Regional Transportation Authority

Study of New and Replacement Rail Transit Alternatives

Phase I Final Report

August, 1978

STUDY OF NEW AND REPLACEMENT RAIL TRANSIT ALTERNATIVES (SONARRTA)

PHASE I

FINAL REPORT

REGIONAL TRANSPORTATION AUTHORITY

AUGUST, 1978

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PREFACE

The Study of New and Replacement Rail Transit Alternatives is a staff project of the Regional Transportation Authority of Northeastern Illinois. The purpose of the project is to develop a system plan for the Chicago metropolitan area's rapid transit and commuter rail network. The study, when completed, will provide a general framework for the evaluation and programming of all rail-related capital projects in the six county area.

This report documents the major accomplishments of the study completed under Phase I of an UMTA technical study project grant. During Phase I of the study, the development of the analytical tools necessary to evaluate over 200 proposed projects was completed. In addition, a mathematical programming approach was proposed as part of the Phase I research and will be utilized for Phase II of the study. Finally, an evaluation package was utilized to screen the numerous rapid transit projects by corridor. The results of this screening are contained in Part 2 of this report.

The analytical methods presented in this report will be further refined during Phase II of the SONARRTA study. The analysis and refinements will then be used to provide recommendations of the study.

CHAPTER I

INTRODUCTION

The Problem

A large number of rapid and commuter rail projects have been proposed for the Chicago metropolitan area. These projects include extensions of existing rapid transit lines, entirely new lines, and extensions and abandonments of existing commuter rail lines.

Currently, the Chicago Transit Authority must operate a rapid transit system with almost half its mileage on maintenance intensive, environmentally intrusive, elevated structure built around the turn of the century. Similarly, many of the commuter railroads must operate a system which is in need of capital intensive maintenance and improvement. Decisions concerning the renovation and replacement of much of the rapid and commuter rail systems must be made in the near future.

In the past, decisions as to the replacement, renovation, or extension of major rail facilities in the Chicago area have been based on detailed study of the affected corridor. This approach has never addressed regionwide concerns as to the need for the facility and the resultant implications of the level of investment required for implementation.

Due to the expensive nature of constructing new and replacement facilities, it is clear that not all potential projects can be financed under future capital budgets. Trade-offs must be made between maintaining and renewing segments of the regional rail transit (commuter and rapid) system, replacing current segments of the system, and adding new lines to the system. Further trade-offs must be made between building new rail transit lines and improving or abandoning service on existing rail lines.

It is also clear that there is a basic deficiency in the annual planning and programming process when a regionwide strategy for long range development of the rail system is lacking. The assessment of each project cannot be undertaken without a guide as to the future of the rail lines in question. It is crucial that the programming of capital maintenance and improvement projects reflects the regionwide strategy for investment in order to minimize unnecessary and duplicative expenditures while providing for the optimal development and expansion of the region's rail system.

Study Purpose

The Study of New and Replacement Rail Transit Alternatives (SONARRTA) is a project which, when completed, will provide the basic framework necessary to evaluate major rail capital projects from a consistent, regional perspective. The results of this study will consist of a system plan for the CTA rapid transit system and commuter railroads, as well as a schedule for detailed corridor studies. This will, for the first time, provide a framework within which short-term capital maintenance projects can be evaluated. For long range planning, the study's conclusions will be utilized as the optimal Year 2000 Plan for the regional rail transit system, thereby providing the context for the evaluation of major new rail capital projects.

The study will enable a determination of priorities for investment of scarce capital dollars for a number of corridors in the region. These decisions involve rehabilitation of existing lines versus building new replacement facilities. Without a guide to the future state of these facilities, expenditures which may be unnecessary and wasteful will be made on structures that are eventually to be abandoned or replaced. A determination of the future of rail facilities allows potential savings in capital maintenance to be realized and thus enable an increase in available funding for improving and expanding the existing rail system.

The subsequent detailed corridor-level studies that are suggested by SONARRTA will have an iterative relationship with the long-range conclusions. As changing economic, land use, and social factors may in the future alter the validity of SONARRTA's initial conclusions, SONARRTA will be constantly updated in order to adjust the long-range implications of these developments. The study will be reassessed and revised periodically in order to continue to provide an ongoing framework for use in the programming process as well as for evaluation of long-range major capital projects.

Study Design

Due to the multiplicity of transportation needs in the metropolitan area, it is necessary to study all feasible alternatives for expanding or improving the region's rail system to determine their relative merits. Alternatives were derived from various sources including: previous regional and local plans, testimony at recent RTA public hearings, and proposals suggested by staff of the region's transportation and planning agencies. After gathering all of the alternatives, evaluation is undertaken to address the basic study objective:

> "Given various assumptions regarding future capital funds for the six county Northeastern Illinois rail system over the next 25 years, what is the maximum extent of improvement for the region's rail system that can be accomplished."

Improvements are evaluated on a regionwide or network basis. Due to the large number of alternatives and the interdependence of benefits among a series of alternative lines, it is impossible to find the best or optimum rail network by simply evaluating each line individually, and then combining the preferred lines to form the network. The theoretically correct method involves defining all possible combinations of alternatives and then selecting accordingly. However, since approximately 200 lines have been proposed, this would entail evaluating 2^{200}, or more than a trillion combinations.

An evaluation methodology which addresses this problem has been formulated to produce an optimum rail network under a variety of future conditions. The entire methodology is a three stage process of which the study, itself, addresses the first two stages.

1. Sketch Planning - Due to the large number of alternative lines specified for CTA, screening of lines from each corridor was completed. All proposed CTA lines were classified and grouped into corridors. Then, analysis was undertaken to produce a single 'do-something' alternative for each corridor. These selected alternatives, along with the 'do-nothing' alternative for each corridor, are then designated as alternatives for the next step. The results of screening are contained in Part 2 of this report.

2. System Optimization - A search for the optimum rail (commuter and rapid transit) system is initiated in order to provide a set of recommendations from all of the alternatives. A mathematical (combinatorial) programming model is utilized for the search of the best possible network plan. To account for the future uncertainty with respect to such critical variables as gasoline availability, transit funding, and population; various scenarios are utilized to develop an optimum plan under a series of conditions.

3. Corridor-Level Studies - Once the study has been completed, trade-offs among corridors for facility needs will have been determined. For those actions which are considered high priority, detailed studies will be required to determine local impacts of facility design and to reach a final decision regarding justification and implementation of an alternative.

Agency Review

An external task force consisting of representatives from the region's planning and transit operating agencies was formed in order to review the study goals, content, and methodology. The individuals serving on the task force represented the following agencies:

1. Chicago Area Transportation Study
2. Chicago Transit Authority
3. Chicago Urban Transit District
4. City of Chicago - Department of Development Planning
5. City of Chicago - Department of Public Works

6. Illinois Department of Transportation - Division of Public Transportation
7. Northeastern Illinois Planning Commission
8. Passenger-Law Committee (representing the commuter railroads:

    Chicago, Milwaukee, St. Paul and Pacific R.R.
    Chicago & North Western Railway
    Chicago, Rock Island & Pacific R.R.
    Burlington Northern R.R.
    Illinois Central Gulf R.R.
    Norfolk & Western Railway
    Chicago, South Shore and South Bend R.R.)

9. Regional Transportation Planning Board

Working papers, technical memoranda, and discussion papers were distributed to all task force members for periodic review and comment. The participation of these agencies in the study was essential for gathering of the data and providing a balanced perspective as to the transportation needs of the six county area.

Organization of Phase I Final Report

The major accomplishments of Phase I of SONARRTA are summarized in the following chapters:

- Chapter II contains a detailed description of all of the alternative rapid transit and commuter rail lines considered in this study.

- Chapter III presents the analysis of regional rail ridership and the development of the SONARRTA demand models.

- Chapter IV contains a description of the computer demand network that was coded to represent the existing and all possible system combinations. The accuracy and efficiency of the entire demand estimation process is also reported.

- Chapter V is a summary of the capital and operating cost models that were developed as part of the study.

- Chapter VI is a discussion of the proposed evaluation methodology and the issues associated with optimum transit network design.

In Part 2 of this report, the methodology for sketch planning and the results of corridor screening are presented.

CHAPTER II

RAIL LINK ALTERNATIVES

Specification of Alternatives

Over 200 alternative rail transit projects for both the rapid transit and commuter railroad systems have been included for evaluation in SONARRTA. These have been structured so as to include as wide a range of actions as possible. As noted in Chapter I, a variety of contributors participated in the definition of alternatives, including: staff of RTA, the commuter railroads, CTA, various local and county planning agencies, and the public. The 1995 Transportation System Plan[1] was the most important of the many regional and local plans that were consulted. In addition, testimony from recent RTA public hearings provided another source of proposals.

Since evaluation is undertaken on a system-wide or network basis, alternatives have been specified as network links. These links include new lines, replacement projects, extensions to existing lines, and abandonments of existing lines. For each new or replacement line, stations have been defined and the construction option chosen (i.e., subway, elevated, elevated grade).

A. Chicago Transit Authority - Rapid Transit

Over 200 separate alignments have been proposed for replacements, extensions, and renovations to the existing rapid transit system. The alternatives have been screened so that detailed evaluation (system optimization) will be undertaken on only a non-duplicative, logical set of alternatives. The purpose of screening is to reduce the extremely large number of rapid transit alignments to only one 'do-something' alternative for each corridor. (For a detailed explanation of screening, see Part 2). Alignments specified in this chapter that have been selected as a result of the screening phase of the study are denoted by an asterisk (*). The alternatives and existing lines have been grouped according to the following classifications:

1. Constant - These lines are assumed to be in existence through the study's planning horizon of 50 years. This category generally includes lines which were either constructed recently, or do not require major capital maintenance over the planning horizon. The following existing lines are considered as constant:

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[1] Chicago Area Transportation Study, Northwestern Indiana Regional Planning Commission, 1995 Transportation System Plan for the Chicago-Gary Region, Annual Update, March 1976.

a. Howard, Lawrence to Howard
b. Milwaukee, Halsted to North, and Logan Square to Jefferson Park
c. Lake, Laramie to Harlem
d. Skokie, Howard to Central Park
e. Evanston
f. Congress, Halsted to Des Plaines
g. Dan Ryan, Cermak to 95th

2. Replacements, Renovations - The following existing lines have been designated as candidates for renovation or replacement to a nearby new alignment. The proposed improvement alternative for each of these facilities is listed below the existing line:

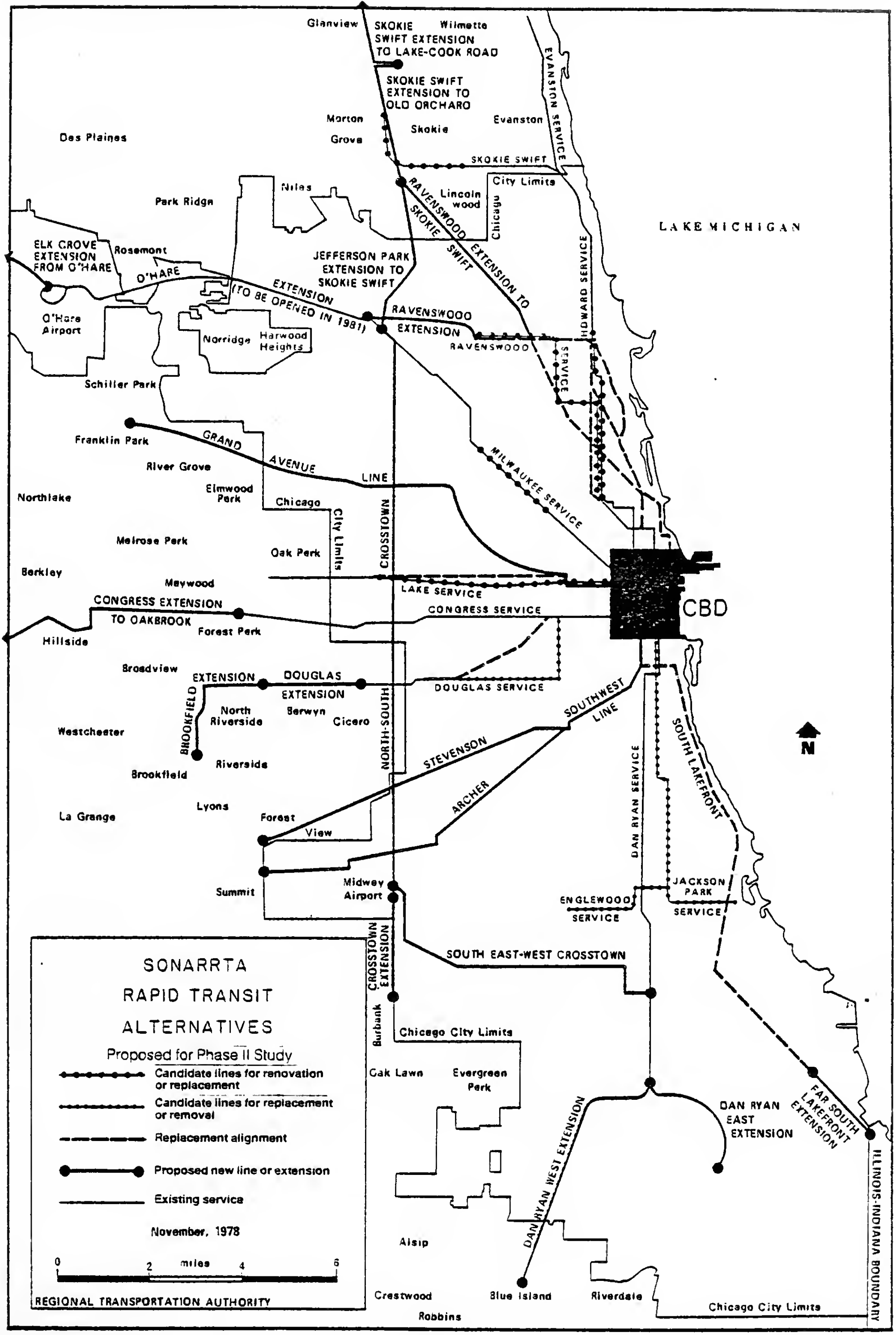
   a. Lake Street Line (Laramie to CBD)
      *New alignment along C&NW elevated grade, Ashland and Des Plaines Avenues
   b. Milwaukee (North to Logan Square)
      Construct subway
   c. Skokie (Central Park to Dempster)
      Grade - separate along existing right-of-way
   d. Howard (North/Clybourn to Lawrence)
      Construct subway along *Sheffield, or *Sheffield-Clark
   e. Ravenswood (Armitage to Kimball)
      Construct subway along *Lincoln Avenue or *Lakefront

3. Removals, Replacement - These existing lines are subject to removal, replacement by a new facility on a nearby alignment, or, remaining unchanged. The lines and the possible new alignments are listed below.

   a. Douglas Line
      *Ogden Avenue alignment
   b. Jackson Park - Englewood Line
      *South Lakefront Line on ICG and ConRail rights-of-way.

4. Proposed New Lines - These rapid transit alternatives include new corridor lines on either entirely new right-of-way, expressway median strip, or existing railroad right-of-way. This category contains the following alternatives:

   a. North-South Crosstown along Cicero Avenue
      *Lawrence-Midway on Indiana Harbor Belt R.R. right-of-way
   b. East-West Crosstown along Belt Railroad
      *Midway - 79th/Dan Ryan on Indiana Harbor Belt R.R. right-of-way
   c. Southwest Line
      Construct new line along *Archer Ave., or *Stevenson Expressway
   d. Grand Avenue
      Construct new line to Franklin Pk. along *Milwaukee Rd. right-of way


SONARRTA
RAPID TRANSIT
ALTERNATIVES
Proposed for Phase II Study
Candidate lines for renovation or replacement
Candidate lines for replacement or removal
Replacement alignment
Proposed new line or extension
Existing service
November, 1978
0
2
miles
4
6
REGIONAL TRANSPORTATION AUTHORITY
Glenview
SKOKIE SWIFT EXTENSION TO LAKE-COOK ROAD
Wilmette
SKOKIE SWIFT EXTENSION TO OLD ORCHARD
Morton Grove
Skokie
Evanston
EVANSTON SERVICE
Des Plaines
SKOKIE SWIFT
City Limits
Niles
Lincoln wood
Chicago
Park Ridge
RAVENSWOOD SKOKIE SWIFT EXTENSION TO
LAKE MICHIGAN
ELK GROVE EXTENSION FROM O'HARE
Rosemont
O'HARE EXTENSION (TO BE OPENED IN 1981)
JEFFERSON PARK EXTENSION TO SKOKIE SWIFT
HOWARD SERVICE
O'Hare Airport
RAVENSWOOD EXTENSION
RAVENSWOOD
SERVICE
Norridge
Harwood Heights
Schiller Park
Franklin Park
GRAND AVENUE LINE
River Grove
MILWAUKEE SERVICE
Northlake
Elmwood Park
Chicago
City Limits
CROSSTOWN
Melrose Park
Oak Park
Berkley
Maywood
LAKE SERVICE
CONGRESS EXTENSION TO OAKBROOK
CONGRESS SERVICE
CBD
Hillside
Forest Park
Broadview
EXTENSION
DOUGLAS EXTENSION
DOUGLAS SERVICE
BROOKFIELD
North Riverside
Berwyn
Cicero
SOUTHWEST LINE
SOUTH LAKEFRONT
Westchester
NORTH-SOUTH
N
Riverside
STEVENSON
Brookfield
ARCHER
DAN RYAN SERVICE
La Grange
Lyons
Forest View
Summit
Midway Airport
JACKSON PARK SERVICE
ENGLEWOOD SERVICE
CROSSTOWN EXTENSION
SOUTH EAST-WEST CROSSTOWN
Burbank
Chicago City Limits
Oak Lawn
Evergreen Park
DAN RYAN EAST EXTENSION
FAR SOUTH LAKEFRONT EXTENSION
DAN RYAN WEST EXTENSION
ILLINOIS-INDIANA BOUNDARY
Alsip
Crestwood
Blue Island
Riverdale
Chicago City Limits
Robbins

5. Extensions - These are alternatives which are extensions of existing lines or future new lines. These alternatives are therefore dependent upon the future of the main lines in question. This category includes the following:

   a. Dougles Extension (Berwyn to Harlem)
   b. Douglas Extension (Harlem to Brookfield)
   c. Crosstown Extension (Midway to 79th)
   d. Far South Lakefront Extension (95th to Indiana State Line)
   e. Dan Ryan East Extension to 111th
   f. Dan Ryan West Extension to Blue Island (via *Interstate 57)
   g. Congress Extension to Oakbrook
   h. Elk Grove Extension (from River Road)
   i. Skokie Swift Extension to Old Orchard
   j. Skokie Swift Extension (Old Orchard to Lake-Cook Rd.)
   k. Jefferson Park Extension to Skokie Swift

B. Commuter Railroads

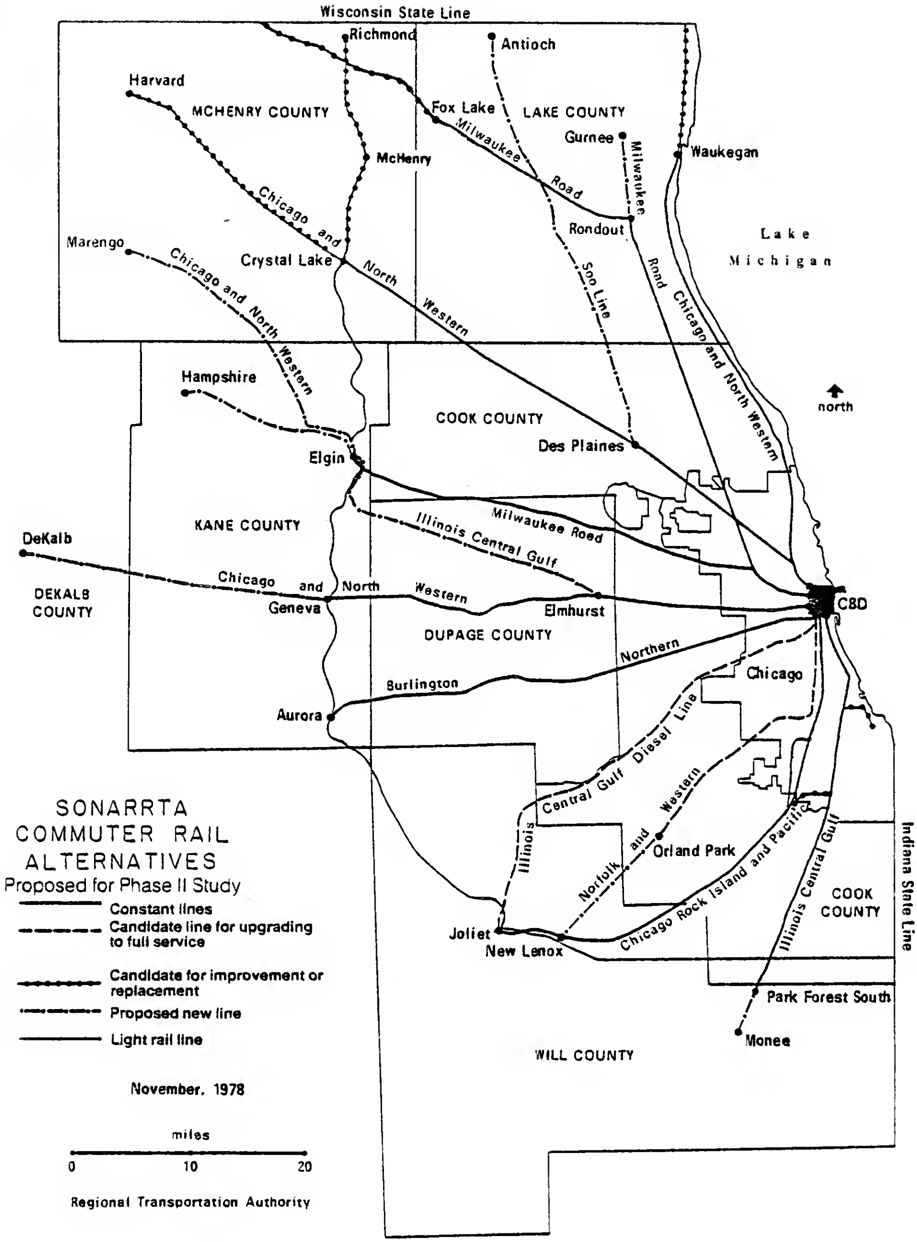
The classification of alternatives for the commuter rail system has the following scheme for the study:

1. Constant Lines - These are defined as existing lines which are maintained at given standard (FRA Class IV) to the Year 2000. No decision as to the future of these lines is necessary, since these lines are assumed to be in existence throughout the study period. This category includes the majority of the existing commuter rail lines:

   a. Chicago and North Western North Line (CBD to Waukegan)
   b. Milwaukee Road North Line (CBD to Rondout)
   c. Chicago and North Western Northwest Line (CBD to Crystal Lake)
   d. Milwaukee Road West Line (CBD to Elgin)
   e. Chicago and North Western West Line (CBD to Geneva)
   f. Burlington Northern (CBD to Aurora)
   g. Chicago, Rock Island and Pacific Main Line (CBD to Joliet)
   h. Illinois Central Gulf Main Line (CBD to Park Forest South)

2. Candidate Lines for Upgrading to Full Service - These lines have infrequent scheduled service at the present time. The study's conclusions will include a determination of whether each line should be upgraded to full service or continue to be maintained at present service levels. This category contains the following lines:

   a. Gulf, Mobile and Ohio (ICG Diesel) to Joliet
   b. Norfolk and Western to Orland Park


Wisconsin State Line
Richmond
Antioch
Harvard
MCHENRY COUNTY
Fox Lake
LAKE COUNTY
Gurnee
Milwaukee
Road
Waukegan
McHenry
Chicago and North Western
Rondout
Lake Michigan
Marengo
Crystal Lake
Soo Line
Road
Chicago and North Western
Hampshire
north
COOK COUNTY
Des Plaines
Elgin
KANE COUNTY
Milwaukee Road
Illinois Central Gulf
DeKalb
DEKALB COUNTY
Chicago and North Western
Geneva
Elmhurst
CBD
DUPAGE COUNTY
Burlington Northern
Chicago
Aurora
Illinois Central Gulf Diesel Line
Norfolk and Western
Orland Park
Chicago Rock Island and Pacific
Illinois Central Gulf
COOK COUNTY
Indiana State Line
Joliet
New Lenox
Park Forest South
Monee
WILL COUNTY
SONARRTA
COMMUTER RAIL
ALTERNATIVES
Proposed for Phase II Study
Constant lines
Candidate line for upgrading to full service
Candidate for improvement or replacement
Proposed new line
Light rail line
November, 1978
miles
0
10
20
Regional Transportation Authority

3. <u>Candidate Lines for Improvement or Replacement</u> - A full range of options will be investigated for lines in this category. The study will determine whether each line should be maintained at existing service levels, upgraded to an increased level of service, or replaced by an alternative service. For inner-city commuter rail branches, the study will also determine the merit of replacing commuter rail service with rapid transit. This category contains five lines:

   a. C&NW North Line, Waukegan to Wisconsin State Line
   b. ICG Blue Island Branch
   c. ICG South Chicago Branch
   d. C&NW McHenry Branch, Crystal Lake to Richmond
   e. C&NW Northwest Line, Crystal Lake to Harvard
   f. Milwaukee Road North Line, Fox Lake to Wisconsin State Line

4. <u>Proposed New Lines</u> - These lines include all extensions to the present commuter rail system, as well as several entirely new lines, and a light rail line which will be evaluated in four individual segments.

   a. N&W extension, Orland Park to New Lenox
   b. ICG extension, Park Forest South to Monee
   c. Milwaukee Road West Line, Elgin to Hampshire
   d. Milwaukee Road North Line, Rondout to Gurnee
   e. C&NW West Line, Geneva to DeKalb
   f. Soo Line, Des Plaines to Antioch
   g. ICG, Elmhurst to Elgin
   h. C&NW, Elgin to Marengo
   i. Light Rail Line:

      1) Crystal Lake - Elgin
      2) Elgin - Aurora
      3) Aurora - Joliet
      4) Joliet - Indiana State Line

CHAPTER III

PATRONAGE ANALYSIS

Patronage and Evaluation

With the gathering of all feasible alternatives for the six county regional rail system, a major element of the evaluation process is the prediction of travel demand and user savings. Since the methods used in predicting demand are major determinants of the study's analytical capability, it was essential that the needs and assumptions associated with the demand prediction process be predetermined and the methodology developed accordingly. The desired features of a demand estimation process for evaluation of a regional rail transit network are summarized below:

- Since SONARRTA is a long range study of the regional rail system, a fixed origin-destination trip table cannot be used. The prediction of demand for facilities years in the future must account for changes in regional population and employment levels, travel costs (gasoline availability), as well as changes in the transport network. Thus, newly generated trips, as well as changes in modal share due to level of service changes, must be explicitly accounted for. Therefore, a predictive demand model that is based on the behavioral aspects of a tripmaker was developed.

- In the evaluation of rail projects, users' benefit is an important criterion. A unique advantage of the behavioral simultaneous demand model is its expression of demand as a direct function of level of service variables. Thus, changes in level of service along with trip volumes are used to estimate users' benefit (through a consumers' surplus calculation).

- The demand estimation process must be computer efficient and inexpensive to operate. This is a necessity for a network study, in order to evaluate individual links, as well as combinations of all of the specified alternatives.

In order to develop a demand estimation process in accordance with the above, existing ridership on the region's rail lines was investigated for significant travel patterns. Table 3.1 is a line by line analysis of commuter rail ridership. Over ninety per cent of the commuter rail trips end in the Chicago Central Business District. Similarly, in Table 3.2, the rapid transit ridership is heavily oriented towards the CBD with over eighty-four percent of its ridership either ending or passing through the CBD. Clearly, the

TABLE 3.1

COMMUTER RAIL RIDERSHIP

LINE	AVERAGE WEEKDAY RIDERSHIP	CBD DESTINED RIDERSHIP
[1] CHICAGO AND NORTHWESTERN		
North	12,540	9,570
Northwest		
-Main	19,900	16,970
-Richmond Branch	180	150
West	12,460	11,190
[2] MILWAUKEE ROAD		
North	7,490	6,460
West	7,920	6,870
[3] BURLINGTON NORTHERN	23,080	19,760
[4] ILLINOIS CENTRAL GOLF (Electric)		
Main	19,860	16,720
S. Chicago Branch	3,250	2,740
Blue Island Branch	2,090	1,760
[5] ROCK ISLAND		
Main	5,110	4,580
Beverly Branch	5,400	4,550

1. From C&NW ticket sale information, February 2, 1977.
2. Based on Milwaukee Road estimates, May 1976.
3. Based on 1976 estimates
4. ICG estimate of 1977 ridership.
5. 1976 one way boarding estimates.

TABLE 3.2

Ridership of Chicago Transit Authority Rapid Transit System [1]

LINE	TOTAL ENTERING VOLUME	ONE-WAY ENTERING VOLUME [2]	ONE-WAY CBD DEST. [3]		ONE-WAY THRU DEST. [4]		ONE-WAY LOCAL DEST. [5]	
RAVENSWOOD	22,300	18,730	14,985	(.80)	1,685	(.09)	2,060	(.11)
DOUGLAS	20,800	15,390	9,855	(.64)	2,000	(.13)	3,540	(.23)
CONGRESS	21,000	14,700	8,380	(.57)	2,645	(.18)	3,675	(.25)
MILWAUKEE	50,100	39,580	28,895	(.73)	4,750	(.12)	5,935)	(.15)
DAN RYAN	69,100	53,900	38,810	(.72)	4,850	(.09)	10,240	(.19)
HOWARD	64,700	50,470	35,830	(.71)	7,065	(.14)	7,570	(.15)
ENGLEWOOD-JACKSON PK.	42,150	29,080	16,285	(.56)	8,235	(.28)	5,185	(.18)
LAKE	28,250	24,010	19,690	(.82)	1,680	(.07)	2,640	(.11)
SKOKIE	3,200	2,720	2,230	(.82)	245	(.09)	245	(.09)
EVANSTON	10,400	8,320	6,240	(.75)	830	(.10)	1,250	(.15)
TOTAL	332,000	256,900	181,200	(.71)	33,985	(.13)	42,340	(.17)

1. Based on Chicago Area Transportation Study - 1970 Home Interview Survey and 1975 C.T.A. Weekday Traffic Counts.

2. One-Way trips may not sum to one-way entering volumes due to rounding error.

3. Number of trips with origins on the line and destinations outside of the CBD.

4. These are trips which originate on a line, pass through the CBD, and have destinations on another line.

5. These are trips with origins and destinations outside of the CBD.

major rapid transit and commuter rail market is oriented towards the Chicago CBD.[1]

Trips on the regional rail system were therefore divided into three major markets of ridership: CBD destined, local, and thru trips. The estimation of demand for SONARRTA is based on three separate travel demand models; a CBD demand model, a local trip model and a thru trip factor. The three segments of demand are then summed to provided total one way ridership by line. The development of each of the travel demand models is described in the remaining sections.

CBD Demand Model

The model developed for predicting CBD work trips is a joint choice demand model. A sequential or standard modelling process was not utilized for two major reasons.

- A sequential demand process contains a series of components (trip generation, distribution, mode split, and assignment) which is expensive to operate. Due to the high cost of applying the entire sequential demand process, it can typically be used only a limited number of times, greatly decreasing its applicability in a network or system optimization study.
- Difficulties arise when segmenting travel demand estimation into a sequence of independent components (trip generation, distribution, mode split, and assignment). Questions concerning the validity of the entire sequential demand process, the propagation of errors, and the sensitivity of demand to policy variables have been discussed extensively in numerous transportation research papers.[2]

For these two reasons, a joint choice demand has been developed to estimate trip generation, distribution, and mode split simultaneously, instead of sequentially. In addition to its simultaneous formation, there are the following important features of the model:

1. The model is structured so as to be directly sensitive to policy variables, such as travel time and travel cost.
2. The model distributes trips from the CBD to each residential zone on a multi-modal basis since there are four basic modes of transportation serving the CBD work trip: automobile, commuter rail, rapid transit and bus.

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[1] An analysis of historical trends for CTA rapid transit ridership over the last fifteen years shows that while total ridership has declined, the percent of riders traveling to the CBD has remained relatively constant.

[2] Stopher, P. Lisco, T., "Modelling Travel Demand: A Disaggregate Behavioral Approach", Transportation Research Forum, 1970, pp. 195-214.

3. The model allows for the measurement of the impact of proposed transit lines on land-use (primarily zonal population), since a long range plan is being developed.

4. The model does not require large amounts of input data, and is computer efficient.

The general model structure is similar to that of a Lowry family model[3] with CBD employment (or simply total CBD trips generated) as the basic independent variable. Basically, the model operates as an allocation process whereby, given total CBD employment, work trips from the CBD via different modes are distributed to the residential area. This distribution is based on the relative attractiveness of both the zones and the transportation modes.

The basic model structure is:

$$T_{ijk} = E_i \cdot \frac{A_j \exp(B \cdot U_{ijk})}{\sum_n \sum_m A_n \exp(B \cdot U_{inm})}$$

Where:

T_{ijk} : Work trips from CBD zone i to zone j via mode k

E_i : Employment in CBD zone i

A_j : Zonal attractiveness of zone j

U_{ijk} : Utility by Mode k from zone i to j

B : A vector of calibration coefficients which are weights for different components of travel utility

n : number of origin zones; (1,2,..., j,...,n)

m : number of modes considered; (1,2,3,4)

The observed data, including the trips from the CBD to residential zone j via mode k and the population of the origin zones, were collected. During calibration, least squares and maximum likelihood analysis were used to further specify the utility function and the parameter values.

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[3] Golden, W., "The Lowry Model Heritage", Journal of the American Institute of Planners, March, 1971.

It is important to note that the travel demand between zones i and j via mode k (t_{ijk}) is not fixed over time and changes in a non-linear fashion. This is one of the most desirable characteristics of the model, in that work trip interchanges and residential population distributions are sensitive to transportation levels of service. In other words, the impact of transportation facilities on land-use is explicitly recognized and measured.

Base Data

The model was developed and will be applied on a basic mile square zone system for the Northeastern Illinois region. A single centrally located zone, containing four square miles was defined as the CBD. For calibration, a twenty-five percent random sample of traffic zones was chosen.

Data was collected for all proposed utility function variables. The 1970 census was the source for: (a) zonal population and family income; (b) CBD employment; and (c) trip interchanges by mode from the zones to the CBD. Airline distances from the zone centroids to the CBD were directly measured, and the travel times representing peak period times via the minimum time path by each mode and the travel costs associated with the path were calculated.

During the data collection phase, it became apparent that the census data did not accurately report the relative proportion of bus and rapid transit trips; and thus that these modes could not be treated independently. Therefore, a combination mode including bus and rapid transit users had to be defined. The utility of the transit mode was then calculated as a weighted average of the bus and rapid transit utilities. The levels of bus and rapid transit usage required to calculate weighted utilities was obtained from the CATS 1970 Home Interview Survey.

Finally, it is important to realize that each zone in the calibration data set represented a data point with a set of independent variables based on zonal characteristics and the average characteristics of each line haul mode from that zone. The dependent variables were the actual trip interchanges observed via each mode. This is significantly different from the standard disaggregate calibration methods using individual trip data. No assumptions concerning the representativeness of the sample of individual trips, nor the guidelines for aggregate travel prediction need to be made, and zonal data is readily available.

Alternative CBD Model Specifications

Given the basic multi-nominal logit model structure; alternative utility function forms, utility function variables, and calibration methods were proposed and then evaluated.

With respect to utility function form, two basic alternatives were examined. The first is the simple linear form which is most typically used in mode-split analysis. The other possibility is the non-linear function which is theoretically superior in that, unlike the linear form, it does not assume that the marginal value of travel cost or time is constant.

