Miami Downtown People Mover Demand Analysis Model

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Various methods for estimating Downtown People Mover (DPM) System demand have been developed and applied in DPM planning activities in many different cities since the early 1970s. In addition, the UMTA Office of Planning Methods and Support sponsored the development of a report of state-of-the-art methods for DPM system planning that included suggested DPM demand estimation procedures. As part of the detailed studies and evaluations conducted in accordance with UMTA guidelines, the city of Miami, Florida, adopted the method suggested by UMTA, with some modifications, and applied it to the Miami DPM system (Metromover) preliminary engineering project. The full Miami system, consisting of the Central Business District (CBD) Loop with the Omni and Brickell legs, was selected and adopted through this process. Because there was insufficient federal funding for the entire project, it was agreed that the downtown loop would be built initially. The CBD Loop portion of Metromover became operational in April 1986. The completion of the full Metromover system with the Omni and Brickell legs is in the process of Environmental Impact Statement (EIS) preparation. For the Omni and Brickell legs EIS project, it became possible to update the Metromover demand analysis model and validate it against actual Metromover ridership. This paper presents a description of the Metromover demand analysis model, the model validation process and results, and the model's application to future Metromover legs. Recommended future modifications to the Metromover demand analysis model also are discussed.

Since the early 1970s, Metro-Dade County, Florida, has maintained a consistent policy of promoting public transportation as a major component of the regional transportation system. A comprehensive planning and preliminary engineering program led to the construction of the first phase of the Metrorail system, which is currently in operation. It was recognized that the metro line's location along the fringe of downtown Miami created the need for a distribution system to move people between Metrorail's downtown stations and their eventual destinations within the central business district (CBD).

In 1974, the Urban Mass Transportation Administration (UMTA) announced the Downtown People Mover (DPM) Demonstration Program. The underlying objective of this program was to demonstrate the viability of fully automated people mover systems in urban settings. Miami was selected to participate in the program on the basis of the merits of its proposed downtown application.

Detailed studies and evaluations conducted in accordance with UMTA guidelines resulted in the selection of a Metromover line consisting of a 1.9-mi loop around the traditional core of downtown Miami (the CBD Loop), a 1.4-mi connection to the Omni area (the Omni Leg), and a 1.1-mi connection to the Brickell area (the Brickell Leg).

Because traditional travel demand forecasting procedures are limited in their ability to evaluate downtown circulation and distribution travel demands, specialized travel demand forecasting techniques were required. A set of DPM demand estimation procedures was recommended by UMTA in the report *Planning for Downtown People Movers* (*1*). These procedures were based primarily on an integrated set of activity center travel demand models developed and applied to predict circulation and distribution travel in downtown Los Angeles. Modifications were made so that the models would be generally applicable to other U.S. cities.

The demand estimation procedures used in selecting the full 4.4-mi Metromover alignment were based on this travel demand model and validated for Miami. Because of the complete lack of data for any downtown DPM system at the time, the original Miami model (*2*) was validated by using the downtown circulator bus system. Preliminary engineering studies were conducted in 1980 for the full system. Because of insufficient federal funding, the project was separated into two parts: first, the CBD Loop, and second, the Omni and Brickell legs. It was agreed that the CBD Loop would be built initially.

In December 1985, Congress legislated preparation of the Environmental Impact Statement (EIS) for completion of the Metromover System. The EIS is required to present the projected transportation and environmental impacts for the legs (the Build Alternative) and the base (No-Build Alternative). To predict the transportation impact of the legs, the model had to be able to simulate two different transportation functions: the distribution of trips from the region into the expanded CBD, and the capabilities of the legs to act as an integral part of the circulation system for intra-CBD trips.

The Metromover CBD Loop opened for service on April 17, 1986. This was the first DPM system operational in a downtown environment in the United States. As a result, data were available for the first time to validate the previously developed DPM demand estimation procedures. The following sections present a description of the updated Metromover demand analysis model, the model validation process and results, and the model's application to the future Metromover legs. Recommended future modifications to the Metromover demand analysis model also are discussed. Detailed description of the original UMTA model can be found in *Planning for Downtown People Movers* (*1*).

