Queens Subway Options Study Station Access Forecasts

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ABSTRACT

In 1968, New York's Metropolitan Transportation Authority (MTA) embarked on a large subway expansion program. Two projects were started and are nearly finished in the program affecting the fast growing Borough of Queens: a new East River tunnel from 63rd Street, Manhattan; and a new subway on Archer Avenue in eastern Queens. Escalating costs and fiscal crises halted further work. These two unconnected sections, which are intended to relieve overcrowded conditions, will provide no relief unless linked in some way. The Queens Subway Options Study (QSOS) evaluated five alternative courses of action. Key evaluation criteria included the degree of overcrowding relief to existing Queens lines, and the extent to which committed capital investment is utilized. This paper contains a description of an evaluation methodology developed for this study that combines computer-based Urban Transportation Planning System (UTPS) network assignment techniques, 1980 Census socioeconomic tract data, and detailed land-use information, especially as they relate to the area of influence of proposed heavy rail transit stations. The potential for proposed stations to attract riders from overburdened existing facilities demands realistic assessment of trip origins and destinations, station access modes, and ridership. The specific travel demand characteristics for each station are needed to: (a) evaluate the options, (b) dimension the frequency of service provided on affected rail and feeder bus lines, and (c) evaluate the environmental costs of introducing a new service into developed urban environment having a complex existing public transportation network. Characteristics of travel behavior and land use within station tributary areas provided by this methodology can be used to prepare functional designs to accommodate transfer demands that minimize negative impacts and enhance development opportunities.

The 230-mi New York City subway links three of New York City's outer boroughs and that portion of Manhattan north of 60th Street to the Manhattan Central Business District, a 9-mi^2 district containing approximately 2 million jobs. Housing and population growth in the Borough of Queens, the last of the outer boroughs to develop, has outpaced subway facilities that had been completed by 1955. As a result, subway lines that link Queens and Manhattan are among the most heavily used and overcrowded heavy rail transit facilities in the United States. The 53rd Street Tunnel, the East River crossing with the highest weekday use, regularly carries more than 55,000 passengers during the morning peak hour on one inbound track.

In response to the need to alleviate this congestion, an ambitious construction program was initiated in the mid-1960s. The heart of this plan was a new East River Tunnel between Manhattan and Queens connecting with new and existing subway lines in both boroughs. Although it was eventually recognized that the entire plan could not be carried out in the near future because of cost escalation and New York's fiscal problems, construction of the 63rd Street Tunnel together with connections to two existing Manhattan lines had already begun, and is nearing completion. In Queens, however, the tunnel has not yet been linked to any existing lines, and instead terminates at an isolated station at 21st Street shortly after crossing the East River. In addition, a small segment of one of the other planned new lines, the Archer Avenue Subway and its connections to two existing Queens subway lines in eastern Queens, is also virtually complete, but not yet in use. The New York City Transit Authority (NYCTA), a constituent agency of the Metropolitan Transportation Authority (MTA), constructed these lines and also operates New York City's Subway System.

The New York MTA assembled a study team to carry out the Queens Subway Options Study (QSOS). The team consisted of members of the MTA Planning Department, including systems analysis personnel and staff urban planning consultants, as well as selected outside consultants. In order to select a preferred improvement option that would effectively utilize the facilities currently under construction and relieve overcrowded conditions that now prevail in the Queens corridor, the following five options were evaluated:

1. No additional construction
2. Queens bypass express
3. Queens Boulevard line local connection
4. Subway/Long Island Rail Road (LIRR)--Montauk transfer
5. Montauk-Archer Avenue subway connection

Under the first option, only the work now nearing completion would be finished and placed in operation, and no further construction would be undertaken. This option requires no further capital expenditures, and no new stations are involved except for opening the six under construction. However, extensive feeder bus changes are proposed to several of the new stations.

The second option represents the original 1968 proposal that was deferred when costs escalated and New York City's fiscal crisis hit. Although found to be the most costly option, it provides the greatest improvements in service. Two new stations and one rebuilt station are involved.

The third option is a short link from the end of present construction to a connection with the nearby local tracks of the overcrowded four-track Queens Boulevard Subway line. After making certain service adjustments, the local tracks have capacity available to utilize the new 63rd Street Tunnel to approximately one-half of its capacity, thus affording a meaningful degree of relief. This is the least costly of the "build" options. Although no new stations would be built, a new subway-subway transfer connection between two nearby stations is needed to restore a link disrupted by the service adjustments.

The final two options make use of the lightly used, mostly freight Montauk Branch of the LIRR. Under the fourth option, the LIRR, an MTA-owned facility, would operate service from Southeast Queens to a new under-over transfer station to be built in western Queens where passengers would change to 63rd Street subway trains to complete their journey to Manhattan. In addition to this new suburban rail-subway transfer station, six existing LIRR stations would also be upgraded. Feeder bus service would be enhanced, and some intermodal bus transfer facilities provided.

