Transportation Sketch Planning with Land Use Inputs

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As a result of the 1990 Clean Air Act Amendments, greater attention is being focused on the regional land use policies available for mitigating congestion and reducing the total vehicle miles of travel. Land use changes are made using trip origins and destination flows from a sketch-planning network of the northeastern Illinois region and tested using a combined model of travel choice. Five general scenarios are considered: dense corridors, dense clusters, growth boundaries, urban infill, and a suburb-to-suburb rail project. The results indicate that compact patterns of regional densities for residence and employment with or without transit enhancements decrease many of the results related to vehicle miles traveled. Future work with sketch networks and the combined model will involve link pricing, regional economic analyses, and air quality modeling.

As a result of the 1990 Clean Air Act Amendments, greater attention is being focused on the regional land-use policies available for mitigating congestion and reducing the total vehicle miles of travel. In this report, a preliminary analysis is performed in which land-use changes are made in an existing base of travel demand and the outputs examined. The land-use changes consist of additions and subtractions to zonal origin and destination trip end flows, which simulate the addition or removal of residences and employment to and from the zone. The five scenarios considered are described below. The data used for the analysis reported here are for 1980 for the Chicago region. A sketch-planning or aggregated zone system and network were used in the analysis with 317 zones; the Illinois zones are indicated in Figure 1. The highway network has 2,902 links; the transit network is represented by a fixed matrix of travel times and fares. Each of the five scenarios is a "slice" of the same 1,194,983 peak-hour trip origins and destination flows that existed in 1980. The knowledge gained from analyzing these scenarios is applicable to current land-use and transportation planning problems.

The first formulation of a combined model was made in 1956 by Beckmann et al. (*1*) about the same time that the sequential procedure was first conceived. This kind of formulation was specialized for the trip distribution model being used in the sequential procedure in 1973 by Evans (*2*). Evans proposed an algorithm for solving the model as well as proving that the solution does converge to the desired conditions previously outlined. A combined model—including trip distribution, mode, and route choice—was first implemented on a network of realistic size for the Chicago region by Boyce et al. (*3*) in 1982. The development and implementation of similar models for the northeastern Illinois region based on a sketch-planning network and zone system have been the subject of ongoing research involving the staff and faculty of the University of Illinois at Chicago and the Chicago Area Transportation Study. The present paper is an extension of a report by Boyce et al. (*4*) [see also Boyce et al. (*5*) and Tatineni et al. (*6*)].

The sketch or aggregated planning approach does not include a trip-generation step at this time. Auto ownership is assumed and auto occupancy is a fixed parameter. Travelers' behavior is cost minimizing. As a result, this analysis sets up an abstract travel demand problem and solves it without addressing the intricacies of residential choice theory, trip rates or trip types as functions of population density, nonmotorized travel, and the many other model components that might be desired. However, within the bounds of this abstract approach, a starting point for study, as well as reasonable results, is found.

Because the Clean Air Act of 1990 served as a catalyst for this study, a rating of the air quality impacts of each scenario might be expected. A rough measure of these impacts is provided by examining the total vehicle miles traveled and the total congested vehicle miles traveled (VMT). Future work with the sketch-planning models may include analysis of loaded link volumes and the resulting estimates of auto pollutants.

It is the intent of the authors, although not in this report, to discuss at length the notion of scale in zonal structure and in networks. The aggregated scale of sketch planning was necessary in 1975 when it was first formulated because the smaller dimensions of its components reduced both computing time and expense. Now aggregation and the resulting loss of detail may be too high a price to pay. For example, many of the details of access to transit, that is, the increase in the number of walk trips to transit as a result of transit-oriented development, are lost in the zonal averages that provide transit access characteristics in the current sketch-planning model.

The land-use scenarios in this analysis were solved on a Sun SPARCstation 10 with 64 megabytes of memory at the Chicago Area Transportation Study. Solving the model at CATS for 20 iterations takes 45 minutes, that is, 2.5 minutes per iteration.

DESCRIPTION OF SCENARIOS

These five scenarios were set up to look at the following questions: (a) Do regional growth boundaries reduce total VMT? (b) Does an imposed density of abstract households and/or employment affect total VMT? (c) How does the imposition of dense corridors compare with that of dense nodes? How does the location of the area to be densified (i.e., urban versus suburban or central versus peripheral) affect the result? (d) How do VMT reductions compare in scenarios with and without a related transit improvement?

The percentage of origin and destination trip ends that were relocated is presented in Table 1. It should be noted that the percentage of trip origins and destinations moved to create each scenario is very small. Relatively sparse suburban zones most often served as the study zones from which a proportion of trip ends was subtracted.

