Enhancements to Circulator-Distributor Models for Chicago Central Area Based on Recently Collected Survey Data

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The city of Chicago is evaluating alternative methods of providing for the distribution and circulation of commuters to and workers, visitors, and residents in the vibrant and growing central area of Chicago. In 1990 and 1991 an alternatives analysis/draft environmental impact statement was prepared for a circulator-distributor system for the central area of Chicago. The planning for the locally preferred alternative, a light-rail-transit circulator-distributor system, has now entered the preliminary engineering/final environmental impact statement (PE/FEIS) phase. Refined travel forecasts are being prepared for the PE/FEIS by using refined travel models calibrated with recently collected mode-of-egress survey data. The calibration of the refined circulator-distributor travel models is discussed. In addition the implications for future circulator-distributor and regional modeling efforts that incorporate nonmotorized modes in the choice process are presented.

In 1990 and 1991 an alternatives analysis/draft environmental impact statement (AA/DEIS) was prepared for a circulator-distributor system for the central area of Chicago. Ridership forecasts for the AA/DEIS were prepared by using downtown people mover (DPM) modeling techniques first pioneered for Los Angeles in the early 1970s and later applied in Miami and Detroit (*1–3*). These models were transferred to the Chicago area and were adjusted to reproduce aggregate travel statistics such as average trip lengths by mode and overall mode shares (*4*).

The planning for the locally preferred alternative, a light-rail-transit (LRT) circulator-distributor system, has now entered the preliminary engineering/final environmental impact statement (PE/FEIS) phase. On the basis of the experience in applying the travel forecasting models developed for the AA/DEIS and the need for increasingly detailed travel forecasts, a number of refinements to the circulator-distributor modeling process have been made:

- Representation of the transit, taxi, and automobile networks has been refined.
- Coefficients for the distributor mode-choice model have been estimated on the basis of locally collected data.
- Model formulations have been revised.

The last two points are the major focus of this paper. The first point, network representation and path-building refinements, is documented by Chang and Kurth in another paper in this Record.

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The travel demand forecasting procedures were applied to a portion of the Chicago region including and surrounding the traditional Loop area (Figure 1). The area modeled encompassed approximately 6.5 mi^2 and was projected to have more than 83,000 households and 890,000 employees by 2010. The area is the focus of regional transit services including commuter-rail, rapid-rail, and bus lines.

Figure 1 also shows the detailed zone structure used for the modeling process. Zones within the Loop are generally defined by blocks. Outside the Loop two or more blocks might constitute a single zone. External stations are also defined wherever transit lines cross the study area boundary and for the six major commuter-rail stations included in the study area:

- North Western Station,
- Union Station,
- LaSalle Street Station, and
- Metra Electric commuter-rail stations at Randolph Street, Van Buren Street, and Roosevelt Road.

Two types of internal trips are the primary candidates for travel on a central area circulator-distributor system: internal-internal (circulator) trips and the secondary portion of external-internal and internal-external (distributor) trips. These two types of trips are characterized by marked differences in terms of peaking, activity linkages, regularity, and purpose. Distributor trips are made primarily by central area workers who use regional transit to travel to and from the central area. In the morning these travelers must choose a transit stop at which to leave the transit vehicle that takes them to the central area and the mode of travel (walk, circulator-distributor system, taxi, or a portion of another regional transit route) from the transit stop to the final destination. In the evening the same basic choices are reversed.

In addition to being a major employment and commercial center, the Chicago central area is also a residential area, a cultural center, and a convention center. Thus circulator trip-makers can be divided into several groups on the basis of whether they are residents of the central area, nonresidents of the central area with work as their major purpose for being downtown, or nonresidents of the central area who are downtown for nonwork purposes.

For the Chicago central area the above definitions were used to stratify the travel forecasting model into manageable submodels. Two times of day were explicitly modeled: the morning peak period and midday. Distributor and circulator trips were modeled for both. In the morning peak period the main function of the central