Under the last option, subway trains would operate directly over the tracks of part of the LIRR Montauk branch to a connection with the nearly completed Archer Avenue Subway. Three new stations would be built and one existing LIRR station would be upgraded, and feeder bus service would be enhanced. One of the new stations, Fresh Pond, is the example discussed in this paper. The five options are shown in Figure 1.

With the exception of the first option, each option assumes construction of new lines that would permit the integration of the new tunnel with existing Queens subway lines. The QSOS was structured to adhere to UMTA Alternatives Analysis and Draft Environmental Impact Statement (AA/DEIS) procedures in order to meet federal requirements. Because the options involve new subway services and stations that will be integrated into a complex existing system, the study objectives are broader than would be the case for a single line, new start system.

One of the most important system-wide study objectives was the need to forecast the passenger volumes that use each East River crossing. This was critical to the study because the utilization of the new 63rd Street Tunnel and the relative change in overcrowding of the parallel crossings were important criteria in option evaluation. The nature of subway service in Queens is such that the choice of Manhattan entry point is a rather complex issue. Each line ties into a unique service area in Manhattan, but the rider is generally provided with a choice of routes before leaving Queens. This choice is provided by either the use of multiple routes serving the same station (flexing), or by the provision of relatively convenient free transfers. The new routings assumed for the various options increased the range of choice to include the new 63rd Street Tunnel. Consequently, the study team had to forecast paths based on extensive origin and destination data and a complex route structure.

The other major, system level concern that influenced station use analysis is the complexity of the extensive bi-modal subway and feeder bus system that is already in place in Queens. Each new station or revised bus route will draw riders from stations or routes that are currently in use. Normally, a new transit line draws trips from the automobile mode, so the former path of the diverted trip is not a matter of concern. However, in many parts of Queens, transit is by far the dominant mode for Manhattan-bound work trips. (In some places, the share exceeds 80 percent of total travel.) Consequently, trips using the new stations are generally diverted from another station and line. Because this shift, if it results in a reduction in crowding, is desired, the study team had to closely account for every trip to measure system loading for each option.

In addition, the complexity of the transit system coupled with the rather dense development in many parts of Queens increases the importance of local neighborhood characteristics. In cases where stations are close together, a physical barrier or an unattractive land use might have a more important influence on station choice than simple walking distance. In other instances, two bus routes passing within blocks of each other might serve two totally different subway lines.

These factors determined the choice of an evaluation methodology that combined both system-wide analysis and detailed station-area analysis. The main outputs expected from it are as follows:

1. Year-2000 peak-hour forecasts of subway system use reflecting shifts in station and route loading that will result from proposed new stations,
2. Ridership estimates for each proposed station by mode of access, and
3. Identification of bus and pedestrian flow characteristics.

System volumes and station ridership forecasts contribute to a justification of the choice of an option and delineate the volume and frequency of service that has to be provided in the future subway line and the feeder bus system. The volume of each access mode has a strong influence on station design with regard to modal interchange facilities and access and fare collection location. The three outputs combined contribute to determining the extent of the physical and social impact of the location of a station in each particular neighborhood.

EVALUATION APPROACH

In order to meet the specific requirements stated previously, the study team developed an analysis approach that combined computer-based UTPS network assignment techniques with a more fine-grained, detailed analysis of each station area's physical, land use, population, and travel behavior characteristics. The key to this approach was the juxtaposition of census tracts and UTPS zones. In this way, the census tracts could be used as the basic analysis unit for detailed analysis while maintaining controls for system level network assignments based on UTPS zones. Thus, more detailed information was included in the analysis without increasing the complexity of network coding and data processing. At the same time, the battery of planning and analysis programs available in UTPS could be used for system analysis and corridor-wide summaries.

Census tracts were chosen as the minimum physical unit for this analysis, although site level land use information was used when the distribution of housing within the tract was important. Socioeconomic and travel information data at tract level were available from the 1980 Census.

The basic information that was utilized is as follows:

1. 1980 Census data at tract level
   a. Subway work trips to Manhattan
   b. Income levels
2. New York City Department of City Planning 1981 Land Use Maps
   a. Residential locations
   b. Housing typology
   c. Physical barriers to pedestrians
   d. Street patterns

