

Evaluating the Effects of Transit Station and Access Improvements

Part I: Quantifying the Value of Improvements

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The goal of the Congestion Management and Air Quality (CMAQ) program is to improve air quality by reducing auto use and highway congestion. The effects of improving transit service by extending service, reducing travel times, increasing speeds and lowering fares are generally well understood and are represented in conventional travel forecasting models. Much less well understood are how more general improvements in transit stations and access to transit affect transit ridership and, in turn, highway volumes and air quality.

This paper describes work that was conducted to quantify the effects of changes that could be made to the Chicago rapid transit system's stations and central area pedestrian access to improve conditions for existing riders and attract new riders. The study was based on an in-depth computer-based survey of a sample of people who either currently use rapid transit or who make trips that could reasonably be served. The preference information was collected using hybrid conjoint methods whereby the survey respondents trade off the features as they would when making their actual travel choices.

The study found that a modernized station provides an equivalent benefit of approximately \$0.23 to \$0.37/trip depending on the specific components included in the renovation. Perceived benefits of individual components such as landscaping, lighting, security, improved mezzanines and better weather protection were found to vary in value from \$0.02 to \$0.05/trip. Enclosed walkways for downtown stations have an overall value of about \$0.11/trip but this value increases during inclement weather.

These equivalent benefits can be used with travel forecasting models to evaluate the impacts of the potential station improvements on rapid transit and auto use and the resulting air quality impacts, as described in a companion paper.

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INTRODUCTION

The goal of the Congestion Management and Air Quality (CMAQ) program is to improve air quality by reducing auto use and highway congestion. Improvements in public transit can reduce traffic volume. The effects of improving transit service by extending service into new areas, reducing travel times, increasing speeds and lowering fares are generally well understood and are represented in conventional travel forecasting models. Much less well understood are how more general improvements in transit stations and access to transit affect transit ridership and, in turn, highway volumes and air quality.

The purpose of this study was to identify the types of changes that could be made to the Chicago Transit Authority (CTA) rapid transit system's stations and pedestrian access to improve conditions for existing riders and attract new riders. The study was based on an in-depth survey of a sample of people who either currently use the CTA rapid transit system or who make trips that could reasonably be served by the system. The survey questionnaire collected information about the respondents' current use of transit and about their preferences among a wide variety of transit station features. The preference information was collected by having the respondents compare various combinations of these features, trading off the features as they would when making their actual travel choices.

This report outlines the approach that was used for the study, the key findings from the survey research that was conducted and the procedure that can be used to apply the results to calculations of transit ridership/air quality benefits. The report appendices contain detailed tabulations from the survey data.

THE STUDY'S APPROACH

The benefits that could accrue from improving transit stations depend both on the preferences of travelers and on the current condition of the stations. The focus of this study was on measuring the preferences of travelers but the sampling was conducted in a way that allows differences among stations to be accounted. The results of the survey can thus be applied to the rapid transit stations as they are currently configured as well as to the stations as they are improved.

The survey instrument that was designed for the study used conjoint analysis to measure preferences among transit station features. Conjoint analysis is a behavioral intention research technique in which individuals trade-off (consider jointly) levels of attributes so that the relative importance, or utility, of the attributes and levels can be determined. There are different types of conjoint analysis and variations on the implementation of the concepts. Two primary types of conjoint analysis, Adaptive Conjoint Analysis ("ACA") and Choice Based Conjoint ("CBC") were used in combination in this study, employing advantages that each approach offers.

Adaptive Conjoint Analysis ("ACA") was developed in the 1980s as a market research tool to estimate consumer preferences among larger numbers of product features ("attributes") than could be evaluated using the conjoint methods that had been previously developed. ACA is a computer-based method that statistically estimates each respondent's preferences as the survey progresses and "adapts" the questions in a way that allows the effects of the many features to be measured. ACA is a useful tool for developing information about the relative preferences among many features but it does not measure the interactions among those features.

Choice Based Conjoint ("CBC") or stated preference methods that have traditionally been used in transportation planning surveys can be used to measure those effects among a smaller number of features. Choice-based conjoint can also be used to estimate interaction effects among attributes and to more accurately predict the utility of price and the dollar value of the features against which it is traded-off.