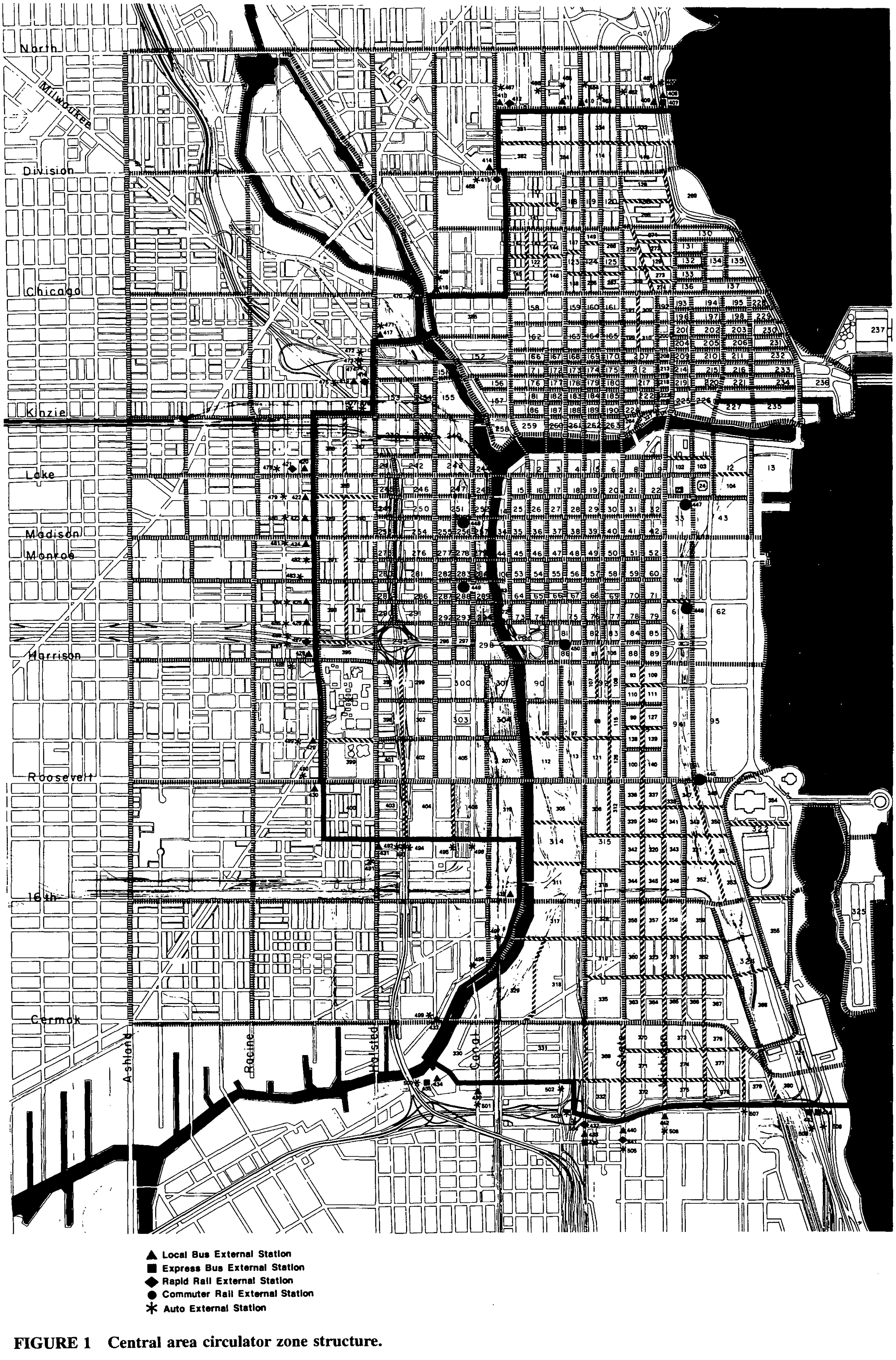

FIGURE 1 Central area circulator zone structure.

area transportation network is the distribution of external-internal trips from regional transit services and commuter rail stations to final destinations. At midday its main function is to provide for central area circulation. The following submodels were developed for forecasting travel within the central area:

- Morning peak period distributor model.
- Morning peak period circulator model for central area residents.
- Midday distributor model.
- Midday circulator model for central area workers.
- Midday circulator model for nonworkers in the central area.
- Midday circulator model for central area residents.

Mode-choice models were developed for the distributor models for both times of day for all trips entering the central area through one of the six central area commuter-rail stations.

The submodes considered at the stations are

- Walk,
- Transit (local bus, express bus, rapid rail, distributor), and
- Taxi.

The submodes provide means to travel from the rail stations to the final destinations in the central area. The trips from commuter-rail stations to final destinations are assigned by submode to their respective networks.

The original DPM models (e.g., for Los Angeles) used a multinomial logit formulation to model mode choice. The modeled distributor systems were "exotic" transit systems such as automated guideway people movers and were considered unique, independent transit modes. The choice alternatives for this model formulation are shown graphically in Figure 2(*a*).

For the AA/DEIS the choice model was modified to the form shown in Figure 2(*b*). The distributor alternatives considered for Chicago (transportation system management bus and LRT) were considered to be within the range of transit alternatives already available for distribution purposes. The distributor was modeled as an alternative path of a generic transit mode rather than as an independent mode.

For the PE/FEIS a nested-logit formulation was used to account for the fact that the proposed alternatives are not truly independent [as in Figure 2(*a*)], and the use of an LRT distributor system is not the same as riding local buses to final destinations [Figure 2(*b*)]. The PE/FEIS mode-choice model formulation is shown in Figure 2(*c*); "local" represents local bus service, and "premium" represents express bus service and LRT.

External-internal trips entering the central area on rapid-rail and bus lines must also be distributed to their final destinations. However unlike trips entering the central area on commuter rail lines, travelers entering the central area are not forced to change their mode at one easily identifiable transit transfer station within the central area. Rather they can ride to the stop nearest their final destination and then walk. Since the transit network in the Chicago central area is so extensive, the distribution of transit riders (i.e., rapid-rail and bus passengers) to their final destinations is accomplished solely through trip assignment techniques. The transit assignment process determines the optimal time paths from "external" transit stations to final destinations and assigns the trips to those paths. The optimal time paths account for in-vehicle travel times, wait times (for transfers), and walk times for transfers and to the final destination.