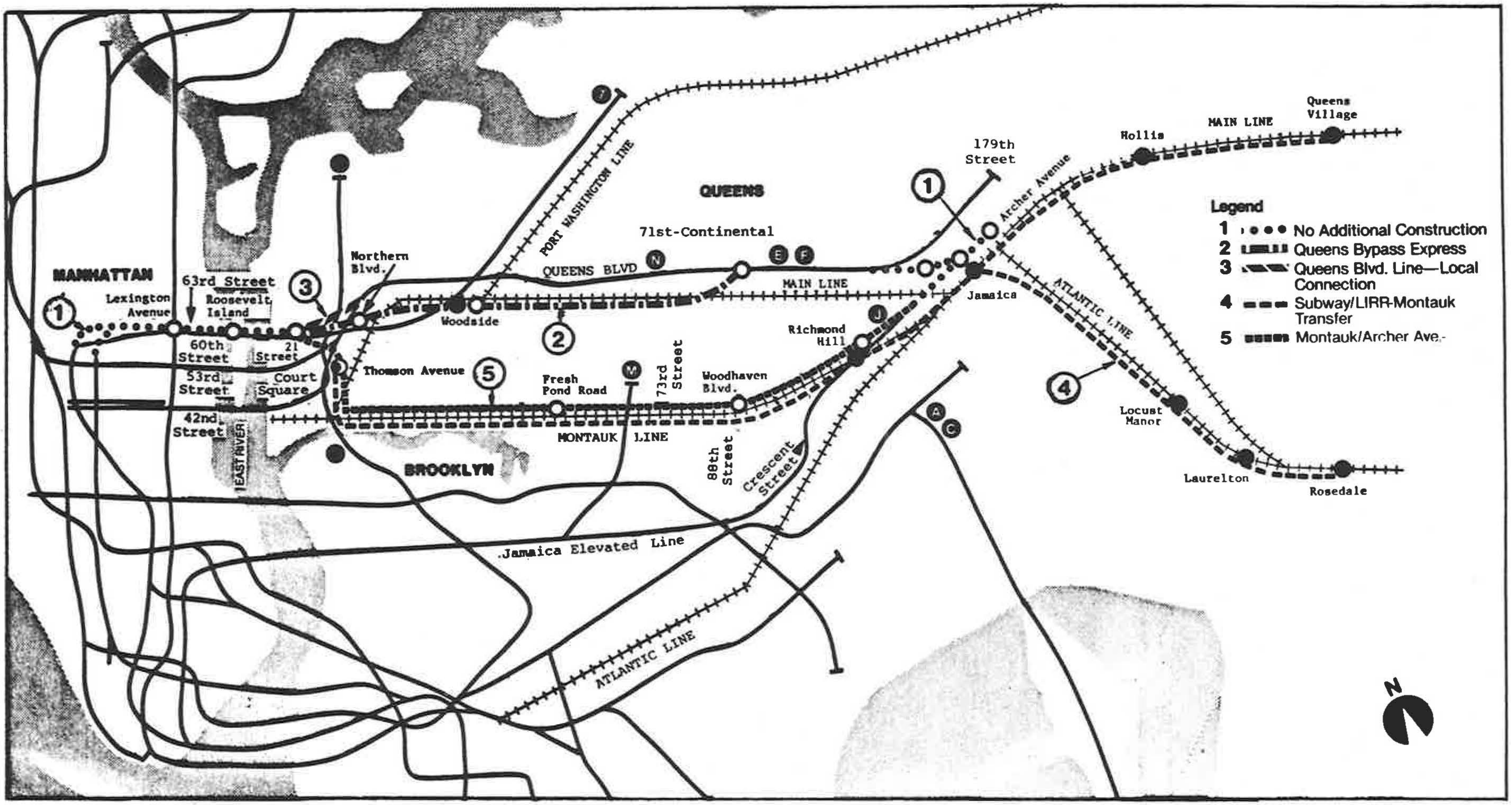

FIGURE 1 All alternatives—QSOS.

3. UTPS Trip Tables and Networks
4. NYCTA City Wide Origin and Destination Survey
5. Existing subway, bus and commuter rail schedules
6. Walking reconnaissance of the community

The City Planning Land Use Maps were adopted as a working base and all basic information was added to these maps. Census Tract boundaries and the UTPS grid were superimposed on the land use information. Existing and proposed station locations were plotted. Physical barriers to pedestrians were established. The location of trip origin location and trip densities were also plotted at the tract level. Public transportation routes for all modes available in the area were mapped on the same base. Finally, a walking reconnaissance of the community confirmed the up-to-date validity of the information and, in some cases, identified relevant new information. In this way, all basic information was visually correlated.

The analysis at the tract level is flexible and allows several simultaneous station options for each tract, even if stations may be located outside the tract. Furthermore, it is possible to assume that the tract is served by several modes of access. The share of walk access is related to the distance and accessibility to the station and the share of bus-drive access of the remaining trips is related to the future bus service availability within the tract.

Station Area Evaluation

In order to explain the station area evaluation methodology in detail, a specific case has been selected from the study area. A typical application is shown for UTPS Zone 344 for the Montauk-Archer Avenue Subway Connection Option within the Fresh Pond station area of influence. This zone constitutes a good example because it is located in an area currently being served by several existing subway stations and bus lines. Zone 344 contains the origins of most of the walking trips to the proposed Fresh Pond station. In addition, the Fresh Pond station can be expected to have the largest volume of walking trips within the Montauk-Archer Avenue Subway Connection Option, as well as the largest volume of bus-automobile trips from within its area. Some bus-automobile trips will also come from distant zones.