The survey questionnaire that was developed for this study used ACA to measure respondents' relative preferences among 14 transit station-related features that were selected for analysis:

1. Way of Getting to Another Floor
2. Spacious Platform
3. Protection from Weather on Platforms
4. Active Neighborhood
5. Station Area Landscaping
6. Bicycle Storage
7. Interior and Exterior Lighting
8. Security Cameras
9. Police Presence
10. Real-Time Schedule Information
11. Mezzanine Appearance
12. Reduced Noise
13. Maps and Attraction Information
14. Cleanliness

For each of these features, up to five levels were specified. In addition, to quantify air quality benefits requires that the levels of preference for each of these features be related to a service feature that is included in a travel demand forecasting model. For this study, levels of preference for the 14 station features were measured relative to the type of station access and three key transit service variables: transit fare, travel time and train headway. The resulting 18 features is many more than could be measured using the stated preference methods that are most commonly used in transportation planning surveys.

The ACA approach for this study included three parts. First, the rank order of the levels within each attribute was determined. Second, the best and worst levels of each attribute were displayed and the respondent indicated on a five-point scale the importance rating for obtaining the preferred level of that attribute. This rating information is used to determine the importance of one attribute relative to another for each individual respondent. Third, a series of pair-wise trade-off scenarios were presented with two or three attributes shown at a time. In each scenario, respondents were asked to choose between a highly valued level of one attribute and a highly valued level of another attribute (Figure 1). Each highly valued level is paired with a less preferred level of the other attribute. Respondents use a nine-point scale to indicate the pair they prefer and the strength of their preference. Each pair-wise trade-off question is customized using a respondent's answers to previous questions.

Figure 1: Example ACA Trade-Off Screen

Which improvements would you prefer for the stations that you use?
(Assume all else about the stations is acceptable.)

LEFT OPTION			RIGHT OPTION	
Platform area has SOME protection from wind, rain, and snow	and	OR	Platform area has GOOD protection from wind, rain, and snow and is HEATED	and
Train arrives every 4 minutes			Train arrives every 8 minutes	

4 3 2 1 0 1 2 3 4
prefer the left option no preference prefer the right option

NEXT Question 1 of 20

After the ACA section, respondents were given information about potential future improvements to the Chicago CTA train stations. The improvements were described as a subset of the station feature improvements that were shown previously in the ACA level descriptions. Most attributes that were tested in the ACA section were included in the definition of a “modernized station” (Figure 2). A separate survey screen expanded the modernized station concept by describing a modernized station with “architectural” features in the survey, includes additional features beyond those that make up a modernized station (Figure 3). These definitions were presented prior to the stated preference trade-off screens, so that the two levels of a hypothetical modernized station could be traded off in the upcoming stated preference section.

Figure 2: Definition of Modernized Station Presented to Survey Respondents

When Chicago CTA train stations are modernized, they will be completely redesigned and rebuilt. For the next section, assume travel time and time between trains are unchanged and a “MODERNIZED” station includes these potential station improvements you learned about in the previous section:

- Renovated entrance and mezzanine
- Well lit station interior and exterior
- Good protection from wind, rain, and snow on platform
- Graffiti-free surfaces
- Stairway and elevator to a spacious platform
- Reduced noise levels on platform
- Improved information about neighborhoods and attractions
- Well landscaped outside station area

Figure 3: Definition of Architectural Design Presented to Survey Respondents

Additional “ARCHITECTURAL DESIGN” features would include:

- Artwork and creative design in mezzanine and platform area
- Restoration of quality historic features or designs
- Creative use of color and lighting

In some cases this “MODERNIZED” with “ARCHITECTURAL DESIGN” station will be one of your choices.

Figure 4: Example Stated Preference (CBC) Survey Screen

Under the weather condition listed, which option would you prefer for your trip?