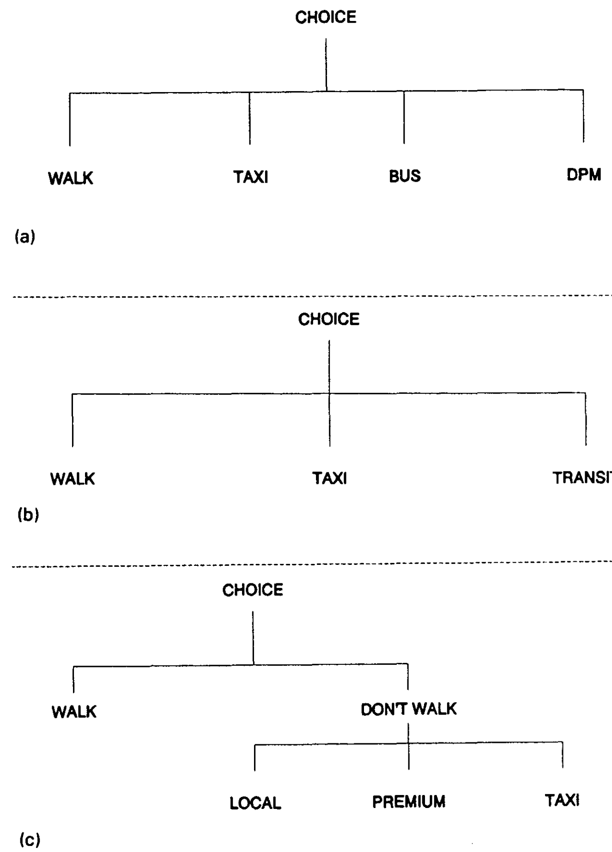

FIGURE 2 Mode-choice model structure: (*a*) Original DPM multinomial logit (*b*) AA/DEIS distributor multinomial logit, and (*c*) PE/FEIS distributor nested-logit.

The estimation of travel in the central area in the circulator mode requires the application of all phases of the travel modeling process: trip generation, trip distribution, mode choice, and trip assignment. Trip generation is based on models developed by Chicago Area Transportation Study (CATS) that generate total person trips, including walk trips, and on the results of a downtown building survey. Trip distribution and mode choice are accomplished through models estimated specifically for the central area. As with the distributor models for trips from commuter-rail stations, circulator trips were assigned to their respective networks by submode. Again the circulator was considered to be part of the premium submode.

A number of observations regarding the simultaneous trip generation, trip distribution, and mode-choice circulator trip modeling methodology used for the AA/DEIS were made. First, the model was difficult to "control." The variables associated mainly with trip distribution interacted with (and sometimes overwhelmed) the mode-choice variables and vice versa. In addition no behavioral explanation could be attributed to the main distribution variable—the natural log of the area of the zone. Finally a matrix balancing technique had to be employed to obtain a reasonable and stable trip distribution.

Two alternatives to the AA/DEIS circulator choice model form were considered for the PE/FEIS model. The first was a fully

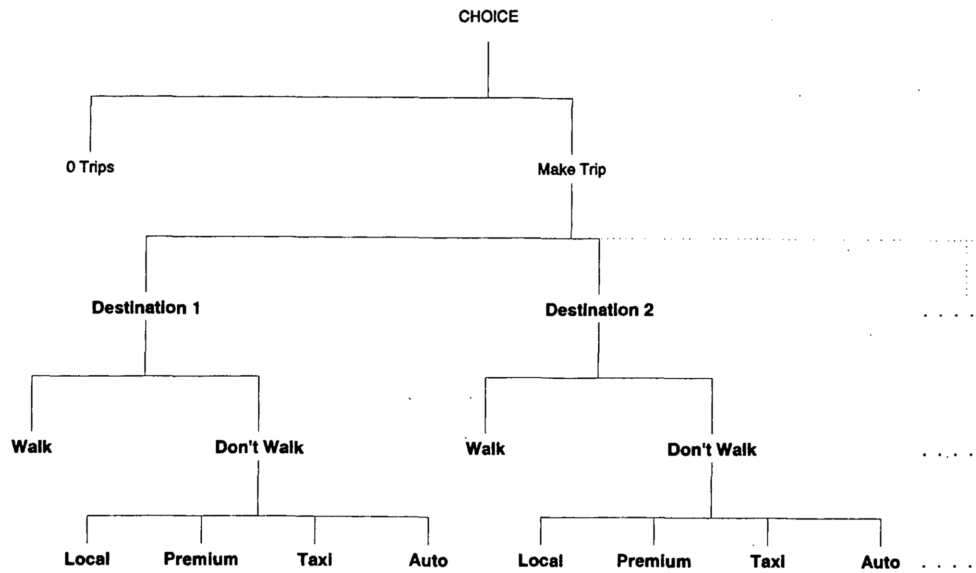

FIGURE 3 Fully nested circulator choice model.

nested choice model as shown in Figure 3. This model form can be hypothesized as a more appropriate structure for the circulator models and should resolve many of the difficulties noted with the AA/DEIS model form. Unfortunately no disaggregate choice data were available to estimate the model coefficients for fully nested choice models. The second, chosen, alternative was to disaggregate the circulator choice models into their component parts and use a more traditional sequential modeling process.