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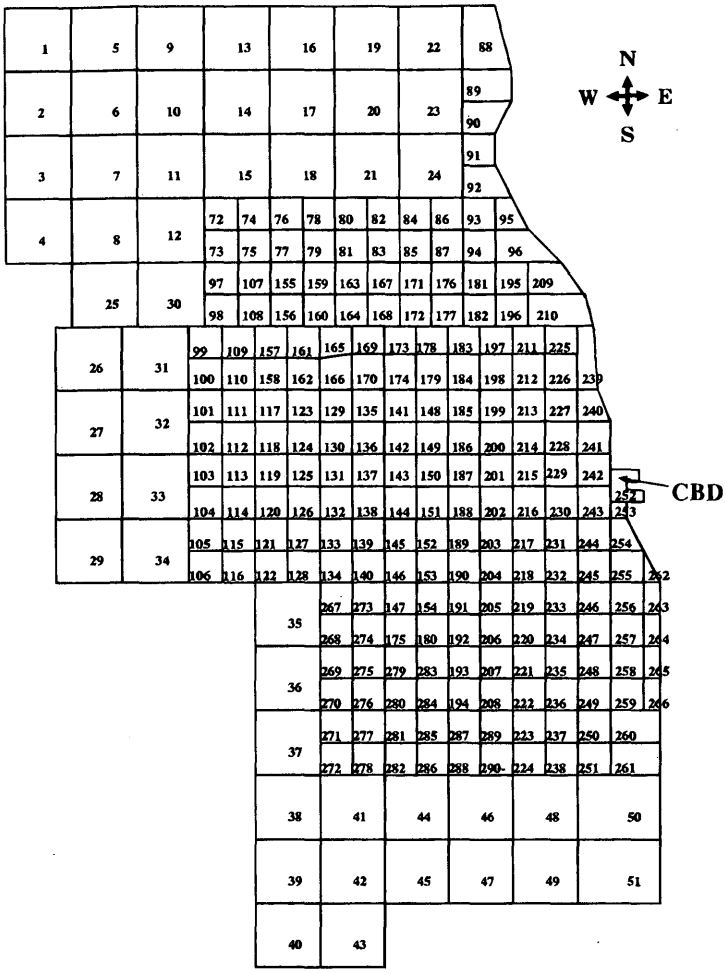

FIGURE 1 **Sketch-planning study zones.**

Five land-use scenarios are represented:

- A regional corridor development scenario;
- A dense regional center scenario;
- A regional growth boundary scenario using as target zones three dense suburban centers, "edge cities," in the region;
- A regional growth boundary scenario comparing the allocation of trips with an urban zone and a far suburban zone; and
- A regional growth boundary scenario using as target zones three dense suburban centers, edge cities, connected by suburb-to-suburb rail.

Regional Corridor Development, the Finger Plan

The concept of the "finger" plan is that growth be encouraged to locate in fairly narrow corridors along the existing commuter lines radiating from Chicago (see Figure 2). Major expressways would lie in the corridors as well, with regional centers of activity spaced at intervals close to transportation. The spaces or wedges between the corridors would be reserved for estate-type housing, parks, and forest preserves. The goal of this pattern of development is to plan for transportation, employment centers, open space, industry, residential communities, and natural resources by designating certain corridors for intense development and the interstices for no development (*7*).

Dense Regional Centers

A regional center is a large-scale area of concentrated development often 160 acres (64.78 hectares) or larger, characterized by a diversified mix of mutually supportive land uses, including substantial percentages of employment and housing. It has a unique character and a well-developed internal transportation system (*8*). Ten such centers were chosen for analysis in a single scenario: Crystal Lake, Waukegan, Lake-Cook Road corridor, Aurora, Elgin, Glen Ellyn, Oak Park–Austin, Ford City, Matteson, and Joliet. These centers are spread geographically around the region (see Figure 3). Most of the zones have some transit service and good access to the highway network. The goal of this pattern of development is to enhance transportation efficiency.

Regional Growth Boundary With Dense Suburban Centers (Edge Cities)

An "edge city" is defined as having (a) 5 million ft^2 (464,684 m^2) or more of leasable office space; (b) 6,000 ft^2 (558 m^2) or more of retail space; (c) a population that increases at 9 a.m. on workdays, marking the location as primarily a work center, not a residential suburb; (d) a local perception as a single end destination for mixed use; and (e) a history—30 years ago—in which the site was by no means

TABLE 1 Percentage of Regional Trip Ends Relocated for Land Use Scenarios

Scenario	% origins relocated	% destinations relocated
Finger plan	3.366	2.618
Regional centers	3.162	2.890
Growth boundaries		
1 tier	0.0027	0.0034
2 tier	0.0088	0.0070
Growth boundary		
Urban center	0.0027	0.0034
Far suburban center	0.0027	0.0034
Growth boundary with "Edge Cities" and rail	0.0027	0.0034

