated costs below are based on broad assumptions of typical work that would occur to complete the necessary improvements. Costs reflect a 2004 dollar value and have been adjusted to fit regional pricing for construction.)

#### Pedestrian Travel

- Sidewalk system completeness (extending and/or widening sidewalks)
- Additional signalized intersections with crosswalks and pedestrian improvements at intersections
- Additional transit stops for existing transit services in the vicinity (stop signage, shelters etc.)
- Enhancing the setting's general conduciveness to pedestrian travel (i.e. additional street trees, reduced driveway cuts, etc.)

#### Bicycle Travel

- Bicycle system improvements (adding on street lanes and/or shoulders in rural areas)
- Extending/adding multi-use pathways

To determine the cost of increasing an areas index classification by one level, the project team plotted aerial photos of 3 TAZ areas in each level of the index. They then estimated the level of physical facilities needed in each area to achieve the next highest level of the index (i.e. from 1 to 2, from 2 to 3, from 3 to 4, from 4 to 5, and from 5 to 6) and calculated the potential capital construction costs of providing these facilities.

Construction cost estimates were derived based on the following planning-level unit costs:

- Multi-use pathways/trails: \$1,056,000 per mile
- Bicycle shoulders/stripping: \$350,000 per mile
- Street retrofit/curbing moved/bike lanes added: \$1,000,000 per mile
- New sidewalks (6 feet average): \$850,000 per mile one side; \$1,700,000 per mile both sides
- Existing sidewalk widening/repairs: \$850,000 per mile both sides
- Signalized intersection improvements with crosswalks, curb cuts, etc. \$300,000 per intersection
- Minor intersection modifications: \$50,000 per intersection
- Bus stops: \$50,000 per location
- Miscellaneous streetscape enhancements/driveway cut consolidation, etc. \$250,000 per mile

Costs for pedestrian and bicycle improvements for each TAZ were calculated and then divided by the total number of acres in each TAZ to get a per acre cost for improvements. The per acre costs for each TAZ were then averaged to determine one overall average per acre cost for pedestrian facility improvements and one overall average per acre cost of bicycle facility improvements. The construction costs per acre were then increased by 50 percent to cover the additional costs of administration, design, permitting, environmental work, and contingencies consistent with industry practices. The resulting costs per acre were as follows:

- Pedestrian Improvements: \$42,125 per acre
- Bicycle Improvements: \$14,595 per acre

These estimates include all costs that might be associated with increasing an area's index classification by one level. For pedestrian improvements, the \$42,125 per acre estimated capital cost

translates to a total cost of \$234,748 per acre for an assumed 20-year life of the improvements/facilities<sup>3</sup>. For bicycle improvements, the \$14,595 per acre estimated capital cost translates to a total cost of \$81,318 per acre for an assumed 20-year life of the improvements/facilities. With more extensive research, cost estimates could be developed that differentiate by area type.

### **I-405 Corridor Test Results**

The results from the research were incorporated into the TEEM model and used to test the potential effectiveness of increasing pedestrian and bicycle access broadly throughout the I-405 corridor. The base non-motorized mode share for work trips in the corridor was 1.7%. In testing the impact of increasing the index for bicycle access and pedestrian access by one unit in every zone, the bicycle improvements increased the non-motorized mode share to work by 7% from 1.7% to 1.8%. The pedestrian improvements increased the non-motorized mode share for work trips by 24% from 1.7% to 2.1%. Increasing the index for both bicycle and pedestrian access by one unit each resulted in a 30% increase in non-motorized commute trips from 1.7% to 2.2%.

While the percentage increase in non-motorized commute travel was significant in the I-405 test, the annualized cost associated with reducing peak period travel was significantly higher than other strategies tested on a cost-per-vehicle-trip-reduced basis. One reason for this is that the full cost of the bicycle and pedestrian improvement were attributed to the reduction of commute travel only. The same improvements would likely provide significant non-work travel benefits, as well as recreational opportunities, but since the available CTR data only included commute trips, the methodology developed for the project could not quantify non-work travel benefits.

### **Suggestion for Future Research**

While the research reported in this paper provides useful information for screening of strategies for cost-effectiveness in reducing peak-period commute trips, additional research could make the analysis tool that resulted from the research more useful for project planning. Some of the ways in which the tool could be enhanced would be by making the index more quantitative and less reliant on the subjective assessments of the model developers or users. The tool could also be improved if support programs that encourage walking and bicycling to work could be added to the physical infrastructure improvements now in the model. Additional research might also help to eliminate correlation with other factors that are not now being captured in the indices. Density of roadway network, topography, and economic characteristics of the surround neighborhoods are a few of these potential factors.

### **References**

DKS Associates, Mirai Associates and OTAK, *Final Report, Modeling TDM Effectiveness: Enhancements to TEEM and Case Studies for the I-405 Corridor*, prepared for the Washington Department of Transportation, Urban Planning Office, February 2005.