UTPS Zone 344 is illustrated in Figure 2 showing its relation to the Fresh Pond station and other existing stations, and to the physical barriers that impede pedestrian flow. Figure 3 shows the census tracts that are totally or partially within the zone.

The method that determines passenger volumes and mode of access to intermodal transfer facilities includes the following four phases:

- Allocation of census tract information to UTPS zones;
- Walking access determination;
- Mode allocation of nonwalk trips; and
- Year-2000 peak-hour volume projection by mode of access.

Allocation of Census Tract Information to UTPS Zones

In order to link the detailed census analysis with the UTPS network assignment analysis, each census tract segment was allocated to a specific UTPS zone. There are 17 tracts or tract segments in UTPS Zone 344. Some of them lie within two or more adjacent UTPS zones.

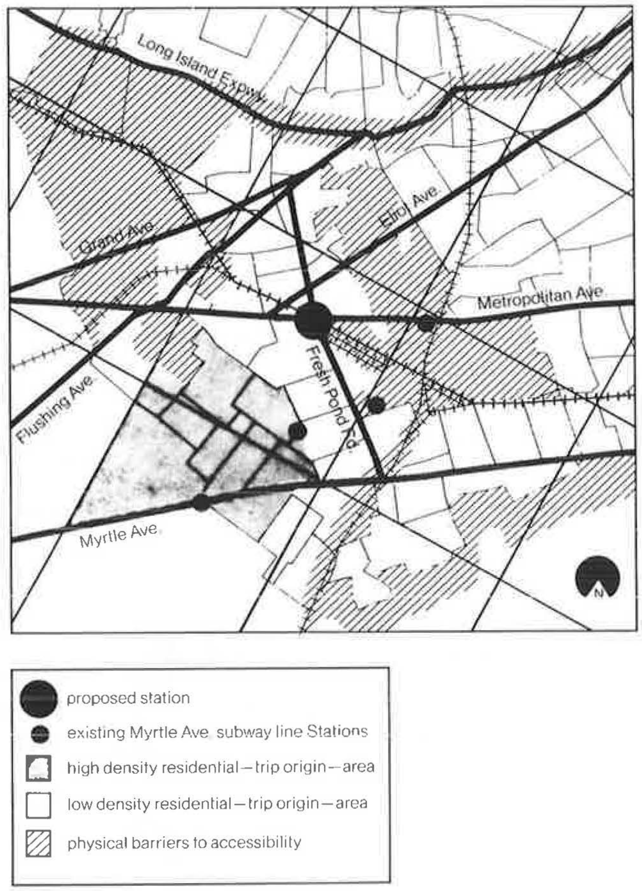

FIGURE 2 Fresh Pond station—tributary area and physical barriers.

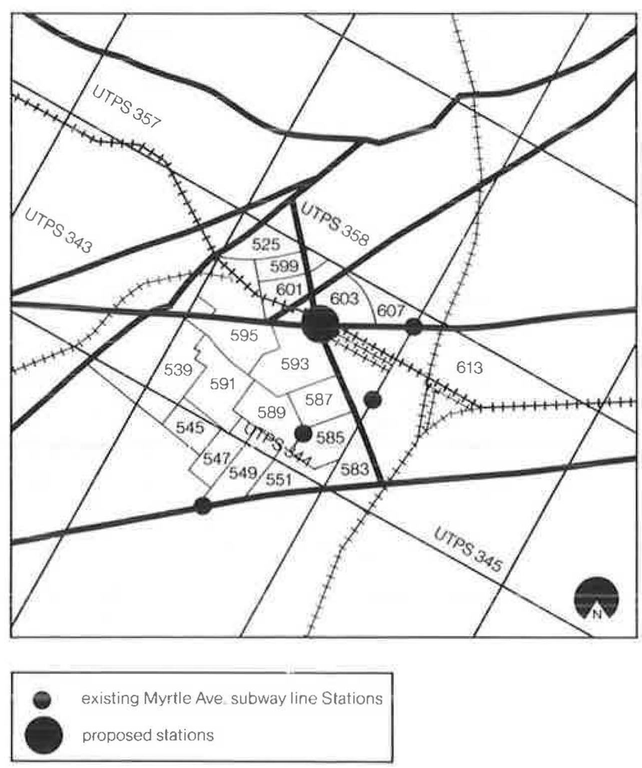

FIGURE 3 Fresh Pond station—UTPS zones and census tracts.

The data sources cited previously indicate that residential areas were generators of these trips. The land use analysis provided a good notion of densities related to housing typology. City Planning 1981 Land Use Maps indicated the following residential uses: one-family detached, one-family attached, two-family, walk-up multiple, and elevator multiple. With this information, the distribution of population within a tract could be determined. Therefore, tract allocation to UTPS zone could be conducted by considering actual resident population distribution rather than in proportion to surface area, which would have been a less accurate approach.