The separation of the simultaneous distribution–mode-choice models into their component parts was a drastic change in the modeling methodology. To maintain some impact of the entire transportation system on the trip distribution, the log sum of the mode-choice model was used to define the impedance, or separation, between zones. A traditional gravity model formulation was then used to distribute the trips. Since the original AA/DEIS distribution–mode-choice model included a matrix balancing step to ensure trip attraction balancing in all zones, the conversion to a gravity-type distribution model with composite impedances defined by the denominator of the mode choice model was reasonable.

The circulator mode-choice model form is shown in Figure 4. The model form is very similar to the distributor model form shown in Figure 2(*c*), with the exception that the premium transit submode is replaced by two submodes: express bus and LRT. This was done to allow for the use of a separate mode bias coefficient for LRT for the circulator markets for central area workers and central area nonworkers. This procedure is consistent with the procedure used in the AA/DEIS and accounts for the hypothesis that, all other travel characteristics being equal, travelers in the central area worker and nonworker markets will select a light-rail vehicle over a bus.

CALIBRATION OF PEAK DISTRIBUTOR MODEL

In 1989 Metra performed a mode-of-access survey on commuter-rail lines in the Chicago area (*5*). The self-administered survey was conducted on the trains and included detailed mode-of-egress and final destination questions. This provided a rich data base of 10,741 individual observations for the estimation of central area travel models.

Table 1 summarizes the calibration data. The average walk time for walk egress trips was 12.4 min, or about 0.6 mi. This is substantially longer than the 0.33 mi maximum walk distance used

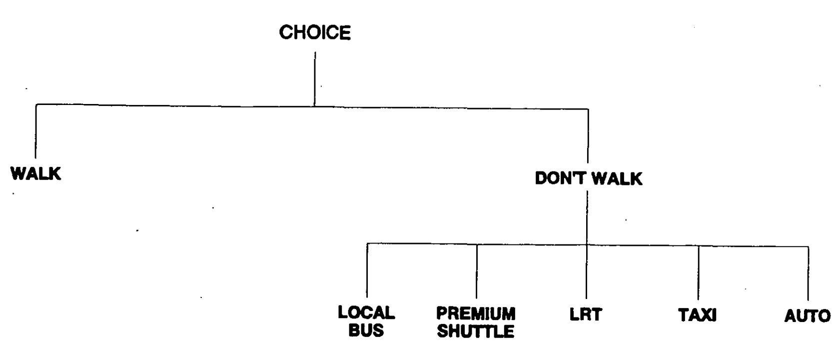

FIGURE 4 Circulator mode-choice model.

TABLE 1 Summary of Metra Calibration Data

			Mean Values for Alternative Modes								
			Walk	Taxi			Transit				
Chosen Mode	Number of Observations	Percent of Observations	Walk Time (Minutes)	Walk Access Time (Minutes)	In-Vehicle Travel Time (Minutes)	Fare (Cents)	Walk Access & Transfer Time (Minutes)	Wait Time (Minutes)	In-Vehicle Travel Time (Minutes)	Number of Boardings	Fare (Cents)
Walk	9,694	90.3%	12.4	3.9	2.7	142	5.7	1.2	2.8	1.01	90.2
Taxi	109	1.0%	21.7	3.9	4.9	191	6.0	1.7	5.1	1.07	90.9
Transit	938	8.7%	26.2	4.1	5.9	215	4.9	1.8	6.6	1.07	91.0

as a rule of thumb in many regional modeling processes. However for the same trips 3.9 min would be spent, on average, walking to and from taxis, and 5.7 min would be spent walking to and from transit stops. As would be expected the average walk times (for the walk mode) are substantially higher when taxi or transit was the chosen egress mode.

A logit model estimation program (*6*) was used to estimate the peak period distributor market mode-choice model. Two preconceived notions guided the calibration. The first was the desire to disaggregate travel time into its component parts—walk time, wait time, and in-vehicle time. The original Los Angeles DPM models used only one travel time variable. This resulted in models that were equally sensitive to changes in walk, wait, or in-vehicle travel times. This situation was modified in the transfer of the models to Chicago for the AA/DEIS through the addition of a walk distance variable. This variable was necessary to reproduce aggregate mode shares by distance, but since a constant walk speed was used in the modeling process, the variable had the same effect as increasing the walk time coefficient. The second notion was that a nested structure was appropriate for the choice process. The results of the model estimation process led to the final nesting structure used for the peak distributor model [Figure 2(*c*)].

The final distributor mode-choice model is shown in Table 2 along with the coefficients for models used for the Los Angeles DPM models, the original AA/DEIS study for the Chicago central area circulator, and regional models used in Chicago. It was necessary to create a composite travel time variable for wait time and in-vehicle travel time to obtain a reasonable model coefficient for in-vehicle travel time. All attempts at different model structures that included in-vehicle travel time as an independent variable resulted in positive in-vehicle travel time coefficients. Review of the data summarized in Table 1 provides a reason for the incorrect sign: in-vehicle travel times occur only for the transit and taxi modes, the modes more likely to be used for longer egress trips. Thus the existence of in-vehicle travel time becomes a good variable for explaining why transit or a taxi is used. Both taxi and transit have very similar travel times for the interchanges included in the calibration data set, and taxi has relatively few observations.