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DPM DEMAND ANALYSIS MODEL

There are two potential trip markets for downtown areas. The first market consists of trips with either an origin or a destination outside the downtown area, referred to as the external-internal trip market. The second market consists of trips that are generated and have destinations within the downtown area, referred to as the internal trip market.

The external-internal market is separated into three segments on the basis of the mode used to enter the downtown area: automobile, rail, and bus. The model predicts the parking location for automobile trips entering the study area and the mode of travel to the final destination from the parking lot. The modes available for the final segment of the automobile trip include walking, riding the regional transit (Metrobus and Metrorail), or using the distribution and circulation (D/C) system, including the Metromover System. Metrorail trips that enter the downtown area are handled in a similar manner. The model predicts the station that each rider uses to exit the Metrorail system. From that station, the Metrorail rider can complete the trip by walking, riding Metrobus, or using the D/C system to arrive at the final destination. The Metrobus trips that enter the downtown area are assigned directly to the transit network on the basis of the minimum travel path. The D/C system will receive riders from these Metrobus trips only if the minimum travel path uses the system.

The internal trip market focuses on trips made by employees and others after they are in the study area. The internal market segment is separated into two categories: workplace-based trips and non-workplace-based trips. Workplace-based trips are made by employees within the study area, such as trips for lunch or shopping. Non-workplace-based trips include other trips in the downtown area that are not related to the workplace of the tripmaker.

The model directly estimates trip generation and distribution as well as modal split for the internal trip market segment. For workplace-based trips, the trip generation (including a no-trip option) and distribution are functions of the number of employees at the origin and number of trip attractions at all destinations. For non-workplace-based trips, generation and distribution are related to the total attractions within the study area. Both workplace-based and non-workplace-based markets have four modes available for making the trip. These modes are automobile, the regional transit system, the D/C system, and walking.

The demand estimation process was developed to predict the impacts of both potential markets. It was determined that the model used for the previous Miami study (2) should be adopted and updated for the EIS study. The outline of the adopted model structure is shown in Figure 1.

Study Area and Networks

The study area defined for the Miami Metromover EIS Study comprises the Miami CBD and the areas immediately adjacent to the CBD, referred to as the Expanded CBD area. As shown in Figure 2, this area is directly affected by the Metromover system. The study area has I-95 as its western border and includes the community of Brickell, south of the CBD. The study area north of the CBD includes the Omni Shopping Complex and surrounding developments. Biscayne Bay forms the eastern edge of the study area. The study area was divided into 101 internal zones. In addition, 18 external zones were added to represent the remaining Miami region. The external zones represent entry points for both automobile and transit trips to the study area.

After the internal zones were defined, zonal data required for the model were developed for each of the zones. Variables included in the zonal data are parking costs and capacity, employment by classification, and the zone size in acres. Study area employment data for the years 1986 and 2000 are summarized in Table 1.

The next step in describing the study area was the development of the transportation networks. Each travel mode within the study area has a separate network coded to represent the travel characteristics associated with that mode. The networks are designed solely for the segment of the trip within the study area. UMTA's Urban Transportation Planning Systems (UTPS) package was utilized to simulate these networks.

Step 1. The street and highway network was developed by using the HNET and UROAD programs for the morning peak period and the midday period, separately.