Equations 2 and 3 show the linear and non-linear forms respectively.

$$U_{ijk} = a_1 \cdot t_{ijk} = a_2 \cdot C_{ijk} + a_k \qquad (2)$$

$$U_{ijk} = a_1 \cdot \ln(t_{ijk}) + a_2 \cdot \ln(C_{ijk}) + a_k \qquad (3)$$

With regard to utility function variables, a series of potential variables were identified. These included: (a) door-to-door travel time; (b) total out-of-pocket cost; (c) average zonal household income; (d) distance from residential zone to the CBD; and (e) mode specific constants. The first two variables are typical level of service parameters, while income typically relates to transit utilization, with high income usually associated with lower levels of usage. Distance from the CBD can be viewed as a surrogate for the relative comfort and convenience of the commuter rail and rapid transit modes, whereby the greater the distance from the CBD, the better the commuter rail mode. The coefficients of mode-specific constant variables represent proxies for all unmeasured level of service variables, including comfort, convenience, reliability, and safety.

Finally, with respect to calibration methodologies, two non-linear methods-minimization of unexplained variance (least squares) and maximum likelihood-were considered. A linearization method was not used, since it requires a base data set that includes all combinations of possible zones and alternative modes, which in this case would give an unmanageable 200,000 data points.

The most efficient method of estimating the non-linear models involved calculating partial derivatives for all the coefficients, and simultaneously solving all the partial derivative equations. However, no method for solving such a set of simultaneous equations could be identified or developed. Instead an existing iterative searching process, the Fletcher/Reeves unconstrained non-linear minimization technique, was chosen for use.[4] The process basically searches a plane to determine which coefficient values would either minimize unexplained variance or maximize likelihood.

Initial Calibration and Testing

Once the complete set of alternative models was developed, and the base data compiled, the evaluation of the different models was undertaken. The initial testing involved the calibration of a series of binominal logit mode choice models. These models illustrated that certain potential utility function variables could be eliminated and that there was a need for further refinement of the method of measuring travel utilities.

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4 Fletcher, R. and Reeves, C., "Function Minimizations by Conjugate Gradents", Computer Journal, Vo. 7, 1964, pp. 149-154.

The first conclusion was that the distance variables should be excluded from the utility function. While these variables did have the expected impacts (i.e., coefficient signs), there were two major problems associated with their inclusion: a) their high correlation (ranging from .78 to .88) with the travel time variable; and b) their effect in making the model significantly less sensitive to the time and cost policy variables by both increasing the magnitude of the mode-specific constants and decreasing the absolute values of the time and cost coefficients. In addition, they added little explanatory power to the model.

The second conclusion was based on the fact that in select areas the predicted mode-choices for the commuter rail and rapid transit modes did not correlate with the actual mode choices, and thus, it was felt that the travel utilities as originally measured did not represent actual utilities. This problem involved an over-prediction of rapid transit trips in suburban areas and of commuter rail trips in Chicago.

In order to correct this problem, the original commuter rail and rapid transit utilities were modified through the application of penalties, whereby additional travel time was assigned to the rapid transit mode in the outlying areas and to the commuter rail mode within the city. It is important to note that there is a conceptual basis for such penalties in that: (a) for the rapid transit mode, the method of calculating access time did not adequately account for the disutility associated with a long suburban trip to a rapid transit terminal; and (b) for the commuter rail mode, the disutility associated with basically unattractive inner-city stations is not accounted for in any variable. Also since an assumed regional average of 5 minutes waiting time was used for commuter rail riders, the infrequent service at inner-city commuter rail stations is not reflected.

Evaluation of Utility Function Forms

The next step in the model development process was the evaluation of the two alternative utility function forms. In order to empirically test the linear and non-linear forms, three bi-nominal logit mode choice models were calibrated using the linearization calibration approach and least squares criterion. It should be noted that the linearization calibration approach could be used in this case since there are only three mode-choice combinations.

Table 3.3 shows the three models, their parameters, and the correlation coefficients. As the table illustrates, for each model, the non-linear functional form has a slightly higher correlation coefficient. This slight improvement, coupled with the theoretical superiority of the non-linear form, resulted in its selection as the utility function form, and the elimination of the linear form from further consideration.

TABLE 3.3

COMPARISON OF UTILITY FUNCTION FORMS

MODEL	DEPENDENT VARIABLE	NON-LINEAR UTILITY FUNCTION			LINEAR UTILITY FUNCTION		
		TIME PARAMETER	COST PARAMETER	CORRELATION COEFFICIENT	TIME PARAMETER	COST PARAMETER	CORRELATION COEFFICIENT
Auto-Commuter Rail	Commuter Rail	-1.49	-3.41	.72	-.0055	-.0274	.70
Transit-Auto	Transit	- .84	-3.35	.87	-.0048	-.0043	.87
Commuter Rail-Transit	Commuter Rail	-1.39	-3.22	.87	-.0058	-.0110	.82

Selection of Functional Form

Alternative models, each with a slightly different underlying rationale, were then specified. Using various assumptions for the representation of total utility (travel time and cost) and the form of the zone attractiveness functions, a five parameter model was selected. This model was selected because of its high correlation coefficient and its consistency of parameter values under different calibration methods:

$$T_{ijk} = E_i \cdot \frac{A_j \cdot (t_{ijk})^{a} \cdot (C_{ijk})^{b} \cdot \exp(d_1 X_1 + d_2 X_2 + d_3 X_3)}{\sum_n \sum_m A_n \cdot (t_{inm})^a \cdot (C_{inm})^b \cdot \exp(d_m X_m)}$$

Where: T_{ijk}: work trips from CBD zone to origin zone j via mode k

E_i : employment in CBD zone

A_j : estimated population in origin zone j

t_{ijk}: travel time from CBD zone to zone j via mode k

C_{ijk}: travel cost from CBD zone to zone j via mode k

a,b : calibration coefficients

d_1, d_2, d_3: mode specific constants

X_1, X_2, X_3: dummy variables representing existence of the mode; auto, commuter rail, and transit respectively

Table 3.4 shows the parameter values for the selected model. Three general points should be noted: a) the signs of the time, cost, and income variables are correct; b) the correlation coefficient for the model is quite good; and c) the mode specific constants show that there are biases in the other parameters, but that these are biases that are not significant.

Calibration of the CBD Demand Model

The last step for preparation of a model was a determination as to which calibration method should be used. The least squares method had a consistently higher correlation coefficient for all the models tested, while the consistency of the time and cost parameter values is substantially greater for the maximum likelihood method. This illustrates the superiority of the least squares method in replicating existing data, but also demonstrates that the least squares method's parameter values are inconsistent (statistically biased).

TABLE 3.4

CALIBRATION OF SIMULTANEOUS CBD DEMAND MODEL

Calibration Method	Parameters		Mode Specific Constants			Correlation Coefficient
	Time(t_{ijk})	Cost(C_{ijk})	Auto	Commuter Rail	Transit	
Least Squares	-.841	-.326	-.126	-.148	.275	.76
Maximum Likelihood	-.884	-.409	.134	-.206	.072	.73

This statistical bias is important in that the smaller the variation in the parameter values, the greater the reliability of any one specific parameter value. Examination of the coefficient of the most important variable - travel time - shows that, for the maximum likelihood method, the variation is from -.827 to -.984, while for least squares estimation, the variation is from -.599 to -.864.

Figures 3.1 and 3.2 illustrate the sensitivity of both calibration criteria. In the figures, each contour line represents a 10% decrease in the unexplained variance or a 10% increase in the value of the likelihood function. For least squares calibration (Figure 3.1), the total variance, as well as the amount of explained variance associated with different calibration coefficients, are calculated: and the percentiles which repesent the amount of unexplained variance are drawn. For maximum likelihood calibration (Figure 3.2), the total likelihood indicators associated with different calibration coefficients are calculated, and percentiles which present the amount of likelihood are drawn.

The figures show that the maximum likelihood estimate is far more sensitive to parameter values than is the least squares criteron. In addition, the plane associated with the maximum likelihood method is close to a normal distribution, while the least squares plane has an unknown skewed distribution. This increases the probability that the maximum likelihood method provides less statistically biased parameters than does the least squares method. Thus, it was decided that the maximum likelihood calibration should be used.

The final model to be used is therefore:

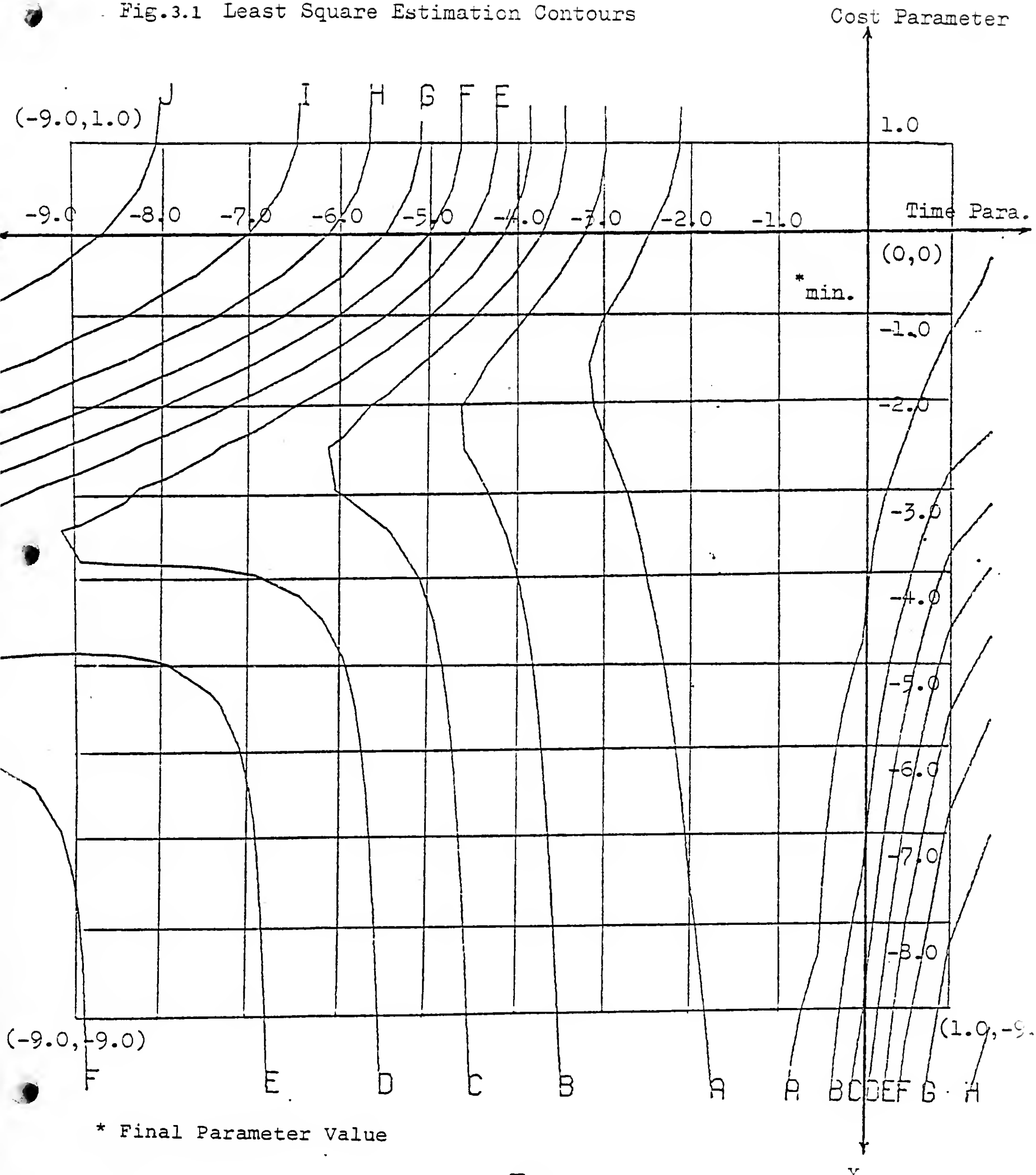
$$T_{ijk}=E_i \frac{A_j(t_{ijk})^{-.88398}(C_{ijk})^{-.40876}\exp(.13377X_1-.20576X_2+.07209X_3)}{\sum_n \sum_m A_j(t_{inm})^{-.88398}(C_{inm})^{-.40876}\exp(.13377X_1-.20576X_2+.07209X_3)} \quad (9)$$

Evaluation of the Model

After the model was chosen, it was evaluated with respect to two criteria: a) goodness-of-fit for the calibration data; and b) reasonableness of parameter values.

For the first criterion, four measures are typically applied: correlation coefficient, root mean square error, percent error, and maximum likelihood indicator. All these measures were calculated and are shown in Table 3.5. In addition, for all calibration zones, estimated and actual non-specific trips were compared. The model only slightly underestimates transit trips (by 0.7 percent) and slightly overpredicts auto demand (by 0.5 percent). Thus, the model is considered satisfactory with respect to the goodness-of-fit criterion.

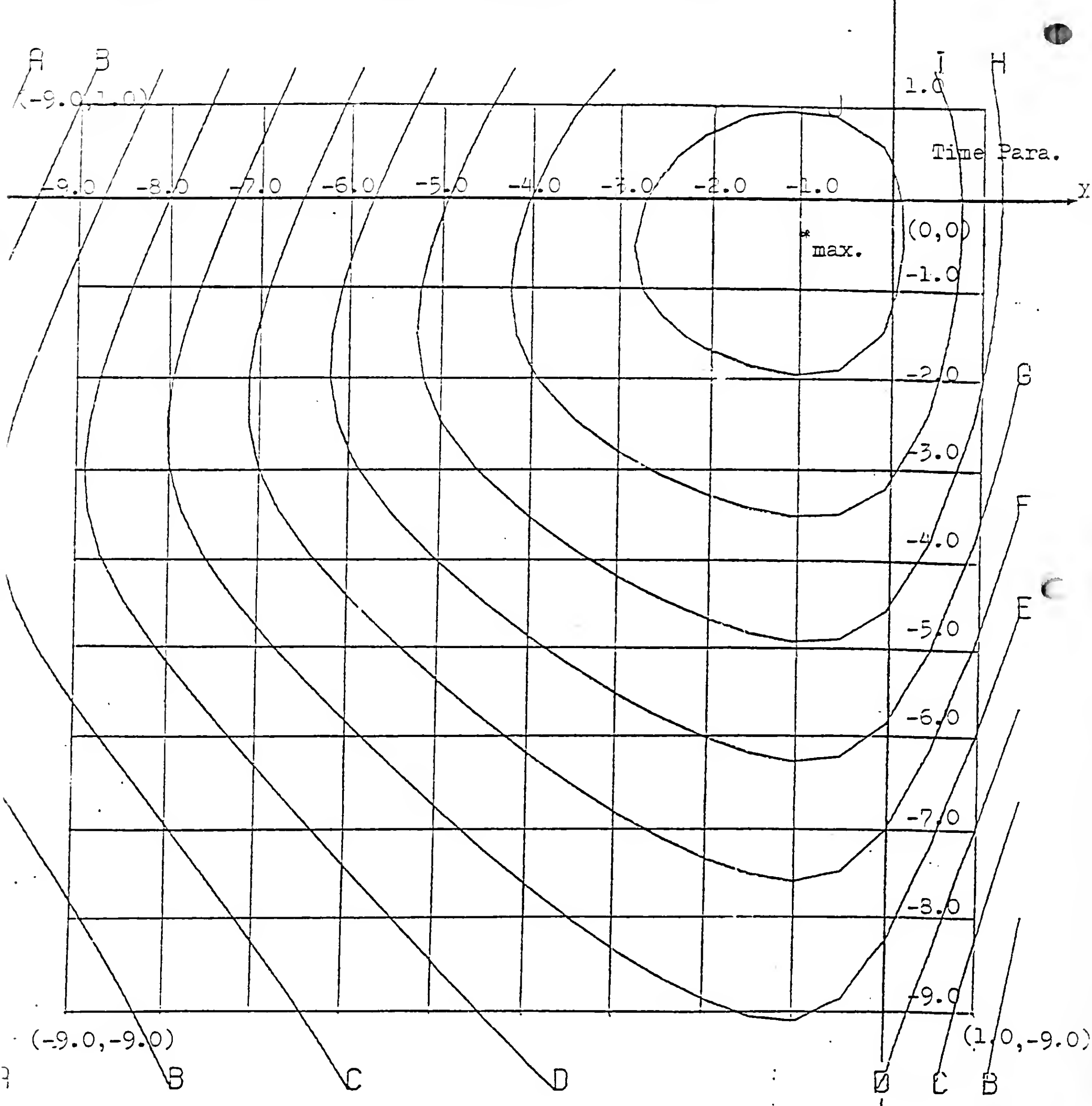
Fig.3.1 Least Square Estimation Contours



* Final Parameter Value

The Least Square Criterion is $\sum_j \sum_k (T_{jk}-\hat{T}_{jk})^2$.

Fig 3.2 Maximum Likelihood Estimation Contours



* Final Parameter Value

The Maximum Likelihood Criterion is $\dfrac{\sum_j \sum_k T_{jk} \, LN(\hat{T}_{jk})}{\sum_j \sum_k T_{jk} \, LN(T_{jk})}$.

TABLE 3.5

VALIDATION STATISTICS

Measure	Value
Correlation Coefficient (χ^2)	.73
Root Mean Square Error	121.3
Maximum Likelihood Indicator	.97
Percent Error	± 22.5

The second criterion, reasonableness of parameter values, can be expressed as two questions: a) whether the model sensitive to level-of-service variables; and b) whether the relationship between the level-of-service variables is accurate.

The first question has been discussed previously, and the model was found to be sensitive to the two most important level-of-service variables, travel time and cost. For example, with respect to travel time, demand elasticity, defined as the percent change in demand for a one percent change in travel time (shown mathematically in Equation 10) is .44 for a mode with 50 percent market share, which implies that the model is sensitive to the travel time variable.

$$E = a\,(1 - P) \tag{10}$$

Where: a: -.88398

P: market share of mode

The second question involves the value of time associated with the model. As previously noted, the value of time is a non-linear function dependent on both the absolute value of the time and cost variable, as well as the ratio of their parameters. Figure 3.3 shows the value of time for different absolute values of time, a fare of 50 cents, and the coefficients for the selected model. For the typical transit situation of 30 to 40 minutes travel time and a fare of 50 cents, the value of one additional minute of travel time is between 3 and 4 cents (i.e., between $1.80 and $2.40 per hour) which agrees with results from other models.

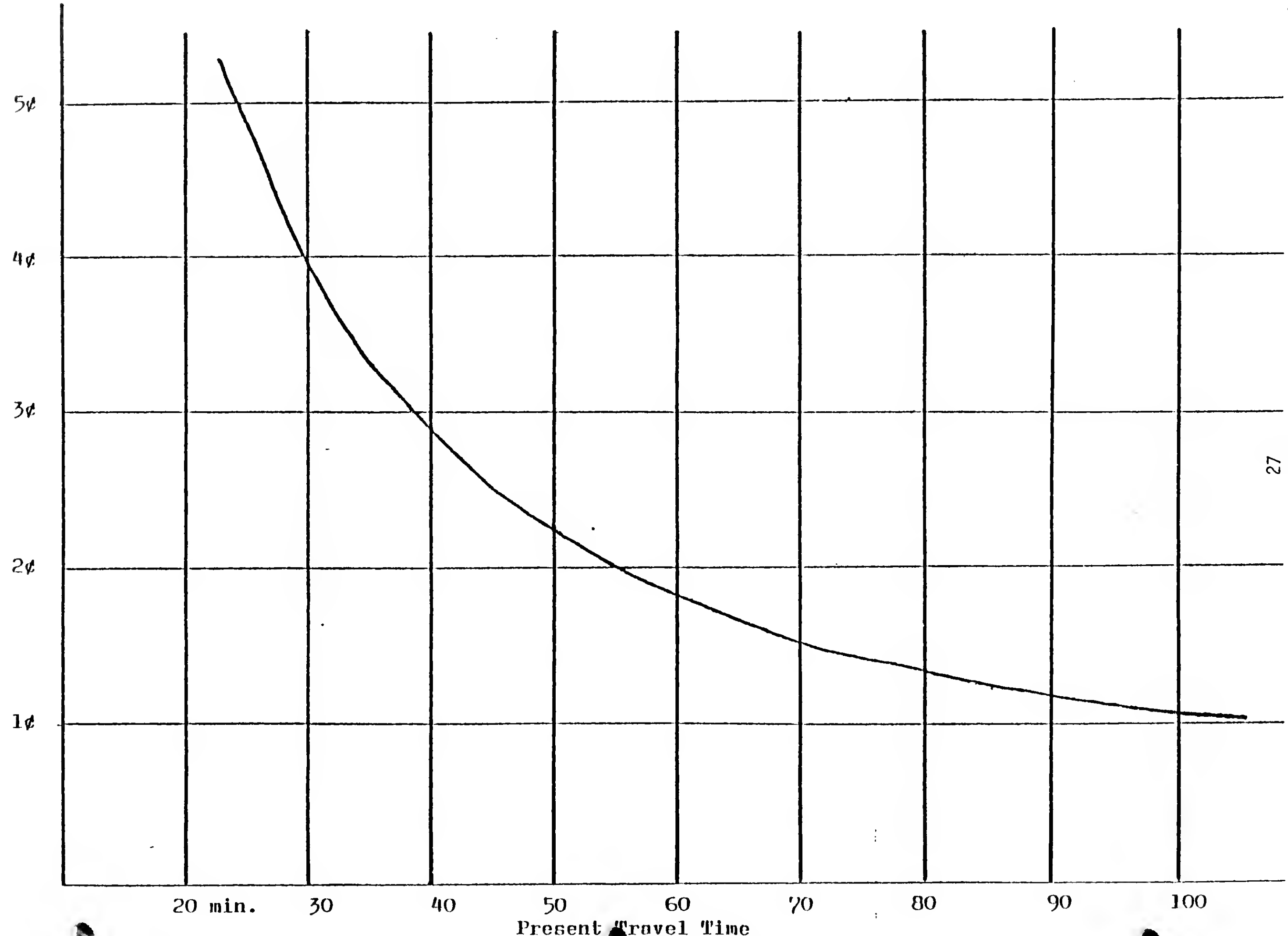
All of the criteria for selection of model for predicting CBD work trips were met by the simultaneous distribution/mode choice demand model. Since CBD trips are such a large segment of the total trips on the region's rail system, it is important that the model have a high degree of precision and also be sensitive to critical policy variables. Based on these factors, the selected model has been found to be acceptable, and therefore is used as the basis for predicting CBD demand in the study.

Local Demand Model

For the development of a demand model to predict local trips on a rapid transit line, the following points had to be addressed:

1. The local demand model should be easily integrated into the study's overall demand estimation process. The prediction of CBD trips is undertaken through the use of a computer program package that is coded to represent the existing and all possible configurations of the regional rail network. Since this computer network is applied many times, it is important that

FIGURE 3.3
VALUE OF TIME FOR ADDITIONAL ONE MINUTE



the prediction of local trips can be integrated easily with the computer package in a manner that is both efficient and accurate. For these reasons, direct demand models are preferred.

2. The model should be based on a relationship between existing local ridership and population and/or employment densities with a high degree of correlation in order to predict local trip generation on new lines.

Local travel demand models have been developed by the Illinois Department of Transportation.[5] The IDOT models and subsequent analysis is summarized in a technical report by the RTA.[6] This technical report details the selection of the local trip model that is utilized for the study.

Table 3.6 is a presentation of ridership (CBD and local) with population and employment by line using 1975 Census information and 1970 CATS Home Interview Survey data. Based on the relationship in Figure 3.6, a simple regression equation which describes the number of local trips per mile on a line as a function of the population density of the line's service area was obtained.

$$\underset{(.5)}{Y = 44} + \underset{(5.1)}{.024X} \qquad R^2 = .97$$

Where:

Y = number of local trips per mile

X = service area population density (per two square miles)

The results of this regression are reliable since there is a significant relationship between the number of per mile local trips on a line and the population density of the line's service area. This relationship is statistically significant at the 99 percent level ($F = 26.37 > F_{1,4.01} = 21.1$). Furthermore, the coefficient of the population variable is significantly different from zero at the 95 percent level ($5.1 > t_{5,\ .95} = 2.6$), however the constant term is not ($.5 < t_{5,\ .95} = 2.6$).

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5 Burns, I., "Estimated Locally Generated Rapid Transit Demand in the Crosstown Corridor", May, 1974
Hovind,M. and Lisco, T., "Estimated Potential Ridership for Alternative Proposed Crosstown Public Transit Systems", June, 1973.

6 Lee, Inwon and Permut, Howard, Methods of Predicting Local Demand for New Rapid Transit Services, RTA Technical Report 75-03, December, 1975.

TABLE 3.6

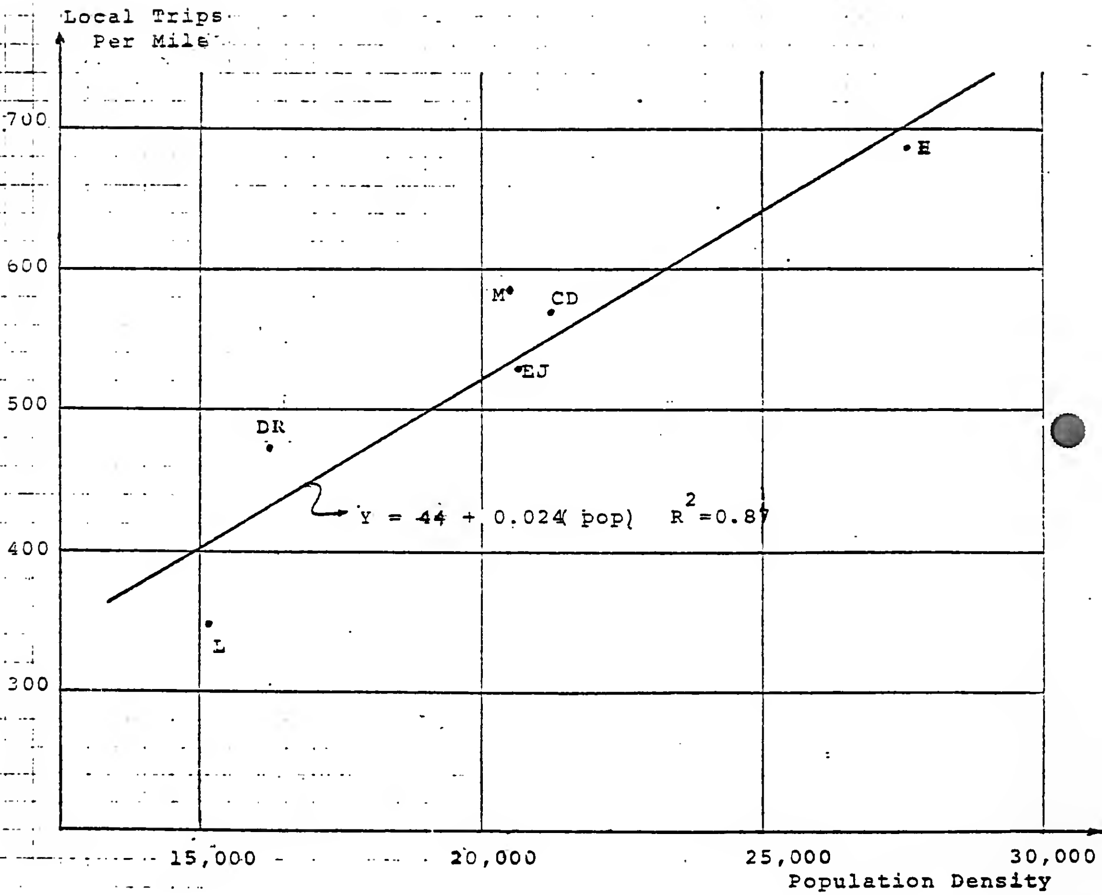
Ridership, Population and Employment Statistics of
Chicago Transit Authority Rapid Transit System

Line	Route Length From Terminal to CBD Boundary[1] (in miles)	Total[@] Population	Total[@] Employment	Population Density[2]	Employment Density[2]	Number of[(b)] Local Trips	%	Number of[(b)] CBD Trips[3]	%	Number of[(b)] Total Trips[4]
Howard & Ravenswood	14.7	406,573	146,838	27,658	9,989	10,070	.126	52,035	.650	79,995
Congress & Douglas	15.1	320,528	138,331	21,227	9,161	8,600	.207	21,645	.521	41,565
Englewood & Jackson Park	10.7	220,855	75,789	20,650	7,084	5,645	.139	17,765	.438	40,515
Dan Ryan	10.8	175,382	76,972	16,240	7,127	5,140	.170	19,905	.657	30,290
Milwaukee	8.1	166,519	63,059	20,558	7,785	4,725	.136	22,920	.657	34,865
Lake	8.0	121,064	90,408	15,133	11,301	2,760	.107	19,840	.768	25,840
TOTAL	67.4	1,411,031	591,407	121,466	52,447	36,940	.146	154,110	.609	253,070

@ 1975 Population & Employment (It is assumed that 1975 data accurately represent 1970 data). Projection of the Northeastern Illinois Planning Commission
(b) CATS 1970 Home Interview Survey

1 The CBD is defined as the area bounded by Chicago/Halsted/Roosevelt. For branch lines, the distance is measured from the terminals to the junction, and from the junction to the CBD.
2 Densities are calculated within one mile on either side of the transit line.
3 This is the number of round trips with origins on the line and destinations in the CBD.
4 Total trips are not the sum of local and CBD trips, since they include thru trips which originate on a line, pass thru the CBD and have destinations on another line.

FIGURE 3.4


Local Trips
Per Mile
700
600
500
400
300
M
CD
EJ
DR
L
E
Y = 44 + 0.024(pop) R
2
=0.87
15,000
20,000
25,000
30,000
Population Density

Other models that expressed local ridership as a function of an employment/population ratio and trip generation rates were also tested.[7] All of the other methods provided accurate results, with the selected model having the lowest percent error in replicating existing volumes. Because of its accuracy and its simple functional form based on direct causality between ridership and population, the selected model is the basis upon which local demand is estimated.

Thru Trip Factor

A "Thru" trip is the third and last type of trip and it is defined as a trip which passes through the CBD (either remaining on the same rapid transit line or transferring to a different line) but does not end there. The number of thru trips originating on a link is estimated by applying a factor (derived from existing trip patterns), to total CBD trips on the link. For completely new lines, the system-wide factor is used; while for corridor improvements, the same corridor factor is used.

As an example, using Table 3.6, the number of thru trips on a line is the remainder of total trips after CBD and local trips are subtracted. For 1975, the system-wide average is .16 thru trip per CBD trip. This factor is then applied for all new lines to predict the number of thru trips. For improvements to existing lines or lines within existing rapid transit corridors, the specific corridor factor can be used.

Prediction of Total Patronage

The prediction of one-way daily trips on the rapid transit system is based on three forecast steps: 1) CBD demand model; 2) local demand model; and 3) thru trip factor. Once these three segments of ridership are totaled, ridership for the rapid transit system can be estimated. However, since the application of the CBD Demand Model requires individual zonal calculations, a more efficient process is required. In the next chapter, the development of the SONARRTA computer network is discussed. The use of the SONARRTA network is not only important in the prediction of ridership, but is necessary for the measurement of such important impacts as users benefit and CBD auto trip diversion.

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[7] Lee, Permut, Methods of Predicting Local Demand for New Rapid Transit Services.

CHAPTER IV

SONARRTA REGIONAL RAIL COMPUTER NETWORK

General Network Characteristics

The SONARRTA computer network was developed in order to evaluate all possible system configurations (i.e., combinations of rapid transit alternatives and commuter rail alternatives) and, therefore, has the capability of estimating demand for the existing system and all possible combinations under a variety of conditions. In addition, the network was designed so as:

1. to be computer efficient
2. to be easily modifiable
3. to be easily integrated into the SONARRTA evaluation process.

During network development, certain technical considerations were built into the network including:

1. minimum utility (travel time and cost) path assignment
2. varying access modes to commuter rail and rapid transit lines, dependent on the geographic location of the origin zone and the distance to the entering rail station
3. varying zonal penalties; and
4. undirectional peak period travel times to the CBD.

Integration With SONARRTA Evaluation Process

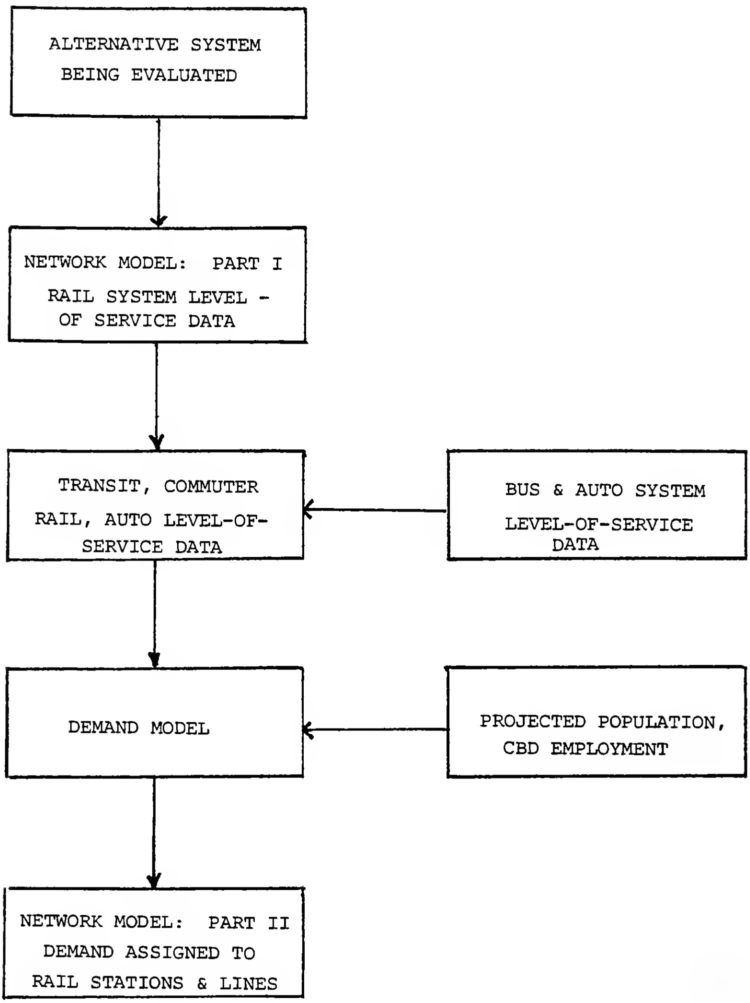
The network is the central tool in the entire demand estimation process. As Figure 4.1 illustrates, the network is integrated with the demand modeling process, and can actually be separated into two distinct parts. The basic function of the network is that of the standard urban transportation network - the user selecting alternative system designs and the computer producing station volumes by line.

The first function of the network involves the generation of level-of-service data for the rail modes. For each system input, minimum utility paths from every origin zone to the CBD are determined for the commuter rail and rapid transit modes. The times and costs associated with the paths are then determined.

This data, along with bus and auto travel times and costs, is fed into the CBD demand model. Bus and rapid transit times are compared to determine the minimum time (fares are equal), and the time and cost associated with the chosen mode is used as the transit time and cost. Basic population and employment data is also input. The demand model then simultaneously distributes trips from the CBD to origin zones via the selected modes.

FIGURE 4.1

INTEGRATION OF NETWORK IN DEMAND MODELING PROCESS



The second function of the network is to assign the zonal interchange data to specific stations. For the commuter rail mode, this is simply done by assigning all trips to the previously determined minimum utility path (i.e., station). For the transit mode, the bus and rapid rail trips are split by the use of a sub-modal split model. The rapid rail trips are then assigned to the minimum utility path.

Detailed Network Description

A. Geographic Coding

The network zone scheme is based on a single CBD zone[1] and a series of origin traffic zones. The CBD is defined as the area bounded by Chicago Avenue, Halsted Street, Roosevelt Road, and the Lakefront, and its centroid is the intersection of State and Madison Streets (coordinates 0,0).

The center of each origin zone is treated as the zone centroid, and the corresponding coordinates are determined. Figure 4.2 illustrates the regional zone scheme. All alternatives which are to be considered in the study have been included. Stations have been mapped to corresponding coordinates for all existing and proposed commuter rail and rapid transit lines.