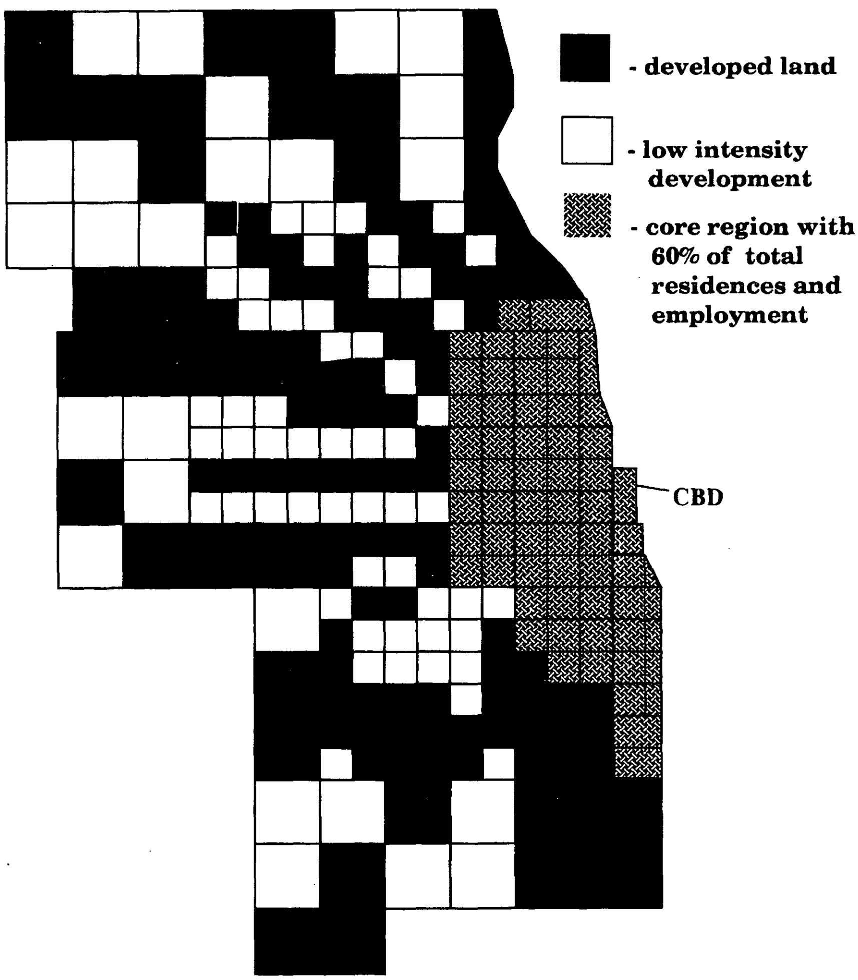

FIGURE 2 Coding scheme for regional corridor development.

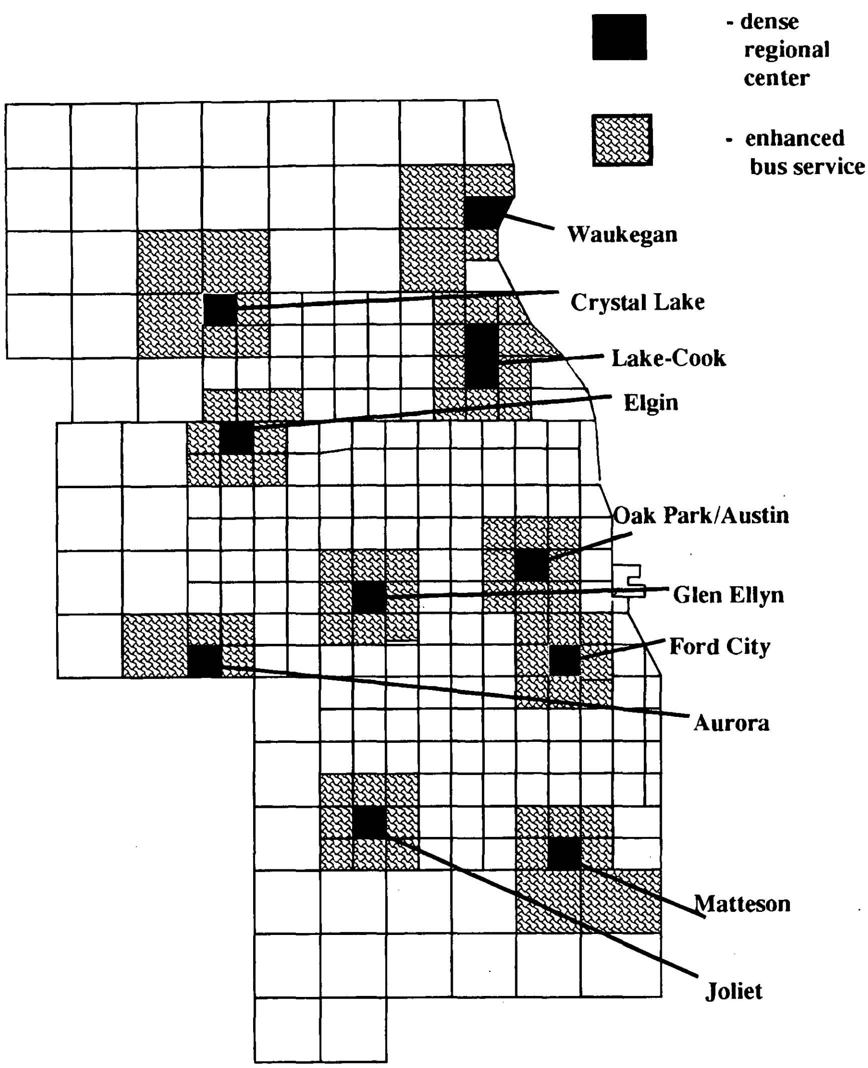

FIGURE 3 Dense regional centers.

urban but was overwhelmingly residential or rural in character. The region has five of these edge cities: (a) the central business district (CBD); (b) the Schaumburg area, including the Woodfield Mall; (c) the O'Hare Airport area; (d) the Illinois research and development corridor, including the area around Oak Brook, Lisle, Naperville, Aurora, and the East-West Tollway; and (e) the Lake-Cook corridor, around the Edens Expressway and the Tri-State Tollway (*9*). These edge city zones differ from the 10 regional centers in that they have densified naturally with the highway and transit access that accompanies or precedes development. We examine the results of further intensifying three of them—the Lake-Cook area, the Schaumburg area, and the Naperville area—using a growth boundary to gather origin and destination trip ends. This scenario was run using first one tier of peripheral zones and then two tiers (see Figure 4).

Regional Growth Boundary With a Comparison Between Urban Infill and Far Suburban Infill

In this scenario, the one-tier urban growth boundary described previously is activated and the resulting origin and destination trip ends applied first to an urban and then to a far suburban zone. The goal is to compare the results of applying densification in two very different locales. The highway network remained constant; identical enhanced bus service was provided to each infill zone in turn. This scenario is depicted in Figure 5.