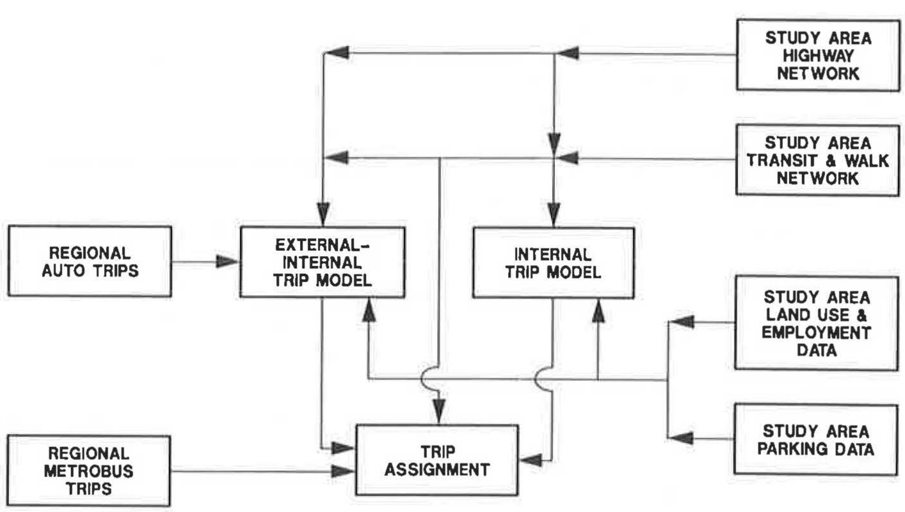

FIGURE 1 Metromover demand estimation procedure.

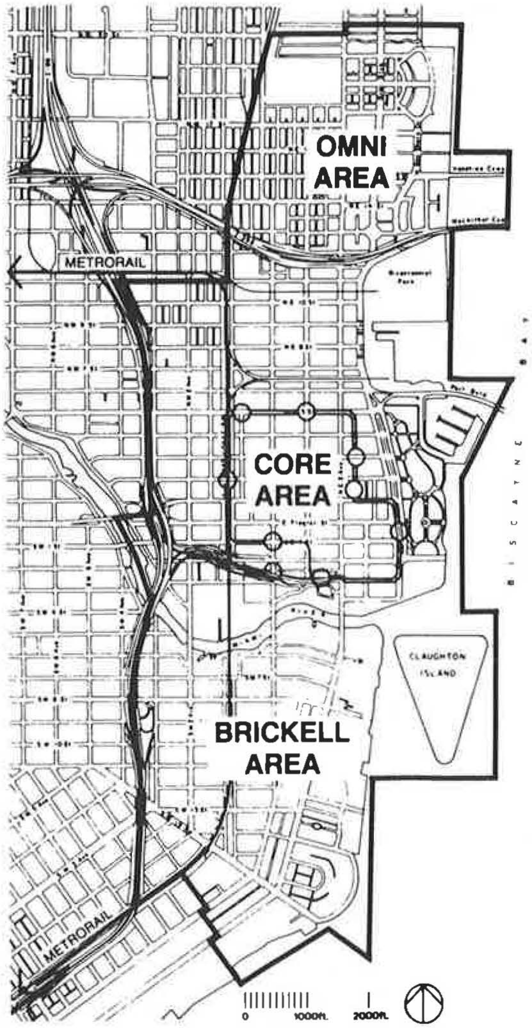

FIGURE 2 Study area with existing loop component of Metromover system, No-Build Alternative.

Step 2. Metrobus and Metrorail networks were developed individually for both the morning peak and midday periods. The congested highway time in the morning peak was read by the INET program, and regional transit time was then calculated on the basis of highway speed. The programs UPATH and UPSUM were used to conduct the path search and produce the travel time matrix. The time calculation was performed in a similar manner for the midday regional transit network, except that the uncongested highway travel times were used as input to INET. The D/C network also was developed for both the morning peak and midday periods.

Step 3. A morning peak transit network was developed to include all transit modes, regional transits, and D/C systems for use in assigning the Metrobus trips from the Metro-Dade Regional Model.

Step 4. The walk network was developed by using the optional nontransit links as input to INET. The nontransit links were developed from the highway network, excluding only those links that are freeways or ramps. The walk network has speed coded at 2.5 mph and is assumed to be constant throughout the day. UPATH and UPSUM were used for path searching and producing the travel time matrix.