Walking Access Determination

1980 census tract subway trips to Manhattan were allocated by mode of access to the stations. The first mode to be allocated was the walking mode. For each census tract, real average walking distances to the station were determined. Trip origin distribution was not considered homogeneous within each tract, but was related to the actual residential distribution within it. Rather than using airline distances, walking distances were measured over the land use map that shows residential location, existing street network, and physical barriers. It was assumed that the probability that people will walk to the stations following optimal walking paths is a function of walking distances. A probit model describing this relationship was developed for the QSOS study (see Figure 4). The Citywide Origin and Destination Survey prepared by the NYCTA, was the primary source of data used to establish this probability. Only zones in Queens with characteristics similar to the study area were considered in developing this probability curve.

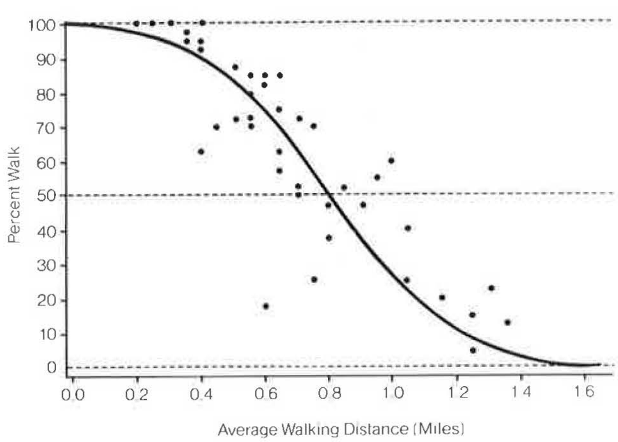

FIGURE 4 Probit walk access model.

If a tract had more than one station option on subway lines having similar destinations, it was assumed that the choice would be the nearest station. When several subway lines with different destinations were competing with the future stations, trip assignments by tract were made according to destination and time saving. In the Fresh Pond station example, the new station would compete with the existing Myrtle Avenue (M) and Canarsie (LL) lines, which are within walking distance from some tracts, and with more distant Queens Boulevard line and Flushing line stations reachable by feeder bus. Based on UTPS network and trip table values, it was determined that 25 percent of the trips would use the Myrtle and Canarsie lines to reach Wall Street areas while 75 percent of the trips had midtown destinations and would use the new station.

Allocation of Nonwalk Trips

Riders who would not be expected to walk to the stations according to the walk probit prediction because their origin was too distant from the station were assumed to use a bus or automobile to reach the station. Bus route information was combined with census tract subdivision and residential distribution in the allocation of trips to a specific bus route and station destination. The possibility of extending existing bus routes or slightly modifying them to cover more demand was also considered. Additionally, bus-automobile estimates were augmented with UTPS trips that had their origin in zones that were distant from the stations, and that the detailed method now described could not account for. The bus-automobile mode split for nonwalk trips in tracts with available bus service was made according to a model that relates the probability of automobile usage to the number of peak-hour buses serving each station. Because bus routes in the study area generally use the higher level arterial streets (freeways are extremely congested), it was assumed that automobile trips would choose the same station as bus trips. In this way, every 1980 subway work trip to Manhattan was assigned a specific station origin, a mode of access to the station, and, in the case of feeder bus, a specific bus line.

Year-2000 Peak-Hour Volume Estimation by Mode of Access

The initial allocation of trips by mode to each station was done by using tract data from the 1980 census. However, resident-based work trips could not be used for subway-system volume estimates because other trip purposes were not accounted for and no indication of time of day is included. For system analysis, the UTPS trip table and network were calibrated for the morning inbound 8:00 to 9:00 a.m. peak hour. The peak hour was used because this time period corresponds to the time of day when Queens subway riders are currently subject to extreme overcrowding. To reconcile the census work trips with peak period inbound travel, a peak adjustment factor was developed for each UTPS zone. This factor is given in Table 1 for the Zone 344 example. The 0.519 factor is typical of Queens where the dominant subway trip purpose is Manhattan-bound work travel. These peak factors were reviewed for each zone. Adjustments were made to the 1980 UTPS trip table where the factor fell outside of the expected range of variation.

Future travel for the QSOS was forecast for the morning peak hour in the inbound direction for the year 2000. First, the 1980 trip table was calibrated to reflect 1980 morning peak-hour volumes. Then, by utilizing econometric modeling techniques, the anticipated increase in peak-hour ridership was determined for the year 2000. These models established aggregate ridership controls for NYCTA rapid transit lines at the East River and western terminals of the LIRR. The forecast ridership was allocated to zones by computing zonal growth factors based on study area districts and then applying these factors to the 1980 zone-to-zone trip table. The output of this step was a detailed inventory of year-2000 travel in the study area at the zonal level.