To test the effect of the lack of difference between the transit and taxi in-vehicle travel times, a special run was performed. The calibration data were modified to reduce the taxi in-vehicle travel time by a factor of 2 for all observations in which a taxi was the chosen mode. This run resulted in the in-vehicle travel time coefficient's being the correct sign and significantly different from zero.

These results suggested that it would not be possible to estimate a reasonable, independent coefficient for in-vehicle travel time with the available calibration data. As a result a composite variable combining one-half of the in-vehicle travel time with the wait time for transit and one-half of the in-vehicle travel time for taxi (taxi wait time was assumed to be zero) was created. This resulted in a model in which the ratio of the wait time coefficient and the in-vehicle travel time coefficient was 2.0. This ratio was consistent with the regional mode-choice model recently calibrated for Metra.

The creation of a composite travel time variable was not the desired method for model estimation. However on the basis of the analysis of the calibration data and an analysis of the options available it was deemed the best solution. Several other options existed. The first would have been to exclude in-vehicle travel time from the model. If this had been done a model with reasonable coefficients for wait time, walk time, and travel cost could have been estimated. It could be argued that the data showed that travelers have little sensitivity to in-vehicle travel time for the portion of their trip from the commuter rail station to their final destination. However, the resulting model would have been valid only for a very limited set of alternatives, since it would not have passed a basic "reasonability" test. Specifically one use of the model will be to test alternative LRT alignments. If in-vehicle travel time is not included in the utility equation, two different alignments would give the same mode choice for a specific interchange as long as walk access and egress distances and headways are the same, even if the in-vehicle travel time of one of the alignments was twice the in-vehicle travel time of the other. Although this example is somewhat illogical, it serves to identify the problem: over what range of travel time differences would the model be valid? A model that excluded in-vehicle travel time as a variable was rejected as illogical.

A second option would have been to transfer a model from a different area. This was the approach used for the AA/DEIS version of the model. That model produced acceptable results for the AA/DEIS study and could possibly have been refined for the PE/FEIS study. It could be argued that this was, in effect, the option chosen. The relationship between the in-vehicle travel time and wait time coefficients was transferred from a regional model estimated by Chicago. Transferring that part of the regional model and rigorously estimating the rest of the model coefficients produced a model more specific and applicable to the Chicago area than transferring a model from another city.

One of the most interesting results of the model calibration was the need to stratify the walk time variable by walk time. The

TABLE 2 Comparison of Distributor Model Coefficients

Coefficient	Recommended PE/FEIS Model Coefficient	(t-Score)	LA DPM Model	Original AA/DEIS Model	Metra Regional Model	CATS Regional Model[b]
Walk Time	—		-0.09790	-0.2400[a]	-0.1122	-0.0468
0 - 10 minutes	-0.09152	(-2.8)	—	—	—	—
10(+) - 20 minutes	-0.3461	(-6.0)	—	—	—	—
20(+) - 30 minutes	-0.2385	(-5.6)	—	—	—	—
> 30 minutes	-0.1736	(-4.3)				
Wait Time	-0.09081	(-1.8)	-0.09790	-0.0900	-0.1122	-0.0173[c] -0.0290[d]
In-Vehicle Travel Time	-0.045405	(-1.8)	-0.09790	-0.0900	-0.05611	-0.0159
Travel Cost	-0.01125	(-4.6)	-0.00954	-0.01065	-0.1837	-0.0085
Loop Dummy (on Walk)	0.5600	(3.6)				
Nesting Coefficient	0.8943	(6.5)	—	—	0.8843[e] 0.7064[e]	—
Constants						
Transit (Local & Premium)	-4.250					
Taxi	-5.380					
Statistics						
Log-Likelihood	-2178.6					
ρ^2 (w.r.t. zero)	0.7843					
ρ^2 (w.r.t. constants)	0.3242					
Value of Time	$2.42		$6.16	$5.07	$1.83	$1.12
Year for Dollars	1985		1975	1985	1970	1980?
Value of Time (1985 $)[f]	$2.42		$12.32	$5.07	$5.07	$1.46
Walk / IVTT Ratio	2.0-7.6		1.0	2.67	2.0	2.94
Wait / IVTT Ratio	2.0		1.0	1.0	2.0	1.1-1.8

[a]Coefficient on walk distance was converted to time and added to coefficient on walk travel time.
[b]From CATS regional model for home-based work trips to the Central Business District.
[c]First wait time.
[d]Transfer wait time.
[e]First nesting coefficient is for lower level sub-mode choice nest and second nesting coefficient is for upper level walk versus drive to transit level nest.
[f]Conversion to 1985 $ made using US average CPI-U values.

model coefficient for the shortest walk time range, 0 to 10 min, is very similar to the coefficient for wait time. This is consistent with many regional models in which walk and wait times are often grouped into one composite out-of-vehicle travel time variable. The disutility for the second walk time increment, 10 to 20 min, is more than three times as onerous as that for the first walk time increment. Walk times of between 10 and 20 min receive the full disutility of walking for 10 min (i.e., -0.9152) plus the incremental disutility for the portion of the walk greater than 10 min; walk times of between 20 and 30 min receive the full disutility for 20 min (i.e., $-0.09152 \times 10 + -0.3461 \times 10 = -4.3762$) plus the incremental disutility for the portion of the walk greater than 20 min but less than 30 min, and so on.