B. Basic Network Operation

The network operates in a basic four step fashion:

1. establishes all possible paths, and calculates their travel utilities;

2. determines the minimum-utility path for the commuter rail and rapid transit modes;

3. estimates the travel times and costs associated with the minimum-utility path; and

4. assigns zonal rail trip interchanges to the minimum utility path; and calculates total line volumes and user savings.

The first step involves the determination of a maximal station-zone matrix where for the commuter rail and rapid transit system all origin zones are assigned to all potential stations. Thus, each station has a maximal market area which includes all zones that _might_ use the station as the access point to the system. Care was given so that every zone was assigned to at least one station which could not be removed (i.e., was located on a constant line). In general, stations had approximately five to ten zone market areas, and zones were assigned to one to five stations.

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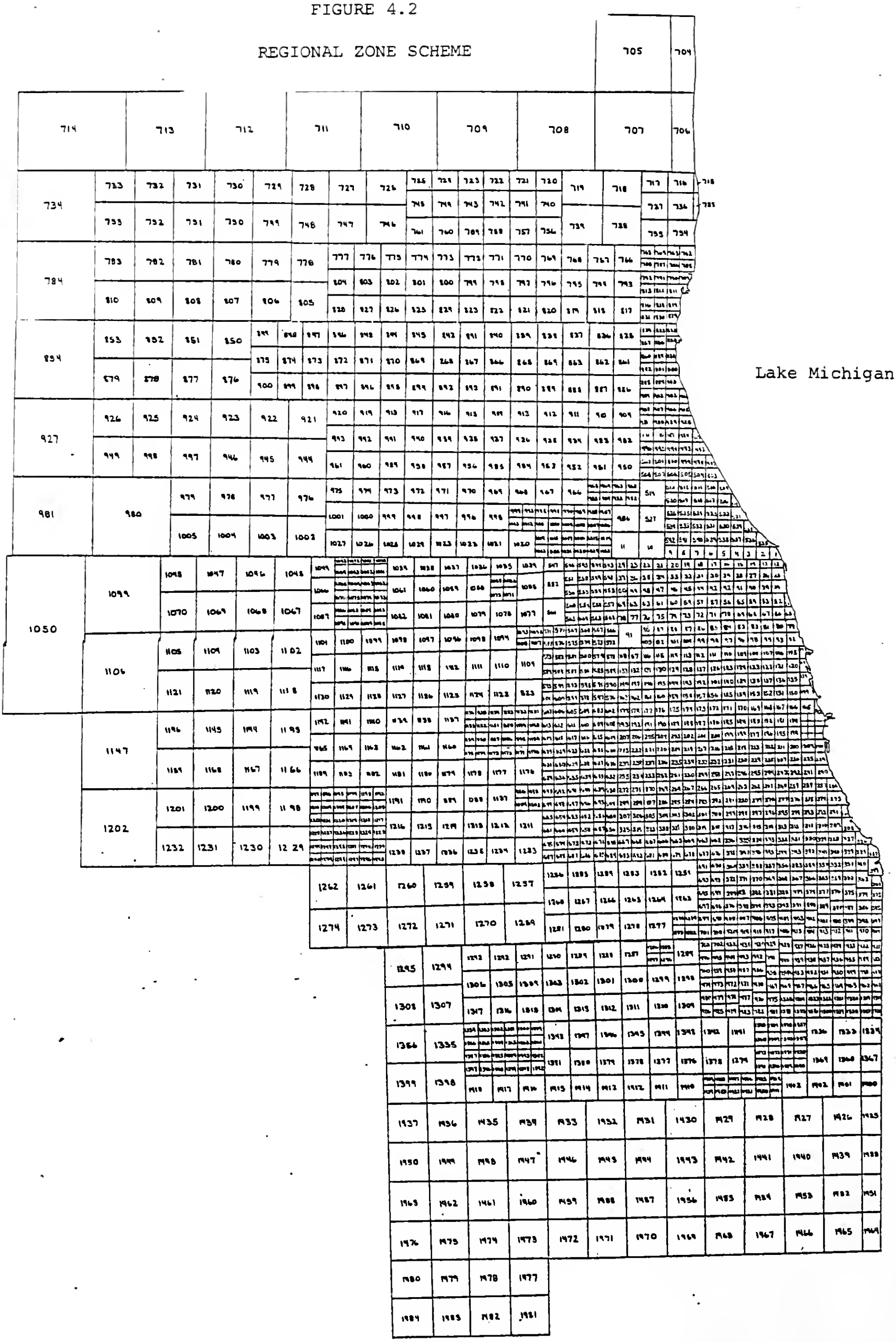
[1] The network has the capability to handle a CBD which is fractured into smaller, multiple zones.

FIGURE 4.2

REGIONAL ZONE SCHEME



The second step involves determining, for a given system plan (this translates to the opening and closing of certain stations), the minimum utility path (i.e., the line and entering station which will be used by trips originating in the zone). The minimum path algorithm basically operates by building "commuter trees (paths)" from the CBD to the origin zone, and determining the minimum path. Separate paths are determined for the commuter rail and rapid transit modes.

The third step is calculating, for the minimum utility path, the travel time and cost associated with the path. In short, this involves decomposing the measured utility into its two original components, time and cost. Finally, once inter-zonal demand is calculated, rail demand is loaded onto the rapid transit and commuter rail networks by assigning trips to the minimum utility path.

The procedure to determine steps two and three is discussed in detail below.

C. Network Calculations

The network calculates minimum utility paths and total travel times and costs by calculating time, costs, and utilities for the components of the entire trip: access, station entrance, waiting, line-haul and cordon. For rapid transit, the cordon portion of the trip is the time/cost from the CBD boundary to the final CBD destination. For commuter rail, it is the time/cost from the CBD terminal to the final CBD destination.

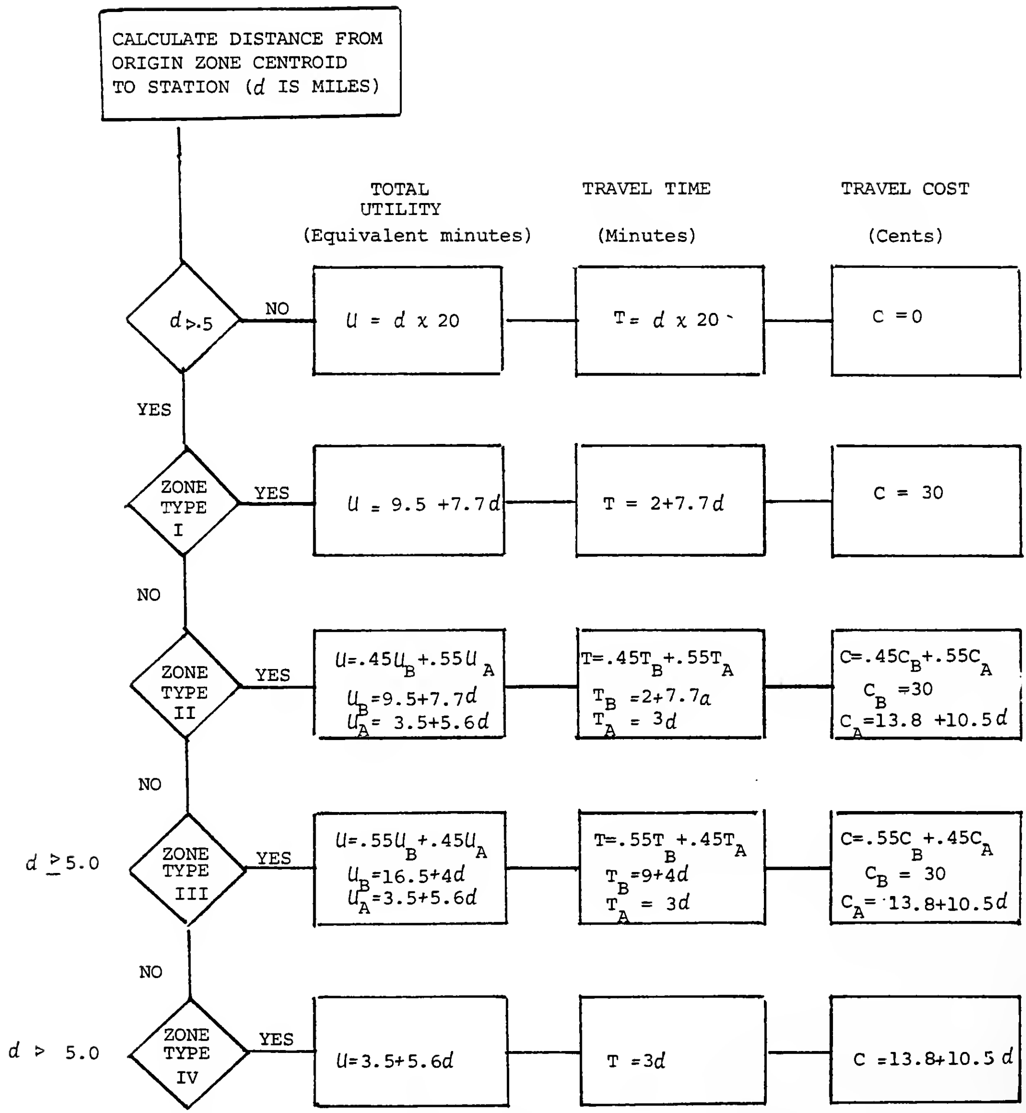
The utility function used to determine minimum paths includes time and cost (valued at 4 cents per minute). Since the alternative paths are for the same line-haul modes, the only difference in cost for competing paths occurs in access cost (for example: when one path requires a bus access mode and the other, a walk access mode). Therefore, to determine the minimum utility path, total travel time and access cost (expressed in minutes) by the competing paths were required; and line-haul fares were unnecessary.

D. Access Component

The procedure for calculating access time and cost varies by mode and by geographic location of the origin zone. Figure 4.3 illustrates the procedure for the calculation of access utility and its component parts of access time, and access cost for the commuter rail mode, while Figure 4.4 gives the same information for the rapid transit mode. Figure 4.5 illustrates the boundaries of the zone types for the existing network.

FIGURE 4.3

ACCESS TRIP COMPONENT FOR COMMUTER RAIL



U_B= UTILITY FOR BUS MODE
U_A= UTILITY FOR AUTO MODE
T_A= TIME FOR AUTO MODE
T_B= TIME FOR BUS MODE

FIGURE 4.4

ACCESS TRIP COMPONENT FOR RAPID TRANSIT

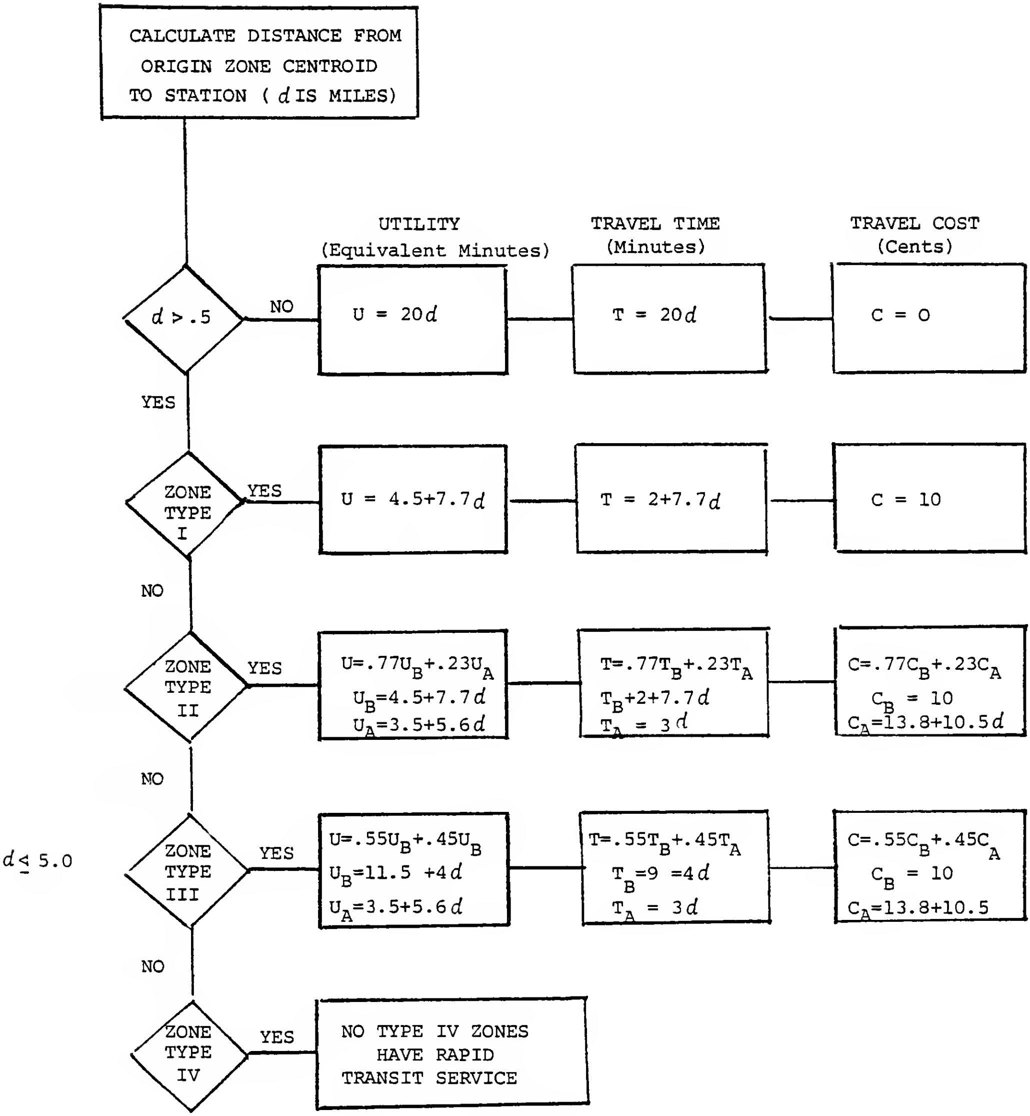
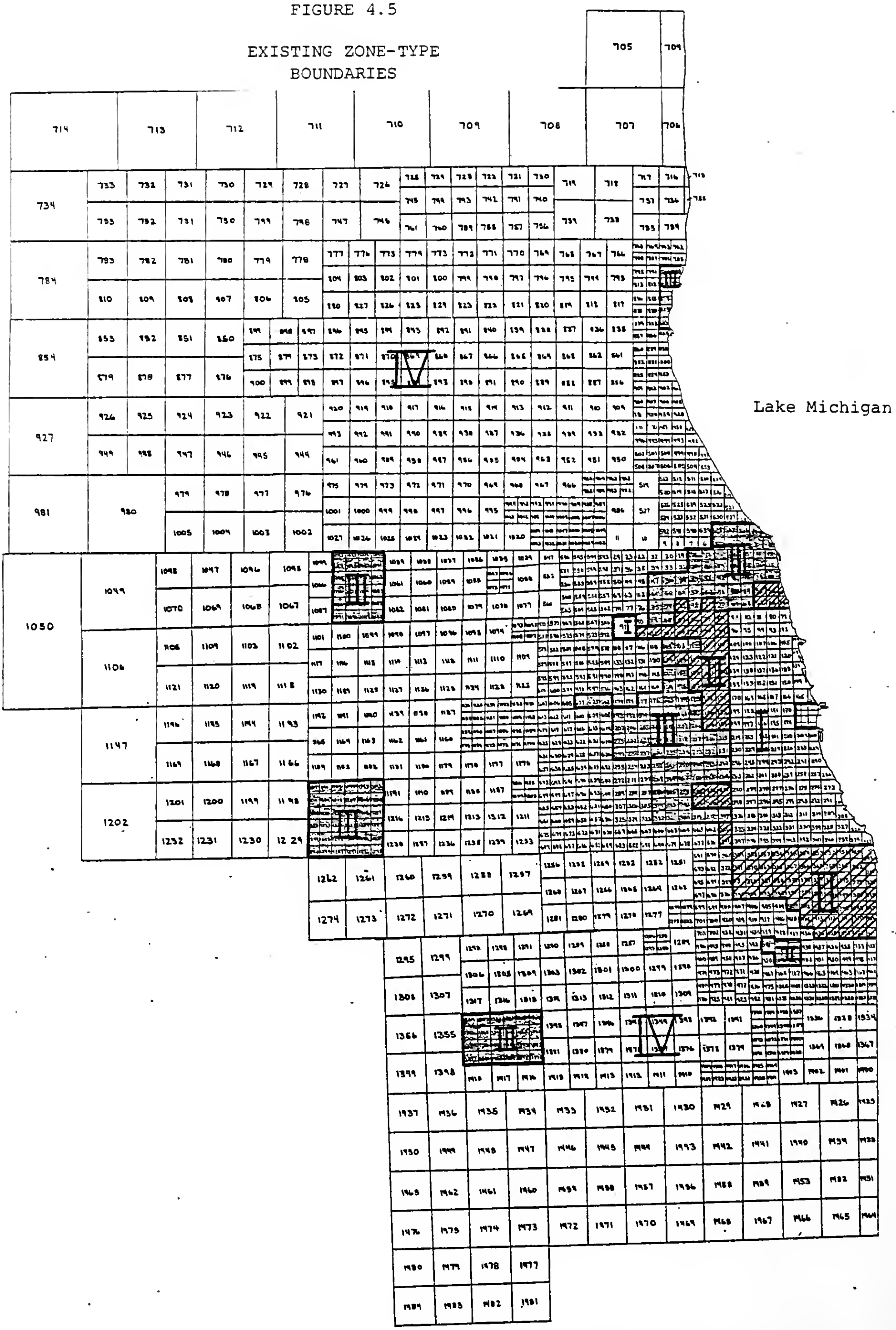


FIGURE 4.5

EXISTING ZONE-TYPE BOUNDARIES



The basic concept behind zone types is that travel patterns to rail stations vary depending on station location, and distance from the zone to the station. Distance is defined as street (or right-angle) distances from the zone centroid to the station. It should be noted that, regardless of zone type, all zones less than .5 miles from a station have walking as the access mode.

Zone Type I contains zones in the inner portions of the City of Chicago, where it is assumed all commuters take the bus to the station.

Zone Type II contains zones in the outlying portions of the City of Chicago. It is assumed that 77 percent of all rapid transit users use bus as the access mode and 23 percent use the automobile, while only 45 percent of all commuter rail users have a bus mode, and 55 percent have an auto mode.[2]

Zone Type III contains zones located in the suburbs which have feeder bus service. It is assumed that 55 percent of all rail users have bus as the access mode and 45 percent have auto. For evaluation purposes, it is assumed that all zones within 5 miles of a rail station have feeder bus service.[3]

Zone Type IV contains zones located in the suburbs which don't have feeder service; and thus, 100 percent of the users have auto as the access mode. It is important to realize that during system evaluation, zones are classified as Type III or IV depending on the set of specific lines being evaluated.

Station Entrance and Waiting Component

Station Entrance Time was computed as 1.5 minutes for all rapid transit stations, and 1.0 minutes for all commuter rail stations. Waiting time was defined as one-half the headway, not to exceed 5 minutes. Headways for the existing rapid transit system are shown in Table 4.1. It is assumed that all new rapid transit lines will have a 3 minute headway. Both existing and new commuter rail lines have assigned waiting times of 5 minutes.

Line-Haul

Line-haul time represents the time to travel from the entering station to the CBD Cordon Line. For existing rapid transit lines, line-haul travel time was based on CTA time-point data. For new lines, an acceleration curve

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2 Sadjovec, N. and Tahir, N., Development of Disaggregate Behavioral Mode Choice Models for Feeder Bus Access to Transit Stations, Office of Research and Development, Illinois Department of Transportation, Chicago, Illinois, 1976.

3 For the existing rapid transit system, a few zones which are greater than 5 miles from a station were classified as Type III.

Table 4.1

Headways of Rapid Transit Lines

ROUTE	STATION TYPE	HEADWAY (MINUTES)
North-South	A	6
"	B	6
"	AB	3
West-Northwest	A	6
"	B	6
"	AB	3
West-South	A	6
"	B	6
"	AB	3
Ravenswood	A	8
"	B	8
"	AB	4
Evanston	AB	4
Skokie Swift	AB	5

representing high-speed CTA lines was used to convert interstation distance to travel time.

Rapid transit costs for majority of existing and proposed stations are 50 cents. Stations on the existing Evanston and Skokie lines, as well as on the proposed Oakbrook, Elk Grove Village and Lake-Cook extensions, are assumed to have fares which reflect RTA Board Policy.

For existing commuter rail lines, line-haul travel time was based on schedules where the travel time of the fastest train stopping at the station was used. For proposed new lines, an acceleration curve representing simulated (by GM Electromotive Division)[4] travel speeds on a rebuilt Rock Island Railroad was used to convert interstation distances to travel times.

Commuter rail fares for both existing and proposed lines are based on the new RTA zone fare structure, and represent a weighted average fare. For all existing lines, the percentage breakdown of passengers by type of ticket was determined, and an average one-way fare (assuming 44 rides per month and 20 rides per week) calculated. Table 4.2 shows the fares used for the existing system.

For the proposed non-radial light rail line, a zonal fare system is used, where a trip within a zone (this includes transfers to radial lines) costs 50 cents, while one crossing a zone costs an additional 50 cents. Zones are: Crystal Lake-Elgin, Elgin-Aurora, Aurora-Joliet, and Joliet-Indiana State.

Egress Component

Egress time represents the travel time from the cordon line to the final CBD destination. The times were originally developed to represent the travel time from the cordon line to the intersection of State and Madison Streets, and then were modified to approximate the average travel time of all users of a line to their final CBD destination. This assumes a 3 block walk from all rapid transit lines except the Franklin which has a 4 block walk. All commuter rail stations have a 2 minute exit time plus a 5 block walk, except the ICG which has a 4 block walk.

Table 4.3 illustrates the egress times for the rapid transit lines, while Table 4.4 gives the egress times for the commuter rail lines. A detailed discussion of these times is contained in a working paper of the study.[5] No costs are associated with the egress portion of the trip.

There are a series of important assumptions concerning egress times:

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4 GM Electro-Motive Division, Proposed Commuter Locomotives for the Regional Transportation Authority, Product Application, April 20, 1976.

5 Lee, Inwon, and Permut, Howard, SONARRTA Working Paper III, CBD Demand Estimation Models, Appendix A, September 1976.

TABLE 4.2

ZONAL FARE STRUCTURE

ZONE DISTANCE FROM CBD	DAILY ONE-WAY FARE FOR: Chicago and Northwestern and Illinois Central Gulf (Electric) Lines*	DAILY ONE-WAY FARE FOR: Milwaukee Road, Burlington Northern and Rock Island Railroads**
0 - 5.0	.63	.59
5.1 - 10.0	.74	.70
10.1 - 15.0	.86	.81
15.1 - 20.0	.98	.91
20.1 - 25.0	1.10	1.01
25.1 - 30.0	1.22	1.12
30.1 - 35.0	1.34	1.22
35.1 - 40.0	1.46	1.33
40.1 - 45.0	1.58	1.42
45.1 - 50.0	1.70	1.53
50.1 - 55.0	1.82	1.63
55.1 - 60.0	1.94	1.73
60.1 - 65.0	2.06	1.83
65.1 - 70.0	2.18	1.94
70.1 - 75.0	2.30	2.05
75.1 - 80.0	2.42	2.16
80.1 - 85.0	2.54	2.27
85.1 - 90.0	2.65	2.38

* The average fare is (1.23) (monthly fare pro-rated daily). All proposed extensions to these lines except the CNW line to marengo are assigned this fare schedule.

** The average fare is (1.14) (monthly fare pro-rated daily). The ICG Diesel and the Norfolk and Western are assumed to have this fare schedule. All proposed extensions to these lines, plus the proposed CNW line to Marengo have this schedule.

Table 4.3

RAPID TRANSIT EGRESS TIMES

LINE	CORDON POINT	EGRESS TIME
Loop (North)	Chicago	6.1
Loop (South)	Roosevelt	10.9
Loop (South	Cermak	13.3
Loop (West)	Halsted	11.1
State Subway (N)	Chicago	10.1
State Subway (S)	Roosevelt	10.4
State Subway (S)	Cermak	12.8
Dearborn Subway (N)	Halsted	10.5
Dearborn Subway (W)	Halsted	11.6
Franklin (South)	Cermak	14.3
Franklin (North)	Chicago	12.7
Distributor (N)	Chestnut	11.0
Distributor (W)	Halsted	12.8

TABLE 4.4

COMMUTER RAIL EGRESS TIMES

LINE	STATION	EGRESS TIME
Chicago & Northwestern	Northwestern	12.0
Milwaukee Road	Union	12.0
Burlington Northern	Union	12.0
Illinois Central Diesel (GMO)	Union	12.0
Illinois Central Electric	Roosevelt	13.8
Norfolk and Western	Union	12.0
Rock Island	Union	12.0

1. the Dan Ryan line is routed through the State Street Subway;

2. the Englewood-Jackson Park line is routed through the Franklin Subway; and

3. the Rock Island terminates at Chicago Union Station.

Penalties

Prior to the final calculation of commuter rail and rapid transit times and costs, one remaining modification is made: the application of penalties which prohibit the basic use of mode. Based on the penalties for factors other than time or cost (as discussed in Chapter II), changes in some of the zonal mode utilities were made.

Penalties are added to the total travel times and costs and, given their large magnitude, effectively replace the calculated times. For the rapid transit mode, Type III zones outside the maximal rapid transit service area and all Type IV zones receive penalties. Figure 4.6 shows the boundary of the rapid transit service area, as well as the boundary of the zones which receive a penalty for the commuter rail mode. The actual penalties used are 600 minutes in travel time and $9,999.99 for travel cost.

Special Network Structures

Finally, two special network characteristics should be mentioned: transfer capability and computer efficiency measures.

With regard to transfers, two critical assumptions were made in the development of computer network:

1. passengers are not allowed to transfer once they entered a station on a radial rail line; thus only passengers entering proposed crosstown lines could transfer, and

2. the associated transfer times are 3.5 minutes for rapid transit and 10 minutes for commuter rail. This was due to the basic radial structure of the regional rail network.

A strategy was developed to increase the computer efficiency of the network in its evaluation of alternative plans. While evaluating a series of plans, zonal level-of-service data is only calculated for certain select zones. These are zones which would be affected by changes in the given plan from the previous plan. If only changes are being evaluated with respect to the rapid transit service, an area within the CTA market area (approximately 700 zones) is analyzed. Similarly, analysis of commuter rail changes does not include zonal level of service changes for 200 inner-city zones.

Figures 4.7 and 4.8 illustrate, for the existing transit system, the service areas of the different rail lines. Note that Figure 4.7 also illustrates those zones for which the bus provides the best service. Also, note

FIGURE 4.6
COMMUTER RAIL & RAPID TRANSIT
PENALTY AREAS

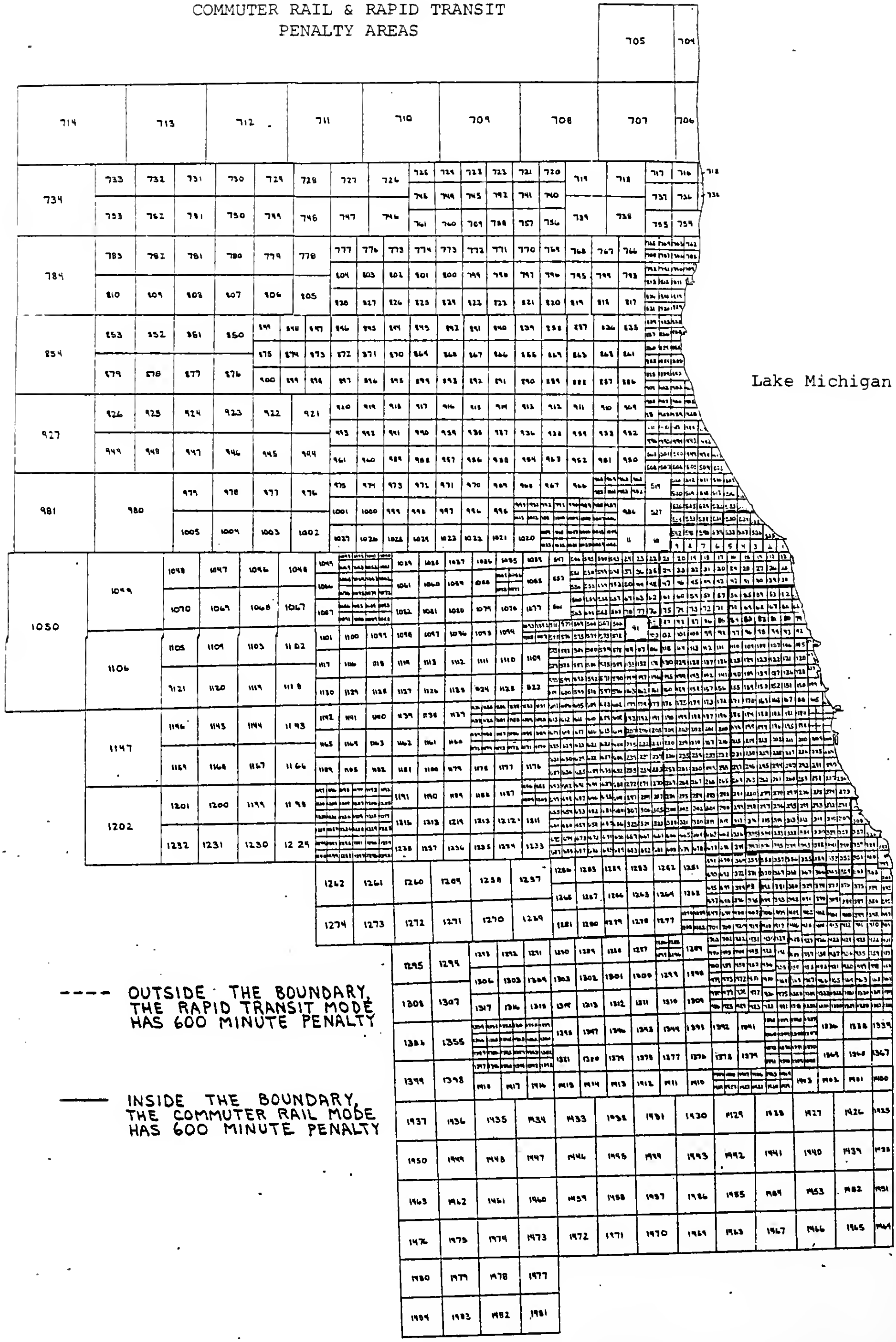


FIGURE 4.7

RAPID TRANSIT SERVICE AREAS

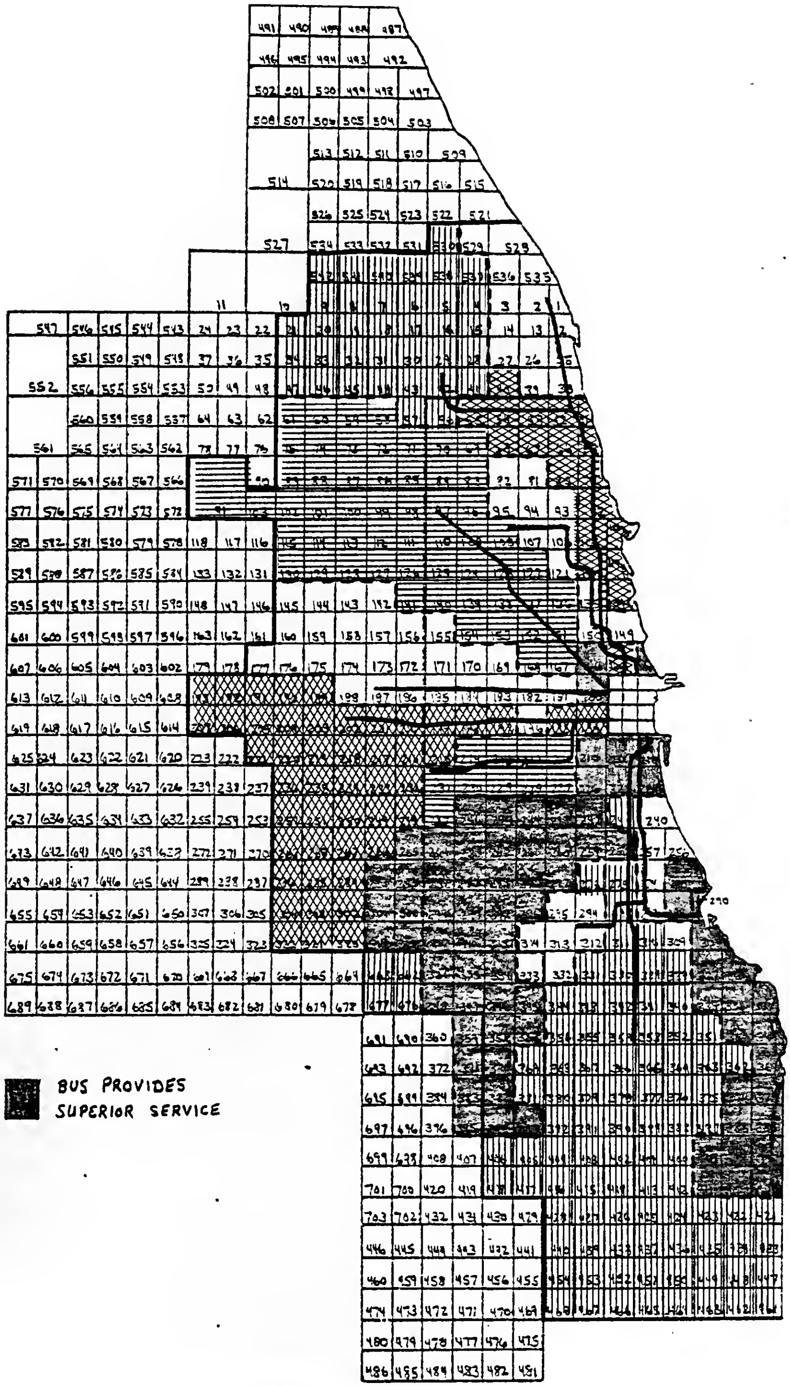
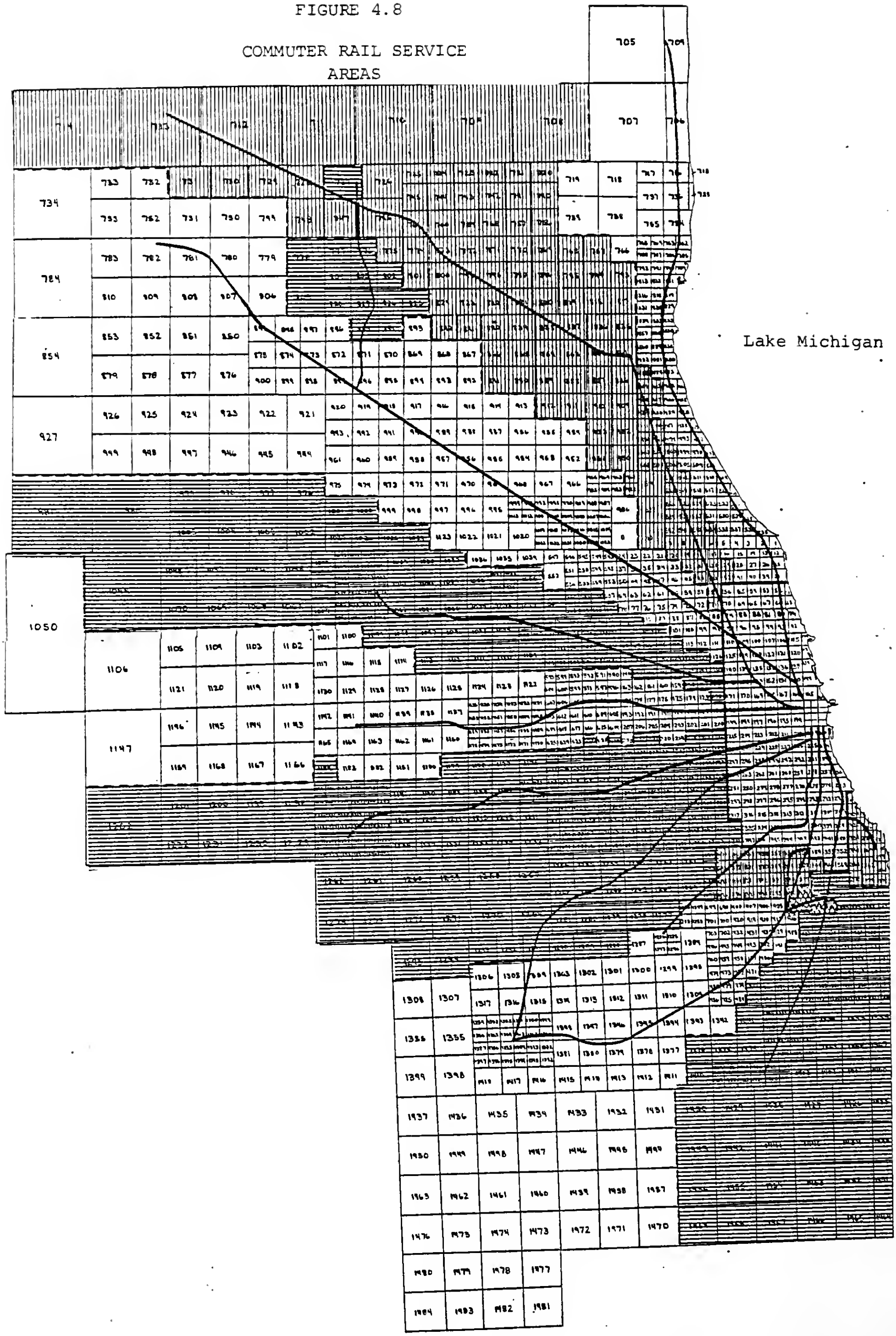


FIGURE 4.8

COMMUTER RAIL SERVICE AREAS



that, because of the minimum level of service, Figure 4.8 assumes that the Norfolk and Western and GMO have no service areas.