TABLE 1 ZONAL DATA SUMMARY

	1986	2000
Developed acreage	1,167.7	1,214.1
Employment		
Office	44,559	79,204
Retail	16,036	20,048
Service and institutional	26,778	32,856
Wholesale and manufacturing	16,099	16,464
Others	6,196	6,239
Total	109,668	154,811

External-Internal Trip Model

The first step of the external-internal trip model distributes the automobile and Metrorail trips entering the study area to parking lots and rail stations from external zones. This develops an intermediate trip table among the internal study area zones that represents the last segment of a external-internal trip. This segment consists of the trip from the parking lot or rail station to the final destination.

The second step of the external-internal model provides the mode split to the walk mode, the regional transit mode, and the D/C system mode for these trips between the parking lot or rail station and their final destination. The validated mode choice model logit equation utility coefficients and the parking location model and station location model logit equation utility coefficients are shown in Tables 2 to 5, along with the original coefficients.

TABLE 2 MODE CHOICE MODEL FOR THE EXTERNAL-INTERNAL TRIP (PARKING LOT TO FINAL DESTINATION)

Utility	Variable	Validated Model	UMTA Model
U (Walk)	Constant	+4.7180	+2.2900
	Walk time	−0.0637	−0.0979
	Uphill grade	−1.4610	−1.4610
U (Regional transit)	Constant	−1.6470	+0.2050
	Transit time	−0.0637	−0.0979
	Transit fare	−0.0287	−0.0095
U (D/C system)	Constant	None	None
	Circulator time	−0.0637	−0.0979
	Circulator fare	−0.0287	−0.0095

NOTE: Logsum = ln{exp[U (Walk)] + exp[U (Regional transit)] + exp[U (D/C)]}.

As described previously, Metrobus trips that enter the downtown area are assigned directly to the transit network on the basis of the minimum travel paths. For these trips, the D/C system is assigned trips only if the minimum travel path uses the system.

Internal Trip Model

The internal trip model performs trip generation, distribution, and modal split in one step. As stated before, for the workplace-based trips, generation and distribution (including a no-trip option) are a function of the origin zone employment and of the calculated attractions to all possible destinations. Non-workplace-based trip generation and distribution are controlled by the total attractions calculated for every zone. These attractions

TABLE 3 PARKING LOCATION MODEL

Variable	Validated Model	UMTA Model
Auto cost	−0.0485	−0.0161
Walk distance	−9.175	−9.1750
Ln (parking capacity)	+1.0	+1.0
Logsum	+1.0	+1.0
Auto travel time	−0.1077	−0.1655

NOTE: Utility = *U* (Parking zone).

TABLE 4 MODE CHOICE MODEL FOR THE EXTERNAL-INTERNAL TRIP (METRORAIL STATION TO FINAL DESTINATION)

Utility	Variable	Validated Model	UMTA Model
U (Walk)	Constant	−1.2900	+2.2900
	Walk time	−0.0637	−0.0979
	Uphill grade	−1.4610	−1.4610
U (Regional transit)	Constant	−3.0620	+0.2050
	Transit time	−0.0637	−0.0979
	Transit fare	−0.0287	−0.0095
U (D/C system)	Constant	None	None
	Circulator time	−0.0637	−0.0979
	Circulator fare	−0.0287	−0.0095

NOTE: Logsum = ln{exp[*U* (Walk)] + exp[*U* (Regional transit)] + exp[*U* (D/C)]}.

TABLE 5 METRORAIL STATION LOCATION MODEL

Variable	Validated Model	UMTA Model
Walk distance	−9.175	Not used
Logsum	+1.0	
Rail travel time	−0.1077	

NOTE: Utility = *U* (Station zone).

are converted to productions and distributed to all destinations on every available mode. Validated internal trip model logit equation utility coefficients are shown in Tables 6 and 7, along with original coefficients.