Assume the weather is: **Snow or rain**

OPTION 1	OPTION 2
Weather protected enclosed walkway available for MOST of your route to or from the downtown station	Weather protected enclosed walkway NOT AVAILABLE for your route to or from the downtown station
Travel time on train is 4 minutes LESS than current travel time	Travel time on train is 2 minutes LESS than current travel time
Stations are MODERNIZED	Stations are MODERNIZED
Fare is 25¢/trip MORE than current fare	Fare is 25¢/trip LESS than current fare

I prefer Option 1 when the weather is: **Snow or rain**

I prefer Option 2 when the weather is: **Snow or rain**

NEXT Question 1 of 8

In a second trade-off section, stated preference (CBC) methods were used to measure the overall effects of key service variables, including a package of the 14 station attributes (“modernized station”), pedestrian walkways, weather and the transit service variables of travel time and fare (Figure 4). A total of five attributes (three with three levels, two with four levels) were tested in the CBC trade-off section (Table 1).

Table 1: CBC Attributes and Levels

Attributes	Levels
Station Modernization	1 Stations are MODERNIZED with ARCHITECTURAL Design 2 Stations are MODERNIZED 3 Stations are NOT MODERNIZED
Pedestrian Walkways	1 Pedway available for ALL of route to/from station 2 Pedway available for MOST of route to/from station 3 Pedway NOT available for route to/from station
Fare	1 Fare is 25¢/trip LESS than current fare 2 Fare is 10¢/trip MORE current fare 3 Fare is 25¢/trip MORE than current fare 4 Fare is 50¢/trip MORE than current fare
Travel Time	1 Travel time on train is 4 minutes LESS than current travel time 2 Travel time on train is 2 minutes LESS than current travel time 3 Travel time on train is the SAME as current travel time
Weather	1 Below freezing 2 Raining or snowing 3 Hotter than 80 degrees 4 Moderate temperature, dry

The stated preference section relied primarily on a two-choice fixed fractional factorial experimental design, with a randomized component. The orthogonal design, which allows collection of the most information possible with the fewest questions, included three or four variables, depending on the respondent’s origin and destination stations. Respondents whose trip did not include a station within the downtown area were not presented with the pedestrian walkway attribute. For the weather attribute, a random one of the four levels was selected for each screen and applied to both options shown on the screen at that time. The 16-experiment design was presented to respondents in randomized combinations and order on eight survey screens. The stated preference responses were used to compute the fare and travel time equivalents of the station features.

The questionnaire collected information about respondents’ use of the CTA rapid transit system, such as the stations where they get on and off the train, the amount of time they spend making the trip, how they get to and from the stations, and the frequency with which they ride the train. Additional background data included gender, age, employment status, zip code, and income. This current trip information and background data can be used to segment the survey sample.

The instrument that was used to administer the questionnaire was a computer-assisted self interview (“CASI”). The questionnaire was programmed so that it could be administered on stand-alone laptop computers or over the Internet. Clusters of laptop computers, including some with touchscreens for those unfamiliar with computers, were set up in a variety of locations within the CTA rapid transit system service area. Two or three survey staff attended each cluster. Potential respondents were screened and recruited to complete the questionnaire on the computers or, for those with access, over the Internet.

The survey was administered over a 12-day period in September 1999 to a total of approximately 500 travelers. The survey sites included a variety of public and private buildings in a variety of geographic locations.

SUMMARY OF FINDINGS

TRANSIT SERVICE EFFECTS

The primary purpose of the study was to determine how changes in transit stations would benefit travelers. One indicator of this is the amount that travelers are willing to pay for station-related features. This “willingness to pay” can be determined by having travelers compare options that involve different fares and features, as was done in the conjoint portions of the survey. The stated preference conjoint measured relative preferences among different levels of transit fare, travel time, walkway extent and overall station design. This analysis indicates that the surveyed travelers, on average, value their travel time at about \$0.10/minute. They also value each minute of reduction in train headways at about the same level – \$0.10/minute. Since average wait times are approximately one-half of the headway, this means that the effective value of average wait time is about twice that of travel time. These values of time are within the range of what is typically found in travel demand models and are consistent with the findings of other studies that have been conducted in the Chicago area.

OVERALL STATION RENOVATION

The stated preference responses show that travelers place an overall value of about \$0.23/trip on the full package of station improvements¹. This is the average value of the package of station features included in the “modernized station” definition. Respondents value improved architectural design in conjunction with station improvements at an extra \$0.02/trip, so a modernized station with architectural design would be worth \$0.25/trip on average. The utility of a modernized station would be approximately equivalent to 2.3 minutes of travel time savings without the architectural design and 2.5 minutes with the architectural design.