Regional Growth Boundary With Dense Suburban Centers (Edge Cities) and a Rail Project

In this scenario, the edge city zones used before are connected by a premium service commuter rail that corresponds to the middle circumferential commuter rail project in the Chicago Area Transportation Study regional plan for 2010 (*10*). The right-of-way for the rail is Lake-Cook Road and the existing Illinois 53 right-of-way owned by the Illinois Department of Transportation (*11*). Because of its circumferential route, this proposed railway would provide transfers to and from the CBD via five existing Metra commuter lines. (See Figure 6.)

The bus and rail service that was included in two scenarios is designed to replicate the base service characteristics of local bus and

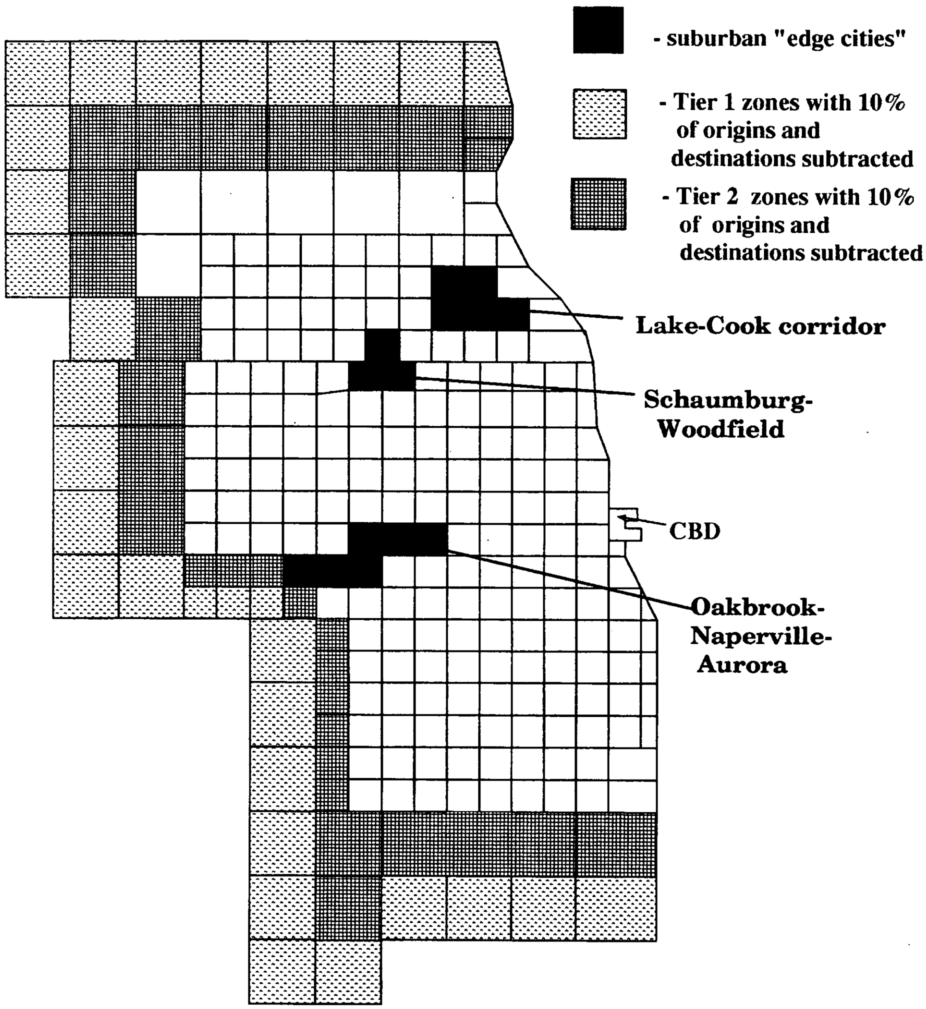

FIGURE 4 **Regional growth boundary with "edge city."**

premium rail as they exist in the northeastern Illinois region. Cost analyses from the point of view of the transit service provider will not be provided.

OUTPUTS FOR ANALYSIS

Six measures are selected to evaluate each scenario: mode choice, mean trip length, total and congested vehicle miles of travel, mean travel time, and mean generalized cost of travel. Highway costs are a weighted sum of the operating cost on the link as a function of flow, parking in each egress zone, walk time in each access zone, auto occupancy factor, and a fixed auto travel cost. Transit costs are a weighted sum of the transit in-vehicle time, transit fare, transit out-of-vehicle time, and a transit bias coefficient. Congested vehicle miles are the total vehicle miles on all links with flow exceeding capacity.

EFFECT OF REGIONAL CORRIDOR DEVELOPMENT

According to the original finger plan, the part of the region lying roughly in Cook County should ideally account for 60 percent of the residences and employment in the region. The remaining 40 percent would be divided into fingers (regional corridors) and interstices, the largely empty space between the fingers. Metra rail service and major highways would define the fingers. The sketch network zonal values were examined. The 1980 data showed that an approximate 60–40 split between Cook County and non-Cook counties was indeed the case. So the finger land-use scheme was constructed by removing all trip ends from the non-Cook interstices and adding them proportionately to the fingers. The results of assuming a regional corridor development plan on each of the output variables considered are presented in Table 2 and may be summarized as follows.

Effect on Mode Choice

With the incorporation of regional corridors, transit use increases slightly. That auto is still the overwhelming choice for travel to work suggests that many work trips do not begin and end in the same regional corridor.