Figures 4.9 and 4.10 show the travel times associated with the existing transit and commuter rail system.

The entire demand process, including the network and the demand models, was evaluated. Both the service areas and times seem realistic. A test of the computer network to see how well it replicates existing ridership trends is described in the following section.

Evaluation of Computer Network Demand Estimation Process

A detailed test of the demand estimation process was undertaken to determine its reliability. Paramount was an evaluation of the accuracy of the process, and a determination as to its applicability for estimation of ridership on proposed alternatives to be evaluated in SONARRTA.

The testing procedure is somewhat similar to standard analysis in that it measures to what extent the modeling process can replicate existing patterns, and provides an indication of the reliability of the process in estimating ridership on proposed new alternatives.

The test is rigorous in that it requires the process, given only total CBD trip generation and origin zone population, to replicate line-by-line entering volumes for the entire regional commuter rail and rapid transit system. It should be noted that, as the different components of the prediction process were developed (i.e., local demand models, CBD demand models, and the computer network), they were individually evaluated in terms of their reliability. However, by applying the models as a complete set, a more complete picture of their accuracy is obtained.

The evaluation of the demand estimation process was undertaken to determine the degree to which existing travel patterns could be matched. Given the relative importance of CBD destined trips, much attention was focused on this component. The two critical items were: CBD-oriented boardings on the individual lines, and total travel, by mode, to the CBD.

The other important criterion was the degree to which the entire process could predict total transit trips, with the important value being line-specific total boardings.

The method of applying the demand estimation process to test its accuracy is quite similar to the manner in which the model will be used to predict demand on proposed new lines. The test evaluates the degree to which the process can predict ridership on the existing system. It should be noted,.however, that certain small changes in the existing network have been assumed for the test, including:

FIGURE 4.9

COMMUTER RAIL TRAVEL TIMES

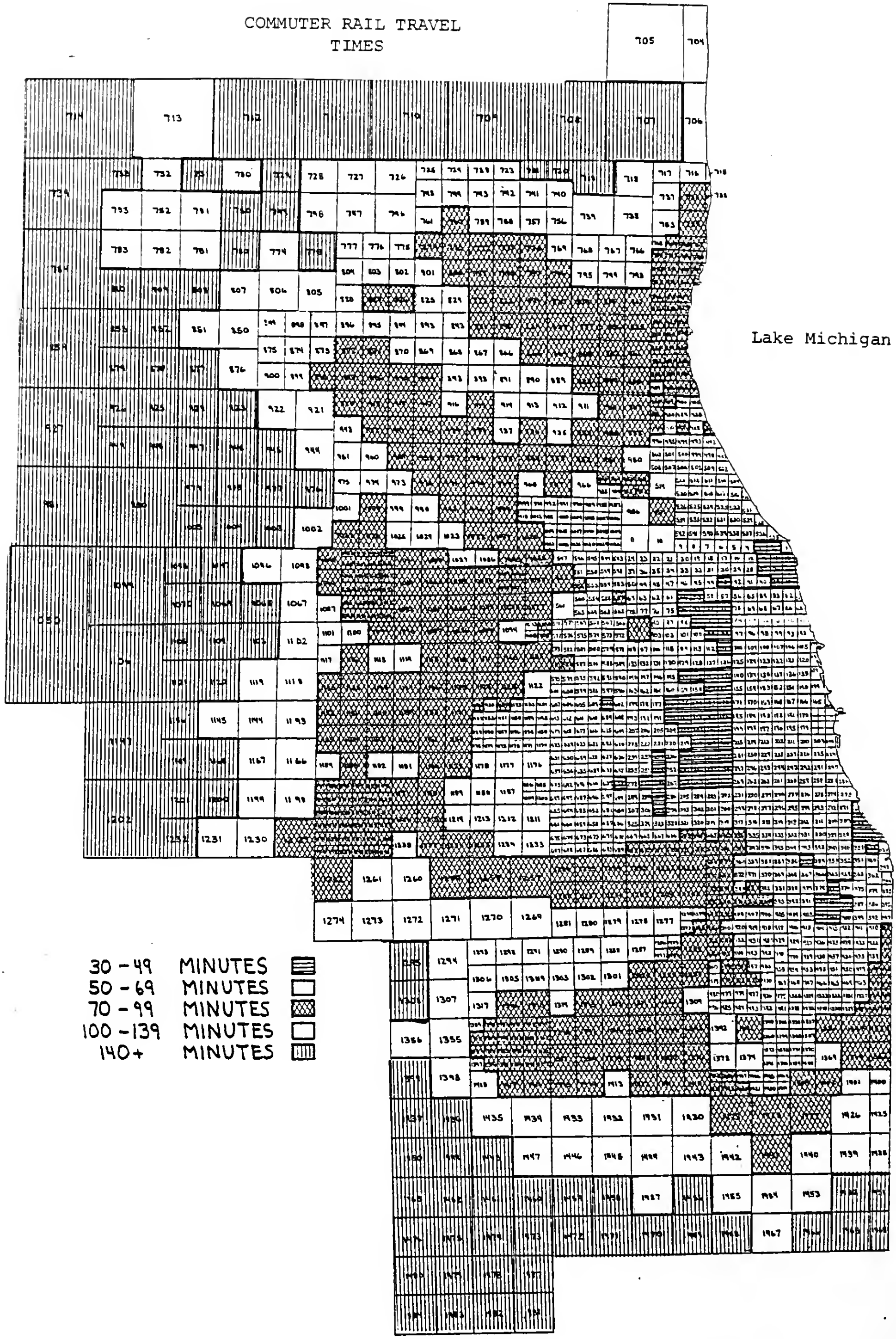


FIGURE 4.10

TRANSIT TRAVEL TIMES

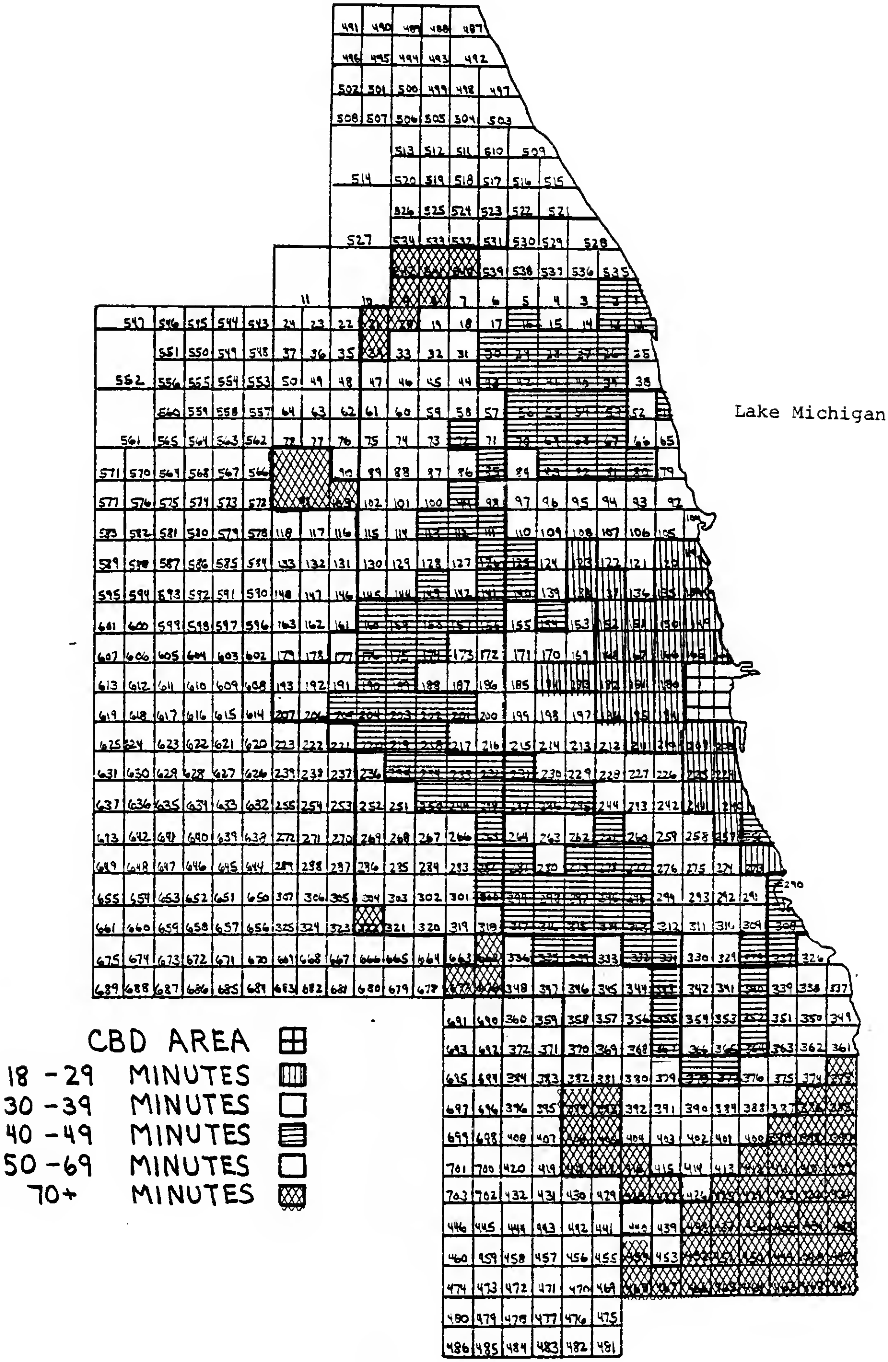
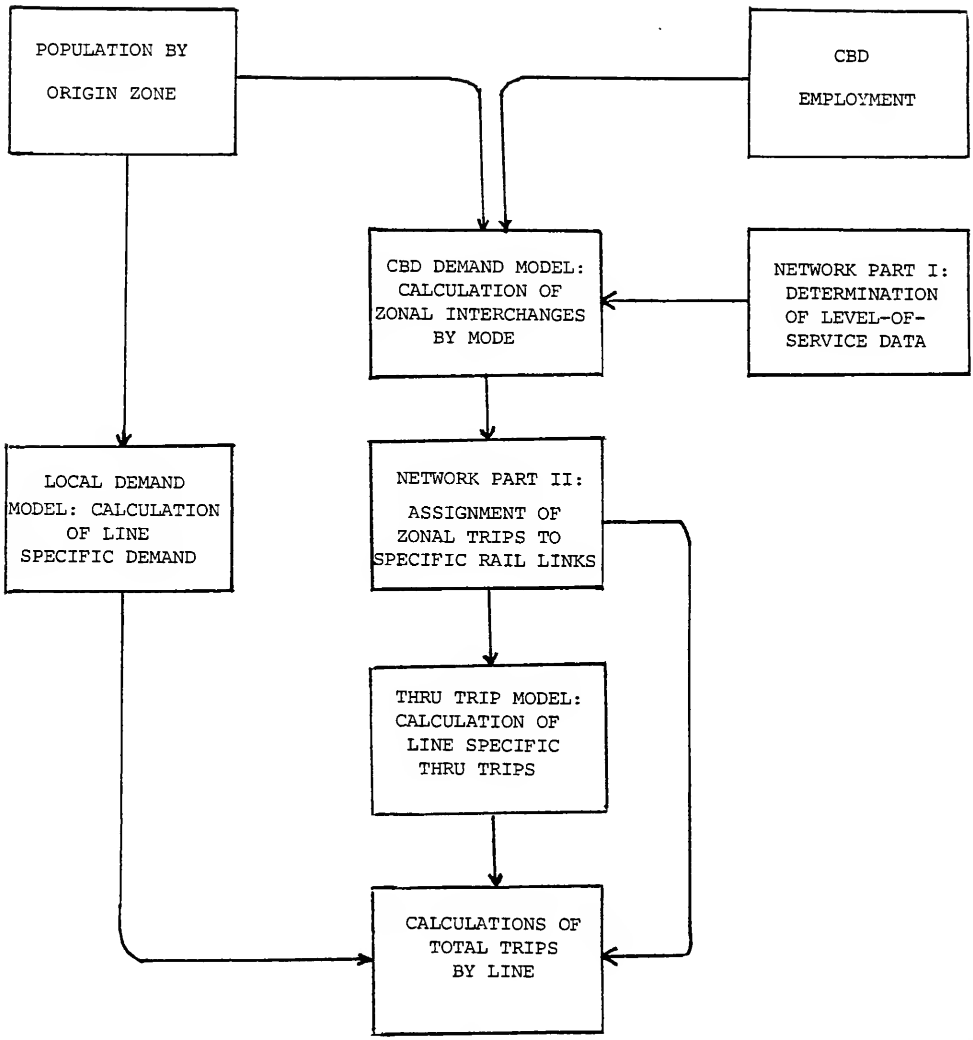


FIGURE 4.11

DEMAND ESTIMATION PROCESS



1. the Dan Ryan line is routed through the State Street Subway, and the Englewood--Jackson Park line is routed through the Franklin Subway;

2. the Rock Island is routed into Union Station; and

3. the Norfolk and Western and Illinois Central Gulf (Diesel) are assumed not to be in operation (since passenger volumes for these low level of service lines are small).

Estimated CBD Volumes

Given the assumptions noted above, CBD demand was estimated using the simultaneous distribution mode choice model. Table 4.5 presents a comparison between actual travel volumes by mode to the CBD, and estimated mode-specific volumes.

As the figure shows, the process accurately predicts total CBD volumes with an average total mode error of approximately 8 percent. The major problem is the underprediction of auto trips and the corresponding over-estimation of CTA trips.

Estimated CBD Line Volumes

The second evaluation is a comparison, on a line-specific basis, of estimated and actual one-way CBD trips. As previously noted, the relative magnitude of this trip component makes this comparison important. Table 4.6 summarizes these results.

A crucial test for the model is the prediction of trips for areas where commuter rail and rapid transit both compete for patronage. The forecasts show that the model predicts well for these areas. Both the Lake Street and Evanston lines predicted volumes are within six percent error. With regard to most of the rapid transit lines, the model predicts extremely well with an average percent error of ten percent.

Only three lines (Milwaukee, Congress and Skokie) are overpredicted significantly by the model. The Milwaukee line's volume is overpredicted by approximately twenty percent and is due to the model's estimation of CBD trips from inner-city neighborhoods whose actual orientation of trips to the CBD is not strong. Since the Milwaukee line is considered a constant line (i.e., it's future is not being evaluated), this inaccuracy is relatively unimportant.

For the Skokie line, the overprediction was due to the fact that the fare was assumed to be substantially lower than the actual fare of 70 cents in 1975 (a.m. and p.m. average). The overprediction of volumes on the Congress line occurred mainly at stations west of Western Avenue, and was due to both changing population distributions, and the fact that the inadequate parking at Des Plaines Avenue was not reflected in either station

Table 4.5

COMPARISON OF ACTUAL AND ESTIMATED ONE-WAY CBD TRIPS BY MODE
(ESTIMATES BASED ON 1975 POPULATION DATA)

	Automobile	Commuter Rail	CTA Bus	CTA Rapid Transit	Total
ACTUAL	238,060	107,530	104,965	181,200	632,520
ESTIMATED	213,246	105,813	113,432	200,029	632,520
DIFFERENCE	24,814(-10.4%)	1,717(-1.6)	8,467(+8.1)	18,829(+10.4)	

TABLE 4.6

COMPARISON OF ACTUAL AND ESTIMATED ONE-WAY
CBD TRIPS BY LINE
(ESTIMATES BASED ON 1975 POPULATION DATA)

LINE	ACTUAL CBD VOLUME	PREDICTED CBD VOLUME	DIFFERENCE	PERCENT DIFFERENCE
RAPID TRANSIT				
Howard	35,830	38,737	2,907	8.1%
Ravenswood	14,985	13,700	1,285	8.6%
Congress	8,380	19,501	11,121	132.7%
Douglas	9,855	8,017	1,838	18.7%
Milwaukee	28,895	35,212	6,317	21.9%
Dan Ryan	38,810	38,192	618	1.6%
Lake	19,690	18,626	1,064	5.4%
Englewood - Jackson Park	16,285	14,201	2,084	12.8%
Skokie	2,230	7,980	5,750	257.9%
Evanston	6,240	5,863	377	6.0%
Sub-Total	181,200	200,029	18,829	10.4%
COMMUTER RAIL				
CNW North	11,000	9,509	1,491	13.6%
CNW Northwest (Main)	17,480	15,918	1,562	8.9%
CNW Northwest (Richmond Branch)	190	292	102	53.7%
CNW West	11,000	14,063	3,063	27.9%
Milwaukee Road (North)	6,770	6,314	456	6.7%
Milwaukee Road (West)	7,990	10,205	2,215	27.7%
Burlington North	18,610	19,871	1,261	6.8%
ICG Main Line	16,260	11,582	4,678	28.8%
ICG Blue Island (Branch)	1,880	1,073	807	42.9%
ICG S. Chicago (Branch)				
ICG (Diesel)*	190	0	190	(100.0%)

Table 4.6
(Cont'd)

LINE	ACTUAL CBD VOLUME	PREDICTED CBD VOLUME	DIFFERENCE	PERCENT DIFFERENCE
Rock Island Main (Line)	5,800	6,069	269	4.6%
Rock Island Beverly (Branch)	6,700	5,341	1,359	20.3%
Norfolk & Western*	560	0	560	(100.0)%
Sub-Total	107,530	105,612**	1,918	1.8
Total	288,730	305,641	16,911	5.9

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* It should be noted that, for purposes of the test, these lines are assumed not to be in operation. Thus the percent error is not included in the analysis.

** This is slightly different than the CBD ridership on the entire commuter rail system since a few commuter rail trips are generated within the penalty area and are not assigned to specific stations or lines.

cost or travel time (The error at this station was an overprediction of approximately 6,000 trips). However, as with the Milwaukee line, both the Congress and Skokie lines are classified as constant lines, thus the overprediction is not critical.

For the commuter rail lines, the model predicts accurately, however, some errors occur due to specific operating characteristics of commuter rail branches located within the City of Chicago. This problem is due to the wide range of level of service offered on the different lines, which is not sufficiently accounted for in the network input data.

As an example, the ICG Main Line is underestimated by 28 percent, however, since more frequent service is offered on this line than the other commuter railroads, the underestimation of trips for this line is logical. On the other hand, both the Milwaukee and CNW West lines are overestimated due to the overprediction of trips for inner-suburban stations. The CBD demand model's estimation of utilities for commuter rail for these stations does not account for the perceived high cost of commuter rail travel for inner-suburban areas and unavailability of parking near these stations.

Once the CBD demand has been estimated and evaluated, the total line-specific volumes are determined. For each individual rapid transit line, this is done by multiplying expected CBD demand by the thru-trip factor, independently predicting local demand, and adding the three trip components together. It should be noted that the percent error in predicted thru-trips is equal to the percent error in estimated CBD trips.

For all but the Skokie Swift lines, local rapid transit trips are estimated using the Local Demand Model. The 1970 service area population is calculated, and the corresponding trips per mile and total one-way trips determined. Since the Skokie line is significantly different from the remainder of the system (with a station spacing of 5 miles as opposed to approximately .5 miles for the entire system), the model was not used, and the percentage obtained from the 1970 CATS data was applied. Table 4.7 presents the local demand totals for the rapid transit lines.

For the commuter rail lines, the one-way CBD volumes are expanded by empirically determined specific factors to account for the percentage of commuter rail trips that are not destined for the CBD.

Table 4.8 summarizes the predicted and actual total one-way trips for the commuter rail and rapid transit lines. For the commuter rail lines, the percent errors (with an average of 25 percent) are exactly similar to the ones for the CBD trips, as estimated total trips are a direct function of estimated CBD trips. The previously discussed comments are applicable.

Table 4.7

ESTIMATED LOCAL DEMAND
FOR
EXISTING RAPID TRANSIT SYSTEM

LINE	ESTIMATED ONE-WAY LOCAL DEMAND
Howard	6995
Ravenswood	3335
Congress	4970
Douglas	3505
Englewood-Jackson Park	5780
Dan Ryan	4685
Milwaukee	4350
Lake	3255
Evanston	1250
Skokie	845
TOTAL	38,970

Table 4.8

COMPARISON OF ACTUAL TOTAL ONE-WAY VOLUMES
AND
PREDICTED TOTAL ONE-WAY VOLUMES

LINE	ACTUAL TOTAL VOLUME	PREDICTED TOTAL VOLUME	DIFFERENCE	PERCENT DIFFERENCE
RAPID TRANSIT				
Howard	50,470	53,370	2,900	5.8
Ravenswood	18,730	18,576	154	.8
Congress	14,700	30,629	15,929	108.4
Douglas	15,390	13,150	2,240	14.6
Milwaukee	39,580	45,350	5,770	14.6
Dan Ryan	53,900	47,651	6,249	11.6
Lake	24,010	23,472	538	2.2
Englewood-Jackson Park	29,080	26,827	2,253	7.8
Skokie	2,720	9,701	6,981	256.7
Evanston	8,320	7,895	425	5.1
Sub-Total	256,900	279,005	22,105	8.6
COMMUTER RAIL				
CNW North	11,700	10,116	1,584	13.5
CNW Northwest (Main)	18,600	16,934	1,666	9.0
CNW Northwest (Richmond Branch)	200	311	111	55.5
CNW West	11,700	14,960	3,260	27.9
Milwaukee Rd. North	7,200	6,717	483	6.7
Milwaukee Rd. West	8,500	10,856	2,356	27.7
Burlington Northern	19,800	21,139	1,339	6.8
ICG Main Line	17,300	12,321	4,979	28.8
ICG Blue Island Branch	2,000	1,141	859	43.0
ICG S. Chicago Branch	3,300	5,718	2,418	73.3
ICG (Diesel)	200	0	200	(100.0)
Rock Island Main Line	6,200	6,456	256	4.1
Rock Island Beverly Branch	7,100	5,682	1,418	20.0
Norfolk & Western	600	0	600	(100.0)
Sub-Total	114,400	112,350	2,050	1.8
TOTAL	371,300	391,355	20,055	5.4

For the rapid transit lines, the total trips are not a function of CBD trips, as local trips are independently generated. The estimated total trips are closer than are the CBD trips, with an average error of seven percent for all lines but the Congress and Skokie lines.

In summary, the models accurately replicate total one-way volumes on the existing regional rail system. Thus, the entire process, including the CBD model, the thru-trip factor, the local demand model, and the computer network can be used for evaluating alternatives in SONARRTA.

CHAPTER V

DEVELOPMENT OF CAPITAL AND OPERATING COSTS

A major criterion for evaluation of alternative rail lines in SONARRTA is the cost for construction and operation of a new facility. However, since this is a long range study, estimates of detailed costs based on engineering and design analysis has not been undertaken for any of these alternatives. The capital cost estimation procedure, therefore, consists of per-mile and per-station construction costs based on the alignments that have already been specified. Similarly, operating costs are derived from the outputs of the demand estimation network package and the application of unit costs. The requirements of the cost estimation procedures necessitate an accurate and reasonable preliminary estimate of costs, based on only limited information.

RAPID TRANSIT CAPITAL COSTS

Construction costs include excavation and structure, signals and interlocks, power and distribution, track work, lighting, fencing, automatic train operation, communications and mechanical equipment, restoration of the right-of-way, and engineering and contingency fees.

Construction cost estimates for conventional two-track rail rapid transit are expressed as per-mile costs, exclusive of stations, in Table 5.1. The costs are classified by construction type: tunnel, cut and cover, elevated, at-grade, and depressed. Station costs are expressed separately in Table 5.1. It is assumed that all construction will take place in an urban non-CBD area.[1] The applicable costs for disruption of underground utilities are included in the construction costs.

The Unit Costs in column one, Table 5.1 will be applied in estimating costs for the study. They are considered to be the most representative figures to use in the Chicago area. They are the "default values" in the Urban Mass Transportation Administration, Characteristics of Urban Transportation Systems, and have been verified through cost comparisons with other systems across the nation. Table 5.1 also shows construction data from several sources for each type of construction. It is recognized that construction costs will vary within a range, depending on the specific characteristics of an alternative. All costs are presented in 1978 dollars, and were inflated as necessary using a standard rate of inflation.[2]

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1 The Chicago Urban Transportation District costs reported in Table 5.1 are for the non-CBD portions of the Chicago Central Area Transit Project.

2 The inflation rates were taken from the Industrial Real Estate Development Guide and the Engineering News Record Cost Indexes.

TABLE 5.1

CONSTRUCTION COSTS

($ Millions, 1978 Dollars)

Construction Type Per Mile	Unit Cost	UMTA[1]	CATS[2]	WMATA[3]	CUTD[4]
Tunnel	34.7	24.0 - 35.0	48.8	N.A.	70
Cut and Cover	20.1	65.0 - 30.4	43.7	30.3 - 38.1	66.6
Elevated	19.4	16.6 - 25.0	19.2	15.7 - 21.8	43.6
At-Grade	7.7	6.3 - 10.6	5.8	7.7	10.9
Depressed	N.A.	N.A.	10.0	N.A.	N.A.
Stations					
Underground	18.9	15.6 - 26.5	4.1[5]	20.0 - 22.5	20.6
Elevated	4.0	3.2 - 7.7	3.9[5]	3.5 - 4.5	10.9
At-Grade	4.0	3.1 - 7.7	1.7[5]	3.3 - 4.5	7.3

1 D.B. Sanders and T.A. Reynen, Characteristics of Urban Transportation Systems - A Handbook for Transportation Planners, prepared for U.S. Department of Transportation, May, 1974.

2 George M. Johnson, "Construction Cost Estimates for Mass Transportation Facilities in the Chicago Metropolitan Area", Chicago Area Transportation Study, December, 1972.

3 Donald O'Hearn, Office of Program Control, Washington Metropolitan Area Transit Authority, Telephone Conversation, May, 1975.

4 Harold Nelson, Executive Director and General Manager, Chicago Central Area Transit Project, Chicago Urban Transportation District, November, 1975.

5 Costs of handicapped facilities added as estimated by CTA Engineering, $2 million - subway, $1.5 million -- elevated, $100,000 - at-grade.

Tunneling

There are two general types of earth excavation techniques used in the Chicago area: 1) excavation using state-of-the-art mechanical excavators; and 2) excavation by a hand-mined, shield driven technique. The former involves a greater initial cost due to the high cost of the mechanical excavating machine (auger or mole). Therefore, this technique becomes economical only for tunnels more than 1000 feet in length. It has both a faster rate of advance and lower labor cost. The per mile cost of mechanically excavated tunnels is $34.7 million.

The high labor costs associated with the hand-mined technique make it economical only over short distances. Labor costs are higher in the hand-mined technique because of the additional number of man-hours needed and the slower rate of advance. It costs approximately 25 percent more than the mechanical excavation technique.[3]

Only the cost of mechanical excavation is given as the unit cost to be applied in the study. This is due to two considerations: 1) mechanical excavation is more commonly used and comparable cost estimates are available; and 2) the decision as to where the hand-mined method should be employed is made only at the project level.

It is assumed that each tunnel will have a 16'6" inside diameter which allows for the passage of the train.[4] The per-mile costs given are for two such tunnels which will accommodate two tracks and allow room for a center platform.

Cut and Cover

The cut and cover method involves bracing the outer limits of the excavation, removing surface material to below the level of utilities, and decking and supporting the exposed utilities. The soil is then removed to the lower limits of the excavation and the enclosing structure built as a double box. The utilities are then reconstructed, the area backfilled, and the surface returned to its original condition. The unit cost is based on a minimum structure 32 feet by 21 feet, with a cut 30 feet below the surface. Costs include all construction elements. The estimated per-mile cost of cut and cover construction is $20.1 million.

Elevated

Depending on their height, elevated structures vary in cost. However, without detailed engineering, it is impossible to determine actual elevation of each of the proposed routes. An average per-mile cost of $19.4 million for elevated construction is used for the study. The structures will be a trough design, constructed of reinforced concrete, with ballasted track.

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[3] Robert S. Mayo, et al, Tunneling the State of the Art, prepared for the U.S. Department of Housing and Urban Development, January, 1968.

[4] This would accommodate a large car such as the State of the Art Car developed by UMTA.

At-Grade

It is assumed that all at-grade facilities will have grade-separated crossings. Costs will vary between alternatives, depending upon the type of grade-crossing used. However, for this study, a single unit will be applied. The per-mile cost of at-grade construction is $7.7 million.

Four Tracking

In cases where four tracks are planned, the cost of a two--track facility, regardless of the construction type, is multiplied by 1.7.[5]

Station Cost

Station costs have been defined for three construction types: underground - $18.9 million; elevated $4.0 million; and at-grade - $4.0 million. These costs are based on the UMTA default value, which was considered the best available figure. The cost estimates include a 600 foot platform, which is the standard size for new system stations throughout the country, as well as for the Chicago Central Area Transit Project, and include handicapped facilities.

Vehicle Cost

The vehicle cost is $510,000 per rapid transit car.[6] This is based on the assumption that the new cars would be built to the same specifications as the newest cars on order for CTA.

For each alternative, the number of required cars will be based on estimated peak patronage trip time, plus an additional ten percent required for spares.

For replacement alternatives, the number of required cars will be based on the additional vehicles required beyond the number used in existing service.

Cost of Support Facilities

The cost of support facilities includes shops, yards, and bus/rail transfer facilities. It is recognized that many support facility costs are incurred on a system-wide basis; however, changes affecting the location of rail facilities will affect the provision of support facilities, thus these costs are also considered applicable for the study.

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5 Source: Metropolitan Transit Authority, New York, Planning Department.

6 Based on the most recent grant to acquire 300 rapid transit cars under the Proposed RTA 5 Year Capital Program FY 1979-83.

Shops

A rapid transit shop unit cost per vehicle services was calculated, based on CTA Engineering Department data which gives the actual cost of constructing the Lake Street inspection shop. This is the newest complete facility, and the cost is considered the best available basis from which to generate the cost estimates for this study. The unit cost is $21,540 per car serviced.

Yards

The cost of a yard is based on the following formula:

1) $\frac{2 \times 50}{5280}$ = .019 = miles of track required per car stored

2) (required track) x (per mile cost of single at-grade track) = yard cost per car

3) .019 x $3.9 million = $74,100 per car

The per-mile costs of at-grade track are used, since the additional cost of switches required for yards is counterbalanced by the deleted cost of signals and interlocks which are not required.

It is recognized that the allocation of yard costs to individual links is extremely difficult. The location of a yard within the context of the entire rapid transit network will determine its size as much as will unit costs multiplied by the number of cars on a single alternative line. Standards for yard space are also difficult to determine. CTA now operates with a minimum yard capacity; however, it is unlikely that this low level of yard space would be planned into a new system.

Staging Costs

The cost of replacing an operating elevated structure with another elevated structure on the same right-of-way while continuing operation is twice as expensive as the cost of building an entirely new structure. This is due primarily to the necessity for staging.

Additional Costs for Difficult Construction

Three cases of difficult construction which involve substantial additional costs beyond the previously identified cost components have been identified.

Major junctions require interlocking systems that cost $3.0 million.

Subway crossings under depressed expressways require reworking of arterial street bridge footings, at a cost of $2.4 million.

Junctions between depressed expressway median lines and subway lines require both the cost of interlocking and bridge reworking for a total of $5.4 million (junctions between depressed expressway median lines and elevated lines involve only the cost of interlocking).

Right-of-Way Acquisition Cost. City owned rights-of-way over streets are considered free.

It is assumed that railroad rights-of-way will be leased. The annual cost, based on the current cost of using the Chicago and Northwestern right-of-way in Oak Park, is $108,600 per mile. Track relocation cost which would result from the placement of a rapid transit line on existing, presently used railroad rights-of-way is the cost of shifting the track of another property 6-8 feet laterally without disassembling it, so as to provide space for a CTA line. This assumes use of the same ballast and no improvement of the right-of-way. The cost of track relocation is estimated at $319,000 per track mile. Private rights-of-way are acquired at costs specific to individual links which will vary over a wide range. Only a minimal amount of private property will be required.

Cost of Demolishing Old Facilities

There is no cost associated with the total demolition of non-operating elevated structures. In the past, demolition contracts have been awarded on a small profit basis, with the amount of profit depending on the market rates for scrap metal and/or any immediate demand for the type of steel obtained in structure demolition. In the case of a federally funded rapid transit project, any profit realized would be applied to the federal share of the funding and would show no profit or loss. No cost is applied in the study.

Capital Cost of Keeping Existing Rapid Transit Facilities in Operation

Major capital costs for the maintenance of all old CTA lines have been estimated through the year 2000 and are shown in Table 5.2. Track, emergency crossover, interlocking, and structure renewal projects are included. The cost is estimated in 1977 dollars, and the approximate starting dates of the projects are indicated. The starting dates reflect the most reasonable time frame to preserve safe service, and are contingent upon existing facilities remaining in a safe, operable condition until the starting date.

The maintenance projects do not include former and presently funded Capital Improvement Projects, stations (discussed below), or the portion of routes which could be retired in conjunction with the CUTD subway project.