TABLE 1 Montauk-Archer Avenue Subway Connection (Zone 344): Manhattan-Bound Workers Using Subway by Station Access Mode

		Fresh Pond Station			BMT Station		
Census Tract	Total Trips	Walk (%)	Walk Trips	Bus Trips	Walk (%)	Walk Trips	Bus Trips
601	193	75	145		25	48	
603	167	75	125		25	42	
599	53	75	40		25	35	
535	19	40	8	11			
595	252	70	176	13	25	63	
525	84	71	60	3	25	21	
539	224	29	65		25	56	103
593	465	75	349		25	116	
613	497	75	373		25	124	
587	439	75	329		25	110	
589	559	60	335	84	25	140	
591	346	65	225	17	25	87	
545	123	35	43		25	31	49
547	95	35	33	38	25	24	
549	95	20	19	52	25	24	
551	245	19	47	69	25	61	63
585	504	60	336	42	25	126	
583	83	52	43	19	25	21	
Total 1980	4,443		2,751	348[a]		1,129	215[b]
1980 PK	2,306		1,428	181		586	110
2000 PK	2,417		1,497	190		614	115

Note: PK = peak.
[a]Includes bus lines B58, B53, Q38, Q39, Q67 to Fresh Pond station.
[b]Includes bus lines B58, Q39 to BMT subway lines.

As with the peak factor, a future factor was developed for each zone. This factor was applied at the tract level so that year-2000 trips could be summarized to UTPS zone and to station of interest. It was then possible for the team to allocate year-2000 peak-hour values by census tract for each mode of access. Tract level forecasts were first aggregated at zone level for the purpose of corridor evaluation and final adjustments. Later, they were aggregated to station influence area for the purpose of station design proposals and for the evaluation of the physical and social impacts of the station on the neighborhood. Knowing the physical location of every tract with regard to stations and the existing street network, the physical impact of the demand flow for each mode could be clearly visualized.

Summary of the Zone 344, Fresh Pond Station Example

Table 1 shows the result of this methodological process for Zone 344 and all the census tracts within it, and Figure 5 shows the physical impact of the demand on the transfer area. In the case of Fresh Pond, the study team found that most of the walking trips originated from census tracts in Zone 344. In addition, some of the tracts in Zones 343, 345, 357, and 358 also generated walking trips to this station. Together, these tracts constitute the Fresh Pond tributary area. This area was also found to produce walking trips to competing stations on the Myrtle Avenue and Canarsie lines. It was estimated that the total Fresh Pond tributary area would produce 1,976 walk trips to Fresh Pond during the year-2000 peak hour. Most of these walk trips come from south and southwest of the station, where the higher residential densities are located and where the pedestrians encounter fewer physical barriers.

Bus trips to Fresh Pond and other existing stations within the Fresh Pond tributary area were also estimated in detail, allowing several simultaneous bus options for nonwalk trips from each census tract. The study team determined that the bulk of the bus trips to Fresh Pond station originated in Zone 345, which is southeast of the station, approaching the transfer from Fresh Pond Road on the B58 bus route. Other bus routes that transfer at Fresh Pond and that bring passengers from within the tributary area are lines B53, Q38, Q39, and Q67. As many as 1,500 bus transfers are expected for the year-2000 peak hour, with 1,000 of them coming from within the detailed study area and 400 from the periphery.

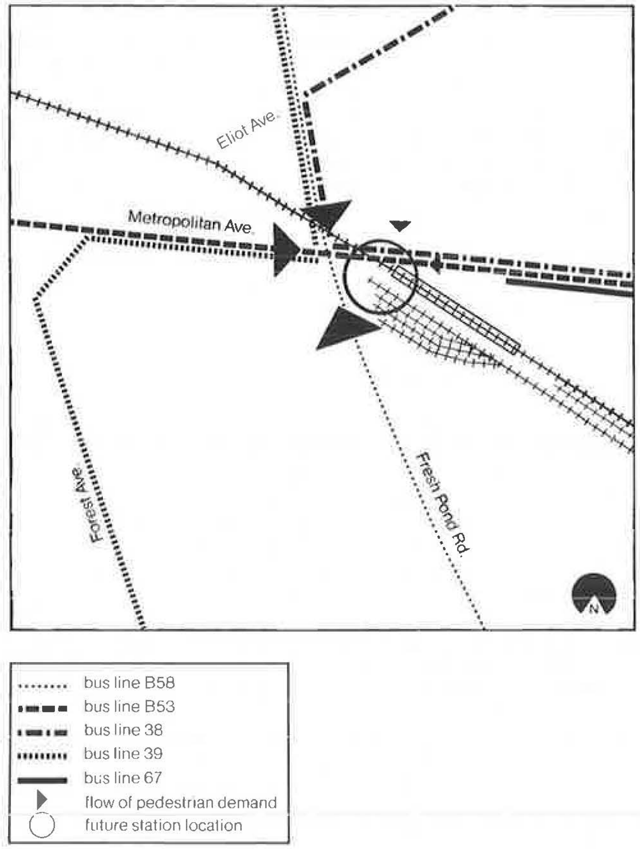

FIGURE 5 Physical impact of transfer demand.