The Loop dummy coefficient is applied to those trips destined to the area bounded by the Chicago River on the north and west, Michigan Avenue on the east, and Congress Parkway on the south. The dummy variable implies that, all other things being equal, travelers are willing to walk longer to destinations inside the Loop than outside the Loop. The willingness of commuters to walk longer distances to Loop destinations is probably an effect of the long history of the traditional Loop area as an employment center served by the existing commuter-rail stations and regular bus service. Historically very little special service (e.g., shuttles) has been provided from the commuter-rail stations to Loop destinations.

The nested model was not statistically significantly better than the root multinomial model with choices between walk, taxi, local bus, and premium transit. The chi-square coefficient comparing the nested model with an equivalent multinomial model (the only difference being the nesting coefficient) was about 0.6. Choosing the nested form did not provide any real improvement in the explanatory power of the model. Nevertheless the nested model was selected since the nesting coefficient was reasonable and the model form fit preconceived notions.

The value of time for the model is about one-half of the value of time for the regional mode-choice model recently calibrated for Metra and for the model used in the AA/DEIS. The value of time was affected by the use of a composite variable to estimate a reasonable in-vehicle travel time coefficient. However the relatively low value of time suggests that commuters are less willing to pay incremental costs to travel from commuter-rail stations to their final destinations.

Table 3 compares the modeled mode shares with the surveyed mode shares by 5-min walk time increments. Figure 5 shows the same information in graphic form. As can be seen in Table 3 and

TABLE 3 Surveyed and Modeled Mode Shares by Distance

Walk Time Range		Surveyed Shares			Modeled Trips		
Begin	End	Walk	Transit	Taxi	Walk	Transit	Taxi
0	5	96.5%	3.0%	0.5%	99.7%	0.0%	0.3%
5	10	99.1%	0.8%	0.1%	99.6%	0.2%	0.3%
10	15	98.3%	1.3%	0.4%	98.2%	1.4%	0.4%
15	20	91.7%	6.9%	1.3%	92.5%	6.2%	1.2%
20	25	75.0%	22.2%	2.8%	74.9%	22.3%	2.8%
25	30	49.3%	45.6%	5.1%	43.6%	52.6%	3.8%
30	35	31.1%	64.2%	4.7%	21.8%	73.8%	4.4%
35	40	18.9%	81.1%	0.0%	14.1%	81.4%	4.5%
40	45	11.5%	85.2%	3.3%	8.4%	87.8%	3.8%
45	50	0.0%	93.3%	6.7%	6.0%	90.5%	3.4%
50	55	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
55	60	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%
60	65	0.0%	0.0%	100.0%	0.0%	100.0%	0.0%
65	70	0.0%	100.0%	0.0%	0.0%	100.0%	0.0%

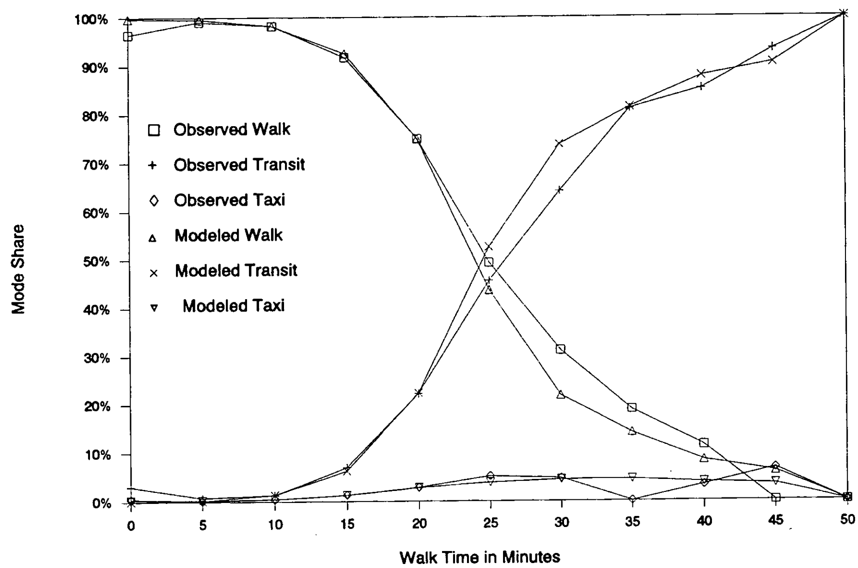

FIGURE 5 Observed and modeled mode shares, peak period distributor trips.