The estimated cost (1977 dollars) of maintaining each line, through the year 2000 as summed from Table 5.2 is as follows:

Table 5.2

RAPID TRANSIT PROJECTS - FUTURE CAPITAL MAINTENANCE FOR THE EXISTING SYSTEM

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
North - South	Northside - Renew Open Deck Track (Clark Junct. to Lawrence, Tracks 2 & 3)	$2,295,000.	June '79
	Northside - Renew Open Deck Track (Armitage to Clark Junct., Tracks 1 & 4)	1,990,000.	June '82
	Englewood - Renew Open Deck Track (59th Junct. to Ashland Terminal)	2,976,000.	June '78
	Southside - Renew Special Track Work (59th St. Junction)	73,000.	June '81
	State St. Subway - Renew invert track (Armitage to 15th St.)	11,756,000.	June '83
	All Branches - Renew emergency cross-overs.		
	Englewood (59th Junct. to Ashland Term.)	145,000.	June '85
	Southside (59th Junct. to 15th St.)	680,000.	June '85
	State St. Subway (15th St. to Armitage)	290,000	June '85
	Northside (Armitage to Howard)	1,450,000.	June '86
	Northside - Interlocking at Howard	4,240,000.	Oct. '80
	Northside - Interlocking at Wilson	3,000,000	Oct. '79

Table 5.2 (Cont'd)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
North - South (Cont'd)	All Branches - Renew Terminal and Yard Special Track Work.		
	Englewood (Loomis Street)	430,000.	June '8
	63rd Street Lower Yard	720,000.	June '8
	Southside (61st Street)	1,570,000.	June '8
	Northside (Wilson)	390,000.	June '8
	Northside (Howard)	1,330,000.	June '8
	All Branches - Renew Yard Storage Tracks.		
	Englewood (Loomis Street)	1,630,000	June '8
	63rd Street Lower Yard	820,000.	June '8
	Southside (61st Street)	1,630,000.	June '8
	Northside (Wilson)	820,000.	June '8
	Northside (Howard)	1,380,000.	June '8
	All Branches - Renew Columns, Footings and Profile Structure.		
	Northside (Armitage to Lawrence)	36,110,000.	June '8
	Southside (15th St. to 59th Junct.)	30,320,000.	June '8
	Englewood (59th Junct. to Ashland)	14,270,000.	June '8

Table 5.2 (Cont'd)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
North South (Cont'd)	All Branches - Renew Top & Bot. Cross Girder Flange Angles.		
	Northside (Armitage to Lawrence)	$ 3,650,000.	June '78
	Southside (15th St. to 59th Junct.)	3,206,000.	June '80
	Englewood (59th Junct. to Ashland)	1,429,000.	June '82
	Northside - Remove Concrete incline structure to Milwaukee Road (Wilson to Montrose)	113,000.	June '80
	Jackson Park - Renew Track Stringer and Cross Girder Flange angles, Column bases and footings, expansion pockets and profile structure (61st St. Yard)	5,140,000.	June '78
	Englewood - Same renewal as above (Loomis/Ashland Yard not inc. new extention)	4,650,000.	June '78
	Northside - Same renewal as above (Wilson Yard)	3,020,000.	June '85
	All Branches - Renew track stringer flange angles (Restart Cycle).		
	Southside (15th to 63rd St.)	2,200,000.	June '82
	Englewood (59th Junct. to Ashland)	2,100,000.	June '80
	Northside (Armitage to Lawrence)	3,300,000.	June '82
	Southside - Renew State St. Subway retaining walls @ S. Portal	3,800,000.	June '80
	SUB TOTAL	151,203,000.	

Table 5.2 (Continued)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
West - Northwest	Douglas Park - Renew ballasted Track (Keeler to 54th Terminal)	$ 3,450,000.	June '79
	Congress - Renew ballasted Track (Halsted to DesPlaines Term.)	17,250,000.	June '99
	Lake-Douglas Connector - Renew open deck track (Lake & Paulina to Harrison & Paulina)	510,000.	June '81
	Congress - Renew Special Trackwork (Loomis Junction)	60,000.	June '83
	Dearborn St. Subway-Renew invert Track (Evergreen to Halsted)	10,990,000.	June '99
	All Branches - Renew emergency crossovers.		
	Douglas Park (Congress to 54th Terminal)	630,000.	June '85
	Congress (Halsted to DesPlaines Terminal)	750,000.	June '86
	Dearborn St. Subway (Halsted to Evergreen)	180,000.	June '86
	Milwaukee (Evergreen to Logan Blvd.)	140,000.	June '85
	All Branches - Renew Terminal and Yard Special Track Work.		
	Congress (DesPlaines)	340,000.	June '93
	Douglas (54th Street)	240,000.	June '87
	All Branches - Renew Yard Storage Tracks.		
	Douglas (54th Street)	1,100,000.	June '87

Table 5.2 (Continued)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
West - Northwest (Cont'd)	All Branches - Renew Columns, Footings and Profile Structure.		
	Douglas Park (Congress to Keeler)	26,380,000.	June '78
	Milwaukee (Evergreen to Logan Blvd.)	12,220,000.	June '80
	All Branches - Renew Top & Bot. Cross Girder Flange Angles.		
	Douglas Park (Congress to Keeler)	2,300,000.	June '78
	Milwaukee (Evergreen to Logan Blvd.)	1,560,000.	June '79
	All Branches - Renew Track Stringer Flange Angles (Restart Cycle).		
	Douglas Park (Congress to Keeler)	2,200,000.	June '80
	Milwaukee (Evergreen to Logan Blvd.)	900,000.	June '79
	SUB TOTAL	$ 81,200,000.	
West - South	Lake St. - Renew emergency crossovers (Ashland to Harlem Terminal).	340,000.	June '86
	Lake St. - Renew Terminal and Yard Special Track Work (Hamlin Yard)	30,000.	June '98

Table 5.2 (Continued)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
West - South (Cont'd)	Lake St. - Renew Columns, Footings and Profile Structure (Ashland to Rockwell).	$ 6,920,000.	June '80
	Lake St. - Widen Structure, install new Columns & Footings and Profile Structure (Rockwell to Laramie).	9,100,000.	June '81
	Lake St. - Relocate Columns in Street Intersection (Ogden Ave.)	240,000.	June '82
	SUB TOTAL	16,630,000.	
Ravenswood	Ravenswood - Renew ballasted Track (Campbell to Kimball Terminal).	2,000,000.	June '81
	Ravenswood - Renew emergency cross-overs (Clark Junct. to Kimball Terminal).	240,000.	June '87
	Ravenswood - Renew Terminal and Yard Special Track Work (Kimball).	720,000.	June '91
	Ravenswood - Renew Yard Storage Tracks (Kimball).	1,580,000.	June '91
	Ravenswood - Renew Columns, Footings & Profile Structure (Clark Junct. to Campbell).	19,300,000.	June '82
	Ravenswood - Renew Top & Bot. Cross Girder Flange Angles (Clark Junct. to Campbell).	2,400,000.	June '80
	Ravenswood - Renew track Stringer Flange Angles (Restart Cycle, Clark Junct. to Campbell).	1,600,000.	June '81
	SUB TOTAL	27,840,000.	

Table 5.2 (Continued)

ROUTE	DESCRIPTION	ESTIMATED COST	APPROX. STARTING DATE
Skokie Swift	Skokie Swift - Renew ballasted Track (Howard Term. to Dempster Term.)	8,540,000.	June '82
	Skokie Swift - Renew emergency crossovers (Howard Term. to Dempster Term.)	140,000.	June '81
	Skokie Yard - Renew Yard Special Track Work.	580,000.	June '81
	Skokie Yard - Renew Yard Storage Tracks	2,467,000.	June '81
	SUB TOTAL	11,727,000	
Evanston	Evanston - Renew ballasted Track (Howard Term. to Linden Term.)	3,300,000.	June '78
	Evanston - Renew emergency crossovers (Howard Term. to Linden Term.)	530,000.	June '82
	Linden Terminal - Renew Terminal and Yard Special Track Work.	460,000.	June '84
	Linden Yard - Renew Yard Storage Tracks	790,000.	June '84
	SUB TOTAL	5,080,000.	
	ALL ROUTES TOTAL	$294,450,000.	

Table 5.2 (Cont'd)

GENERAL NOTES

(1) Projects as listed are in addition to former and presently funded Capital Improvement Projects.

(2) Estimated costs are based on 1977 rates.

(3) Approximate starting dates as listed are contingent upon existing facility remaining in a safe, operable condition till renewal date.

(4) Elevated station facilities (platforms, canopies, stairs, handrail etc.) are not included in projects as listed but should be included in future complete renewal projects.

(5) Projects as listed do not include the portion of routes which could be retired in conjunction with the CUTD subway project (Loop, Lake St. from tower 18 to Ashland, Northside from Tower 18 to Amitage, and Southside from Tower 12 to 17th Street).

(6) Approximate service life and character of new facilities ins as follows:

(a) Ballasted Track - 35-40 years
(b) Open Deck Structure Track - 25-30 years
(c) Steel Elevated Structure - 50-60 years
(d) Station Facilities - 50-60 years
(e) Subway Track - 40-50 years
(f) Normal Maintenance (painting, patching, spot renewals etc.) will begin from 5 to 20 years after initial construction of facility with painting as the most frequent maintenance function.

Source: Chicago Transit Authority

Southside	15th Street to 59th Street	$ 36,479,000
Jackson Park	59th St. to Stony Island (does not include ICG bridge replacement)	9,880,000
Englewood	59th Street to Ashland	27,630,000
Lake Street	Clinton to Harlem	16,630,000
Milwaukee	Evergreen to Jefferson Park	14,820,000
Congress	Clinton to Des Plaines	18,400,000
Douglas	Polk to Cicero	36,300,000
Northside	Clybourn to Howard	63,088,000
Ravenswood	Clark to Kimball	27,840,000
Skokie Swift	Howard to Dempster	11,727,000
Evanston	Howard to Linden	5,080,000
TOTAL		$267,874,000

COMMUTER RAIL CAPITAL COSTS

Most of the capital costs associated with the commuter rail alternatives necessitate upgrading existing railroad right-of-way. Since the existing conditions of the track and roadbed vary considerably for these alternatives, a preliminary engineering estimate for rehabilitation was completed for each alternative line by the RTA's Engineering Department. These estimates are therefore based on different assumptions for each line. In some cases, costs of upgrading two existing tracks were included while in other cases, upgrading one existing track and building one totally new track were calculated. Other assumptions include percent of existing ties be replaced, ballasting, number of road crossings, turnouts, signalling, and railroad bridgework. Diesel operation is assumed for all lines except for the ICG Electric lines. All new major lines and extensions are to be built at FRA class IV standards, while upgrading of the individual branches is dependent upon the existing conditions of the track and roadbed, and the type of service to be offered. For example, for upgrading the McHenry Branch of the C&NW, it is anticipated that there would be no need to maintain this branch above FRA Class III. A summary of the costs used in the study is presented in Table 5.3.

TABLE 5.3

COMMUTER RAIL

CAPITAL COSTS (1977 PRICES)

UPGRADING	COST	$ PER TRACK MILE
Replacing Ties	$30 ea.	$97,500 (100% new ties)
Ballast Resurfacing	$2.00/ft.	$10,560
115 CWR Track	$30/ft.	$158,400
136 CWR Track	$35/ft.	$184,800
All new track (ties, resurfacing included)	$100/ft.	$528,000
Road Crossings	$50,000-$60,000 ea. (dependent on highway width)	
Crossing Signals	$60,000 ea.	
Shelters	$20,000 ea.	
Stations	$250,000 ea.	
Turnouts	$20,000 ea.	
Interlocking	$180,000 ea.	
Signalling		$12,500-22,500
Electric Lines:		
Overhead Catenary	$30,000 per structure	
Overhead Wire		$25,000
Substation	$250,000 ea.	
Abandonment Costs		$15,000
Removing Street Crossings	$8,000 ea.	
Remove Stations	$6,000-$10,000 ea.	

Source: RTA Engineering Department

The following is a brief description of terms used in the commuter rail cost estimates. Detailed line-specific capital maintenance costs will be compiled during Phase II of the study.

Replacing Ties - Based on an evaluation of the rail line's present condition, the percentage of ties to be replaced was determined.

Ballast Resurfacing - The cost for resurfacing with new stone ballast.

Track - The cost for upgrading existing track with new continuously welded rail and fastenings.

All New Track - This cost is based on building a completely new track and roadbed, and therefore includes all costs for ties, resurfacing, and track.

Road Crossings, Crossing Signals - Costs are dependent on highway width and traffic volume.

Stations - Cost for a new enclosed, heated, lighted space with awnings. It also includes building of new platforms, but no provisions are made for parking.

Abandonment Cost -The cost of retiring existing track right-of-way when rail services (freight and passenger) are ended. These costs are associated with regulations for restoring waterways and road crossings.

RAPID TRANSIT OPERATING COSTS

Annual operating costs are calculated on a per vehicle-mile basis. They include vehicle maintenance, fuel and power, reserve for injuries and damages, labor operations and trainmen and fixed costs. Total CTA rail operating costs are $2.08 per vehicle mile.[7]

The per vehicle mile station cost which is included in the $2.08 total per vehicle mile cost has been separated out, in order to calculate the impacts of various station spacing schemes on the cost of a rapid transit mile. The per vehicle mile cost of station maintenance and operation is $0.64.[8] The 0.64 station cost, subtracted from the $2.08 total operating and maintenance cost, leaves $1.44. This is the per-vehicle mile cost with station costs deleted. Station costs are reintroduced to the total cost on the basis of $224,500 per station.

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7 Chicago Transit Authority, Operating Location Cost Report, Sept. 3, 1977.

8 Costs were taken for the first half of 1977 and then projected to arrive at an annual cost of $31,879,324. This number was a) divided by 142 stations to arrive at the per station cost, and b) divided by total rapid transit vehicle miles in 1977 to arrive at the per vehicle mile cost. Because only direct costs were used, these are conservative estimates.

Operating and maintenance costs will generally remain constant, both for existing and new rapid transit lines. This is due to the fact that the labor costs associated with janitorial, agent, and train operations are daily costs and are not associated with structural repair.

COMMUTER RAIL OPERATING COSTS

A simple method to evaluate changes in commuter rail operating costs is also required for evaluation of the commuter rail alternatives in SONARRTA. Only net increases in operating costs over the existing situation (existing service levels) will be calculated based on each alternative. Changes in operating costs are then used to account for changes in subsidies. The following set of actions would cause a change in operating costs:

1. A change in line length (abandonments, extensions) will cause a net increase or decrease in operating costs due to a change in car miles, or train miles operated.

2. A change in demand for a commuter rail line will occur with an improvement, extension, or abandonment of a rail line. Changes in adjacent services, population, gasoline prices, etc. would also cause a change in a line's patronage. Ridership changes will necessitate a change in peak vehicles, car miles, and/or number of trains.

In order to provide the most equitable basis from which to evaluate alternatives for different corridors, a single cost structure must be assumed. A regional rail network study for a year 2000 system should not attempt to predict specific operator and service characteristics for each individual alternative. Furthermore, the evaluation of commuter rail alternatives should not be biased due to the variations in operating costs that occur today. For example, the evaluation of possible extensions to the C&NW and the Milwaukee Road should not be influenced by the fact that currently the C&NW has lower operating costs per car mile. A uniform cost estimation model thus provides a basis for proper trade-offs among different alternatives based on corridor and not operator characteristics. Use of a single operating cost model is also reasonable given that RTA, through its purchase of service agreements, will create a trend towards a more uniform cost structure.

Table 5.4 summarizes operating costs and selected service indicators for each commuter rail line. By dividing operating costs by car miles, a simple comparison can be made. The Norfolk and Western and Chicago and NorthWestern have the lowest costs per car mile ($2.32 and $2.54 respectively), while all of the other railroads have approximately a $4.00 cost per car mile. No relationship regarding the service levels and per car mile costs can be developed, especially since the Burlington and C&NW operations provide a high level of service but vary considerably in per car mile costs.

TABLE 5.4

OPERATING CHARACTERISTICS FOR COMMUTER RAILROADS

Commuter Rail Division	Operating Costs	Car Miles[1]	Peak Vehicles[2]	Trains	Train Miles	Operating Cost/ Car Mile
Burlington Northern	16,156,000	3,936,000	119	19,136	1,489,439	$4.10
C.M.S.P.&P.	13,800,000	3,646,549	103	24,180	1,006,884	$3.78
Norfolk & Western	499,000	215,000	9	520	26,794	$2.32
C&NW	29,841,000	11,728,103	306	58,760	2,478,657	$2.54
CRI&P	9,471,000	2,121,821	106	18,720	544,065	$4.46
ICG Diesel	280,000	57,054	3	520	19,018	$4.90
ICG Electric	20,310,000	4,595,308	161	76,544	1,489,439	$4.42

1. All totals are annualized; Fiscal Year 1976. From 1976 RTA Annual Report.

2. Car Miles; as reported by railroads, FY 1976.

In the past two years, RTA has added service to the existing commuter rail lines. Since RTA funds all services through its Purchase of Service agreements with the railroads, all changes in operating costs must be estimated beforehand, using the prescribed formula in the agreements. These changes in operating costs offer an excellent basis for estimating per car-mile or train-mile costs of changes in level of service on commuter railroads. Based on recent service changes for the Milwaukee Road and Burlington Northern, a $3.97 per car-mile cost and a $10.73 per train-mile cost was calculated.[9]

Because the changes in car miles is a simple basis from which to calculate operating costs (changes in train miles would require that the number of cars per consist be constant for all commuter rail lines), it will be used to calculate net changes in operating costs for commuter rail operations.

Abandonments will result in elimination of required car miles of operations, while new lines will require an increase in car miles. Improvements to existing services will most likely result in an increase in patronage. Under this situation, the additional number of cars to accommodate the increased demand will be calculated based on present loading standards. The increased annual number of car miles can then be derived. Every alternative for the commuter rail network will result in a change in annual car mileage. The net change in operating cost will thus be figured by applying the per mile cost on an incremental basis.

CALCULATION OF CAPITAL AND OPERATING COSTS

In the proposed optimization algorithm, costs are introduced by totaling the costs for a proposed network to ensure that a budget constraint is not violated (See Chapter VI). Capital and operating costs for each link are annualized into one figure by alternative. The operating and capital maintenance costs for the base (constant) system is not included. All costs for construction and operation of a transit link are therefore interpreted as the net increase (or decrease) over operating and maintaining the base existing commuter rail and rapid transit system with the implementation of that link. The following summarizes the procedure for calculation of costs for each project category.

I. Rapid Transit

A. <u>Constant Lines</u>

No additional costs are assumed.

B. <u>Replacement of Renovation</u>

1. If line is replaced or renovated then:
Operating - No change (new line will only minimally affect vehicle miles);

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[9] This figure is based on a $642,428 annual increase in operating costs due to a service change resulting in an increase of 161,742 car miles and 59,883 train miles per year.

Capital - Add construction cost and cost of abandonment of existing facility.

2. If line is not replaced, then:
Operating - No change;
Capital - Add annualized capital maintenance cost of line to the year 2000.

C. <u>Removal</u>

1. If line is abandoned (removed) then:
Operating - Determine reduction in operating cost with removal of line;
Capital - Add cost of abandonment.

2. If line is not abandoned, then:

Operating - No change;
Capital - Add annualized capital maintenance cost of line to the year 2000.

D. <u>New Lines</u>

Operating - Add operating cost of new line, subtract operating cost of express bus service in corridor (if any);
Capital - Add construction cost.

E. <u>Extensions</u>

Operating - Determine cost of operating of entire line with and without extension, difference is the increase in operating cost;
Capital - Add construction cost.

II. Commuter Rail

A. <u>Constant Lines</u>

No costs are assumed.

B. <u>Upgrading to Full Service</u>

Operating - Add increase in operating costs;
Capital - Add necessary rehabilitation costs.

C. <u>Abandonments</u>

Operating - Determine change in operating costs with and without link, difference is reduction in operating costs;
Capital - Add cost of abandonment subtracting any capital maintenance cost to the year 2000.

D. New Lines

Operating - Add increase in operating costs (for extensions: add difference in operating costs);

Capital - Add costs of construction and/or rehabilitation.

CHAPTER VI

SONARRTA EVALUATION METHODOLOGY

Introduction

Research in Phase I of SONARRTA has centered on the development of analytical tools in order to evaluate all of the alternatives for the regional rail system. In the development of reliable methods to estimate impacts due to changes in the transit network, a critical tool is a clear and consistent method to process all of the relevant information, so that a network plan can be evaluated. A basic part of the Phase I research has been the development of an evaluation methodology and the research is summarized in this chapter.

Figure 6.1 is a presentation of the study's overall scheme for selection of rail links and the creation of an ongoing process for evaluation of all rail-related improvement projects in the region. The recommendations of the study are the final products of Phase II. By determining the priority of rail link improvement, studies can be initiated for the most critical needs of the six county region. Once these studies are completed, the requirements of UMTA's Alternative Analysis regulations will have been fulfilled and a final decision can be made regarding implementation of an alternative.

SONARRTA will constitute the first step in providing a region-wide perspective for the completion of detailed corridor studies and resultant improvements. Furthermore, the entire process will be an ongoing evaluative framework that will be a basic tool in the annual programming of projects and improvement of the rapid transit and commuter rail systems. The study results must be updated to reflect changing economic and social factors, as well as changes in policy and available funds. The importance of the study is not its long range recommendations, for these are of a preliminary nature; but its role in providing a long range perspective in the evaluation of all rail-related capital projects.

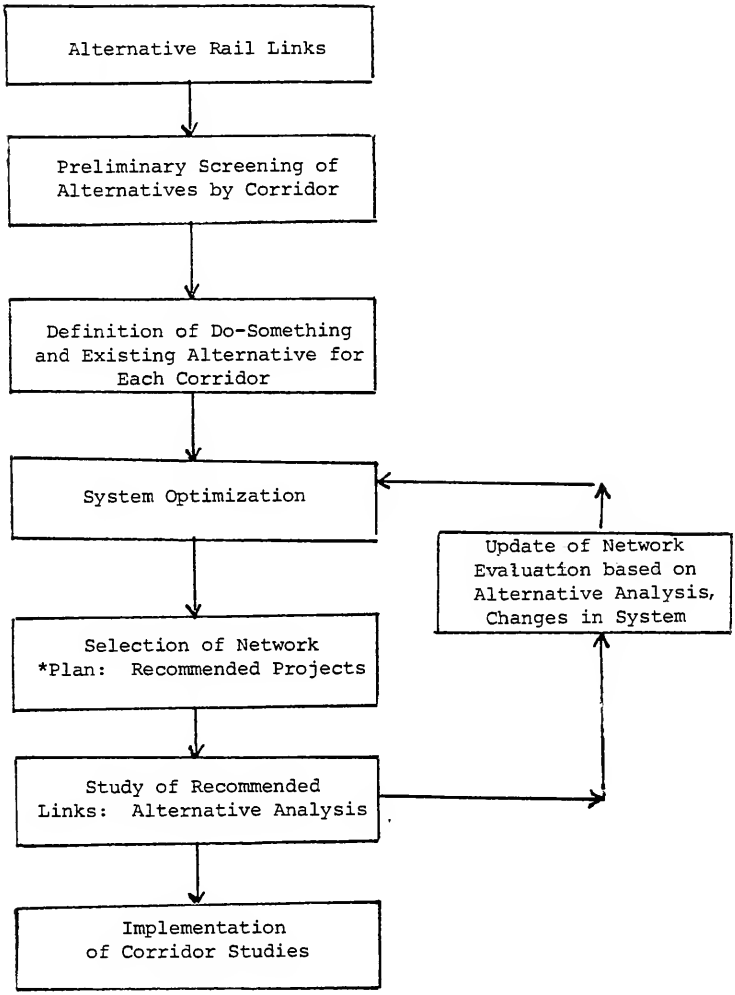
The recommendations of the study will be used as a guide in the decision making process. Flexibility of application of the analytical tools has been maintained so that changes in policy can be evaluated from a long range perspective. In this way, decision-makers will participate in the updating process by varying the assumptions used as inputs for the study.

Network Evaluation Model

Central to the evaluation of rail links is the development of a unified plan for the commuter rail and rapid transit network. SONARRTA is a study of the entire regional rail transit system, therefore evaluation

FIGURE 6.1

SONARRTA EVALUATION PROCESS



*Phase II results

is undertaken on a network basis. The calculation of the costs and benefits for each alternative is based on the estimated marginal charges from the existing rail transit system. The determination of the best network plan is the major output of the System Optimization Process. Selection of a system plan is based on the analysis of trade-offs among all alternatives; among existing and proposed lines, and among commuter rail and rapid transit lines. The methodology for developing this information is a mathematical programming approach which consists of testing a full range of alternative network combinations for optimality. After the application of the network evaluation model, links that perform well are selected for further analysis. This analysis consists of studying the detailed corridor impacts of the recommended link, as well as examining trade-offs with other possible alternatives for the corridor, such as providing express busway service. After these steps, the links that have been determined as high priority become the basis for the final recommendations of the study.

In this chapter, the proposed optimization algorithm is presented. During Phase II of the study, the algorithm will be refined and applied and the steps occuring after optimization will be further detailed.

Issues In Network Optimization

The development of an optimal regional rail system for the Northeastern Illinois region has associated with it several major conceptual difficulties which must be addressed in the formulation of an evaluation method. Generally, the problems involved with optimal network design can be grouped under three major categories:

1. Quantification of Optimization Criteria

   Various schools of thought have developed concerning the proper valuation of benefits for a transportation facility. Economists have argued that most transportation benefits to the user can be approximated by assigning dollar amounts to a tripmaker's time savings. Other perspectives include natural resource savings, assessment of environmental impacts, and the use of distributional standards in order to correct geographical or social imbalances.

   The multitude of concerns necessitates the subjection of transportation plans to a multi-dimensional evaluation. Unfortunately, conventional uses of mathematical programming techniques usually involve optimization of only a single criterion or dimension (i.e., dollars).

2. Interdependence Among Alternatives

   Given that a criterion for benefit (users benefit, transit patronage, environmental impact, etc.) is selected, the computed benefit of an alternative will vary depending on whether other proposed alternatives (lines) are assumed to be in existence. Evaluation of a proposed rail facility cannot be undertaken without investigating the probable impacts of other proposed links on the facility's expected performance. The assumption that total regional network benefit is the sum of individual link benefits is, in most cases, incorrect.

One solution to the problem of alternative interdependence would be the direct evaluation of every conceivable network, based on combinations of all of the proposed alternatives. Unfortunately, a complete enumeration of all possible networks based on 50 proposed link alternatives would necessitate 2^{50}, or more than a trillion separate network evaluations.

3. Uncertainty

Uncertainty regarding individual travel behavior can be handled by certain assumptions. Assumptions regarding future activity levels for key variables such as availability of gasoline, subsidy dollars, population trends, etc., can be introduced in the SONARRTA demand model. However, assuming or predicting the future state with respect to all of these areas in order to produce one future situation would be a highly tenuous basis for evaluation. Uncertainties may be reduced if a broad spectrum of future situations is used in a series of optimizations. Schofer suggests an alternative futures methodology, in which the selection of alternatives is based on a series of evaluations under a variety of conditions[1].

These three concerns necessitate that the optimization approach be used carefully and applied numerous times - in fact, as many times as possible to provide reliable information. The use of the alternative futures approach requires that a number of optimal networks are generated under various scenarios for land use, population, gasoline availability, and many other critical variables. Similarly, the multi-dimensional aspect of transportation planning necessitates that more than one objective (objective function) be utilized, thereby also requiring a number of applications of the optimization methodology. Finally, the interdependent nature of transit link benefits restricts network evaluation to either direct evaluation of every conceivable combination of alternatives, or to more sophisticated techniques.

Because of these difficulties, a selection of an optimization technique necessitates that compromises be made between the goals of providing a realistic framework upon which to base evaluation, and that of limiting the approach within the constraints of computing time.

SONARRTA Optimization Approach

In Figure 6.1, the development of the network plan is represented as a step occurring after the screening and selection of alternatives for each

[1] Schofer,J.L., "Evaluating Transportation Alternatives", Paper presented at the Seminar on Emerging Transportation Planning Methods, Daytona Beach, Florida, December, 1976.

corridor. The selection of an optimal network is actually a comprehensive process that is based on the performance of each alternative under a variety of objectives and assumptions. In Figure 6.2, the system optimization process is presented in further detail.

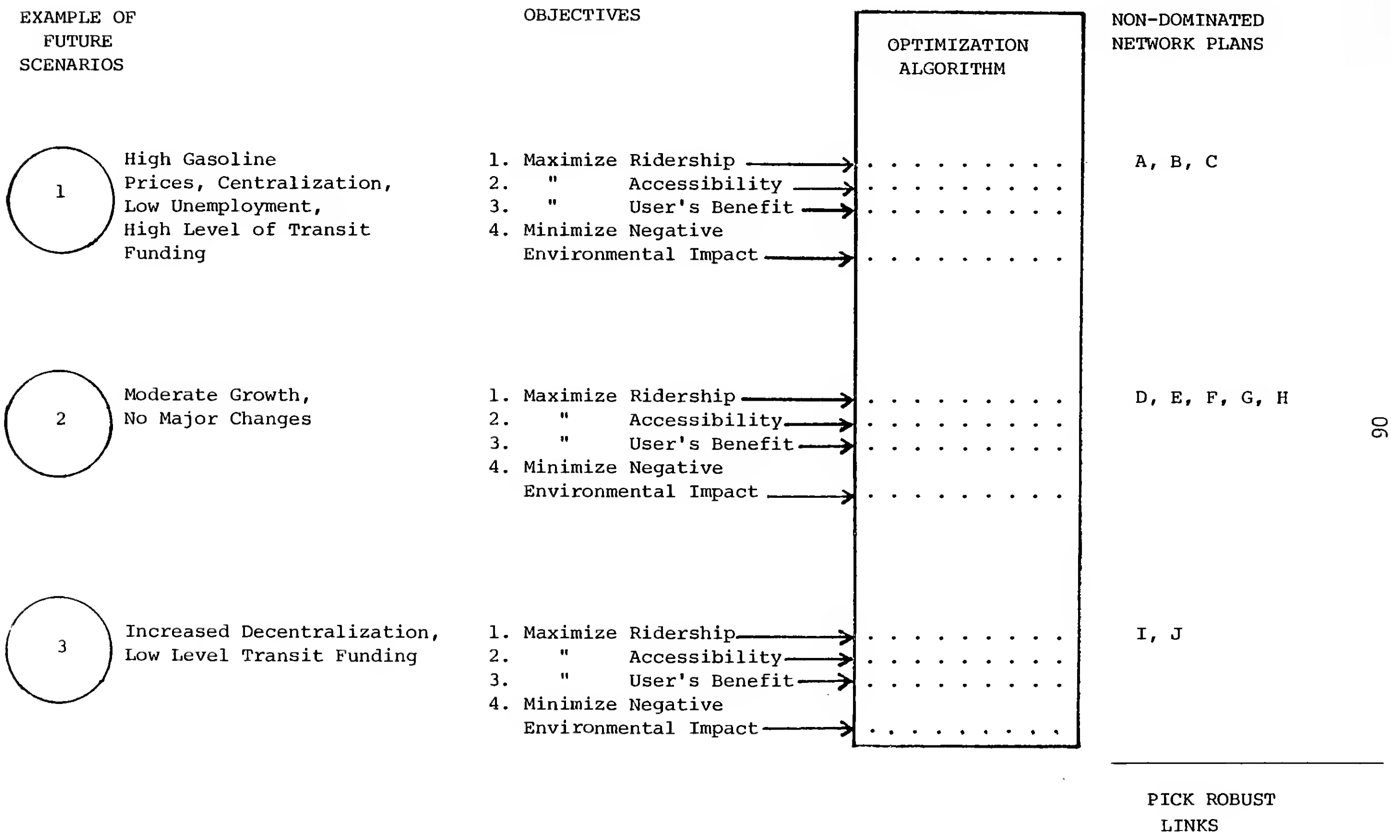
Based on the multi-dimensional nature of transportation impacts, a multi-objective approach has been adopted for the study. In Figure 6.2, four objectives are shown; however, it is feasible to increase or decrease the number of objectives. With a single objective, the network optimization model measures the level of network performance under a criterion. The degree of network performance with respect to that objective can be calculated, and the optimal network selected. Under a multi-objective optimization, the algorithm can select all non-dominated network plans with respect to a set of objectives. A network plan is termed non-dominated if there exists no other network that is superior to that selected plan with respect to performance under each of the objectives. In Figure 6.2, non-dominated plans are denoted as the final output of the optimization algorithm.

The selection of an optimal plan for each objective is still a tenuous basis for evaluation if all estimates of benefits and costs are calculated under the same set of assumptions. With the critical element of uncertainty in forecasting population, travel costs (gasoline availability), employment, transit funding levels, etc., one set of assumptions for developing optimal network plans is a limited and possibly distorted basis for evaluation. One set of internally consistent assumptions with respect to all critical variables is termed a scenario, the use of an alternative futures approach therefore requires evaluation under a variety of scenarios. In Figure 6.2, three different scenarios are shown as an example. Actual determination of each scenario with regard to setting levels for each critical parameter will be a major task in Phase II of the study.

The evaluation process as shown in Figure 6.2 requires three separate applications of the optimization algorithm, or one application for each scenario. For each application, a set of non-dominated plans is produced with respect to the selected set of objectives. Each non-dominated network contains a set of alternative links. Some links might appear in more than one selected network because of their ability to perform well under a variety of conditions or their contribution to attainment of more than one objective. Other links might appear in only a few of the optimal networks because of their limited performance under a narrow range of future conditions, or only one objective. The links that appear in a variety of selected plans are termed "robust" alternatives. Because of the nature of their performance, these links are assured of being the most viable investment.

A major tool in this entire process is the optimization algorithm. In the following sections, the analysis and assumptions that are the basis for the optimization algorithm are detailed further.

FIGURE 6.2 SONARRTA NETWORK EVALUATION PROCESS



Optimization Algorithm

Programming models have become important tools for capital investment decisions in both private and public management. In transportation planning, significant improvements have been achieved enabling optimal network design methods to be used as an increasingly realistic evaluation and design tool. Generally, optimal network design methods are utilized with normative link assignment procedures.[2] Recently, behavioral responses to network changes have been considered in network optimization.[3] These recent advancements have enabled an optimization approach to be integrated with the SONARRTA behavioral demand model. Along with improvements in optimal searching algorithms, the use of a joint choice demand model permits application of optimization techniques on a more realistic basis.

The optimization method that has been proposed for SONARRTA is a multi-objective Branch and Backtrack algorithm. In the next four sections, the methods required for applying the algorithms are described. In order to present a description of the study's proposed optimization algorithm, an algorithm for optimization under a single objective (function) is presented as an example. A discussion of expansion of the algorithm for evaluation under multi-objectives then follows.

Methods of Quantifying Alternative (Link) Benefit

The optimization or mathematical programming model can be stated simply as follows:

Maximize $Z = b_1x_1 + b_2x_2 + \ldots. b_ix_i + \ldots. b_nx_n$

Subject to $c_1x_1 + c_2x_2 + \ldots. c_ix_i \ldots. c_nx_n \leq B$

Where x_i is a (0,1) integer designating the existence, non-existence of alternative i

B is the available budget

C_i is the cost of alternative link i

b_i is the coefficient of link-specific benefit obtained through the use of the SONARRTA evaluation program

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2 Normative or prescriptive link assignment is flow-optimized on a system-wide basis. In contrast, the SONARRTA demand estimation process is descriptive, based on the behavioral attributes of the tripmaker.

3 Hodgson, M.J., Highway Network Development and Optimal Accessibility Change in the Toronto-Centered Region, Ph.D. Diss. University of Toronto (1972).

Morlok, E.K., et. al., Development and Testing of a Transportation Planning Tool for High Accessibility Urban Corridors: Final Report, Vol. 1 and Vol. 2, University of Pennsylvania, Philadelphia, Pennsylvania (1975).

In the SONARRTA evaluation package, quantification of benefits is obtained on a network basis. In order to derive link-specific benefits, the net system change in benefits can be attributed to benefits for a specified link. This method requires designating a base network and then attributing the alternative link benefit as that change in net system benefit when the link is added to the base network. For the SONARRTA study, the base network is defined as the existing rail system.

As an example in measuring link performance under an objective, a sample objective can be investigated. A common objective in transit design is maximization of user's benefit (or alternately, minimize user's cost). In order to measure user's benefit, a method to measure the change in user's benefit from the base system is determined. In the SONARRTA study, consumer's surplus has been identified as a good measure of user's benefit.[4] The consumer's surplus relationship can be written as follows:

$$B^n = \tfrac{1}{2} \sum_{i,j,n} (T^N{}_{ijn} + T^B{}_{ijn}) \times (C^B{}_{ijn} - C^N{}_{ijn})$$

Where B^N is the net difference in benefit for two networks (it can therefore be used as the link-specific coefficient of benefit for the objective function).

$T^N{}_{ijn}$ is the total number of trips from zone i to j by mode n as a result of new network N.

$T^B{}_{ijn}$ is the total number of trips from i to j by mode n as a result of the base network B.

$C^N{}_{ijn}$ is the travel cost (time and out of pocket cost) from i to j by mode n under network B.

$C^B{}_{ijn}$ is the travel cost under the base network B.