Effect on Trip Length

As indicated in Table 2, the incorporation of regional corridors is marked by a decrease in the average trip length for both modes, with

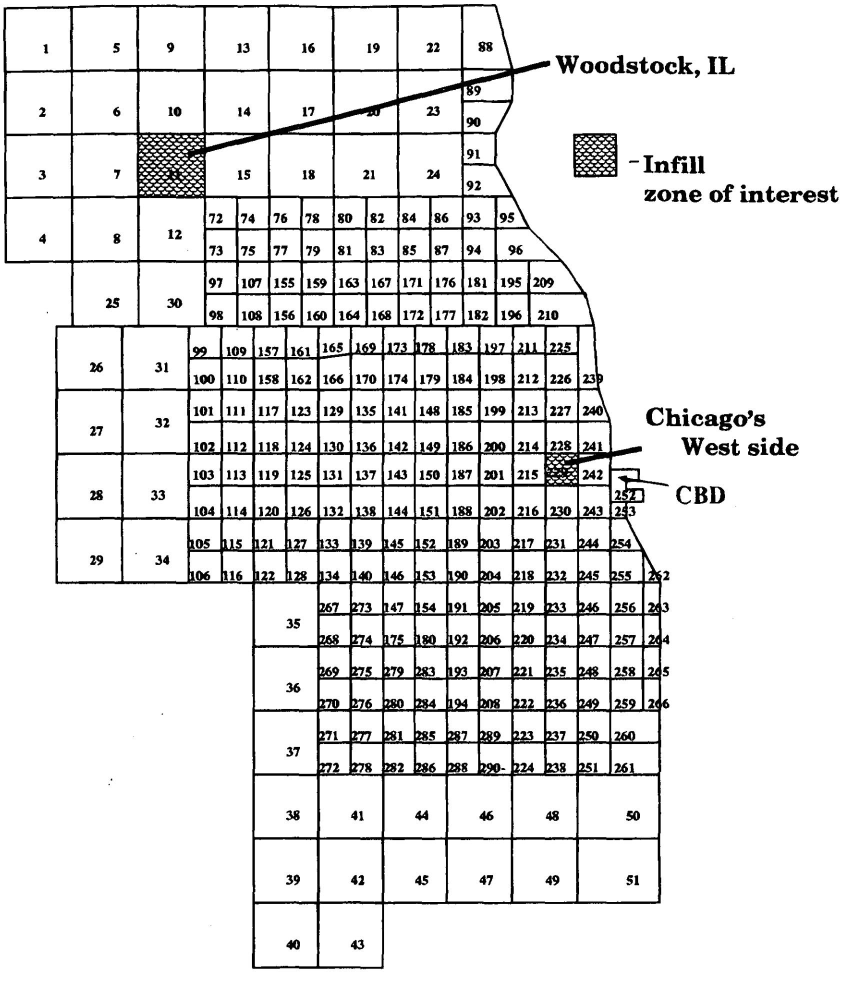

FIGURE 5 Comparison of urban versus far suburban infill.

auto showing a stronger decreasing trend. In suburban areas, the corridor zones contain virtually all of the residence and employment trip ends. The result is a rough auto-based jobs-housing balance that overall produces shorter mean trip lengths.

Effect on Travel Time

Auto travel time decreases due to an 18 percent increase in intrazonal auto trips; transit time increases slightly.

Effect on Vehicle Miles and Congested Vehicle Miles

Freeway congested vehicle miles of travel increase while total congested vehicle miles decrease. It might be expected that some highway paths combined with denser settlement patterns would increase congestion, and that this increase is exceeded by the benefits of shorter trips due to a jobs-housing balance.

Effect on Generalized Costs

The average generalized cost decreases for auto due to shorter trip lengths and times. Transit generalized cost increases slightly because of longer travel times.

EFFECT OF DEVELOPING DENSE REGIONAL CENTERS

Ten regional centers were defined (see Figure 4). To build them, 10 percent of the origin and destination trip ends were subtracted from the zones surrounding the zone of interest and added to the regional center zone. The output values were then calculated. A two-way bus that connects each surrounding zone to its regional center was added. Ten bus services were added. The buses travel at a mean speed of 12 mph (19.3 km/hr) with headways of 5 minutes and with a fare comparable to the base Chicago Transit Authority fare. The goal of adding this bus service was to link the center zone with the surrounding zones with convenient inexpensive transit service. The changes due to defining and developing these regional centers for the regional center scheme both with and without bus are presented in Table 3.

These effects may be summarized as follows.

Effect on Mode Choice

Transit use increases when the regional center zones are defined and increases again when they receive transit enhancements. That the first increase in transit use occurs when no transit projects are added indicates that population and employment density influence mode