Trip Assignments

The external-internal model produces daily estimates of walk trips, regional transit trips, and D/C system trips in a productions and attractions (P&A) format. For the purpose of this study, the assignment focuses on those trips that actually use the D/C system. To get the morning peak hour and midday 1-hr assignments for the external-internal market, the daily D/C system trips are factored to obtain morning peak hour and midday 1-hr trips in origin and destination (O&D) format prior to trip assignment. In addition, the daily internal trips are factored by using observed hourly percentages from the Miami Downtown Survey (*3*) to create values for the internal trip market during the morning peak hour and midday 1 hr. The trips from these two markets are then combined and assigned to the D/C system network.

TABLE 6 WORKPLACE-BASED TRIP MODEL

Utility	Variable	Validated Model	UMTA Model
U (No trips)	Constant	+4.9816	+9.294
	Origin employee density	+0.0008552	+0.0008552
U (Walk)	Constant	+5.036	+3.034
	Walk time	−0.0598	−0.0919
	Uphill grade	−1.52	−1.52
	Trip distance	−3.0	−3.0
	Trip attraction density	+0.00767	+0.00767
	Ln (zonal area)	(not used)	+1.0
U (Regional transit)	Constant	+2.802	+2.90
	Transit time	−0.0598	−0.0919
	Transit fare	−0.0412	−0.00896
	Trip distance	−4.2	−4.2
	Trip attraction density	+0.00767	+0.00767
	Ln (zonal area)		+1.0
U (D/C system)	Constant	−0.054	−0.810
	Circulator time	−0.0598	−0.0919
	Circulator fare	−0.0412	−0.00896
	Trip attraction density	+0.00767	+0.00767
	Ln (zonal area)		+1.0
U (Automobile)	Auto time	−0.0598	−0.0919
	Auto operating cost	−0.0412	−0.00896
	Hourly parking cost	−0.0412	−0.00896
	Trip attraction density	+0.00767	+0.00767
	Ln (zonal area)		+1.0

TABLE 7 NON-WORKPLACE-BASED TRIP MODEL

Utility	Variable	Value
U (Walk)	Constant	+3.824
	Walk time	−0.0581
	Uphill grade	−0.540
	Trip distance	−3.0
	Trip attraction density	+0.00378
U (Regional transit)	Constant	+1.011
	Transit time	−0.0581
	Transit fare	−0.0428
	Trip distance	−4.2
	Trip attraction density	+0.00378
U (D/C system)	Constant	−1.038
	Circulator time	−0.0581
	Circulator fare	−0.0428
	Trip attraction density	+0.00378
U (Automobile)	Auto time	−0.0581
	Auto operating cost	−0.0428
	Hourly parking cost	−0.0428
	Trip distance	−0.113
	Trip attraction density	+0.00378
Non-workplace-based trip attraction	Office floor area	+0.23
	Retail floor area	+1.09
	Service floor area	+0.28
	Manufacturing floor area	+0.058

MODEL VALIDATION

A thorough review of the original model and the previous Miami model was performed before the final model validation work was performed. The following material summarizes recommendations made by the technical review committee.

First, external-internal trips, including those by Metrorail users and Metrobus users, should be estimated in two steps on the basis of the original model. The trip table from bus stop or rail station to final destination should be obtained. The original model assumes that the trip table should be obtained from the previous study and performs a modal split by utilizing a recommended logit equation. It was determined, however, that a rail station location model similar to the parking location model should be developed to create a rail-station-to-final destination trip table that is subject to the modal split. It also was determined that the external-internal bus users should be assigned directly to the transit network on the basis of the minimum travel paths, as discussed in the previous section. This way, regional transit users will have choices for their disembarking locations on the basis of alternatives tested.

It was determined that the natural log of total zonal acres should be eliminated as a variable in the internal trip models for the workplace-based trips and the non-workplace-based trips. The study area consists of zones of unequal size and diverse land development. Some zones are relatively empty, and there are many large surface parking lots. The use of land area in this respect has a distorting effect, placing unreasonable quantities of trips in zones with little or no activity.