Figure 5, the model reasonably reproduces the observed shares by walk distance. The ability of the model to reproduce the mode shares for the different distance ranges was improved by the stratification of the walk time coefficient into four range categories. The model overestimates transit shares and underestimates walk shares in the 25- to 35-min time range (on the basis of walk travel times). However the observed mode shares in these time ranges are based on very few observed trips.

Table 4 summarizes the observed and modeled mode shares for five of the six commuter-rail stations in the central area. The model reasonably reproduces the mode shares for the stations, especially the two largest stations, North Western Station and Un-

TABLE 4 Surveyed and Modeled Mode Shares

	Surveyed Mode Shares			Modeled Mode Shares		
Station	Walk	Transit	Taxi	Walk	Transit	Taxi
Van Buren	93.9%	5.1%	1.0%	96.0%	3.4%	0.7%
Randolph	93.1%	5.6%	1.3%	95.9%	3.3%	0.7%
North Western	88.5%	10.6%	0.9%	88.9%	10.1%	1.0%
Union	88.8%	10.1%	1.1%	88.0%	10.9%	1.1%
LaSalle	93.4%	5.6%	1.0%	93.7%	5.3%	1.0%
Total	90.3%	8.7%	1.0%	90.3%	8.7%	1.0%

ion Station. Station-specific constants were investigated to improve the results, but they were rejected since their main justification would be to improve the validation results.

CALIBRATION OF CIRCULATOR MODELS

No disaggregate data existed to rigorously estimate the circulator models. The models were developed on the basis of the relationships determined for the AA/DEIS versions of the models along with the relationships and coefficients determined for the A.M. distributor mode choice models. The assumptions made in the specification of the mode choice model coefficients are summarized below.

- The value of time for A.M. circulation trips for central area residents is comparable with the regional value of time for work trips.
- The value of time for midday circulator trips for central area workers is comparable with the regional value of time for work trips.
- The values of time for midday circulator trips for central area nonworkers and central area residents is one-half of the value of time for midday circulator trips for central area workers.

Table 5 summarizes the final trip generation, trip distribution, and mode-choice model coefficients used for the six market segments used in the modeling process. Table 6 summarizes the observed and estimated mode shares and average trip lengths for the various circulator segment models.

SUMMARY

A detailed distributor mode-choice model was estimated for the Chicago central area on the basis of recently collected survey data. In effect this model is a transit egress mode-choice model. The results of this effort produced several interesting findings:

- A constant value for walk time is not appropriate when the walk time exceeds 10 min. However for walk times of less than 10 min the disutility of walk time is very similar to the disutility of wait time.
- The implied value of time for the distributor (egress) mode-choice model is about one-half of the value of time for the regional mode-choice model.
- If a nested logit model is used, the proper nesting structure is a choice between "walk" and "don't walk" modes, and between the motorized modes beneath the main "don't walk" mode.

The results of this model calibration effort suggest that future DPM modeling efforts should not be based on the Los Angeles DPM model calibrated in the early 1970s. Although the original model coefficients for travel time and travel cost in Los Angeles are similar to the short walk and wait time and the travel cost coefficients calibrated in the effort described here, the model for Los Angeles did not fully account for the disutility of walking long distances. In addition, the model for Los Angeles probably overestimated the disutility of in-vehicle travel time. Although the likely underestimation of the disutility of long walk time and the overestimation of the disutility of in-vehicle travel time have a tendency to cancel each other in DPM-based models for Los Angeles, they could lead to questionable forecasts of future travel on circulator-distributor or DPM systems.

The results of the present model calibration effort also have implications for future regional modeling efforts that incorporate full mode choice that include nonmotorized modes and for present modeling procedures that include walk access and egress times in the mode choice model. First, when walk time is considered, the disutility of walk time is probably not constant across all time intervals. This study suggests that for times under 10 min the disutility of walk time is similar to the disutility of wait time. Many existing modeling processes will not suffer, since a general practice has been to limit walk access and egress to 0.33 mi, or about 6.7 min. However some recent regional modeling efforts have stratified walk access into short walk (less than 0.33 mi) and long walk (0.33 to 1 mi). The results of the present study suggest that the coefficient for the long walk access time should be higher than the coefficient for the short walk access time.

When regional modeling efforts begin to incorporate full travel modes that include nonmotorized modes, the effect of varying the sensitivity to walk time will need to be considered. It is likely that a similar phenomenon will occur for bicycle travel time, although the sensitivity might not be the same as that for walk time. Very little investigation of the use of walk and bicycle modes has been done in the United States, although these modes are typically considered in European cities. Typically travel surveys used for calibrating regional models have not collected information on nonmotorized trips. This has started to change, especially with the recent Clean Air Act Amendments legislation passed by the U.S. Congress.

The final nesting structure that was determined for the circulator model suggests that nested, regional mode-choice models might be very complicated when walk and bicycle modes are added. It is likely that simple multinomial logit models will not suffice. More likely the main mode choice will be between walk, bicycle, and motorized modes or possibly between manual modes (i.e., walk and bicycle) and motorized modes. Under motorized modes the nested choices might be similar to those for current regional mode-choice models.