By adding each link individually to the base network, and determining the change in total network consumer's surplus, the coefficients of the objective function are determined. By measuring benefit in terms of marginal change from the network, problems in defining what portion of a tripmakers total trip benefit should be attributed to the link are overcome. By only adding one link at a time to the base network, all changes in network benefit can be attributed to that specific link. The general process of quantifying optimization criteria is outlined in Figure 6.3.

However, this method of quantifying link-specific benefit does not account for the problem of link interdependence. The benefit of a link (change in network benefit) will vary according to whether other proposed links are assumed in existence. The difference in link benefit can be

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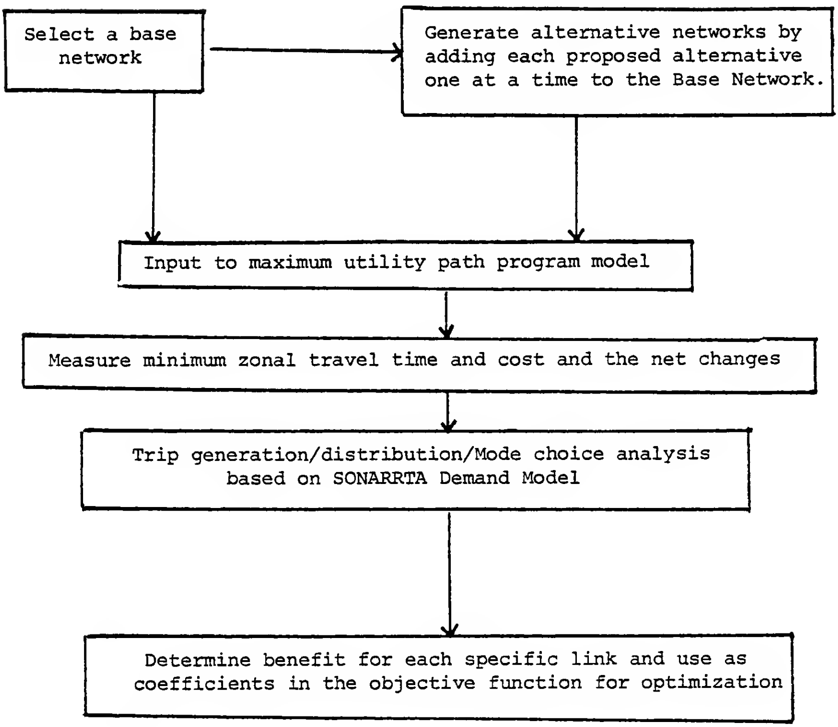
4 Mainzer, Bruce, "An Optimization Strategy for the Evaluation of Rail Networks, SONARRTA Working Paper, Regional Transportation Authority, July, 1976.

FIGURE 6.3 COMPUTATION OF LINK BENEFIT



seen by examining the net change in benefit when a link is added to a network without other proposed links, and then added to a network that has a number of proposed links. The benefits are significantly different, therefore one can assume that use of a constant coefficient for link-specific benefit will not be accurate.[5]

Since the benefits of a link are not constant, a simple linear programming model cannot be used. Alternative methods that avoid excessive computational time (i.e., direct enumeration of all feasible networks) must be designed for the non-linear optimization problem. The following section is a more technical discussion of the direct search optimization algorithm that has been developed for SONARRTA.

Branch and Bound Algorithms

There are many approaches for the solution of the non-linear highway network design problem. The Branch and Bound technique is an efficient procedure that permits the use of predictive link assignment and mode-choice models in an efficient search for optimal networks. However, the use of this algorithm limits the size of the problem, i.e., the number of decision variables (proposed links). A good example of a Branch and Bound Method has been developed by Chan.[6] Chan's problem differs from the SONARRTA approach, in that the objective function is stated as a minimization of total costs. In SONARRTA, the maximization of total regional benefit which is subject to a budget constraint results in rejection of many infeasible solutions (networks costing more than the budget constraint) before an actual search is initiated, thus limiting the computation cost.

The Branch and Bound technique is an algorithm that is used to search for the optimal solution without computing the value of the objective function for every possible combination of the decision variables (i.e., every conceivable network). The use of the branching algorithm is based on the relationship that the objective function ($z(X)$) is a non-linear relationship that is monotonically increasing with the increase in decision variables taking the value of 1. Simply, this means the value of network benefit will increase as more links are added to a network.

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5 Lee, Inwon, Public Transit Network Design with a Joint Destination and Mode Choice Model: An Empirical Examination of Optimizing Interdependent Rapid Transit Projects, Unpublished Ph.D. Dissertation, Northwestern University, Evanston, Illinois, June, 1978.

6 Chan, Y.P., Optimal Travel Time Reduction in a Transport Network: An Application of Network Aggregation and Branch and Bound Techniques, Research Report R68-47, M.I.T., Dept. of Civil Engineering, Cambridge, Massachusetts, (1969).

This relationship would seem to hold in most cases. However, from the literature in highway research, Braess' paradox is a phenomenon that has been shown to illustrate exactly the opposite; adding certain links might actually decrease benefit (increase total travel time).[7] This is due to a new highway link's potential for diverting auto drivers from other roads until the level of service has decreased system-wide due to congestion caused by insufficient capacity. However, Braess' paradox should not hold for rail transit design in Chicago because time decreases on a rail link as patronage increases due to the policy of increasing the level of service (increasing trains thereby reducing waiting times) as ridership increases. A monotonically increasing relationship for network benefit can therefore be assumed for this study.

The Branch and Bound algorithm operates by rejecting all solutions that are infeasible under the budget constraint. It then compares solutions starting at the do-everything (all links in existence) network until the optimal solution is found. Thus, if all solutions were feasible (meet a budget constraint), the optimal network would be the do-everything network. The number of networks to be evaluated is reduced by not evaluating other network solutions which consist of a lesser number of links than a previously discovered feasible solution. It is known that these other networks will result in a lower value for the objective function because of the assumption of monotonicity.

The branching algorithm can be represented as a node tree as drawn in Figure 6.4. Each node represents a network solution; the nodes in the network tree represent all possible combinations of a four link example problem. Level 0 of the tree consists of the do-everything solution ($X = (1,1,1,1)$), all links are assumed in existence. Level 1 represents networks with one less link in the solution. The branching scheme continues until Level 4, where no links are assumed in the solution.

This branching algorithm can still result in an unwieldy number of networks that must be evaluated. The number of feasible solutions to be enumerated in such a problem can be expressed as the factorial $\binom{N}{K}$ where K is the number of decision variables that can take the value of 1 under a budget constraint and N is the total number of links (decision variables). For a network design problem of over twenty links where K=10, almost nine hours of computer time are required to evaluate all of the required node comparisons. Further refinement of the algorithm is therefore necessary.

Bounding or Backtracking

Bounding refers to the searching operation necessary for examining successive nodes (network solutions) in an order so that the most promising solution can be found quickly. This is accomplished by branching from the node that shows the highest value for the objective function and then searching over the rest of the nodes so as to eliminate the maximum num-

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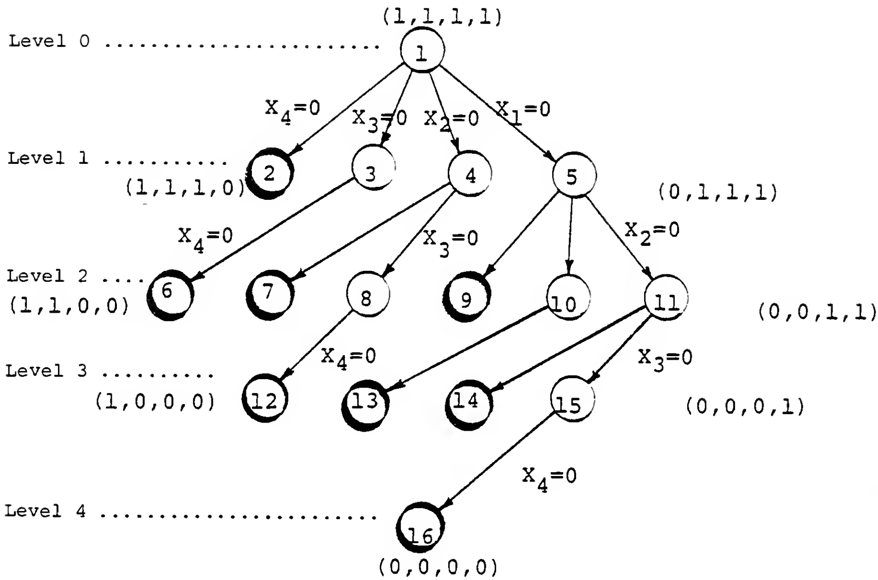
[7] Murchland, J.D., "Braess' Paradox of Traffic Flow", Transportation Research, 4; pp 391-394 (1970).

FIGURE 6.4

BRANCHING SCHEME



ber of feasible solutions. However, the bounding operation, even for a moderate size network problem, requires excessive computer storage. The number of feasible solutions that needs to be ordered and then stored proliferates dramatically with the number of decision variables.

Backtracking is a simple searching or ordering rule that needs minimal computer storage. Backtracking refers to returning to an active node (one that is feasible under the budget constraint) according to a predetermined tree searching order. This order can be achieved by ranking each alternative link according to a simple rule (such as link-specific demand or a benefit-cost ratio). Network solutions to be evaluated are chosen in order, based on the combined rankings of the individual links assumed in existence. The function can consist of estimates of link-specific benefit as coefficients for each decision variable. The order of evaluation is therefore based on the simple linear approximation of total network benefit. Since there always exists a probable situation where a network solution in a branch under a node with a less promising solution could be optimal, backtracking would be sufficient to ensure that this solution would be examined earlier than in a simple bounding operation.

Modification of Branch and Backtrack Algorithm With Linear Approximation

Use of Backtracking is efficient because it reduces the number of actual network evaluations, i.e., use of the SONARRTA computer network to estimate network benefit. However, further improvements in efficiency can be made by reducing the number of actual computer network applications. By using the simple linear sum of individual link benefit to approximate the actual network benefit function, it is possible at certain points in the algorithm to avoid use of the computer demand estimation network. The linear sum of benefits can be used for testing against a previously discovered feasible solution. If the linear sum of benefits is less then the actual network benefit of the best solution found so far, than it is known that its actual network benefit is also inferior, and no further evaluation is necessary. In order to substitute the linear approximation of benefit for actual network evaluation, two major assumptions are required:

1. If two proposed transit alternatives compete with another for patronage, the increase in system-wide patronage due to the simultaneous introduction of both of these alternatives is less than or equal to the simple addition of the patronage increases under the independent introduction of both links.[8] Mathematically; if

[8] In the SONARRTA study, alternatives for link construction are created so that rail lines are drawn as complete from the CBD to the endpoint. Intermediate lines are not considered individual alternatives, all decision variables represent an alternative line for the entire length of a corridor. Therefore, competition occurs among two distinct lines if they share the same market area.

the patronage increases due to link A and B under independent introduction to the network are represented by d(A) and d(B) respectively, and the simultaneous introduction of both lines causes a patronage increase of d(A, B), then:

$$d(A) + d(B) \geq d(A, B)$$

2. If a transit line A and another line B are competing for patronage, the consumers' surplus for residents achieved by simultaneously introducing line A and B (i.e., CS(A, B) has the following relationship to the independently quantified consumers' surplus of A and B, CS(A) and CS(B):

$$CS(A) + CS(B) \geq CS(A, B)$$

These assumptions can be proved as mathematical lemmas, and a rigorous proof of the assumptions is contained in a working paper of the study.[9]

These two important relationships imply that if several proposed transit links are competing against one another, and transit patronage and consumers' surplus are quantified by "adding each link individually to the existing base network" approach, then:

1. $d(A)+d(B)+d(C)+ \text{----} +d(K) \geq d(A,B,C, \text{----} , K)$
2. $CS(A)+CS(B)+CS(C) \text{----} +CS(K) \geq CS(A,B,C, \text{----} , K)$.

With this theorem, linear approximation of independently quantified link benefit can be used instead of actual network quantification of benefit in certain limited applications, in order to increase the efficiency of the branch and backtrack algorithm. The ratio between the number of solutions actually examined by the network evaluation program package, and the number of linear approximation calculations decreases as the size of the problem (number of decision variables) increases.

Multi-Objective Optimization

In the previous sections, procedures for reducing the search for an optimal solution with a single objective function have been illustrated. The efficiency of the Branch and Backtrack algorithm is critical for expansion of the search to a multi-objective optimization, i.e., the selection of all non-dominated solutions under a set of objectives.

Traditional approaches to multi-objective optimization utilize a preference or weighting function; the problem can be written as:

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9 Lee, Mainzer, "A Model of Regional Transit Network Optimization", SONARRTA Working Paper #6, November, 1977.

Maximize $W = \mathcal{U}(Z_1(x), \ldots, Z_n(x))$

Subject to $x \in X$

Where $\mathcal{U}$ is a utility function defined over the range of $z_i(x)$ (weighting or preference function).

$z_i(x)$ is an objective function formulated for the evaluation of criteria i.

X is the feasible integer solution space defined by zero-one decision variable x and by a budget constraint $c(x) \leq B$.

A conventional method to solve the above problem is to define a preference or weighting function for the multi-objectives, thereby collapsing all of the criteria into a single objective function. This is commonly achieved by decision-maker review through some type of consensus-reaching technique such as the Delphi method. In the SONARRTA study, it has been found that the derivation of a preference function would be difficult and undesirable. Techniques such as the Delphi method often do not result in meaningful weights. Use of a single weight for each criterion would probably be invalid, since estimation of network benefit is not likely to be a linear function. It is difficult for decision-makers to make judgments relating to all of the factors associated with new rail lines, and even more difficult without some prior experience with network development and change. A better approach would be for decision-making to take place in the context of network optimization; by familiarizing themselves with the capabilities of the SONARRTA evaluation models, decision-makers can assess trade-offs through interactive use of the optimization models. However, this may be unrealistic, as the extent of this involvement would demand a substantial amount of a decision-maker's time.

An alternative method consists of searching all non-dominated solutions with respect to several objectives and then applying a multi-dimensional evaluation technique.[10] A non-dominated (or efficient) solution (x) is achieved if there is no other solution x' such that $z_i(x') \geq z_i(x)$ for all objectives $i = 1, 2, \ldots, k$.

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10 Hill, A., A Method for the Evaluating Alternative Plans: The Goals Achievement Matrix Applied to Transportation Plans, Ph.D. Diss., University of Pennsylvania (1966).

Gemmell, R.S., Peterson, G.L., Schofer, J.L., "Assessment of Environmental Impacts: Multidisciplinary Judgements of Large Scale Projects", EKISTICS, Vol. 37, #218; pp 23-30 (1974).

In order to consider more than one objective function, conversion of the branch and backtracking method necessitates a different evaluation method. Instead of rejecting solutions whose single objective function value is less than the highest value found so far, networks are rejected whose multiple objective function values are all dominated by the current highest values for all objectives. Obviously, a rejection test of this type will lead to a fewer number of network rejections and more testing of successive combinations. The efficiency of the Branch and Backtracking method is therefore decreased by the provision of multiple objectives.

Phase II Research

During Phase II of SONARRTA, methods are being tested for increasing the efficiency of the optimization algorithm. The final form of the algorithm will thus enable a comprehensive search for all non-dominated network plans. This is a major improvement over single objective function techniques in that the set of all non-dominated plans provides a realistic basis for picking robust link alternatives.

The capabilities of the algorithm will also enable use of the alternative futures concept. Instead of finding an optimal transit network under a single land-use plan (and policy scenario), an analysis of the interaction between land-use and the transit network will be utilized. The optimization approach has therefore been structured to incorporate an adaptive planning framework, one that is responsive to the uncertainties inherent in the region's transportation system and the need for a continuing long range perspective in guiding short-term decision-making.

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Part 2

Sketch Planning:

Corridor Evaluations

ACKNOWLEDGEMENTS

We are grateful to Douglas O'Brien for the preparation of maps.

LIST OF MAPS

CHAPTER I

SKETCH PLANNING METHODOLOGY

SONARRTA (Study of New and Replacement Rail Transit Alternatives) has been undertaken to select an optimal subset of rail projects from all of the various proposals that have been made to improve the Northeastern Illinois six county rapid transit and commuter rail system. Evaluation will be completed on a regional network basis in order to produce an optimum system plan. A mathematical programming method will be used in order to test feasible regional rail system configurations for optimality. The application of a mathematical programming method will be undertaken during the system optimization phase of the study.

Because of the large number of links that have been proposed for a rapid transit network, the number of possible alternative networks to be evaluated in SONARRTA is beyond the capacity of present mathematical programming methods. The number of rapid transit alternatives has to be reduced in order to apply the methods of system optimization. Since there are fewer alternatives for the commuter rail alternatives and, more importantly, none of the commuter rail alternatives compete among themselves for ridership within a corridor, sketch planning is only undertaken to screen the large number of rapid transit alternatives.

A method has been developed which addresses evaluation as a three stage process: corridor-specific sketch planning, macro system-wide planning (system optimization), and micro-corridor planning.[1] Corridor sketch planning involves screening alternative links within corridors in order to obtain a single "best" alternative from each set of corridor alternative links. This single alternative is then input as a single "do-something" alternative for each corridor. System optimization thus consists of a series of alternatives for each corridor: (1) do-nothing (keep existing line, existing express bus, or don't construct new facility); or (2) do-something (improve existing line, abandon or build new line). The methods to be used in system optimization are reported in Chapter VI of Part 1 of this report. After the final recommendations of the study are obtained, micro-corridor planning can be initiated through detailed corridor-level studies. These studies are required in order to reach a final decision regarding a new facility, and provide necessary justification for UMTA funds.

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[1] Permut, Howard <u>SONARRTA Evaluation Method</u>, Working Paper #2, April, 1976

I. Corridor Definition

Alternatives for improving and expanding the rapid transit system were gathered from a variety of sources; suggestions from planning and engineering staff at CTA, RTA, the City of Chicago's Department of Public Works and Department of Development Planning, as well as suburban officials and planners. Sources reviewed included the Recommended 1995 Transportation System Plan (CATS), Transit Development Plans of suburban areas, and proposals made at various RTA public hearings.

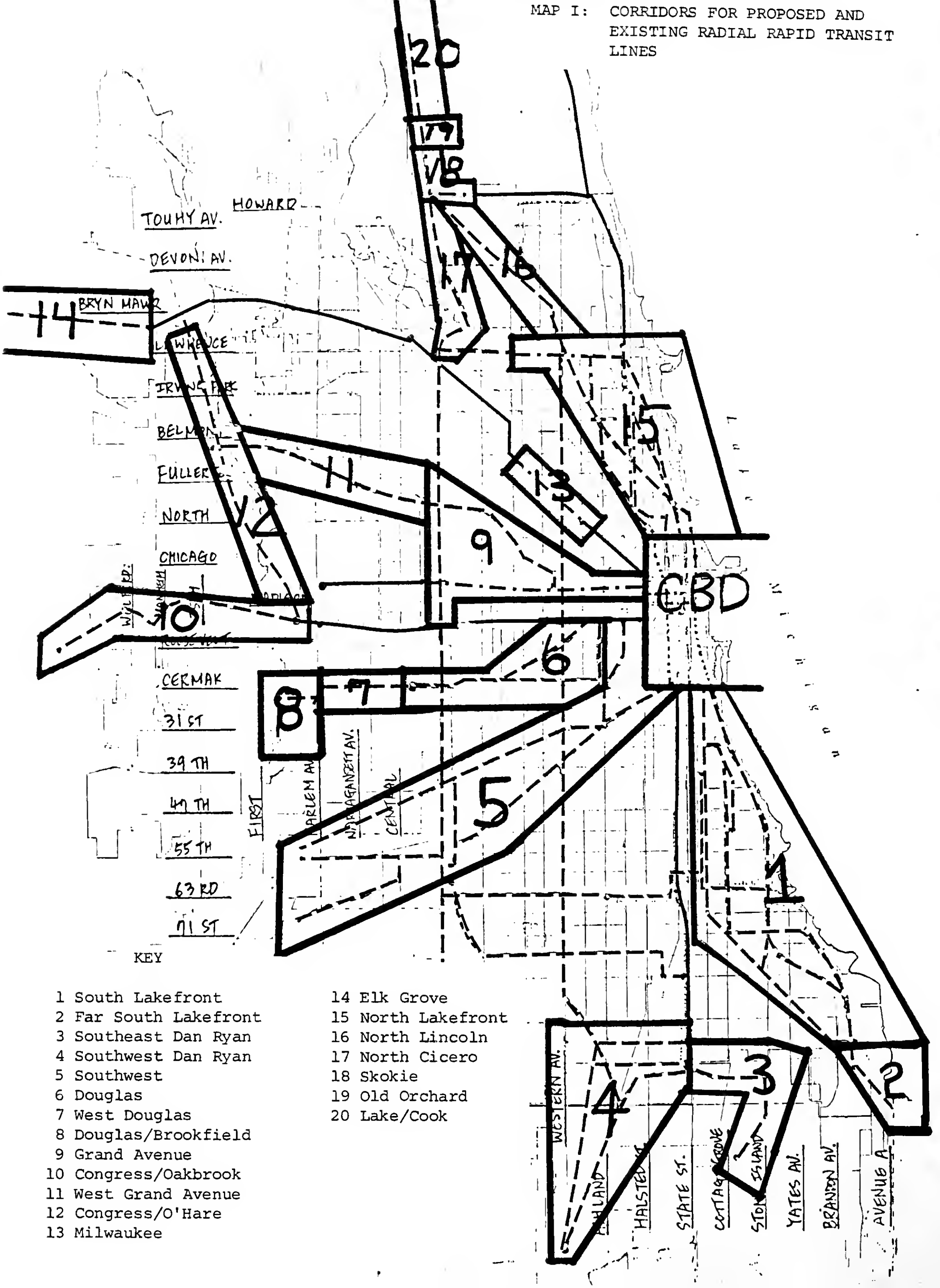
Variable existing lines (lines designated as candidates for replacement or removal), and proposed new lines have been grouped into corridors. Corridors are defined by grouping a geographical set of lines that are similarly affected by changes in other parts of the network. This decomposition of the network into corridors allows screening of alternatives to be undertaken independently of the assumptions of existence of lines in other corridors. Maps I and II illustrate the corridors that have been defined for the Chicago area rapid transit system.

The order of corridor screening is important due to assumptions regarding shared portions of lines between corridors. For example, this problem is evident with regard to treatment of the Crosstown alternatives with the Douglas corridor. The exact order of corridor evaluations has been established in order to control potential biases with respect to allocation of costs and patronage. The rationale for the order of corridor evaluation is given in Working Paper #2.

II. Evaluation Criteria

Sketch planning criteria must allow an efficient "first cut" evaluation of all alternatives for the rapid transit system. In reducing the number of alternatives within a corridor, some alternatives can be quickly eliminated if another alternative is superior with respect to all of the relevant evaluation criteria. When this occurs, the superior alternative is termed as dominating the rejected alternatives. For the alternatives which remain, tradeoffs and cost-effectiveness analysis are undertaken and the rationale for selection is clearly explained.

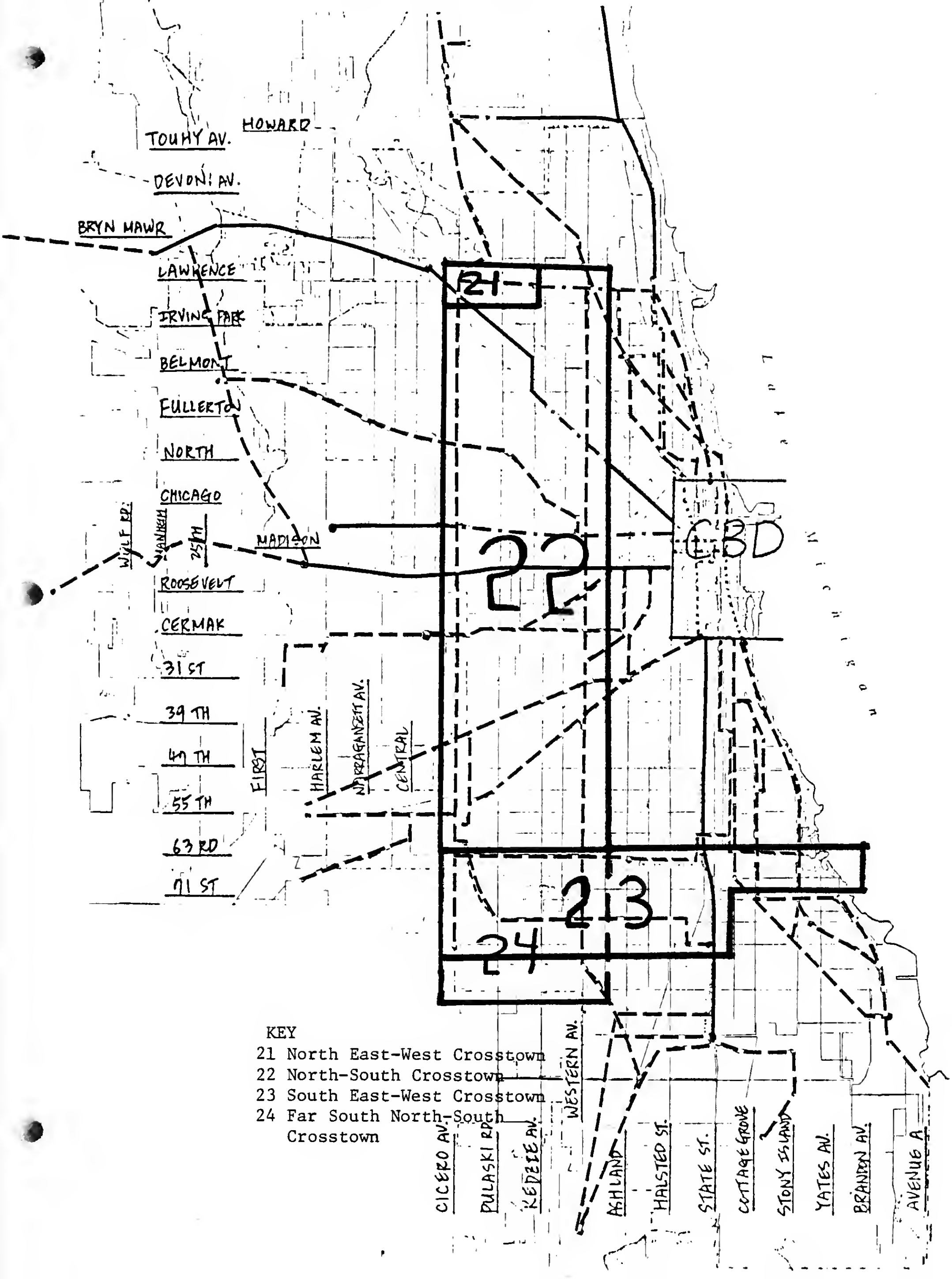
MAP I: CORRIDORS FOR PROPOSED AND EXISTING RADIAL RAPID TRANSIT LINES



KEY

1 South Lakefront
2 Far South Lakefront
3 Southeast Dan Ryan
4 Southwest Dan Ryan
5 Southwest
6 Douglas
7 West Douglas
8 Douglas/Brookfield
9 Grand Avenue
10 Congress/Oakbrook
11 West Grand Avenue
12 Congress/O'Hare
13 Milwaukee
14 Elk Grove
15 North Lakefront
16 North Lincoln
17 North Cicero
18 Skokie
19 Old Orchard
20 Lake/Cook

MAP II: CORRIDOR FOR PROPOSED CROSSTOWN RAPID TRANSIT LINES



KEY
21 North East-West Crosstown
22 North-South Crosstown
23 South East-West Crosstown
24 Far South North-South Crosstown

It should be noted that the evaluation criteria measures and the derived costs and benefits for corridor sketch planning will be used only for evaluation within a corridor and only for the purpose of sketch planning. The information presented should not be extended for any other purpose, for example:

1) <u>Comparison of Alternatives in Different Corridors</u>

Sketch planning is undertaken to select a single alternative from each corridor; not to compare alternatives from different corridors. Therefore, the information presented is only applicable for analysis of alternatives within a corridor. The derivation of costs and benefits for alternatives within a corridor is calculated under the same set of assumptions with respect to operations, capital maintenance, etc. However, assumptions vary from corridor to corridor so that the performance of alternatives in one corridor cannot be compared to alternatives in another. As an example, calculation of capital maintenance savings were not undertaken for a set of corridor alternatives that would serve as replacements for an existing line since these savings would be identical for each alternative. Yet, these capital maintenance savings must be included when analysis of the merit of such an alternative is compared to alternatives in other corridors. Performance of the selected alternatives will be recomputed under a uniform set of assumptions for system optimization (Phase II of the study).

2) <u>Selection of a Specific Alignment</u>

The determination of a corridor alternative in sketch planning necessitates that a single alignment is chosen for the later application of system optimization. However, it is recognized that the selection of an alignment in SONARRTA only constitutes a preliminary recommendation. Actual justification of an alternative alignment must be part of a detailed analysis of the environmental, social, and operational aspects of a corridor. A detailed corridor level study for individual recommendations must be undertaken to provide justification for the alternative, or possibly another corridor alternative. It is also possible for this later corridor study to negate the conclusions of SONARRTA and reach a no-build decision, if due to study of the more detailed impacts, the action cannot be justified.

3) <u>General Evaluation of Rail Transit</u>

The ridership and cost figures prepared for sketch planning should not be extended for a general analysis of the viability of rapid transit vis-a-vis bus or automobile. The presentation of capital and operating costs in sketch planning cannot be used as a general example of the costs of rapid transit, but only for the purpose of screening alternative rapid transit alignments.

4) <u>Evaluation of CUTD* Related Projects</u>

Sketch planning is undertaken assuming that two CUTD lines are in existence (Monroe/Franklin) and the loop elevated is no longer in use. However, the selection of an alignment within a corridor is not affected by the existence of these downtown lines. In addition, the information presented here cannot be extended for evaluation of these CUTD lines, since the future of these lines is an exogeneously assumed condition in sketch planning.

The application of evaluation criteria during sketch planning does not require collapsing all factors to a single measurable dimension. Thus, it is desirable that the screening of alternatives specifically address non-quantifiable issues, which are more difficult to include in the system optimization phase of the study. Subjective criteria can be included at any point during the screening process along with the tangible outputs of the SONARRTA Evaluation Package and cost estimation models. Selection of the best alternative from each corridor will be achieved through a two step application of evaluation criteria.

A. <u>First Step</u>: ELIMINATION OF DOMINATED ALTERNATIVES

Six criteria, representing a wide range of impacts, will form the basis for preliminary corridor evaluation. Each of these criteria is a basic output of either the SONARRTA Evaluation process or relevant cost estimation tools. These individual measures are the basis for any further calculations of secondary impacts that may be relevant. It is obvious that if domination occurs within this set of measures, any further application of criteria will be redundant. These six criteria are discussed in detail below, and are fully detailed in Appendix A.

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*CUTD, Chicago Urban Transit District

1) <u>Ridership</u> (One Way Daily Volumes)

Demand for each alternative is estimated for 1975. The base year for ridership estimation was chosen since it was the most recent year for which a set of zonal population forecasts was available. However, it is important to realize that growth predicted within these corridors fall within the same pattern of residential land use (with some exceptions, i.e., South Loop New Town) so that the selection of an alignment within a corridor will not be seriously affected by the forecast year. Much of the variability between alternatives within corridors can be explained by two factors: (1) differences in market service areas; and/or (2) changes in travel time and cost. Ridership is estimated assuming that only the base system and the proposed line is in existence. Total ridership on a link is also used to compute revenue for the alternative.

2) <u>New Transit Trips</u>

This criterion is the basis for any net regional ridership increase for the entire existing CTA system (bus and rail). It is obtained by calculating the net CTA ridership increase over the existing system (base system and the corridor's existing variable line). This criterion is important in that it identifies whether a proposed line is actually attracting new mass transit trips, or providing a change in routings for existing demand. Due to the nature of the demand estimation process, this criterion will only be calculated for CBD destined trips.

3) <u>Diverted Auto Trips</u>

This criterion further explains patronage flows. Diverted auto trips are obtained by calculating the net change for 1975 over the existing system for total automobile usage. Only CBD trips are investigated. This measure is extremely important, since it is the basis for any calculation of system environmental impacts. Diverted automobile trips is a key element in the reduction of air pollution and conservation of energy in addition to automobile related impacts on land use.

4) Consumer's Surplus (User Benefit)

This criterion is a measure of user's benefit. It is therefore important in illuminating benefits due to the increased level of service within a corridor. The formulation of the consumer surplus measure will be the basis for a user's benefit objective in system optimization. The rationale and economic theory of consumer surplus has been summarized in a previous SONARRTA Working Paper.[1] The consumer's surplus measure is also detailed in Appendix A. The measure is based on change in user travel time and cost savings from the existing system. This criterion is an important indicator for not only transit level of service, but also in determining net regional economic benefits.

5) Annualized Operating and Capital Costs

This criterion consists of annualized costs for capital and operating costs for the planning period (1975-2025). Annualized capital costs are calculated using a capital recovery factor for the appropriated facility life over a uniform series of payments with the opportunity cost of capital set at eight percent. Capital costs consist of all of the costs required in construction and property acquisition for a new facility. All costs are represented in 1975 dollars. Details of cost estimation are described in Appendix A and "Capital and Operating Costs for the Replacement and Expansion of the Chicago Rapid Transit System," RTA Technical Report TR-75-02. The annualized capital cost are added to the expected first year operating costs of the facility. Operating costs are calculated only when an alternative would necessitate increased or decreased car mileage from the existing system.

6) Households Affected

This measure is an important attribute due to the possible impacts of a new transit alignment. It is directly related to the negative environmental impacts of noise, aesthetics, and disruption caused by elevated and at-grade facilities. Since the majority of these impacts falls on residential property and household units, calculation of households within a specified noise impact band (500 feet) of an alignment can be treated as a negative impact.

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[1] Mainzer, Bruce, "An Optimization Strategy for the Evaluation of Rail Networks" SONARRTA Working Paper, July, 1976.

Within corridors, this measure will be an important criterion since the negative impacts of a rail facility is strictly determined by alignment and is not affected by any changes in the network. This criterion is calculated by adding only the net change in total households that will be adjacent to a right-of-way. Therefore, alternatives that require construction of a completely new alignment (except subways) will cause an increase in the households affected category, while alternatives that utilize existing railroad right-of-way will not cause a change.

B. Second Step: PERFORMANCE RANKINGS

After the application of the six criteria to check for dominance, each of the non-dominated alternatives are ranked with respect to the following four criteria:

1) Riders per Subsidy Dollar

Total demand is expressed per subsidy dollar. Total subsidy is the annualized operating and capital costs minus revenue.

2) Capital Cost per New Transit Trip

This measure is calculated by dividing an alternative's capital costs by daily one-way new transit trips.

3) Total Households Affected

4) Consumer's Surplus

Rankings will not be weighted, but displayed in table form in terms of highest, middle, lowest (1,2,3) of performance within each category. These rankings, once placed in matrix form, will be the basis for the final selection of the single "best" alternative from each corridor. Rankings are used as the final basis for subjective evaluation among the tradeoffs of four basic categories; user benefit (consumer's surplus), costs, demand, and environmental impacts. A single score will be calculated, however, it is recognized that such a score would over-simplify evaluation and will not be necessary except in the most extreme cases where two or more alternatives are extremely competitive in all categories.

The two step evaluation process outlined for corridor sketch planning is intended to illuminate the multi-dimensional nature of corridor-level impacts. Thus, subjective or non-quantificable factors can be considered at any point during the evaluation. These additional factors include operational feasibility, aesthetic, social, and economic concerns that are not a strictly defined product of the SONARRTA demand and cost estimation models. The application of the sketch planning criteria outlined here is reported in full detail in the following chapters.

CHAPTER II

North-South Crosstown

The first application of the SONARRTA sketch planning methodology is undertaken to select a single 'best' crosstown alternative for system optimization. Determination of a single crosstown alignment on either Western or Cicero is completed before evaluation of competing alternatives in other corridors in order to reduce major uncertainties associated with the evaluation of rapid transit alternatives:

1) The interdependancy of a crosstown alternative with other proposed links is significant. Demand on a crosstown feeder will increase with each new radial line connection. Evaluation of alternatives in other corridors is therefore simplified with the selection of a single proposed crosstown link.