TABLE 8 METROMOVER DEMAND MODEL VALIDATION SUMMARY: 1986 METROMOVER DAILY PATRONAGE

	Validation Against Free Fare System		Validation Against 25-cent Fare System	
Trip Category	Observed	Estimated	Observed	Estimated
Transfers between Metrorail and Metromover	5,724	5,591	5,724	5,591
Others	6,671	6,138	3,704	3,538
Total	12,395	11,729	9,428	9,129

Time and cost coefficients in the utility equations were reviewed, and it was judged that the model is not sensitive to cost. This issue should be examined in the final model validation process.

Finally, mode-specific constants should be updated on the basis of actual Metromover patronage rather than by validation against the downtown circulator bus and updating of a mode-specific constant for the Metromover that utilizes "image factor," as recommended in the original model.

The model validation procedure was designed to incorporate these recommendations and to check the reasonableness of each of the modeling steps. The results of each step were summarized by trip market to aid in the validation process.

The external-internal trip input from the regional model was summarized for each travel mode. The numbers of automobile and Metrobus external-internal trips by corridor were compared with traffic counts and with transit survey data, respectively. Metrorail trips entering the study area were compared with actual data separately for the three stations in the Expanded CBD area, emphasizing the daily "ons" and "offs" at each rail station. Within the study area, the travel patterns for each external-internal trip market were reviewed in detail; the review included selected paths from zones in the study area. In addition, average trip length, travel time, and the number of trips for each of the competing modes were examined to ensure that all networks within the study area were reasonable.

The internal trips were validated on the basis of the results of Miami Downtown Survey (*3*) for the workplace-based and non-workplace-based markets. These markets were reviewed with emphasis on the total trips generated and the mode split percentages. Again, selected paths from zones in the study area were checked for reasonableness.

The study area zones were aggregated into 11 districts to check the reasonableness of trip length and the movement by mode and by market segment for the trips within the study area.

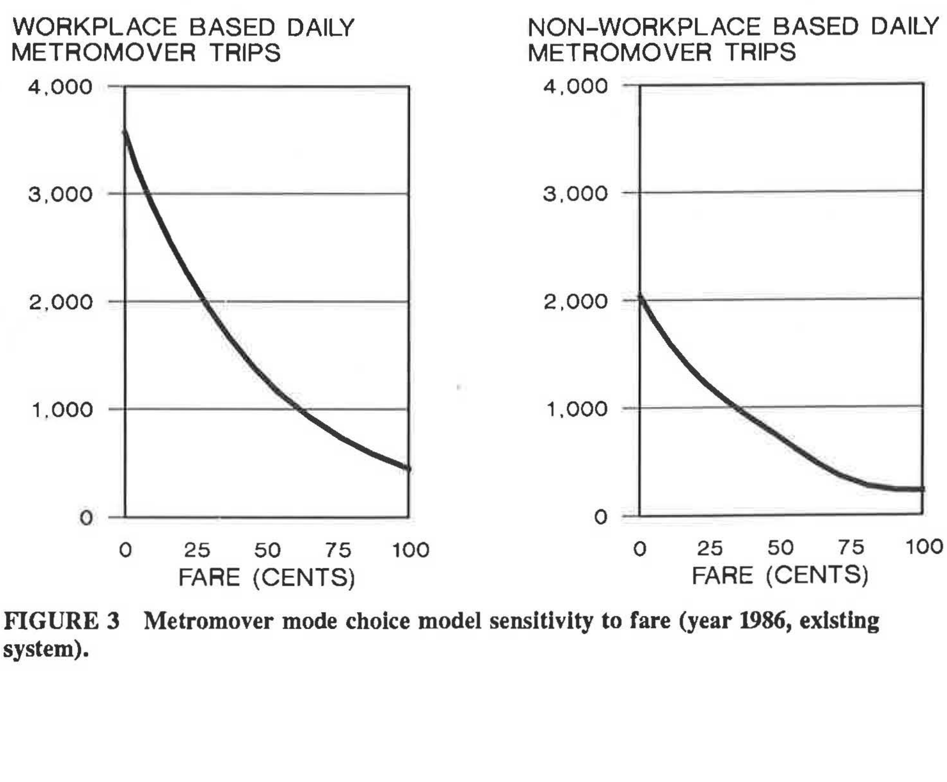

FIGURE 3 Metromover mode choice model sensitivity to fare (year 1986, existing system).