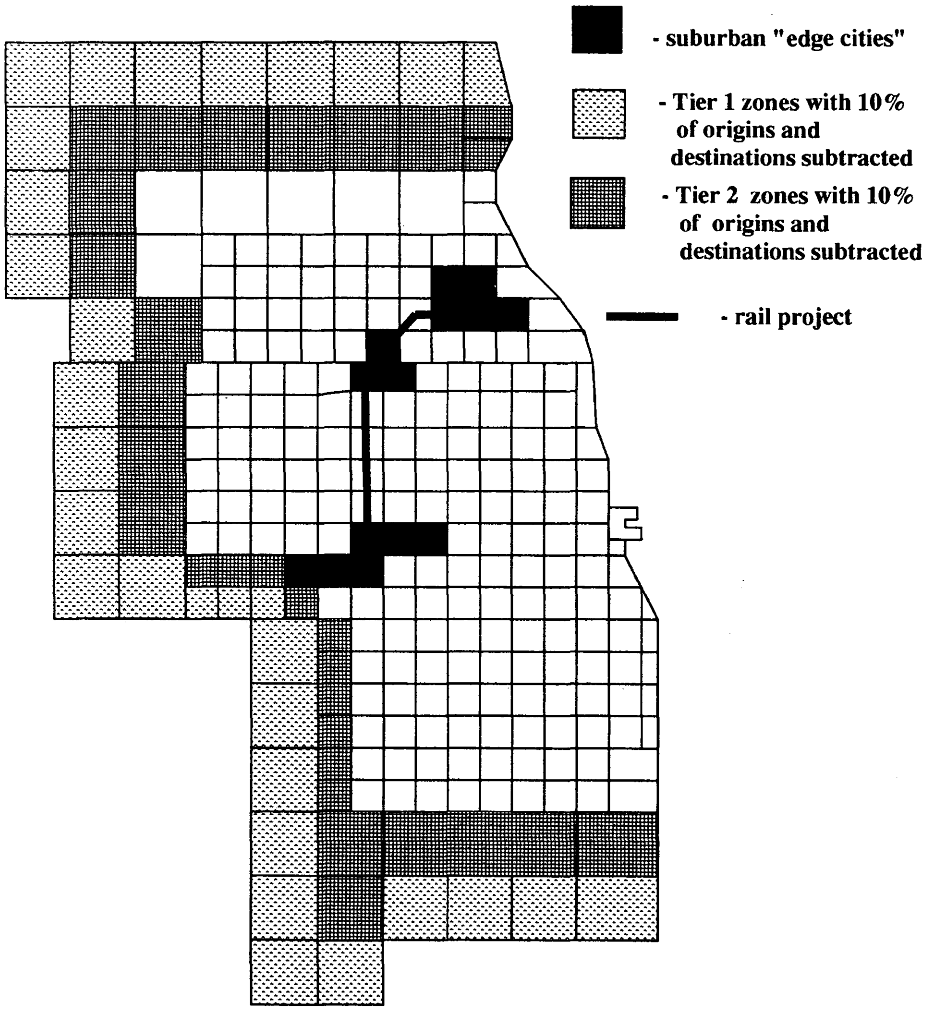

FIGURE 6 Regional growth boundary with "edge cities" and rail project.

choice. The further increase in transit use when bus service is added demonstrates that the service is well placed to serve existing and newly diverted transit work trips around the regional centers.

Effect on Trip Length

When the 10 regional centers are defined, auto trip length decreases due to the more compact nature of the region. When attractive bus service is added, however, local trip makers leave auto for transit, thus driving up the mean auto trip length. Transit trip lengths decrease when the centers alone are defined. This result stems from the addition of short transit trips to the regional mix. When the bus service is added, transit trip length increases to a value higher than in the base.

Effect on Travel Time

The logic of the mean trip length applies to the mean trip time, that is, when auto travel increases and intrazonal auto trips increase, mean auto travel times decreases. When transit increases as a mode and intrazonal transit trips decrease, mean transit travel times increase.

Effect on Vehicle Miles

Vehicle miles traveled decrease due to the more clustered placement of origins and destinations and to the increased number of travelers using transit.

Effect on Congested Vehicle Miles

Total congested vehicle miles decrease due, in part, to the reduction of total VMT. During testing of this scenario, experiments were conducted using higher percentages of trip ends removed from the surrounding zones. These experiments produced congestion hot spots since the existing highway network was unable to serve the increased use.

Effect on Generalized Cost

Generalized cost for auto decreases due to generally shorter trip lengths and times. Transit generalized cost varies due to the shifting mix of bus use.

TABLE 2 Base Versus Regional Corridor "Finger Plan"

		base	corridor
% transit in region		15.963	16.109
Mean trip length	(auto)	10.385 mi	10.143 mi
		16.71 km	16.32 km
	(transit)	9.829 mi	9.746 mi
		15.82 km	15.68 km
Mean travel time	(auto)	26.397	25.966
(minutes)	(transit)	35.227	35.260
Total vehicle miles traveled		8,240,930	8,034,712
Total vehicle kilometers traveled		13,259,656	12,927,852
Congested vehicle miles		4,313,712	4,266,326
Congested vehicle kilometers		6,940,762	6,864,518
Generalized cost	(auto)	2.908	2.866
	(transit)	4.199	4.197

TABLE 3 Base Versus Dense Regional Centers

		base	reg. center	reg. center with bus
% transit in region		15.963	16.005	16.454
Mean trip length	(auto)	10.385 mi	10.380 mi	10.392 mi
		16.710 km	16.70 km	16.72 km
	(transit)	9.829 mi	9.798 mi	10.053 mi
		15.82 km	15.77 km	16.18 km
Mean travel time	(auto)	26.397	26.385	26.400
(minutes)	(transit)	35.227	35.169	36.577
Total vehicle mi traveled		8,240,930	8,232,762	8,198,308
Total vehicle kms traveled		13,259,656	13,246,514	13,191,078
Congested vehicle miles		4,313,712	4,275,289	4,252,069
Congested vehicle kms		6,940,762	6,878,940	6,841,579
Generalized cost	(auto)	2.908	2.908	2.909
	(transit)	4.199	4.190	4.316

EFFECT OF A REGIONAL GROWTH BOUNDARY

In this scenario, two schemes are used: (a) a one-tier reduction scheme in which 10 percent of the origin and destination trip ends are subtracted proportionately from the outer periphery of the region and (b) a two-tier scheme in which the two outer rings receive the treatment (see Figure 5). In both cases, the trips are added proportionately to the three edge city zones. The effects of assuming a regional growth boundary are presented in Table 4 and summarized below.