2) Portions of the proposed Western Avenue alignment is shared with alternative links for the Southwest and Douglas corridors. In addition, an alignment for a Grand Avenue facility could be shared with a Cicero crosstown alternative. Determination of a single crosstown alternative simplifies evaluation in these corridors with regard to allocation of costs and ridership among links on shared or adjacent alignments.

I. Crosstown Issues

The crosstown alternatives present a special case in estimating demand. The use of a rail facility to act as a feeder to other radial lines is a concept that cannot be tested with existing facilities. (The Skokie Swift can be considered a feeder facility, however, its service is limited to a shuttle to only one rapid transit line). The need for this facility would also be demonstrated with its use as a distributor for local trips along a north-south corridor. A crosstown alternative, if successful, would have a definite impact on the traditional orientation of rapid transit for trips to the CBD on both the crosstown and radial facilities. Evaluation of both crosstown alternatives must be undertaken with these issues in mind.

II. Alternative Alignments

A. Cicero

This facility would run from the Montrose station of the Milwaukee line (Kennedy expressway) to either 63rd or 79th Streets. Options exist for running trains to the Jefferson Park Terminal (or River Road for storage on the O'Hare extension) on the Milwaukee line tracks. The alignment would be an elevated grade facility on the present Belt Railroad right of way immediately east of Cicero Avenue.[1] For purposes of evaluation, it was assumed that the line ends at 63rd St.[2]

Stations:

1. Montrose (on Milwaukee Line)
2. Irving Park
3. Addison
4. Belmont
5. Diversey
6. Fullerton
7. Armitage
8. North
9. Division
10. Chicago
11. Lake Transfer
12. Congress Transfer
13. Roosevelt
14. Douglas Transfer
15. 33rd
16. 47th
17. 52nd/Archer
18. Midway
19. 63rd

B. Western Avenue

The Western Crosstown would run from Lawrence and Western via a Western Avenue elevated facility to Blue Island Avenue. From this point, the present Penn Central right of way is used to the Beverly Branch of the Rock Island. This right of way would be used until the terminus at Blue Island. For purposes of analytical consistency with the Cicero alignment, an endpoint at 63rd Street was assumed.

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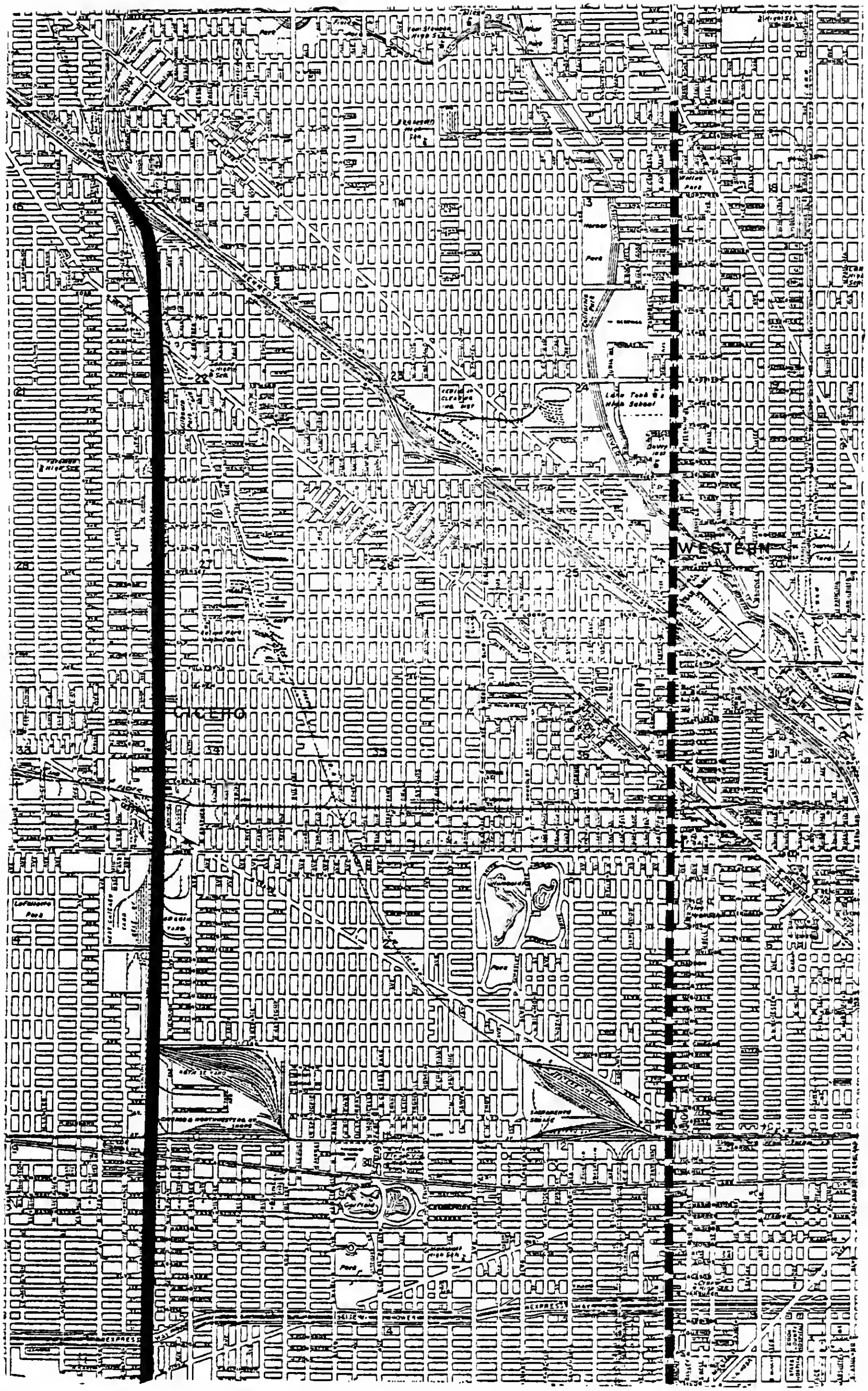
[1] A Cicero crosstown rapid transit facility can also be a median strip alignment of the proposed Crosstown expressway. Demand and capital costs would be similar to the Belt alternative for this facility.

[2] An extension of the Cicero crosstown south of 63rd should be considered as a possible branch of the crosstown since the Cicero facility could be extended eastward (following chapter). An extension to 79th St. can also be evaluated as a possible extension of a proposed Southwest line. This extension will be evaluated in system optimization (Phase II of SONARRTA).



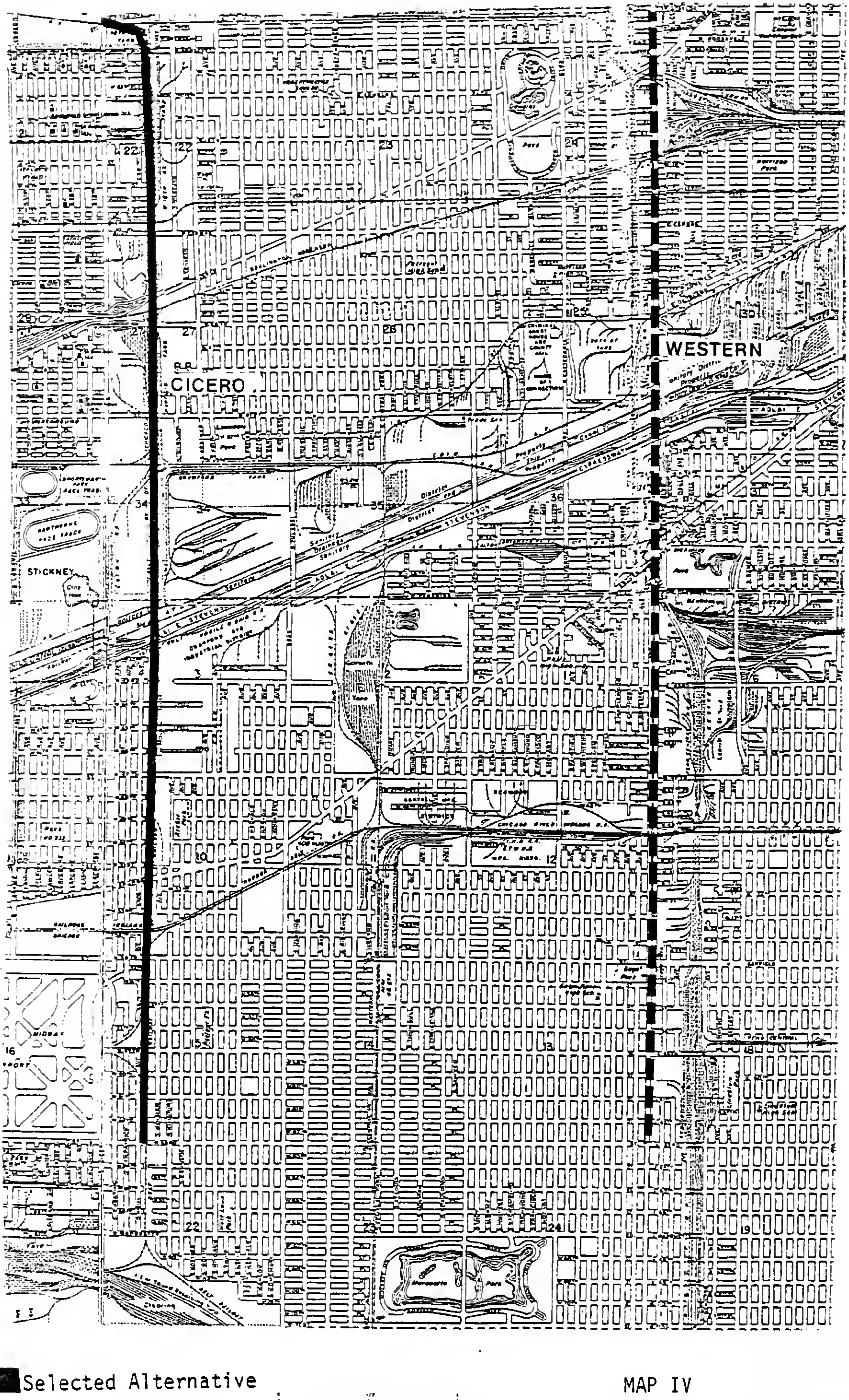
MAP III

North South Crosstown-Northern Section

SCALE OF MILES

Selected Alternative

Other Alternatives



Selected Alternative

Other Alternatives

MAP IV

North South Crosstown-Southern Section

1. Western /Lawrence/Lincoln
2. Irving Park
3. Addison
4. Belmont
5. Diversey/Elston
6. Fullerton
7. Armitage/Milwaukee Transfer
8. North
9. Division
10. Chicago
11. Lake Transfer
12. Congress Transfer
13. Roosevelt/Ogden
14. Douglas Transfer
15. 26th & Blue Island
16. Western/Archer
17. 47th
18. 55th
19. 63rd

III. Sketch Planning Evaluation

Table I presents the summary of the six sketch planning criteria. There is a clear domination in all categories for a Cicero alignment over a Western Avenue facility. A higher level of service is offered, in addition to reduced capital costs and environmental impacts.

A. Demand

Demand for each line can be further broken down into the separate components of trip type predicted by the SONARRTA Evaluation Package:

One-way daily trips	Western	Cicero
CBD	3,520	12,140
Thru	704	2,428
Local	13,015	9,129
One-way Daily Ridership	17,239	23,697

Although it is evident that Cicero attracts more CBD trips, estimated local demand is higher on a Western alignment due to increased population densities in this inner corridor. However, it should be noted that the demand analysis does not take into account the potential for increased transit accessibility to Midway Airport offered by a Cicero crosstown. In addition, no analysis of potential commuter rail traffic transferring to a crosstown rapid transit line has been performed. In this category of demand, the Cicero alignment would be superior; connections could be made with stations on the C&NW Northwest Line, Milwaukee Road North and West Lines, and the Burlington Northern.

TABLE I

CROSSTOWN CORRIDOR EVALUATION

SKETCH PLANNING CRITERIA	WESTERN	CICERO
1. Annual Ridership	10,033,704	13,587,928
2. New Transit Trips (One way CBD Trips-Daily)	117	862
3. Diverted Auto Trips (One way CBD Trips-Daily)	78	576
4. Consumer's Surplus (Daily one way equivalent minutes-CBD Trips)	703	30,988
5. Annualized Capital and Operating Costs	$33,284,000	$29,899,000
6. Total Households within Noise Impact Band	3,534	0

B. Costs

A breakdown of operating and capital costs is summarized in Table II. The Cicero alignment has less total construction costs because of the use of an at-grade alignment as compared to an elevated structure on Western Avenue. Operating costs, rolling stock acquisition, and vehicle mileage are of course higher on the Cicero line due to higher predicted passenger volumes.

III. Summary

The Cicero crosstown clearly dominates the Western alignment with respect to the sketch planning criteria. In addition, many other factors favor the Cicero alignment that have not been specifically accounted for here. These additional factors include access to Midway airport, transfer connections with commuter rail, and a possible future connection or thru-routing over a proposed east-west crosstown rapid transit facility on 63rd or 79th Streets. Based on all of these factors, Cicero will be designated as the north-south crosstown alternative for system optimization.

TABLE II

OPERATING AND CAPITAL COSTS

	WESTERN			CICERO		
	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST						
. Construction, track, right of way	(14.8 mi)	$191,800,000		(13.4 mi)	$88,600,000	
. Station construction	(19)	63,700,000		(19)	62,700,000	
. R.R. track relocation		2,500,000			6,700,000	
. Junctions, difficult construction		0		(2)	5,000,000	
. Yards		4,013,000			6,445,000	
. Shops		1,175,000			1,887,000	
. Rolling stock	(66)	30,096,000		(106)	48,336,000	
. R.R. leasing (annual)			$ 510,000			$ 1,368,000
TOTAL ANNUALIZED CAPITAL			24,112,000			19,681,000
. Operating						
- Vehicle miles			6,344,270			7,270,076
- Station operations			2,948,420			2,948,420
TOTAL OPERATING COSTS			$ 9,292,690			$10,218,496
. Revenue			-5,017,000			-6,794,000
ANNUAL OPERATING SUBSIDY			$ 4,275,690			$ 3,424,500
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$28,388,000			$23,105,000

CHAPTER III

South East-West Crosstown

With the determination of the Cicero alignment as the best crosstown alternative, sketch planning evaluation is undertaken to determine the best east-west southern leg of a crosstown line. The best link in this corridor will be assumed to be a possible extension of a Cicero crosstown, therefore ridership and costs are estimated for the entire length of a Crosstown facility.

I. <u>Alternative Alignments</u>

A. 63rd Street

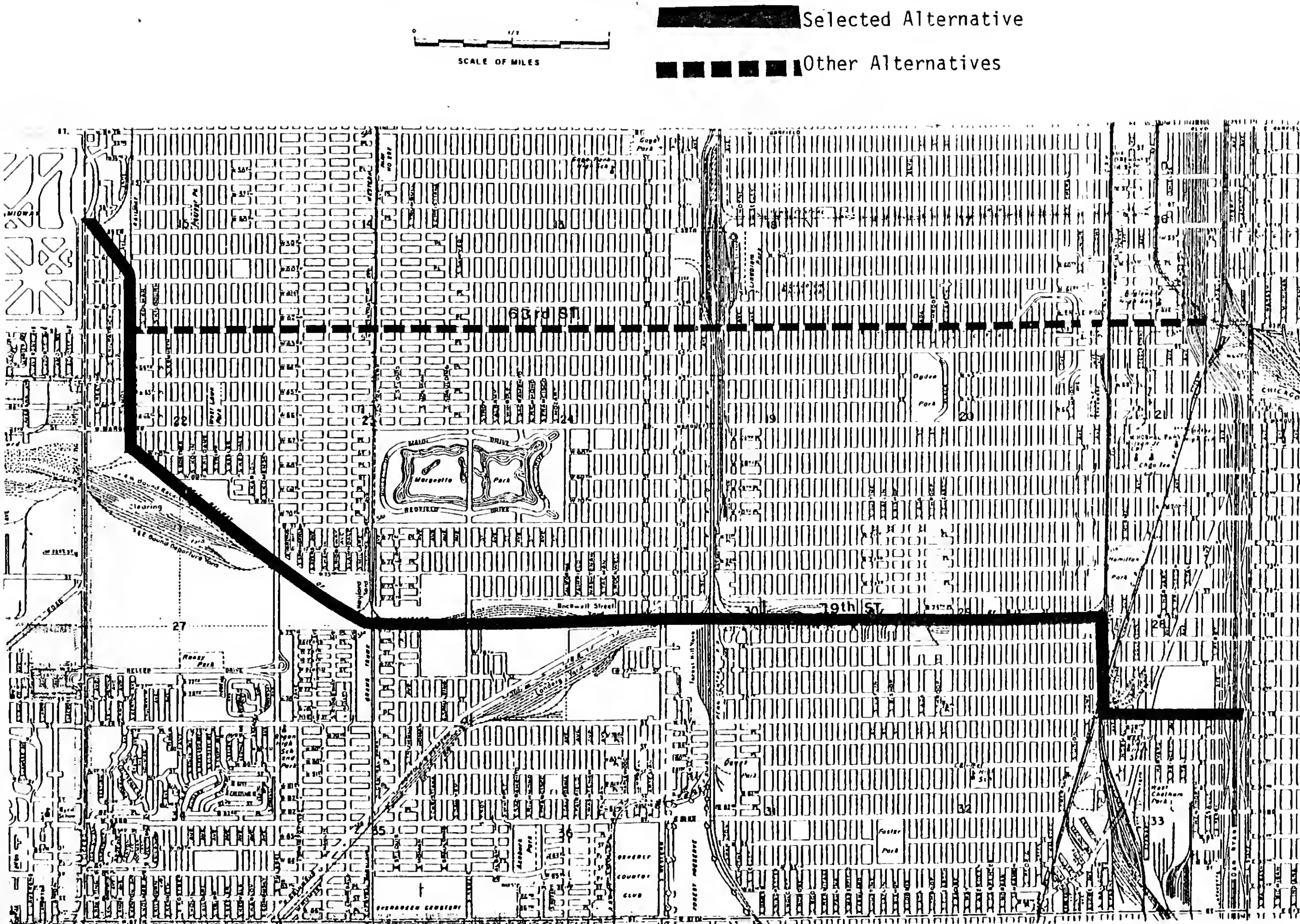
This branch would run from Midway Terminal along the Belt railroad right-of-way to 63rd Street, where it would then become a subway and run along 63rd Street to Jackson Park. However, in order to compare this alignment with the 79th Street elevated, it was assumed that this line would end with a transfer station at the Dan Ryan line.

Stations:

1. Montrose	10. Chicago	19. 63rd/Belt
2. Irving Pk.	11. Lake Transfer	20. Pulaski
3. Addison	12. Congress Transfer	21. Kedzie
4. Belmont	13. Roosevelt	22. California
5. Diversey	14. Douglas Transfer	23. Western
6. Fullerton	15. 33rd	24. Damen
7. North	16. 47th	25. Ashland
8. Armitage	17. 52nd/Archer	26. Halsted
9. Division	18. Midway;63rd Street Leg;	27. DanRyan Transfer

B. 79th Street

This alignment would run from Midway Terminal using the Belt Railroad right-of-way for the entire length until the terminus at 79th and the Dan Ryan line.



MAP V
South East-West Crosstown

Stations:

1. Montrose
2. Irving Park
3. Addison
4. Belmont
5. Diversey
6. Fullerton
7. Armitage
8. North
9. Division
10. Chicago
11. Lake Transfer
12. Congress
13. Roosevelt
14. Douglas Transfer
15. 33rd
16. 47th
17. 52nd/Archer
18. Midway;79th Street leg;
19. 63rd/Belt
20. 72nd/Pulaski
21. 75th/Kedzie
22. Columbus/Western
23. Ashland/Belt
24. Racine/Belt
25. Halsted/Belt
26. DanRyan/79th

II. Sketch Planning Evaluation

Table I presents a summary of the six sketch planning criteria. 79th Street is superior in all categories except for costs and environmental impact. However, since the performance measures in all categories are so close, further evaluation is necessary. Table II presents a breakdown of capital and operating costs for the two alignments. The 79th alignment has higher operating costs due to the longer alignment, and increased demand therefore requiring increased yearly vehicle miles.

Demand for each line can be further broken down into the separate components of trip types:

One-way daily trips	Crosstown with 63rd St. leg	Crosstown with 79th St. leg
CBD	17,833	20,691
Thru	3,567	4,138
Local	13,301	13,793
Total	34,701	38,622

The difference in volumes is not great, however, 79th Street does show a slight superiority in all categories.

III. Selection of Corridor Alternative

Table III presents a ranking of the two alternatives with respect to the four performance rankings. The evaluation shows the 79th Street alternative to be superior.

TABLE I

SOUTH EAST-WEST CROSSTOWN CORRIDOR EVALUATION

(Cicero Alignment Connected With An East-West Leg)

SKETCH PLANNING CRITERIA	63RD ST. LEG	79TH/BELT LEG
!. Annual Ridership	20,265,384	22,555,248
2. New Transit Trips (One-Way CBD Trips Daily)	1,004	1,130
3. Diverted Auto Trips (One-Way CBD Trips Daily)	671	755
4. Consumer's Surplus	31,624	33,147
5. Annualized Capital and Operating Cost	$59,562,000	$62,704,000
6. Households within Noise Impact Band	0	163

TABLE II

OPERATING AND CAPITAL COSTS

	CICERO CROSSTOWN WITH 63rd STREET LEG			CICERO CROSSTOWN WITH 79th STREET LEG		
1. Capital Cost	(Amount)	Total	Annualized Cost	(Amount)	Total	Annualized Cost
a) Construction, right of-way	(18.6 mi)	$188,500,000		(21.4 mi)	$218,800,000	
b) Station construction		187,500,000			85,800,000	
c) R.R. track relocation		7,000,000			10,600,000	
d) Junctions, difficult construction	(3)	7,000,000		(2)	5,000,000	
e) Yards		12,829,000			14,470,000	
f) Shops		3,756,000			4,236,000	
g) Rolling Stock	(211)	86,216,000		(238)	108,528,000	
h) R.R. Leasing			$ 1,433,000			$ 2,182,000
TOTAL ANNUALIZED CAPITAL			$ 43,332,000			$ 39,637,000
2. Operating Costs						
a) Vehicle Miles			$ 11,885,251			$ 19,032,520
b) Station Operations			4,345,040			4,034 680
ANNUAL OPERATING COSTS			16,230,291			23,067,200
Revenue			-10,133,000			-11 278 000
ANNUAL OPERATING SUBSIDY			$ 6,097,000			$ 11,769,000
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$ 49,429,000			$ 51,406,000

TABLE III

RANKING OF ALTERNATIVES

SOUTH EAST-WEST CROSSTOWN EVALUATION

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	HOUSEHOLDS AFFECTED	RANK	CONSUMERS' SURPLUS	RANK
79th Street	.439	1	$35,706	1	163	2	33,147	1
63rd Street	.410	2	$43,159	2	0	1	31,624	2

In order to be completely confident that the best corridor line is 79th, a sensitivity analysis, assuming that the full 63rd Street line with the existing Jackson Park and Englewood branches closed was performed. This would test the feasibility of replacing both branches with a 63rd Street crosstown with riders transferring to the Dan Ryan line. The summary of predicted ridership is presented below:

<u>63rd Street Crosstown - Closing of Englewood and Jackson Park branches (North-South rapid transit service ends at 58th Street)</u>

Daily Ridership

CBD trips	17,988	Consumer's Surplus	31,383
Thru trips	3,577	Diverted auto trips	611
Local	13,301	New Transit trips	914
Total One-Way Daily Ridership	34,766		

As illustrated, this alternative shows no major differences in ridership for the assumed 63rd Street alignment evaluated in Table I. Two thousand trips are affected by the closing of the Englewood and Jackson Park Branches, but instead of using the 63rd Street crosstown facility, the riders prefer direct access to the Dan Ryan line. This seems reasonable given that the inconvenience of transferring from a cross-town to another radial line would negate any advantage of closer access to a rapid transit facility. Viewed from a slightly different perspective, this implies that for short distances, buses provide better feeder service than rapid transit. Since this proposal would be slightly more expensive than an abbreviated 63rd Street Subway (costs are saved in abandoning the branches, however, these are outweighed by the additional construction to Jackson Park), the 63rd Street facility cannot be considered as a superior alternative in any form. The 79th Street alternative will therefore be selected as the corridor alternative line for system optimization.

CHAPTER IV

Douglas Corridor

The selection of the best alternative in this corridor will serve as a possible replacement for the Douglas elevated line. Two alternatives are evaluated; complete replacement of the Douglas "L" structure, or a new alignment along Ogden Avenue starting at the existing Congress line. A third option for construction of a subway under the existing Douglas "L" was originally proposed; however, it was rejected before sketch planning due to the high costs involved.

I. <u>Alternative Alignments</u>

A. Douglas "L" Replacement

This facility is a complete renovation of the existing Douglas "L" structure. Existing stations with low ridership are closed, station spacing is increased to one mile west of Pulaski in order to decrease line haul time.

Stations:

1. Polk
2. 18th
3. Western
4. California
5. Kedzie
6. Central Park
7. Pulaski
8. Cicero
9. 55th

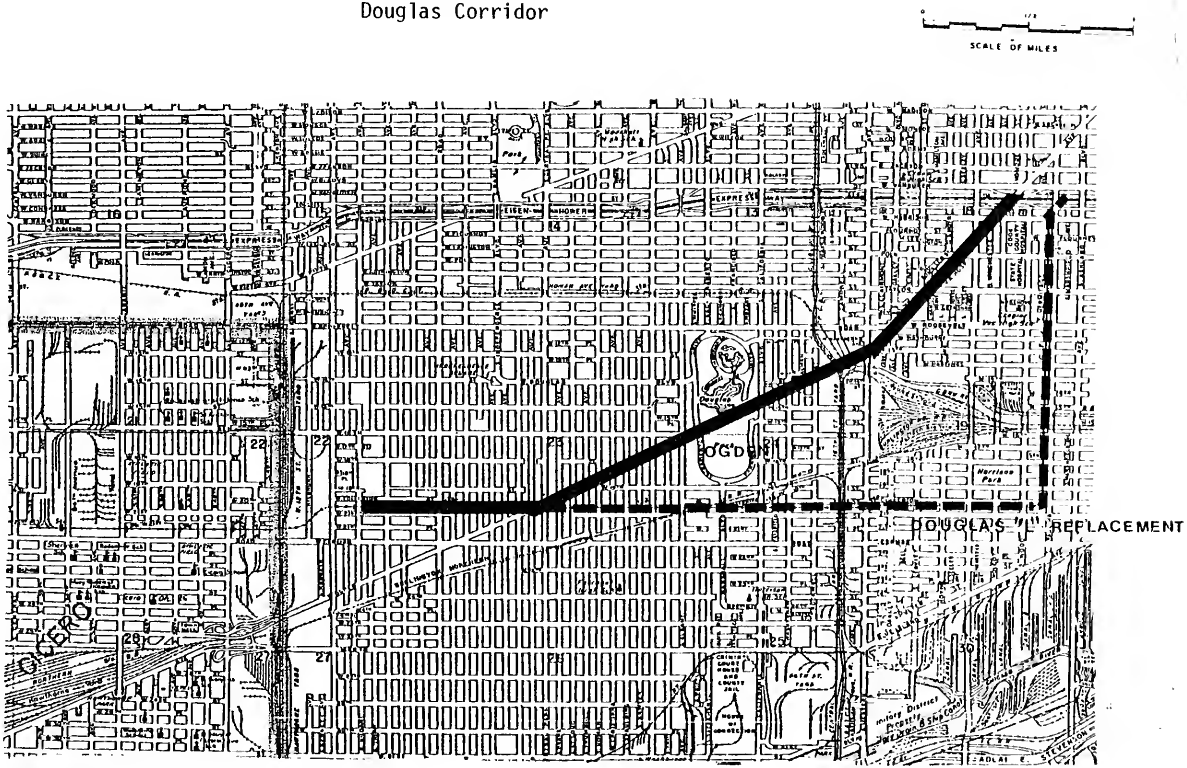
B. Ogden

The Ogden alignment runs from the Congress line along Ogden Avenue until it intersects with the Douglas right-of-way. For approximately ½ mile, the existing "L" structure is rebuilt until the at-grade portion of the Douglas line is reached.

Stations:

1. Western/Roosevelt
2. California
3. Kedzie
4. Central Park
5. Pulaski
6. Cicero
7. 55th

MAP VI
Douglas Corridor



Selected Alternative

Other Alternatives

II. Sketch Planning Evaluation

Table I presents a summary of the six sketch planning criteria. Ogden is superior in all categories. The components of demand for each line is summarized below:

One way daily trips	Douglas Repl.	Ogden
CBD	12,839	15,841
Thru	2,608	3,168
Local	5,157	4,054
One way daily ridership	20,604	23,063

Due to decreased line haul time to the CBD, the Ogden alternative attracts more CBD trips, however, local demand is slightly higher for the Douglas "L" replacement due to its longer alignment. It is interesting to note that both alignments would attract more trips than the existing Douglas facility.

The estimated costs for a Douglas replacement in Table II would be higher due to the provision necessary for staging construction while continuing operations over the same right of way. Provisions for rolling stock, additional yards, or shops are not totaled because both alternatives would require slightly fewer rapid transit cars than the Douglas service due to decreased running times. Existing shops and yards and their locations are not affected by either alternative. Operating costs were not calculated because both alternatives would involve only a marginal decrease in the vehicle mileage currently required for the existing Douglas service.

III. Selection of Corridor Alternative

Since the Ogden alignment clearly dominates renovating the existing Douglas elevated structure, it is selected as the corridor alternative. In system optimization, the Ogden alternative is therefore the 'do-something' alternative to compete against the existing Douglas service.

TABLE I

DOUGLAS CORRIDOR EVALUATION

SKETCH PLANNING CRITERIA	DOUGLAS "L" REPLACEMENT	OGDEN
1. Annual Ridership	12,032,690	13,468,792
2. New Transit Trips (One-way CBD trips - Daily)	289	692
3. Diverted Auto Trips (One-way CBD trips - Daily)	193	462
4. Consumer's Surplus	603	4,278
5. Annualized Capital Costs	$16,756,000	$ 9,809,000
6. Total Households within Noise Impact Band (net)	0	-1345*

* The Ogden alignment would have 1,042 households within its noise impact band, but since 2387 households within the present Douglas 'L' structure would be removed from this category, there is a net decrease

TABLE II

CAPITAL COSTS

DOUGLAS CORRIDOR

	DOUGLAS 'L' REPLACEMENT			OGDEN		
CAPITAL COST	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST						
. Construction, right of way	(6.3 mi)	$100,800,000		(5.2 mi)	$83,200,000	
. Station construction	(9)	29,700,000		(7)	23,100,000	
. R.R. track relocation		0			0	
. Junctions, difficult construction	(1+staging)	74,500,000		(1)	13,700 000	
. Yards		0			0	
. Shops		0			0	
. Rolling stock		0			0	
. R.R. leasing (annual)			0			0
TOTAL ANNUALIZED CAPITAL COST			$16,756,000			$9,809,000

CHAPTER V

Southwest Corridor

There is much discussion at the present time concerning public transportation needs for the Southwest (Archer) Corridor. Many technologies (light rail, rapid transit, exclusive bus lanes, monorail) have been proposed and study is in the initial phases. For the purpose of the SONARRTA rail study, only conventional rapid transit alternatives will be evaluated. Sketch planning is therefore undertaken to determine the best alternative for rapid transit (and serve as a replacement of the Archer Express Bus services).

I. Alternatives

Nine separate alternative alignments have been proposed for a southwest rapid transit line. These consist of three possible choices for a CBD connection, two alternatives (Archer and Stevenson Expressway) for the major length of the alignment, and two choices for a terminus to the Archer alignment. A listing of stations is presented by each link and not by the entire length of each of the nine alternatives.

A. CBD Connection

1. Franklin

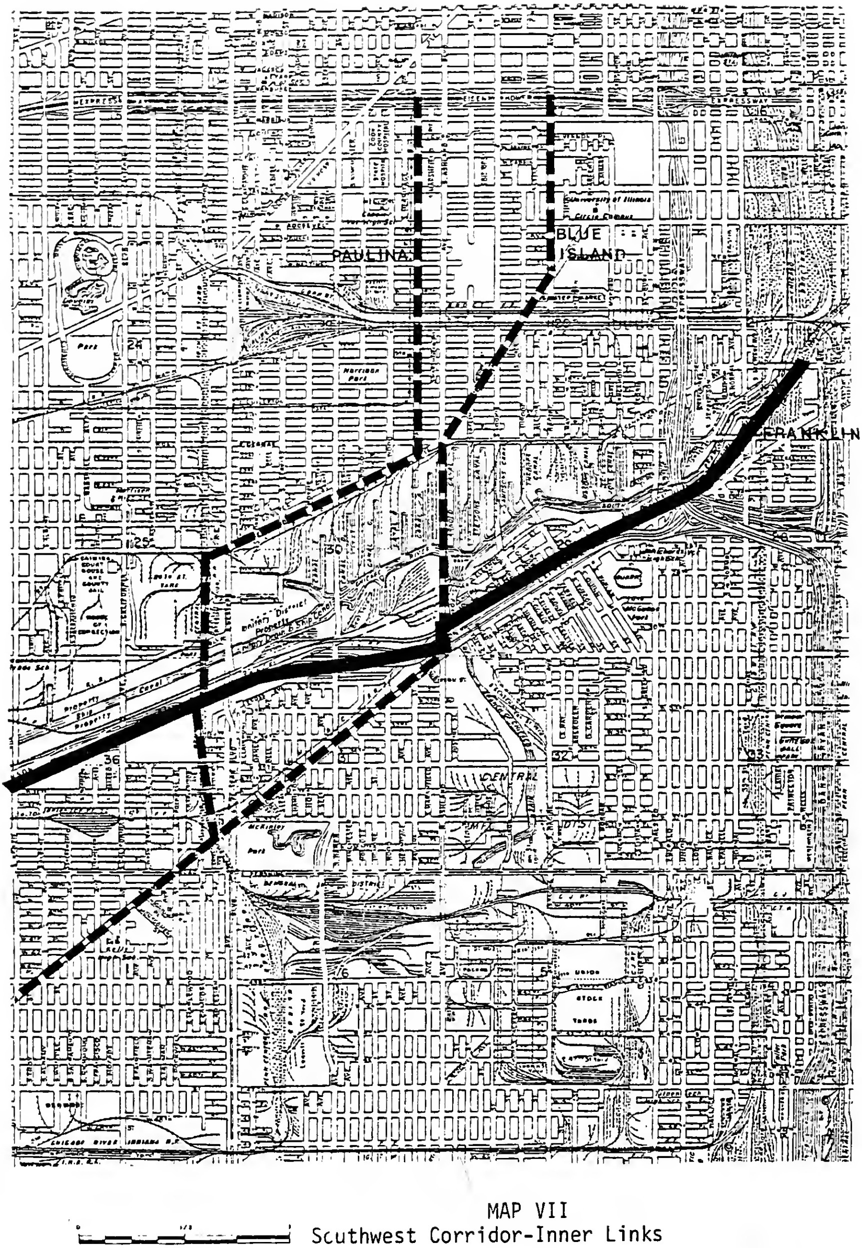
   This facility would connect with the proposed downtown Franklin subway utilizing the GM&O tracks between 18th Street and the intersection of Archer and Ashland (Stevenson Expressway).

   Stations:

   1. Cermak/Archer
   2. Halsted
   3. Ashland/Stevenson Expressway

2. Blue Island

   This link would be a subway connecting with either the Congress line or a future distributor subway. From the intersection with the Congress line, this facility would be a subway running south along Racine, Blue Island, and then Ashland until the link terminus at Ashland and Archer.