Automobile trips to Fresh Pond station were estimated to be 500 for a year-2000 peak hour. Most of them originate from Zone 345 (southeast of the station) within its tributary area. Some automobile trips will come from the periphery, following a similar pattern to the bus trips. In all, it was established that the Fresh Pond station will have to accommodate almost 4,000 trips in the year-2000 peak hour. The tributary area will also produce bus and drive trips to Myrtle Avenue and Canarsie Line stations and to the Hunters Point Avenue station on another line.

Corridor Evaluation

The methodology described in detail for the proposed Fresh Pond station UTPS Zone 344 was carried out for zones encompassing twelve other proposed station sites. Figure 6 shows 14 of the 37 UTPS zones where station area analysis was applied. Although some station sites were unique for a particular option, other sites would be included in a number of options. In these cases, multiple forecasts were generated to take into account variations in service between options.

The detailed station area analysis was incorporated into the systemwide UTPS analysis through a two-step process. While the station analysis was

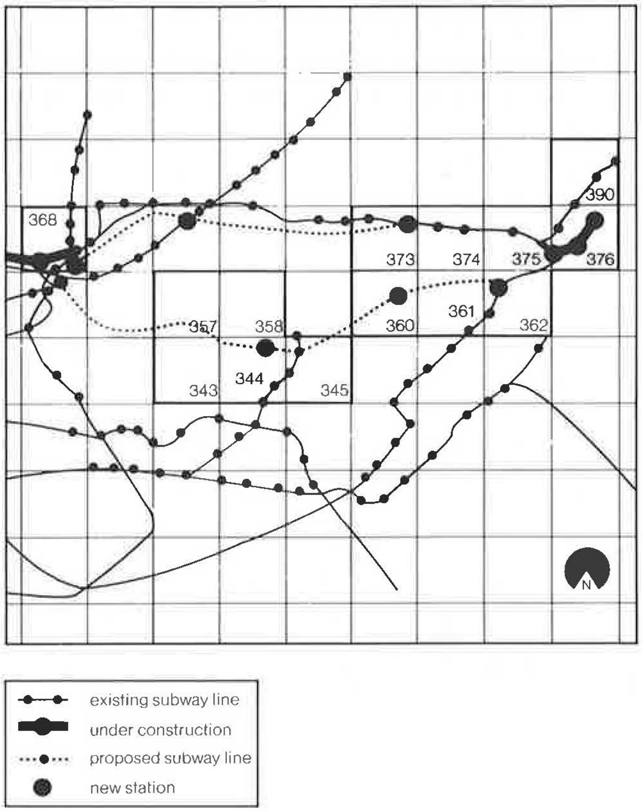

FIGURE 6 Montauk Archer Subway Connection—Detail Analysis Area—UTPS zones.

being developed, interim UTPS assignments were run for each of the five options. In the UTPS model, trips originate at the zone and are loaded onto the system at the station by means of walk links, or by bus transfer links if no station is within the zone. As was shown in the sample station area analysis, the mode of access forecasts were summarized both by station and by UTPS zone. By comparing the zone summaries to the interim UTPS runs, the study team was able to identify differences between the two techniques.

It was possible in many instances to change the UTPS walk links to reflect the more precise access measurements made as part of the detailed analysis. So, although the access link coded for a square-mile zone still represented a generalization of the expected walk trips after adjustment, the link more accurately reflected such things as physical barriers and actual distribution of housing units. In zones not served by subway stations, similar adjustments were made to bus access links. By means of such adjustments, the final UTPS assignment was brought into close agreement with the station area analysis.

In order to maintain consistency with the systemwide forecasts, subway link volumes were based on the UTPS runs. However, the mode of access determinations made as part of the station area analysis were used to establish forecasts superseding those based on UTPS techniques. In some instances, the bus access forecasts were developed by combining UTPS results with station area estimates. In these cases, where the bus tributary area extended beyond zone boundaries used for detailed analysis, UTPS bus route volumes were added to the mode of access estimates.

For the final forecasts that were used in the UMTA AA/DEIS, station, link, and line volumes were taken directly from UTPS output. By using this information, East River crossing volumes for each option were further analized to establish levels of crowding and measures of tunnel capacity utilization. UTPS output was also used to estimate passenger minutes saved for each option and the number of riders who would experience crowding in each option. The data were, in turn, used for the cost-benefit analysis carried out as part of the alternatives analysis.