The average value of a modernized station varied somewhat depending on which CTA train line the respondent travel on. Respondents who boarded the train in downtown valued a modernized station at about \$0.20/trip and architectural design provided little additional worth, whereas respondents whose trip originated along the Blue Line – 54 Cermak indicated that a modernized station would have a value of about \$0.28/trip and architectural design would be worth an additional \$0.04/trip (Table 3).

After the stated preference section, respondents were asked what style of renovation they would prefer if the station where they got on the train were to be modernized. Overall about one third of respondents preferred each of the three styles: historic preservation, contemporary, and futuristic. Among people who preferred the contemporary style there was a nearly even split between subtle and bright colors. Style preference by line suggests there is a somewhat stronger preference for historic preservation for the stations on the northern lines, more of a tendency toward a futuristic style in the southern sections, and, to the west, a general preference for contemporary with slight preference for subtle over bright colors (Figure 5).

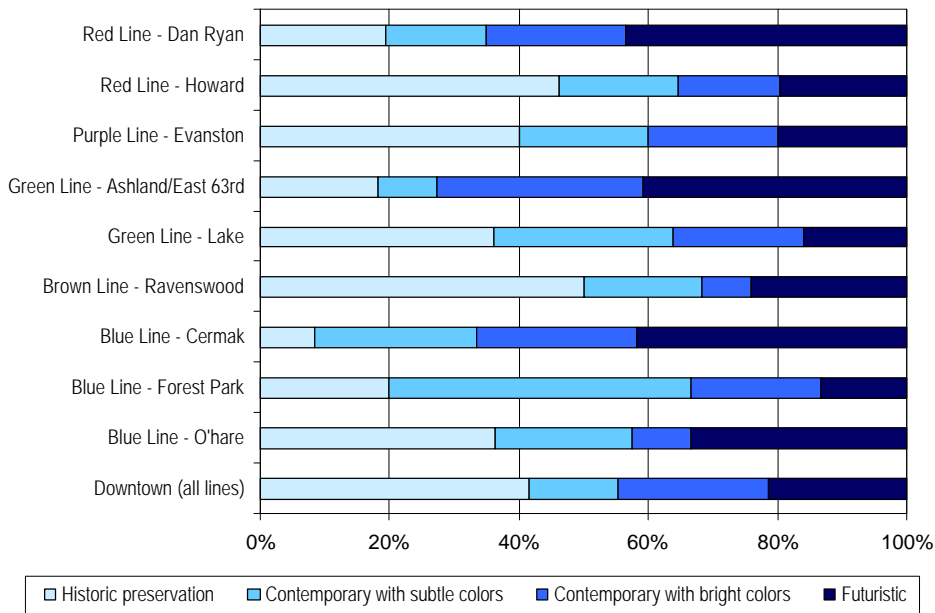
¹ The value of the full package of station improvements of \$.23/trip assumes that improvements are made at both the origin and the destination. The implied value of improving just one station would be about half that or \$0.115/trip.

Table 3: Average Value of Modernized Stations by CTA Rapid Transit Line of Trip Origin

	MODERNIZED	MODERNIZED with ARCHITECTURAL DESIGN	Number of Respondents
Total	\$0.23	\$0.25	508
Blue Line - O'Hare	\$0.27	\$0.32	40
Blue Line - Forest Park	\$0.25	\$0.34	16
Blue Line - 54 Cermak	\$0.28	\$0.32	14
Brown Line - Ravenswood	\$0.24	\$0.25	68
Green Line - Lake-Harlem	\$0.21	\$0.22	27
Green Line - Ashland-East 63rd	\$0.22	\$0.23	21
Orange Line - Midway	\$0.25	\$0.24	32
Red Line - Howard	\$0.21	\$0.23	108
Red Line - Dan Ryan	\$0.21	\$0.24	137
Downtown - Elevated	\$0.20	\$0.20	20
Downtown - Subway	\$0.20	\$0.20	18

*Note: Two lines are excluded from this table because of a small number of respondents.

Figure 5: Station Renovation Style Preference By Line



INDIVIDUAL STATION FEATURES

The relative values for individual features of a “modernized station” were estimated using adaptive conjoint and scaled² so that the total value of the ACA levels that comprise the modernized station equaled the value for all of these features together as estimated from the stated preference responses. The values of the additional attributes tested were scaled relative to the values of the basic station renovation components of the “modernized station.”