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<sup>3</sup> A 20-year life was assumed as an average life of the physical infrastructure improvements considered and was based on experience of the team members developing the costs. There will be some variance in the average life of physical improvements.

Landis, Bruce; Venkat Vattikuti; Russell Ottenberg; Doug McLeod; and Martin Guttenplan; “Modeling the Roadside Walking Environment: A Pedestrian Level of Service,” prepared for the Florida Department of Transportation, November 2000.

Moudon, Anne; Paul Hess; Julie Matlick; and Nicholas Pergakes; “Pedestrian Location Identification Tools: Identifying Suburban Areas with Potentially High Latent Demand for Pedestrian Travel,” November 2001.

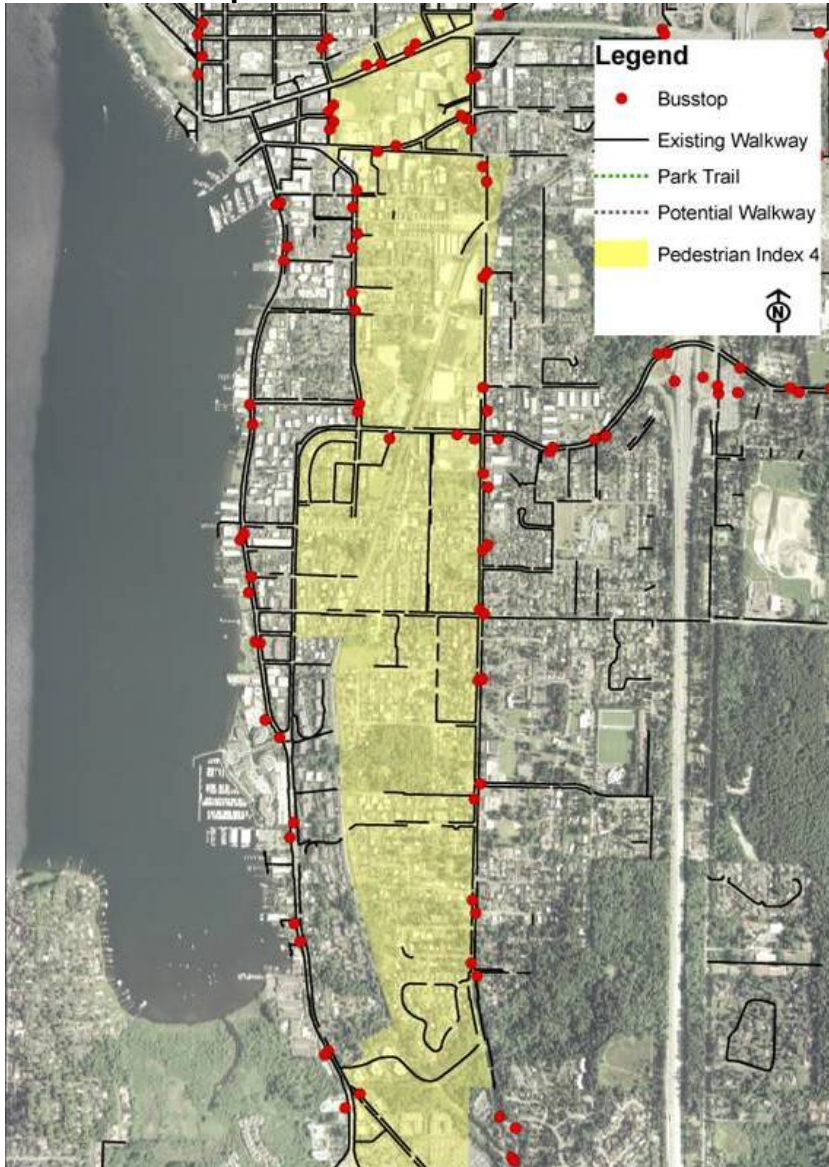
Dill, Jennifer; “Measuring Network Connectivity for Bicycling and Walking,” prepared for the Transportation Research Board Annual Meeting, January 2004.

Roberts, Mandi; OTAK, “Final Memorandum - Methodology for Pedestrian and Bicycle TDM Effectiveness Analysis and Cost Analysis Results,” prepared for the Washington Department of Transportation, Urban Planning Office, July 30, 2004.

**FIGURE 1 GIS Sidewalk Layer for Bellevue**



**FIGURE 2 Sample Aerial of Level 4 Pedestrian Access**



**TABLE 1 – Bicycle Mode Share by Index Value**

Index Value	1	2	3	4	5
Urban	NA	0.6%	1.0%	1.5%	1.9%
Suburban and Rural	0.2%	0.4%	0.5%	0.6%	0.7%
Industrial	0.0%	0.1%	0.2%	0.5%	1.4%

**TABLE 2 – Pedestrian Mode Share by Index Value**

Index Value	1	2	3	4	5
Urban	NA	0.2%	1.6%	2.9%	4.2%
Suburban and Rural	0.1%	0.4%	0.8%	1.1%	1.4%
Industrial	0.1%	0.3%	0.7%	1.7%	4.2%