The Subway-LIRR Montauk Transfer option assumed an upgrading of suburban railroad service to five existing stations in Southeast Queens. For the 23 UTPS zones making up the tributary area for those stations, the methodology used was different from the techniques described in the example. For this option, the new service would be in addition to existing feeder bus service, and was assumed to have higher fares and higher quality service, with greater speeds and more comfortable rolling stock than the four all-subway options. Because of the added number of choice items, a logit type submodal split model was used. (This model is described in greater detail in the Alternatives Analysis Technical Supplement.) As with the example zone, the census tract was the basic analysis unit, and station area measures such as walking distance to stations were developed in the same way. However, for these tracts, income level and various measures of service were explicit model input. Submode choice (and thereby station choice) was developed for each tract based on the probabilities developed from the model. Trips were then allocated to stations or bus routes as was shown in the example.

STATION AREA EVALUATION APPLICATIONS

The main purpose of the station-area evaluation was to produce adjusted travel demand forecasts by mode of arrival by census tract for each station. The objective was to evaluate the viability of proposed stations and the effectiveness of each of the alternatives in the QSOS--that is, to evaluate what service improvements could be achieved, and at what costs in terms of investment and environmental impacts.

The introduction of a new heavy rail service into an older, developed urban environment presents special challenges. The most critical interface between the new facility and existing development occurs at the station. The proposed station facility must be compatible with the urban structure already in place. For bus access, existing service patterns cannot be radically changed as a given route may serve other stations as well as other important trip generators. At the station site, local streets may be heavily used and frequently all land is developed with uses that may or may not be compatible with a transit facility. The detailed tract and land use analysis provides the planning information needed to deal with these concerns.

Impacts on the environment brought about by the insertion of a new transit facility can be both positive and negative in character. Negative impacts often can be controlled, mitigated, and even eliminated with appropriate design of the new facility and with proper design of the operating schemes.

Negative impacts that can be expected are mainly those produced by the increase in traffic activity to and from the station. These impacts were quantified for each station site as part of the detailed analysis. Volume estimates of bus and automobile trips by direction of origin were added to current traffic counts to develop measures of emissions and noise. Both traffic estimates and land use information were used to identify potential problems at intersections, bus stop locations, and pedestrian street crossings. As part of this effort, sensitive land use types such as schools and parks were identified.

The most evident positive impacts will undoubtedly be the accessibility improvements to and from the area and the potential revitalization in the station vicinity. If the new station is combined with additional needed services and commercial facilities, then the whole neighborhood may be upgraded. New development could also be programmed in locations with "soft spots" or on sites that are not fully developed.

By determining the main characteristics of travel behavior and land use for each tract in the station tributary area, the basic information needed to establish a functional design for each intermodal transfer was available. Such a design should not only accommodate flows of pedestrians, buses, and automobiles, it should also minimize the negative impacts expected from the new facility and enhance the development opportunities for the site.

The peak-hour volume forecasts are the main factor for designing these facilities. Forecasts of walk trips from each tract indicate the best location for station entrances. Estimates of expected transfers for each bus route in the area, along with existing patterns of bus stops and terminals, lead to the design of bus facilities. From this information, design requirements for curb space, layovers, turnarounds, and pedestrian crossings can be established, as well as possible modifications to route structures to improve station area circulation. For each station, the volumes of expected transfers will indicate which mode should be given priority and the nature of the design solution proposed for the station site.

The land use in the station vicinity also affects station design. Evaluations of structural condition and use led to the identification of "soft spots" where sites could be acquired for bus access roadways and other station-related uses. In other instances in which analysis showed places where bus circulation might produce negative impacts, solutions such as noise barriers comprised of vegetation were considered. Topographical features were also taken into account in the functional design and, in some cases, multilevel stations were considered to minimize impacts.

Because this was an alternative analysis study, and specific study sites might not have been included in the ultimate preferred alternative, the main use of the functional design process in this study was to develop cost estimates. However, when a preferred alternative is selected and further stages of design are undertaken, the station analysis will have provided the basic information needed to further highlight the positive impacts on the station site. The knowledge of land use and of the availability of commercial and other services in the neighborhood might indicate activities that could be included within the station site to benefit the community and improve station utilization. A properly designed station could lead to the upgrading of the whole neighborhood.

SUMMARY AND CONCLUSIONS

The methodology presented in this paper complements the standard UTPS. The procedure is relatively straightforward, and yields highly reliable data that are critical to developing circulation and station design criteria. In addition, the procedure optimizes the relationship between walk, bus, and automobile access modes to a particular station within a well-defined geographical area. It further allows interfacing of both manual and computer techniques to provide a total picture of projected use of planned subway stations. The procedure reduces the degree of abstraction so that the results are more meaningful and understandable to planners, decision makers, and the public, who generally have a reasonably accurate, comprehensive, and intimate knowledge of their community. Thus, the planning process is improved, and a better facility is likely to be built.

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