² The initial values for individual station features, based on ACA analysis only, were higher.

Figure 6: Value of Station Improvements

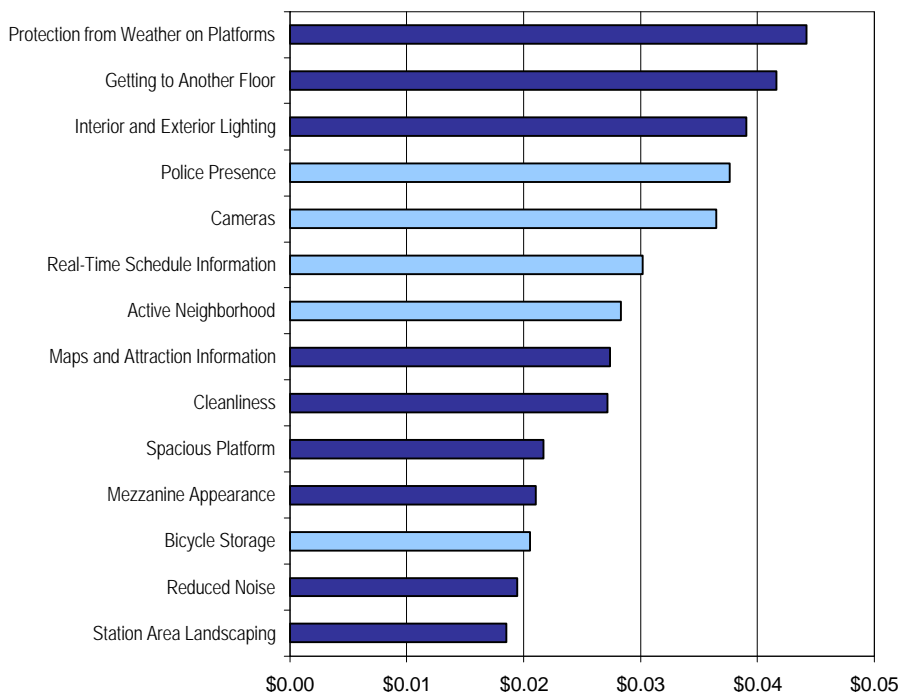


Figure 6 shows the values that were computed for each of the station features tested. In several of the cases, more than one level of the feature was tested and, for these, the values shown here are for the most highly valued among those levels. The dark colored bars represent the attributes whose values are included in the scaling adjustment, and the lighter colored bars indicate the attributes that were not part of the modernized station concept.

The values for individual station features range from about \$0.02/trip to almost \$0.05/trip. In general, the highest values are given to features that affect physical comfort (weather protection, moving between floors) and personal security (lighting, police, security cameras). However, some of the other features have perceived values that could, plausibly, be reasonably high when compared to the costs of the station improvements required to accrue the benefits. These values can be converted into equivalent travel time benefits by dividing them by the computed value of travel time, which is about \$0.10/minute. For example, a value of \$0.05 would be equivalent to a half-minute travel time savings.

While the modernized station concept is valued at \$0.23/trip overall, the value of any other set of station improvements could be computed as the sum of the values of the individual components. For example, providing a “modernized station” plus a security camera would increase the total value by \$.04 to about \$0.27/trip. The sum of the values of all the station features presented in the survey is about \$0.40/trip.

The sections that follow describe in more detail the effects of each of these features. Different levels of each feature were tested: a base (least desirable) level and one or more additional levels. The value for the base level is set to zero and the values associated with the other levels, relative to that base, are shown.

Protection from Weather on Platforms

Platform area has GOOD protection from wind, rain, and snow and is HEATED	\$ 0.046
Platform area has GOOD protection from wind, rain, and snow	\$ 0.025
Platform area has SOME protection from wind, rain, and snow	\$ -

Overall, this was the most valued of the features tested. Weather protection is obviously an issue only at the above-ground stations, however, for those stations respondents indicated a relatively high value for protection from wind, precipitation and cold temperatures. The additional value of heating is almost as great as the value of basic protection from the other elements. This value might have been even higher had

the survey been conducted in the winter as opposed to the mild late summer period when it was administered.