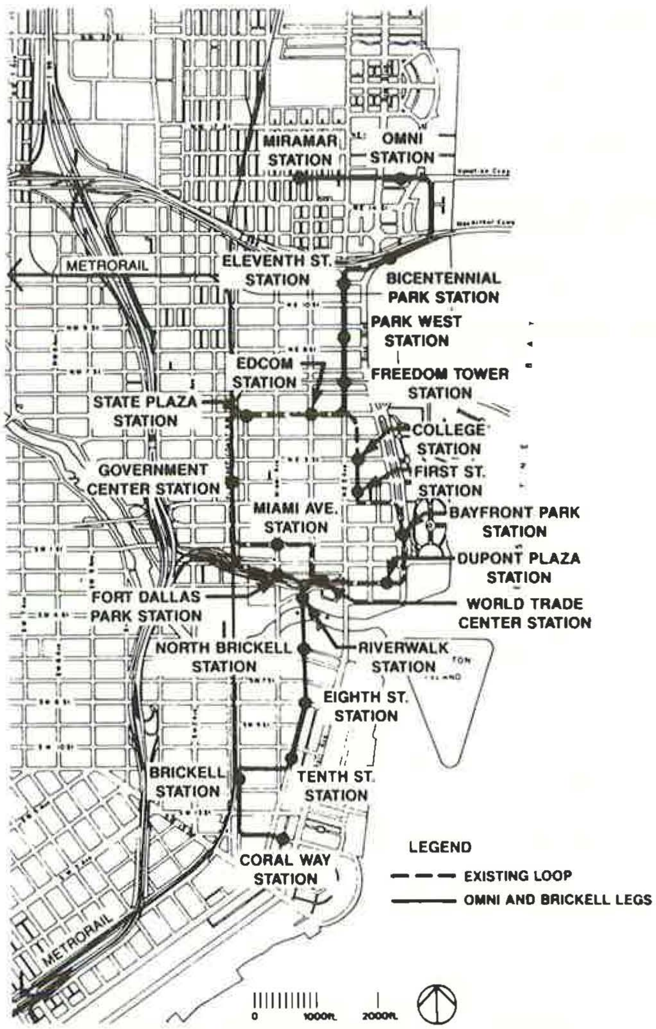

FIGURE 4 Proposed Metromover alignment, Build Alternative.

Finally, estimated Metromover system patronage was checked against observed 1986 Metromover system patronage. Several iterations were required to adjust parameters until the model provided results that satisfactorily matched observed Metromover ridership patterns for both the free fare system and the 25-cent fare system. Metromover was free during its opening period from April to June 1986. Since then, a 25-cent fare has been charged except for transfers from Metrorail to Metromover. The set of validated model equations is presented in Tables 2 to 7.

A comparison of observed and estimated Metromover riderships is given in Table 8. The differences were judged insignificant for both the free fare system and the 25-cent fare system, as indicated in Table 8. Additional fare sensitivity analysis for the internal trips was performed, and results are shown in Figure 3. Both workplace-based and non-workplace-based trips show approximately the same elasticities. Model validation results, including fare sensitivity analysis, were presented to the technical review committee, including representatives from UMTA and MDTA, for approval. The validated model chain was approved by the technical review committee and was then applied to project future Metromover demands for both the No-Build and Build alternatives.

TABLE 9 DAILY TOTAL TRIPS BY MARKET SEGMENT WITHIN THE EXPANDED CBD FOR THE YEAR 2000

Market Segment	No-Build	Build
Internal Trips		
Workplace-based trips	377,316	377,896
Non-workplace-based trips	162,900	162,900
Total	540,216	540,796
External-Internal Trips		
Trips to and from parking lot	479,418	477,955
Trips to and from Metrorail	23,602	25,466
Trips to and from Metrobus	36,820	36,419
Total	539,840	539,840
Total trips	1,080,056	1,080,636

NOTE: Includes all trips by automobile, walking, and transit within the expanded CBD.