- *Effect on mode choice:* very slight decrease in transit share for both one tier and two tiers;
- *Effect on trip length:* very slight decrease for both one tier and two tiers;
- *Effect on travel time:* slight increase in mean auto travel time and slight decrease in transit time;
- *Effect on vehicle miles:* very slight decrease for both one tier and two tiers;
- *Effect on congested vehicle miles:* increase as the trip ends are collected into three already-busy suburban zones; and
- *Effect on generalized cost:* very slight decrease for both one tier and two tiers.

The overall changes in all output variables here are very small, in part because of the tiny percentage of the regional trips that are being moved (see Table 5). The 10 percent of the zonal origins in the one-tier periphery amounted to 0.0027 percent of the region's origin trip ends, although they were in zones that represented 26.6 percent of the region's land. The 10 percent of the zonal destinations in the one-tier periphery amounted to 0.0034 percent of the region's destination trip ends and again 26.6 percent of the region's land. When two tiers of peripheral zones were used, the 10 percent of the zonal origins in the periphery amounted to 0.0088 percent of the region's origin trip ends though they were in zones that represented 45.8 percent of the region's land. The 10 percent of the zonal destinations in the two-tier periphery amounted to 0.0070 percent of the region's destination trip ends and again 45.8 percent of the region's land.

All output measures in this scenario exhibited very little change because a very small percentage of the regional trips were shifted to another zone. That these shifts are small is of less interest to many planners than their very existence.

EFFECT OF A REGIONAL GROWTH BOUNDARY WITH TRIP ENDS ADDED TO AN URBAN VERSUS A FAR SUBURBAN ZONE

In the fourth scenario, origin and destination trip ends are subtracted from one tier of the periphery and added to two zones for comparison purposes. These two zones are a city of Chicago zone that represents a 9-mi^2 section of the near West Side of Chicago and a far suburban zone that represents the 36-mi^2 containing Woodstock, Illinois (see Figure 6). Each infill zone is served by a two-way bus service of the type described in the section on regional centers. Ten percent of the trips in one tier of the peripheral zones were directed to each of these zones in turn. The goal was to compare the results

TABLE 4 Base Versus Regional Growth Boundary

		base	growth boundary 1 tier	growth boundary 2 tier
% transit in region		15.963	15.958	15.945
Mean trip length	(auto)	10.385 mi	10.379 mi	10.375 mi
		16.71 km	16.70 km	16.69 km
	(transit)	9.829 mi	9.796 mi	9.783 mi
		15.81 km	15.76 km	15.74 km
Mean travel time	(auto)	26.397	26.413	26.441
(minutes)	(transit)	35.227	35.210	35.194
Total vehicle kms traveled		13,259,656	13,252,783	13,249,784
Total vehicle mi. traveled		8,240,930	8,236,658	8,234,794
Congested vehicle mi.		4,313,712	4,327,863	4,369,272
Congested vehicle kms.		6,940,762	6,963,531	7,030,158
Generalized cost	(auto)	2.908	2.909	2.911
	(transit)	4.199	4.197	4.197

TABLE 5 Percentage of Regional Trip Ends in One- Versus Two-Tier Scenarios

	One Tier	Two Tiers
% of zonal trips removed	10	10
number of zones used	31	61
% of regional land used	26.6	45.8
% of regional trip origins removed	.0027	.0088
% of regional trip destinations removed	.0034	.0070

of encouraging residential and employment location in an urban infill zone versus a far suburban zone. The results are presented in Table 6 and discussed below.

Effect on Mode Choice

Transit percentage of regional mode split increases in both strategies with a larger increase in the urban infill scheme due to a larger population in the urban area available to use the transit service.

Effect on Trip Length

Mean auto trips length decreases in the urban scheme because of the central location of the zone and in the far suburban scheme because of the growth in intrazonal auto trips. Transit trip length decreases in both schemes due to the addition of new shorter transit trips.

Effect on Travel Time

Auto travel time generally increases due to a rise in congested miles. Mean transit time in the urban infill scheme decreases 2 percent as

TABLE 6 Base Versus Urban Infill and Far Suburban Infill

		base	urban infill	far suburban infill
% transit in region		15.963	16.125	15.956
Mean trip length	(auto)	10.385 mi	10.379 mi	10.378 mi
		16.71 km	16.70 km	16.70 km
	(transit)	9.829 mi	9.589 mi	9.797 mi
		15.82 km	15.43 km	15.76 km
Mean travel time	(auto)	26.397	26.407	26.429
(minutes)	(transit)	35.227	34.351	35.212
Total vehicle mi. traveled		8,240,930	8,220,084	8,235,778
Total vehicle kms traveled		13,259,656	13,226,115	13,251,367
Congested vehicle mi.		4,313,712	4,368,305	4,321,244
Congested vehicle kms		6,940,762	7,028,602	6,952,881
Generalized cost	(auto)	2.908	2.907	2.911
	(transit)	4.199	4.138	4.198

a result of the enhanced bus service provided to eight highly populated Chicago zones, including a part of the extended CBD.

Effect on Vehicle Miles

Vehicle miles traveled decrease in both schemes due to shorter mean auto trip and to the shift to transit.

Effect on Congested Vehicle Miles

Total congested vehicle miles on both arterials and freeways increase in both schemes with the larger increase in congestion occurring in the urban infill.

Effect on Generalized Cost

Generalized costs decrease for both modes due to slightly lower travel times.

The overall results of this scenario demonstrate that constructing a slightly more compact region is marginally more efficient when the densification takes place in an urban zone instead of a far suburban zone.