Getting to Another Floor

Elevator, escalator, and stairs	\$	0.043
Elevator and stairs, but no escalator	\$	0.022
Stairs only, with no elevator or escalator	\$	-

Options for vertical circulation are also highly-valued features. The values associated with elevators and escalators appear to be approximately equal. The combination of the two adds over \$0.04 of value per trip.

Interior and Exterior Lighting

Station exterior and interior are WELL lit	\$	0.040
Station exterior and interior are DIMLY lit	\$	-

Three features related to personal security were tested. Overall, all three were found to have approximately equal value. The difference between dimly and well lit stations provides a value of \$0.04, comparable to the two other security-related features listed below.

Police Presence

Uniformed police are present	\$	0.039
NO visible police presence	\$	-

In the pre-test survey, the presence of guard dogs was also tested but the reaction to the dogs was mixed. By contrast, the presence of uniformed police was more generally indicated to be a valued feature.

Cameras

Security cameras are present	\$	0.038
NO security cameras	\$	-

The value of security cameras is almost as high as that of active police presence. The total value of the three security elements is a little less than \$0.12/trip.

Real-Time Schedule Information

Signs at stations showing minutes until next train arrives	\$	0.031
NO signs at stations showing minutes until next train arrives	\$	-

Traveler information signs showing the amount of time until the next train arrives were given a value of a little over \$0.03/trip. This amount is sufficient to offset an additional headway of about 20 seconds.

Active Neighborhood

Station area is a BUSY neighborhood or retail area	\$	0.029
Station area has little activity and some empty buildings or lots	\$	-

The level of activity around a station can have two types of value: the presence of retail shops and services along the access route provide convenience to the traveler and they can provide the perception of additional security. The overall value of this station feature is about \$0.03/trip.

Maps and Attraction Information

Information and maps of neighborhood and attractions at stations	\$	0.028
NO information and maps of neighborhood and attractions at stations	\$	-

Overall, information about the area around the station has a value of a little less than \$0.03/trip. While this value might vary among types of travelers, overall there is a moderate value from this relatively low-cost feature.

Cleanliness

Station interior and exterior have NO litter or graffiti	\$	0.028
Station interior and exterior have SOME litter and graffiti	\$	-

The cleanliness of a station is perceived as having a moderate value to travelers: also a little less than \$0.03/trip overall.

Spacious Platform

Spacious platform with few obstructions	\$	0.023
No change in platform space	\$	-

Transit users indicated that there is some value – a little over \$0.02/trip – in having platforms without as many posts and other obstructions and, generally, with additional space for waiting. In the pre-test version of the questionnaire, the effects of additional benches were tested and it was found that their value was lower.

Mezzanine Appearance

Renovated entrance and mezzanine	\$	0.022
No change in entrance and mezzanine	\$	-

Travelers indicated that improving the overall appearance of the entry area would add a value of about \$0.02/trip.

Bicycle Storage

Covered bicycle storage	\$	0.021
Bicycle racks	\$	0.012
No bicycle storage	\$	-

Providing open bicycle racks at stations was given a value of about \$0.01/trip, however providing some form of covered storage doubled that value to about \$0.02/trip.

Reduced Noise

Reduced noise level on station platform	\$	0.020
No change in noise level on station platform	\$	-

Transit users value some level of reduction in noise on the station platform at about \$.02/trip.

Station Area Landscaping

Outside station area is WELL landscaped with trees and flowers	\$	0.019
Outside station area is NOT landscaped with trees or flowers	\$	-

Although station area landscaping was given the lowest value overall of the features tested, its value is still close to the \$0.02/trip of the slightly higher-rated features listed above.

DOWNTOWN PEDESTRIAN WALKWAY ACCESS

In addition to the value of the station features, the value of the type and extent of walkway access is of direct interest to this study. A pedestrian walkway attribute was included in both the Adaptive Conjoint Analysis (ACA) and the Choice-Based Conjoint (CBC) sections of the survey. In both cases the survey was dynamically customized so that only respondents who either boarded or alighted the CTA train using a downtown station were presented with the covered pedestrian walkway (pedway) attributes.