TABLE 10 DAILY METROMOVER TRIPS BY MARKET SEGMENT FOR THE YEAR 2000

Market Segment	No-Build	Build
Internal Trips		
Workplace-based trips	3,252	5,942
Non-workplace-based trips	1,650	3,117
Total	4,902	9,059
External-Internal Trips		
Trips to and from parking lot	335	1,099
Trips to and from Metrorail	9,682	14,909
Trips to and from Metrobus	840	18,222
Total	10,857	34,230
Total trips	15,759	43,289

FUTURE METROMOVER DEMANDS

Two alternatives, No-Build and Build, were tested for the EIS process. The No-Build Alternative consists of Metrorail, the existing Metromover loop (Figure 2), and the existing coordinated bus services. This combined Metromover/Metrobus transit system provides service to the entire Expanded CBD. The Build Alternative consists of the Metrorail System, the existing Metromover loop, the Omni Leg (1.4 mi) and the Brickell Leg (1.1 mi), as shown in Figure 4. The Metrobus System is consolidated to provide an extensive, coordinated feeder network. The Metromover patronage forecasts for both alternatives were generated by the validated model discussed in the previous section.

The total number of trips in the Expanded CBD by all travel modes for all potential market segments is shown in Table 9. Both alternatives generate approximately the same number of trips (1.08 million). Of these trips, the number of persons who use the Metromover System for part of their trip is shown in Table 10. By comparing these two tables, it can be seen that the percentage of total trips using the Metromover System increases from 1.5 percent for the No-Build Alternative to 4.0 percent for the Build Alternative.

CONCLUSIONS

The use of the validated Miami Downtown People Mover model chain for predicting downtown people mover demand has proved to be valuable for analyzing alternatives for the EIS project. The results were explicable and acceptable to the technical review committee, including representatives from UMTA and MDTA. However, in the process of validation and applications of the model chain, it was recognized that the current Metromover Model can be enhanced. The following are summaries of basic recommendations on model structure.

Recommendation 1. The regional model should have a capability to handle the external-internal trip markets of Metromover demand, including Metrorail, Metrobus, and automobile users. To accomplish this, network and path-building procedures should be thoroughly reviewed, as should other regional model issues. A parking location concept also should be incorporated.

Recommendation 2. Internal trip markets, including workplace-based trips and non-workplace-based trips, may be analyzed separately from the regional model chain. Further categorization of the internal trip market (with and without automobile accessibility, for example) should be carefully examined.

Recommendation 3. The current Metromover model accomplishes trip generation, distribution, and modal split in one step for the internal trip market. Although there are benefits to the structure, particularly in estimating induced trips, it makes the calibration and validation process more complex. Furthermore, the impacts of individual traditional model steps are difficult to isolate. The advantages and disadvantages of each structure should be evaluated before selecting a modeling procedure for internal trips.

Recommendation 4. Special trip generators that have trip generation characteristics that are significantly different from the average rates for the four employment and land use categories should be treated differently for the internal trip market. The land use categories currently used in the model are office, retail, service and institution, and wholesale and manufacturing. The model chain should be able to accommodate special generators so that more accurate station loadings and link volumes can be obtained. Examples of special trip generators are shopping centers, large department stores, amusement parks, and colleges.

These recommended enhancements will improve the current model chain; however, including the enhancements requires a significant amount of work. Detailed evaluation of each recommendation, including data-gathering efforts, should be made before any modifications are included in the current model chain.

REFERENCES

1. *Planning for Downtown People Movers.* Office of Planning Methods and Support/UMTA, U.S. Department of Transportation, April 1979.
2. Miami DPM Demand Estimation Methodology, Metro-Dade Transportation Administration, Miami, Fla., May 1979.
3. Miami Downtown Surveys, Metro-Dade Transportation Administration, Miami, Fla., Feb. 1986.