EFFECT OF A REGIONAL GROWTH BOUNDARY WITH A RAIL PROJECT

In the final scenario, origin and destination trip ends are subtracted from one tier of the periphery and added proportionately to the three edge city zones. These zones are then connected by a two-way 35-mi (56.3-km) circumferential commuter rail service with 5-minute headways and a mean speed of 45 mph (72.4 km/hr). The fare is distance based. Two-way bus service was added connecting the zones with new rail service to the zones immediately adjacent. The bus service has 5-minute headways, a mean speed of 12 mph (19.3 km/hr), and a fare equivalent to the base Chicago Transit Authority local price. The goal of modeling this somewhat abstract rail service is to examine the regional changes that occur when a very attractive transit alternative is provided.

The transit network in this combined model is a fixed set of four transit matrices. To represent transit projects, the cell values were altered manually after which a shortest path algorithm was applied to the matrix (*12*). This algorithm, which was necessary to incorporate changes in one cell to all origin-destination pairs in the network, had the effect of streamlining the base transit paths. Thus, the base results in Table 6 differ from those in the previous tables.

The effects of assuming a regional growth boundary, densifying suburban edge cities, and building a rail connecting them are presented in Table 7 and discussed below.

Effect on Mode Choice

The transit percentage of regional mode split increases as a result of the attractiveness of the rail project.

Effect on Trip Length

Auto and transit trip lengths increase. Some short suburban auto trips shift to transit due to the rail project and the enhanced bus service. Transit, however, added long trips as well, resulting in a higher mean trip length for transit.

TABLE 7 Base Versus Growth Boundary with Rail

		base	growth boundary with rail
% transit in region		17.7	18.0
Mean trip length	(auto)	10.680 mi	10.687 mi
		17.18 km	17.20 km
	(transit)	9.783 mi	9.896 mi
		15.74 km	15.92 km
Mean travel time	(auto)	27.107	27.121
(minutes)	(transit)	35.906	36.377
Total vehicle miles traveled		8,296,325	8,276,121
Total vehicle kms traveled		13,348,787	13,316,279
Congested vehicle miles		4,509,013	4,481,801
Congested vehicle kilometers		7,255,001	7,211,217
Generalized cost	(auto)	2.975	2.976
	(transit)	4.263	4.347

Effect on Travel Time

Mean auto travel time and mean transit travel time increase because trip length increases.

Effect on Vehicle Miles

Vehicle miles traveled decrease due to the shift to transit.

Effect on Congested Vehicle Miles

Congested vehicle miles decrease based on a lightening of both freeway and arterial congested miles. The rail project acts to decrease some road use. When the densification took place without a new transit alternative (Scenario 3), congested vehicle miles increased.

Effect on Generalized Cost

Generalized costs for transit increased due to longer mean travel time.

The overall results of this scenario demonstrate that constructing a slightly more compact region with well-defined edge cities connected by premium rail service will decrease many of the vehicle miles traveled related outputs under study.

CONCLUSIONS

Land use inputs do not respond in a spectacular fashion to regional modeling strategies. The result of making a significant change, like introducing regional corridors, is a minimal change in the output variables. Effecting a larger change may mean making irrational or infeasible initial assumptions. It helps to recall that it took the automobile and real estate forces 50 years to establish the land-use and transportation system operating now, which responds to the land-use changes reported here with the powerful inertia of urban sprawl. Modeling land use well suggests a travel demand approach designed to be very sensitive to change, using flexible data inputs like parking costs per zone that shift if the zone becomes denser, for instance, and with a long-term (i.e., 20 years or more) horizon.

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REFERENCES

1. Beckmann, M., C. B. McGuire, and C. B. Winsten. *Studies in the Economics of Transportation.* Yale University Press, New Haven, Conn., 1956.
2. Evans, S. P. Derivation and Analysis of Some Models for Combining Trip Distribution and Assignment. *Transportation Research, Vol. 10,* 1976, pp. 37–57.
3. Boyce, D. E., K. S. Chon, and R. W. Eash. Development of a Family of Sketch Planning Models. *CATS Research News,* 1982.
4. Boyce, D. E., M. Tatineni, and Y. Zhang. Scenario Analyses for the Chicago Region With a Sketch Planning Model of Origin-Destination, Mode and Route Choice. *Report to Illinois Department of Transportation,* University of Illinois, Chicago, 1992.
5. Boyce, D. E., K. S. Chon, M. E. Ferris, Y. J. Lee, K.-T. Lin, and R. W. Eash. *Implementation and Evaluation of Combined Models of Urban Travel and Location on a Sketch Planning Network.* University of Illinois at Urbana-Champaign and Chicago Area Transportation Study, Chicago, 1985.
6. Tatineni, M., M. Lupa, D. B. Englund, and D. E. Boyce. Transportation Policy Analysis Using a Combined Model of Travel Choice. In *Transportation Research Record 1452,* TRB, National Research Council, Washington, D.C., 1994.
7. *Diversity Within Order: Coordinated Development for a Better Environment.* Northeastern Illinois Planning Commission, 1967.
8. *Strategic Plan for Land Resource Management.* Northeastern Illinois Planning Commission, 1992.
9. J. Garreau. *Edge City.* Doubleday, New York, 1990.
10. 2010 Transportation System Plan. *Technical Process Report Volume II: Appendices.* Chicago Area Transportation Study, Chicago, 1990.
11. Rail Alternatives Planning Study: Proposed Alternatives for Sketch Planning and Prioritization. *Metra. Report No. 1.* Office of Planning and Analysis, 1989.
12. Murchland, J. D. *A Fixed Matrix Method for All Shortest Distances in a Directed Graph and for the Inverse Problem.* Ph.D. dissertation, Universitat (TH) Fridericiana zu Karlsruhe, 1970.

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