The value of having a covered pedestrian walkway (pedway) available for none, most, or all of the walk to or from the downtown station was tested in the stated preference section. These three levels were tested along with levels of fare, travel time, and station modernization, attributes. A weather attribute was also included so that the interaction effects between the weather conditions and pedway extent could be determined. In the ACA trade-off section an attribute that measured the importance of having retail service along the pedway was included.

The perceived value of station walkway access was found to depend on the weather. In non-inclement conditions, the value of an enclosed walkway along all or most of the route to the station is about \$0.11/trip. The value of a walkway with no retail along it is about one-half the value of one with retail facilities (or approximately \$.06/trip). As Table 4 shows, the value of a pedway along the full route to or from the station increases to a maximum of about \$0.35/trip in cold weather (below freezing) and \$0.28 during rain or snow. For hot weather, the value of a pedway along the full route is slightly lower than a pedway along part of the route, indicating that overall there is a slight preference to walk outdoors for part of the time on hot summer days.

Table 4: Value of Pedway Availability for Downtown Stations

	Most of the way	All of the way
Moderate temperature, dry	\$0.11/trip	\$0.11/trip
Hot - warmer than 80 degrees	\$0.11/trip	\$0.09/trip
Snow or rain	\$0.25/trip	\$0.28/trip
Below freezing	\$0.27/trip	\$0.35/trip

These values for walkways were developed based only on responses from travelers who used downtown stations, as it would be difficult to develop enclosed walkways at outlying stations. A walkway either all or most of the way could provide additional value for a trip that uses a station in downtown. This value is supplemental to the value of other station features that could be added or improved, and the degree of value varies depending on the extent of the pedway and the weather conditions. If the weather is moderate about half the time, hot about one fifth of the time, raining or snowing another one fifth of the time, and below freezing the remaining ten percent of the time, the approximate overall value for a walkway most of the way would be about \$0.16/trip. Providing the walkway would all of the way would increase the value to \$0.17/trip. Changing the weather assumptions would affect the overall value.

USING THE RESULTS

The values derived from this study can be interpreted directly to determine the overall value of station an access improvements. The computed dollar benefits represent the amounts by which fares could be increased while retaining the same overall attractiveness to users. If fares were increased by this amount, there would be no net benefit to existing users and no inducement to others to use the system – the improvements would be a “wash”. If fares were increased by an amount less than the estimated benefits for an improved feature, the additional benefits would become “consumer surplus” making the system overall more desirable to existing users and more desirable to potential new users.

Assuming that improvements were made in one or more of the features, and that fares were not adjusted to exactly compensate for those improvements, there would be some increase in estimated ridership. That ridership increase can be calculated using existing travel demand models by representing the improvements as an effective fare (or travel time – where travel time benefits are computed as 10 minutes travel time reduction/\$ benefit value) decrease to a particular station. The effective fare (or travel time) decrease would be calculated as the total benefit value of the improvements minus the amount of any actual fare increase.³

The travel demand model should show increases in transit use and decreases in auto use and highway volumes from any station improvement whose benefits are not offset by fare increases. These changes can then be associated with changes in air quality using either a regional meso-scale emissions model or a micro-scale air pollution dispersion model⁴.

CONCLUSIONS

This survey research and analyses show the benefits that can be derived from a wide variety of rapid transit station and access improvements. A “modernized station” that includes key features provides an equivalent benefit of approximately \$0.23/trip. The effects of the individual components of this modernized station and of other station features were found to vary in value from \$0.02 to \$0.05/trip. Enclosed walkways for the downtown stations have an overall value of about \$0.11/trip but this value increases during inclement weather. All of these values vary across the population; in some cases, by considerable amounts. For example, bicycle storage and police at the stations are much more important to some segments of the population. On the other hand, features such as improved lighting are more uniformly valued across the population.

³ There is at least one subtlety in this application. The benefits should be applied at only one end of the trip so that improvements are not double-counted.

⁴ A preliminary analysis of the impact of station modernization and pedestrian walkway expansion on transit ridership and air quality is presented in an accompanying paper; “Transit Station and Pedestrian Walkway Improvements: Estimating Transit Ridership and Air Quality Impacts”, Do H. Nam, Parsons Transportation Group, 2000.

The results of this study can be used to estimate the effects of each of these improvements on transit ridership, highway traffic and, ultimately on air quality. Performing that type of analysis will provide an additional measure of justification for future system improvements.