As is typically the case more study and data are required. The current Chicago central area modeling process has been improved by the availability of the Metra mode-of-access and -egress data. However further improvement could be made to the models for the various circulator model segments if comparable data were available for travel made by central area residents, workers, and nonworker visitors. This need will not disappear. It will continue to be necessary as regional planning processes and regional models attempt to consider all travel modes in future modeling efforts.

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TABLE 5 Trip Generation, Trip Distribution, and Mode-Choice Model Coefficients

Coefficient	AM Peak Distributor Model	AM Peak Circulator Model	Midday Distributor Model	Midday Circulator Model-Workers	Midday Circulator Model-Non-Workers	Midday Circulator Model-Residents
Trip Generation Model[a]						
Employment Density (Emp/Ac)—On 0-Trip Util	—	—	—	0.0008552	—	—
Attraction Density (Attr/AC)—On 1-Trip Util	—	—	—	0.00767	—	—
0-Trip Constant	—	—	—	2.75	—	—
Distributor Model[b]						
alpha	—	30	—	30	30	30
beta	—	1.10	—	0.30	0.30	0.90
gamma	—	-0.22	—	-0.50	-0.22	-0.60
Distance Coefficients[c]						
Walk	—	-7.50	—	-8.37	-6.50	-10.00
Transit	—	-5.50	—	-3.50	-1.00	-4.00
Taxi	—	-4.00	—	-2.00	0.0	-2.00
Auto	—	-4.00	—	-2.00	0.0	-2.00
Mode Choice Model						
Walk Time	—	—	—	—	—	—
0 - 10 minutes	-0.09152	-0.09152	-0.09152	-0.09152	-0.09152	-0.09152
10(+) - 20 minutes	-0.3461	-0.3461	-0.3461	-0.3461	-0.3461	-0.3461
20(+) - 30 minutes	-0.2385	-0.2385	-0.2385	-0.2385	-0.2385	-0.2385
> 30 minutes	-0.1736	-0.1736	-0.1736	-0.1736	-0.1736	-0.1736
Wait Time	-0.09081	-0.09081	-0.09081	-0.09081	-0.09081	-0.09081
In-Vehicle Travel Time	-0.045405	-0.09081	-0.045405	-0.09081	-0.09081	-0.09081
Travel Cost	-0.01125	-0.01125	-0.01125	-0.01125	-0.0225	-0.0225
Loop Dummy (on Walk)	0.5600	—	0.5600	—	—	—
Nesting Coefficient	0.8943	0.8943	0.8943	0.8943	0.8943	0.8943
Constants						
Walk	—	—	—	—	—	—
Transit (Local & Premium)	-4.250	-1.15	-4.250	-1.94	-1.045	-1.20
Taxi	-5.380	-1.40	-5.380	-3.44	-2.5	-2.55
Auto	—	0.0	—	-3.21	0.0	-0.15
Value of Time (1985 $)	$2.42	$4.84	$2.42	$4.84	$2.42	$2.42
Walk / IVTT Ratio	2.0-7.6	2.0-7.6	2.0-7.6	2.0-7.6	2.0-7.6	2.0-7.6
Wait / IVTT Ratio	2.0	1.0	2.0	1.0	1.0	1.0

[a]The trip generation model utilities are "added" to the composite utilities used for trip distribution. The choice based trip generation model is used only for trips made by CBD workers.

[b]The gamma function has been used to determine friction factors for the gravity model for trip distribution:

$$F = \alpha \times I^{\beta} \times e^{(I \times \gamma)}$$

where:

F is the friction factor for the interchange
I is the composite impedance for the interchange
e is the base of the natural logarithms (2.7183...)
α, β, and γ are calibrated coefficients

[c]The distance coefficients are applied to the total interchange distance (based on the walk mode shortest travel time paths) and "added" to the composite utilities used for mode choice. This additional utility is used to help control the average trip length by mode.

TABLE 6 Observed and Modeled Mode Shares and Average Trip Lengths, Circulator Model Market Segments

		Mode Share				Average Trip Length (Equivalent Walk Minutes)[a]			
Market Segment		Walk	Transit	Taxi	Auto	Walk	Transit	Taxi	Auto
Peak Circulator—Residents	Observed	51.4%	23.2%	12.6%	12.9%	8.5	21.4	20.1	19.0
	Modeled	51.8%	23.4%	12.2%	12.6%	8.5	25.8	19.3	24.1
Midday Circulator—Workers	Observed	90.1%	6.5%	1.6%	1.7%	4.4	24.7	n/a	n/a
	Modeled	90.1%	6.5%	1.6%	1.7%	4.4	25.6	16.9	23.9
Midday Circulator—Non-Workers	Observed	92.7%	3.5%	0.9%	3.0%	4.4	24.7	n/a	n/a
	Modeled	92.5%	3.5%	0.9%	3.1%	5.3	26.0	10.1	25.5
Midday Circulator—Residents	Observed	92.0%	4.0%	1.0%	3.0%	4.4	24.7	n/a	n/a
	Modeled	91.9%	4.0%	1.0%	3.1%	5.8	23.3	12.2	26.4

[a]All trip lengths are measured using the walk travel times for comparison purposes.

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