MAP VII
Scuthwest Corridor-Inner Links

Selected Alternative

Other Alternatives

Stations:

1. University of Illinois
2. Roosevelt/Racine
3. Cermak/Blue Island
4. Ashland

3. Paulina

This subway could also connect with either a downtown Distributor line or the Congress line. The facility would run under the existing Douglas 'L' along Paulina, south on Blue Island, until Western Avenue where the line would emerge to use the elevated grade right-of-way (Penn Central) to connect south with either the Stevenson Expressway or Archer Avenue.

Stations:

1. Medical Center
2. Ashland/Cermak/Blue Island

B. Southwest Line

1. Archer

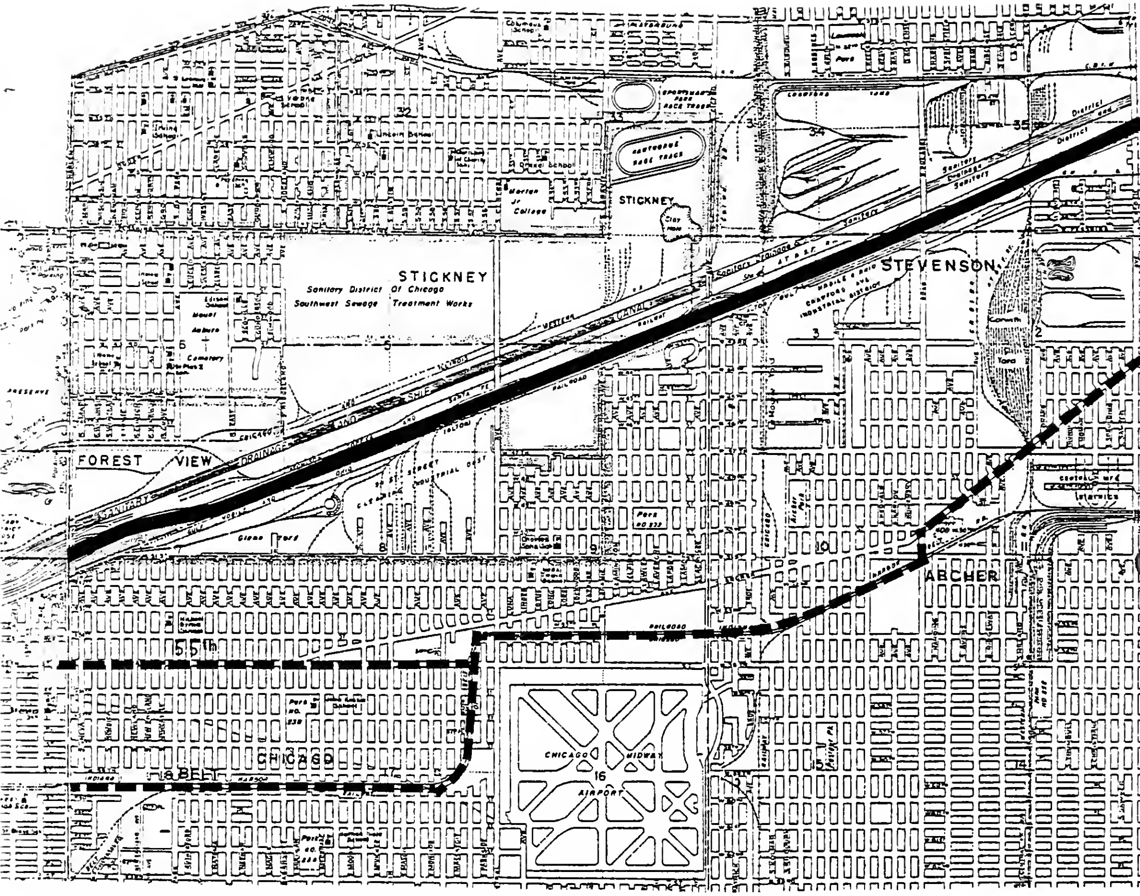
This link would be a subway running down Archer approximately six miles from Ashland (or Western if the Paulina connection is used) until Pulaski where the facility would be elevated to utilize the Belt R.R. right-of-way until the link terminus at Midway Airport.

Stations:

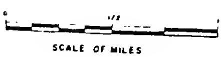
1. Western
2. California
3. Kedzie
4. Pulaski
5. Midway Terminal

2. Stevenson Expressway

This line would be an elevated grade facility running along the Stevenson Expressway from Ashland until Harlem Avenue. Either the GM&O right-of-way adjacent to the Stevenson or the median strip can be utilized.



MAP VIII
Southwest Corridor-Outer Links



Selected Alternative

Other Alternatives

Stations:

1. Western
2. California
3. Kedzie
4. Pulaski
5. Belt ~~(Western)~~ Cicero
6. Central
7. Harlem

C. Terminus for Archer Line

1. Belt

This alternative would continue from the Midway Terminal around the northern edge of the airport using the Belt right-of-way until the terminus at 59th and Harlem.

Stations:

1. Austin/Belt
2. Narragansett/Belt
3. Harlem/Archer

2. 55th Avenue

This line would continue on the north side of the airport along 55th Avenue until the terminus at Harlem.

Stations:

1. Austin/Archer (55th)
2. Narragansett/Archer
3. Harlem/Archer

II. Evaluation

Table I is a presentation of the six sketch planning criteria. As can be readily seen, there is a fundamental difference between the Stevenson and the Archer alternatives. Basically, the Archer alternatives attract a larger ridership due to its more favorable location for direct access. In addition, an Archer facility would provide direct service to Midway airport. In contrast, the Stevenson alternatives show substantially less riders because of their location along the less densely populated corridor along the expressway. But the Stevenson alternatives are advantageous because of the low cost involved in median strip construction. Consequently, none of these alternatives can be eliminated

TABLE 1

SOUTHWEST CORRIDOR EVALUATION

ONE WAY DAILY PATRONAGE	Franklin-Archer-1. Belt	Blue Island-Archer-2. Belt	Paulina-Archer-3. Belt	Franklin-Archer-4. Harlem	Blue Island-Archer-5. Harlem	Paulina-Archer-6. Harlem	Franklin-7. Stevenson	Blue Island-8. Stevenson	Paulina-9. Stevenson
CBD trips	18,792	19,208	18,596	19,330	19,830	19,220	15,549	16,640	16,231
Thru trips	3,758	3,858	3,719	3,866	3,966	3,854	3,109	3,328	3,246
Local trips	5,217	5,609	4,892	4,398	4,871	4,892	3,606	4,079	4,085
Total Daily One-Way Trips	27,767	28,755	27,207	27,594	28,667	27,966	22,264	24,047	23,562
1. Annual Ridership	15,746,392	16,370,685	15,808,888	116,114,896	16,741,528	16,332,144	13,002,176	14,043,448	13,760,208
2. New Transit Trips (CTA One-Way Daily CBD Trips)	1,407	1,497	1,266	1,656	1,747	1,510	712	783	715
3. Diverted Auto Trips (CTA One-Way Daily CBD Trips)	940	1,000	846	1,106	1,167	1,009	476	523	478
4. Consumer's Surplus	83,784	85,595	79,923	93,132	95,212	88,680	65,776	67,094	64,863
5. Annualized Operating and Capital Cost	$37,692,000	$38,642,000	$38,216,000	$36,718,000	$39,175,000	$38,587,000	$17,968,000	$23,761,000	$23,899,000
6. Total Households within Noise Impact Band	1,291	2,045	992	1,616	2,370	1,317	0	754	75

due to domination. For example, the Franklin-Stevenson alternative has the lowest ridership and lowest scores on three of the other categories, however, it has absolutely no impact on the households affected category and has the lowest cost. In contrast, the Archer alternatives have higher ridership but necessitates expensive subway construction.

All of the services would draw some ridership away from the Douglas line, with the Paulina alternatives having the largest impact, draining some thirty-five percent of the Douglas' patronage. There is not much change in impact on the Douglas between the Stevenson and Archer alternatives, with the Stevenson having a slightly higher impact. A Franklin alternative would have the most impact on the Dan Ryan Line, drawing five percent of its ridership.

III. Selection of Corridor Alternative

A complete breakdown of costs is presented in Table II. In Table III, all of the alternatives are ranked according to the four performance criteria. As can be seen, with respect to cost-effectiveness and environmental impact, the Franklin-Stevenson alternative is the best. The basic distinction is between the high cost Archer subway and the low cost, low ridership Stevenson alternatives. The problems associated with constructing a subway down Archer Avenue (i.e., high costs, disruption impacts) seems to outweigh any of the user benefits in providing this kind of facility. In addition, connection of the line with the Franklin subway seems the most advantageous in limiting competition with the Douglas line and providing quick access to the CBD.

TABLE II

CAPITAL AND OPERATING COSTS

SOUTHWEST CORRIDOR

	Franklin-Archer-Belt			Blue Island-Archer-Belt			Paulina-Archer-Belt		
1. Capital Cost	(Amount)	Total	Annualized	(Amount)	Total	Annualized	(Amount)	Total	Annualized
a) Construction, right of way	(11.1 mi)	$179,500,000		(11.7 mi)	$189,400,000		(11.6 mi)	$186,400,000	
b) Station Construction	(11)	122,400,000		(11)	122,400,000		(11)	122,400,000	
c) R.R. Track Relocation		1,600,000			1,600,000			2,300,000	
d) Junctions, difficult construction		2,500,000			16,600,000			4,500,000	
e) Yards		5,897,600			4,864,000			5,350,400	
f) Shops		1,726,600			1,424,000			1,566,400	
g) Rolling Stock	(97)	$ 44,232,000		(80)	$ 36,480,000		(88)	$ 40,128,000	
h) R.R. Leasing (Annual)			$ 325,800		•	$ 325,800			$ 483,270
TOTAL ANNUALIZED CAPITAL			$29,944,000			$31,099,000			$30,459,000
a) Vehicle Miles			$ 6,040,000			$ 5,837,926			$ 6,050,378
b) Station Operations			1,706,980			1,706,980			1,706,980
2. TOTAL OPERATING COSTS			$ 7,748,000			$ 7,543,000			$ 7,757,000
Revenue			- 7,873,000			- 8,185,000			- 7,944,000
ANNUAL OPERATING SUBSIDY			$ (125,000)			$ (642,000)			$ (187,000)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$29,819,000			$30,457,000			$30,272,000

TABLE II - (cont'd)

CAPITAL AND OPERATING COSTS

SOUTHWEST CORRIDOR

	Franklin-Archer-Harlem			Blue Island-Archer-Harlem			Paulina-Archer-Harlem		
1. Capital Cost	(Amount)	Total	Annualized	(Amount)	Total	Annualized	(Amount)	Total	Annualized
a) Construction, right of way	(10.7 mi)	$174,100,000		(11.36 mi)	$184,000,000		(11.23 mi)	$180,900,000	
b) Station construction	(11)	122,400,000		(11)	122,400,000		(11)	122,400,000	
c) R.R. Track relocation		400,000			400,000			1,100,000	
d) Junctions, difficult construction		2,500,000			16,600,000			4,500,000	
e) Yards		5,897,600			6,444,800			6,444,800	
f) Shops		1,726,600			1,886,800			1,886,800	
g) Rolling Stock	(97)	44,232,000		(106)	48,336,000		(106)	48,336,000	
h) R.R. Leasing (annual)			$ 76,020			$ 76,020			$ 233,490
TOTAL ANNUALIZED CAPITAL			$29,155,000			$31,029,000			$30,515,000
a) Vehicle miles			$ 5,855,643			$ 6,439,318			$ 6,365,754
b) Station operations			1,706,980			1,706,980			1,706,980
2. TOTAL OPERATING COSTS			$ 7,563,000			$ 8,146,000			$ 8,073,000
Revenue			- 8,057,000			- 8,371,000			- 8,166,000
ANNUAL OPERATING SUBSIDY			$ (494,000)			$ (225,000)			$ (93,000)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$28,661,000			$30,805,000			$30,421,000

TABLE II - (cont'd)

CAPITAL AND OPERATING COSTS

SOUTHWEST CORRIDOR

	Franklin-Stevenson			Blue Island-Stevenson			Paulina-Stevenson		
1. Capital Cost	(Amount)	Total	Annualized	(Amount)	Total	Annualized	(Amount)	Total	Annualized
a) Construction, right of way	(9.81 mi)	$62,800,000		(10.41 mi)	$95,200,000		(9.81 mi)	$97,200,000	
b) Station construction	(10)	33,000,000		(10)	57,600,000		(11)	69,900,000	
c) R.R. Track relocation		1,200,000			0			400,000	
d) Junctions, difficult construction		2,500,000			16,600,000			4,500,000	
e) Yards		4,316,800			4,316,800			4,316,800	
f) Shops		1,263,800			1,263,800			1,263,800	
g) Rolling Stock	(71)	32,376,000		(71)	32,376,000		(71)	32,376,000	
h) R.R. Leasing (annual)			$ 238,920			0			$ 88,880
TOTAL ANNUALIZED CAPITAL COSTS			$11,743,000			$17,210,000			$17,518,000
a) Vehicle miles			$ 4,672,941			$ 4,958,671			$ 4,672,941
b) Station operations			1,551,800			1,551,800			1,706,980
2. TOTAL OPERATING COSTS			$ 6,225,000			$ 6,551,000			$ 6,380,000
Revenue			6,501,000			7,022,000			6,880,000
ANNUAL OPERATING SUBSIDY			$ (276,000)			$ (471,000)			$ (500,000)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$11,467,000			$16,739,000			$17,019,000

TABLE III

RANKING OF ALTERNATIVES

SOUTHWEST CORRIDOR

Alternative	Annual Riders / Annual Subsidy Dollar	Rank	Capital Dollars / New Transit Trip	Rank	Consumer's Surplus	Rank	Households Affected	Rank	Overall Score
Franklin-Archer-Belt	.528	8	21,282	5	83,784	5	1,291	5	23
Blue Island-Archer-Belt	.538	6	20,774	6	85,595	4	2,045	8	24
Paulina-Archer-Belt	.525	9	24,059	8	79,923	6	992	4	27
Franklin-Archer-Harlem	.526	4	17,605	2	93,132	2	1,616	7	15
Blue Island-Archer-Harlem	.543	5	17,761	3	95,312	1	2,370	9	18
Paulina-Archer-Harlem	.537	7	20,208	4	88,680	3	1,317	6	20
Franklin-Stevenson	1.134	1	16,493	1	65,776	8	0	1	11
Blue Island-Stevenson	.838	2	21,980	7	67,074	7	754	3	19
Paulina-Stevenson	.809	3	24,500	9	64,863	9	75	2	23

CHAPTER VI

South Lakefront Corridor

Sketch planning is undertaken in the South Lakefront corridor in order to determine the best replacement for the Englewood-Jackson Park rapid transit service. In addition, it is assumed that the Illinois Central Gulf South Chicago branch commuter rail service and CTA South Lakefront Express bus services are ended. All of the alternatives evaluated were assumed to connect with a future Franklin Street subway, however, the possibility exists for a future connection to a downtown distributor rapid transit line.

I. Alternatives

The total number of possible alignments for a future South Lakefront line consists of four possible alignments from Cermak to 71st Street, and three distinct alignments from 71st to 95th Streets. The total number of alternatives is therefore equal to twelve. In addition, a South Lakefront extension from 95th to the Indiana state line is proposed; however, this extension will not be evaluated in sketch planning. For simplicity, a total listing of stations is presented below by individual link, not by the full length of each of the 12 alternatives.

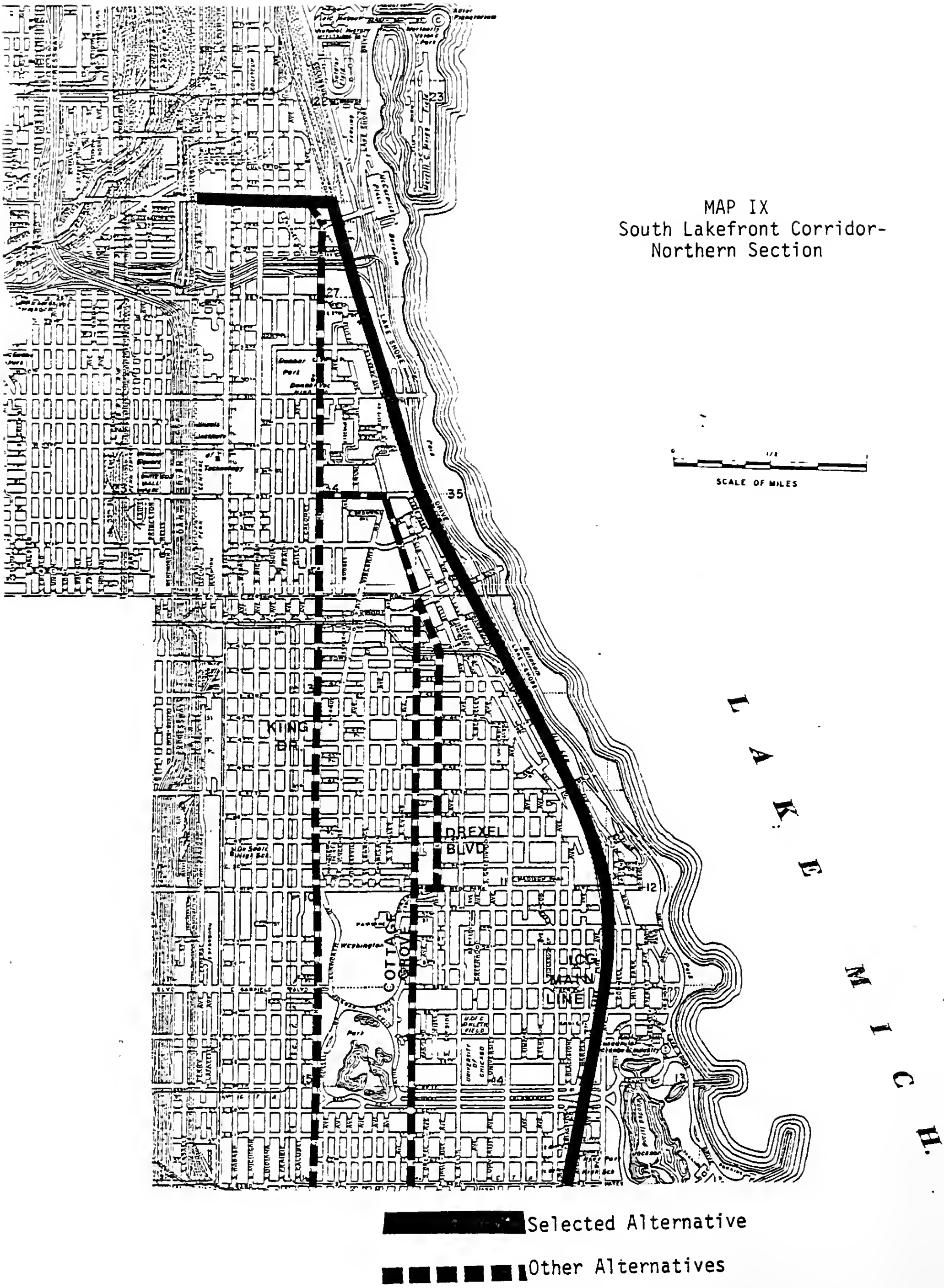
A. Cermak to 71st

1. King Drive

This facility would be a new elevated structure starting from a Cermak subway and running the entire length along King Drive until it intersects with the Penn Central right of way. From there, the right of way is used until the link terminus at 71st and Cottage Grove.

Stations:

1. Cermak/Chinatown(Subway)
2. 23rd/King(Subway)
3. 31st/King
4. 35th/King
5. Pershing/King
6. 43rd/King
7. 47th/King
8. 51st/King
9. Garfield/King
10. 63rd/King
11. 71st/Cottage Grove



MAP IX
South Lakefront Corridor-
Northern Section

2. Cottage Grove

This link would be a new elevated structure running along King Drive to 35th, west on 35th to Cottage Grove. The alignment then runs down Cottage Grove until the junction with the Penn Central right of way at 71st.

Stations:

1. Cermak/Chinatown(Subway)
2. 23rd/King(Subway)
3. 31st/King
4. 35th/King
5. Pershing/Cottage Grove
6. 43rd/Drexel
7. 47th/Drexel
8. 51st/Cottage Grove
9. Garfield/Cottage Grove
10. 59th/Cottage Grove
11. 63rd/Cottage Grove
12. 71st/Cottage Grove

3. Drexel Boulevard

This elevated facility would be identical to Cottage Grove, except for the use of Drexel Boulevard between Pershing and 51st.

Stations:

1. Cermak/Chinatown(Subway)
2. 23rd/King(Subway)
3. 31st/King
4. 35th King
5. Pershing/Cottage Grove
6. 43rd/Drexel
7. 47th/Drexel
8. 51st/Cottage Grove
9. Garfield/Cottage Grove
10. 59th/Cottage Grove
11. 63rd/Cottage Grove
12. 71st/Cottage Grove

4. Illinois Central Gulf Main Line

This rapid transit service would share the existing ICG right of way with the ICG commuter rail service on a four track right of way. Station spacings would be altered on the existing commuter rail service, with the possibility of running express commuter rail service and local rapid transit service over the shared portion of right of way.

Stations:

1. Cermak/Chinatown(Subway)
2. 23rd/King(Subway)
3. 31st/ICG
4. 35th/ICG
5. Pershing/ICG
6. 43rd/ICG
7. 47th/ICG
8. 53rd/ICG
9. 59th/ICG
10. 63rd/ICG
11. 71st/ICG (Constructed only when linked to B&O or PC links)

B. 71st to 95th

1. ICG South Chicago Branch

This link would use the existing ICG South Chicago Right-of-Way. It is assumed (as in all of the alternatives) that the South Chicago branch commuter rail service is abandoned.

Stations:

1. Stony Island/71st
2. 71st/Jeffrey
3. 75th/ICG
4. 79th/ICG
5. 83rd/ICG
6. 87th/ICG
7. 91st/ICG
8. 95th/Penn Central

2. Baltimore & Ohio

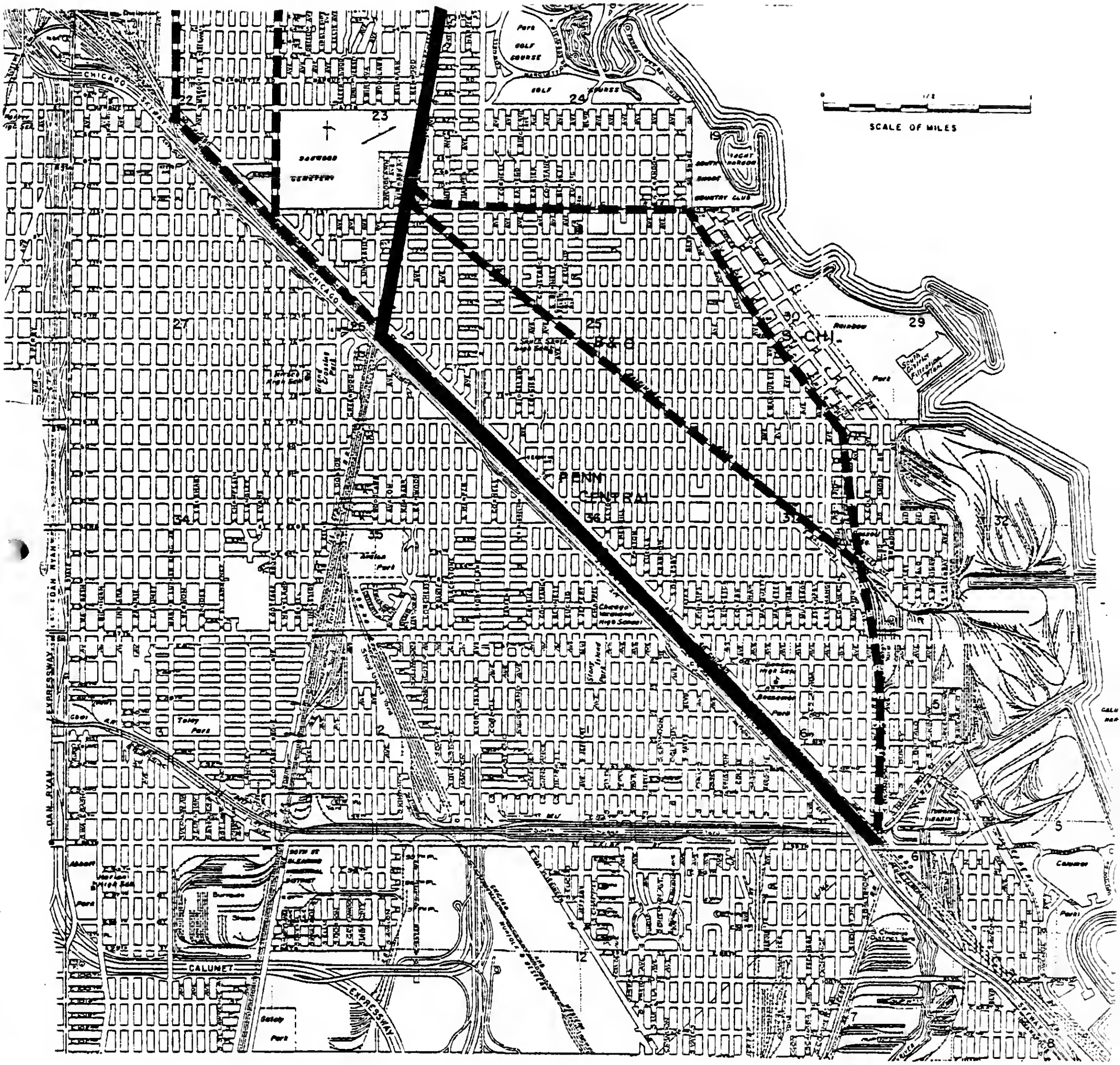
This link consists of a portion of freight railroad right of way between the ICG main line at 71st and the South Chicago branch at 85th. From 85th to 91st, the South Chicago branch is used.

Stations:

1. 73rd/Stony Island
2. 75th/Jeffrey
3. 79th/Yates
4. 83rd/ICG
5. 91st/ICG
6. 95th/Penn Central

3. Penn Central

This link utilizes the existing Penn Central elevated garde right of way between Cottage Grove and 71st to 95th Street.



MAP X
South Lakefront Corridor-Southern Section

Selected Alternative

Other Alternatives

Stations:

1. 75th/Penn Central
2. 79th/Penn Central
3. 83rd/Penn Central
4. 87th/Penn Central
5. 95th/Penn Central

II. Evaluation

Performance of the twelve separate alternatives is summarized in Table I. All of the alternatives show a loss in total transit patronage (CTA and commuter rail) over the existing situation. This is reflected in the negative value for diverted auto trips.[1] Due to the large number of alternatives, a full accounting of all capital and operating costs could not be estimated for each alignment. The dollar amounts include only basic line and station costs - however, these costs do not vary substantially among alternatives. The use of only construction costs should therefore be sufficient in a first cut evaluation of alternatives.

All of the alternatives have similar impacts on adjacent transit services. The Dan Ryan line experiences approximately a fifteen percent increase in ridership with the closing of the Englewood-Jackson Park line. The ICG main line's ridership would increase by ten percent due to roughly half of the previous South Chicago branch riders diverting to the main line. Depending on the attractiveness of the rapid transit alternative, a diversion of six to twelve thousand lakefront express bus riders to rapid transit is expected.

Investigation of the individual alignments reveals that the Penn Central link is the most direct and fastest alternative for the southern end. All of the four inner links perform better in attracting CBD work trips when joined with the Penn Central. Local demand is lowest for alternatives using the ICG mainline due to its location alongside the lake, therefore having a service area only to the west.

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[1] This estimated loss is due to the demand modelling assumption that a major mode, commuter rail, is lost for numerous zones due to the closing of the South Chicago Branch. However, this prediction of a loss would not be apt to occur in a real life situation due to the increase in service on rapid transit that is offered to former commuter rail patrons. A larger number of riders would switch to rapid transit than what the CBD demand model predicts.

TABLE I

SOUTH LAKE FRONT CORRIDOR EVALUATION

ONE-WAY DAILY PATRONAGE	1. ICG S. CHICAGO	2. ICG B&O	3. ICG PENN CENTRAL	4. DREXEL S. CHICAGO	5. DREXEL B&O	6. DREXEL PENN CENTRAL	7. COTTAGE GROVE S. CHICAGO
1. CBD Trips	17,484	17,623	19,134	15,413	15,350	17,039	16,101
2. Thru Trips	8,392	8,459	9,184	7,198	7,368	8,176	7,728
3. Local Trips	7,559	7,717	7,602	9,427	9,419	9,029	9,029
Total Daily One-Way Trips	33,435	33,799	35,920	32,238	32,137	34,246	34,137

SKETCH PLANNING CRITERIA	1. ICG S. CHICAGO	2. ICG B&O	3. ICG PENN CENTRAL	4. DREXEL S. CHICAGO	5. DREXEL B&O	6. DREXEL PENN CENTRAL	7. COTTAGE GROVE S. CHICAGO
1. Annual Ridership	19,526,000	19,739,000	20,977,000	18,827,000	18,768,000	20,000,000	19,422,000
2. New Transit Trips (CTA; One-Way Daily CBD Trips)	1,180	1,251	1,175	906	834	893	950
3. Diverted Auto Trips (One-Way Daily CBD Trips)	-1,562	-1,514	-1,566	-1,747	-1,755	-1,756	-1,717
4. Consumer's Surplus (Time Savings: Daily One-Way Equivalent Minutes - CBD Trips)	2,903	4,226	3,603	-892	787	98	-537
5. Annualized Capital Cost	$20,623,000	$20,129,000	$16,327,000	$34,002,000	$32,803,000	$28,251,000	$38,256,000
6. Total Households Within Noise Impact Band	85	85	85	3,980	3,980	3,859	1,622

TABLE I

SOUTH LAKE FRONT CORRIDOR EVALUATION
(Continued)

ONE-WAY DAILY PATRONAGE	8. COTTAGE GROVE B&O	9. COTTAGE GROVE PENN CENTRAL	10. KING DRIVE S. CHICAGO	11. KING DRIVE B&O	12. KING DRIVE PENN CENTRAL
1. CBD Trips	15,465	17,158	18,983	18,371	19,838
2. Thru Trips	7,423	8,236	9,112	8,818	9,522
3. Local Trips	9,419	9,029	9,211	9,203	8,706
Total Daily One-Way Trips	32,307	34,423	37,306	36,392	38,066
SKETCH PLANNING CRITERIA					
1. Annual Ridership	18,867,000	20,103,000	21,787,000	21,253,000	22,231,000
2. New Transit Trips (CTA; One-Way Daily CBD Trips)	938	939	1,002	990	946
3. Diverted Auto Trips (One-Way Daily CBD Trips)	-1,725	-1,724	-1,682	-1,690	-1,720
4. Consumer's Surplus (Time Savings: Daily One-Way Equivalent Minutes - CBD Trips)	-446	465	325	295	464
5. Annualized Capital Cost	$37,352,000	$32,506,000	$26,395,000	$25,196,000	$20,394,000
6. Total Households Within Noise Impact Band	3,622	3,501	3,332	3,332	3,211

However, the ICG mainline is the preferred alignment for inexpensive line construction. The other three inner links (Cottage Grove, Drexel, King Drive) have higher construction costs and severe disruption impacts upon residential land use.

Based on the relative scores for the six sketch planning criteria, it is possible to eliminate seven alternatives. All of the alternatives utilizing the Drexel and Cottage Grove links are dominated by the ICG mainline alternatives. In addition, the ICG South Chicago alignment is dominated in all categories by the ICG - B&O. The remaining alternatives therefore consist of two ICG mainline alignments (B&O and Penn Central) and all of the King Drive alignments. These five alternatives are evaluated in depth in order to select the best corridor alternative.

III. Selection of Corridor Line

The complete breakdown of capital and operating costs are presented for the five non-dominated alternatives. Table II does not include the costs of vehicle procurement since a south lakefront facility is assumed to use the rapid·transit cars allocated for the existing Jackson Park - Englewood service. All of the alternatives would require slightly less than the number of rapid transit cars currently operating on the Jackson Park - Englewood service (based on equipment needs not related to thru routing with Howard, the present south side service requires 115 cars). Capital costs for the location of new yards and shops are totaled. All of the alignments include an additional 2.5 million dollar cost for construction of an alignment to the Franklin subway.

In Table III, all of the alternatives are ranked according to the relative performances on the four final categories. The lowest overall score for rankings therefore corresponds to the alternative with the best relative rankings across all four performance criteria.

The ICG - Penn Central alignment is the superior alternative with regard to these rankings. This alignment will therefore be evaluated in the system optimization as the best replacement for the existing Englewood - Jackson Park service. This alignment is also advantageous in that it will be located further away from the existing Dan Ryan line than any of the other alternatives and the existing Englewood - Jackson Park service. This will provide additional benefits in increasing the spacing between rapid transit services.

TABLE 11

CAPITAL AND OPERATING COSTS

	ICG-B&O			ICG-PENN CENTRAL			KING DR.-S. CHICAGO		
	(Amount)	Total	Annualized	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST									
. Construction, right of way		$124,200,000			$85,900,000			$197,400,000	
. Stations	(17)	80,700,000		(15)	74,100,000		(19)	87,300,000	
. R.R. track relocation		3,300,000			5,400,000			400,000	
. Junctions, difficult construction		2,500,000			2,500,000			2,500,000	
. Yards		5,350,400			5,350,400			5,897,600	
. Shops		1,566,400			1,566,400			1,726,800	
. Rolling stock		0			0			0	
. Annualized R.R. leasing			$ 1,118,580			$ 1,188,580			$ 553,860
TOTAL ANNUALIZED CAPITAL			18,956,000			15,457,000			24,739,000
. Vehicle miles			5,998,363			5,998,363			6,917,170
. Station operations			2,638,060			2,327,700			2,948,420
TOTAL OPERATING COSTS			$ 8,636,423			$ 8,326,063			$ 9,865,590
. Revenue			-9,869,000			-10,489,000			-10,891,000
ANNUAL OPERATING SUBSIDY			$(1,232,600)			$(2,162,900)			$(1,027,410)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$17,723,000			$13,294,000			$23,712,000

TABLE II

CAPITAL AND OPERATING COSTS
(Continued)

	KING DR.-B&O			KING-PENN CENTRAL		
	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST						
. Construction, right of way		$191,000,000			$141,100,000	
. Stations	(19)	87,300,000		(16)	77,400,000	
. R.R. track relocation		400,000			2,600,000	
. Junctions, difficult construction		2,500,000			2,500,000	
. Yards		5,897,600			5,350,400	
. Shops		1,726,800			1,566,400	
. Rolling stock		0			0	
. Annualized R.R. leasing			$ 510,420			$ 803,640
TOTAL ANNUALIZED CAPITAL			24,172,000			19,695,000
. Vehicle miles			6,699,338			6,107,743
. Station operations			2,948,420			2,482,880
TOTAL OPERATING COSTS			$ 9,647,758			$ 8,590,623
. Revenue			-10,626,000			-11,115,000
ANNUAL OPERATING SUBSIDY			$ (978,242)			$(2,524,377)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$23,194,000			$17,171,000

TABLE III

RANKING OF ALTERNATIVES

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	HOUSEHOLDS AFFECTED	RANK	CONSUMERS' SURPLUS	RANK	SCORE
IC-B&O	1.114	3	$15,152	2	85	1	4226	1	7
IC-Penn Central	1.578	1	$13,155	1	85	1	3603	2	5
King-S. Chicago	0.919	4	$24,690	5	3332	3	325	4	16
King-B&O	0.916	5	$24,416	4	3332	3	295	5	17
King-Penn Central	1.295	2	$20,819	3	3211	2	464	3	10

CHAPTER VII

Southwest Dan Ryan Corridor

Sketch planning is undertaken in a corridor running from 95th Street and the Dan Ryan to Blue Island in order to best determine a possible southwest extension to the existing Dan Ryan Line. (An extension to the southeast has been proposed and will be evaluated in system optimization). A southwest Dan Ryan extension could serve as a replacement for the Illinois Central Blue Island Branch and the Rock Island Beverly Branch. The alternatives were evaluated with both of these commuter rail branches assumed to be closed.

I. <u>Alternative Alignments</u>

A. I-57

This alignment would be an at grade median facility. The present station spacing on the Dan Ryan is continued until the link terminus.

Stations:

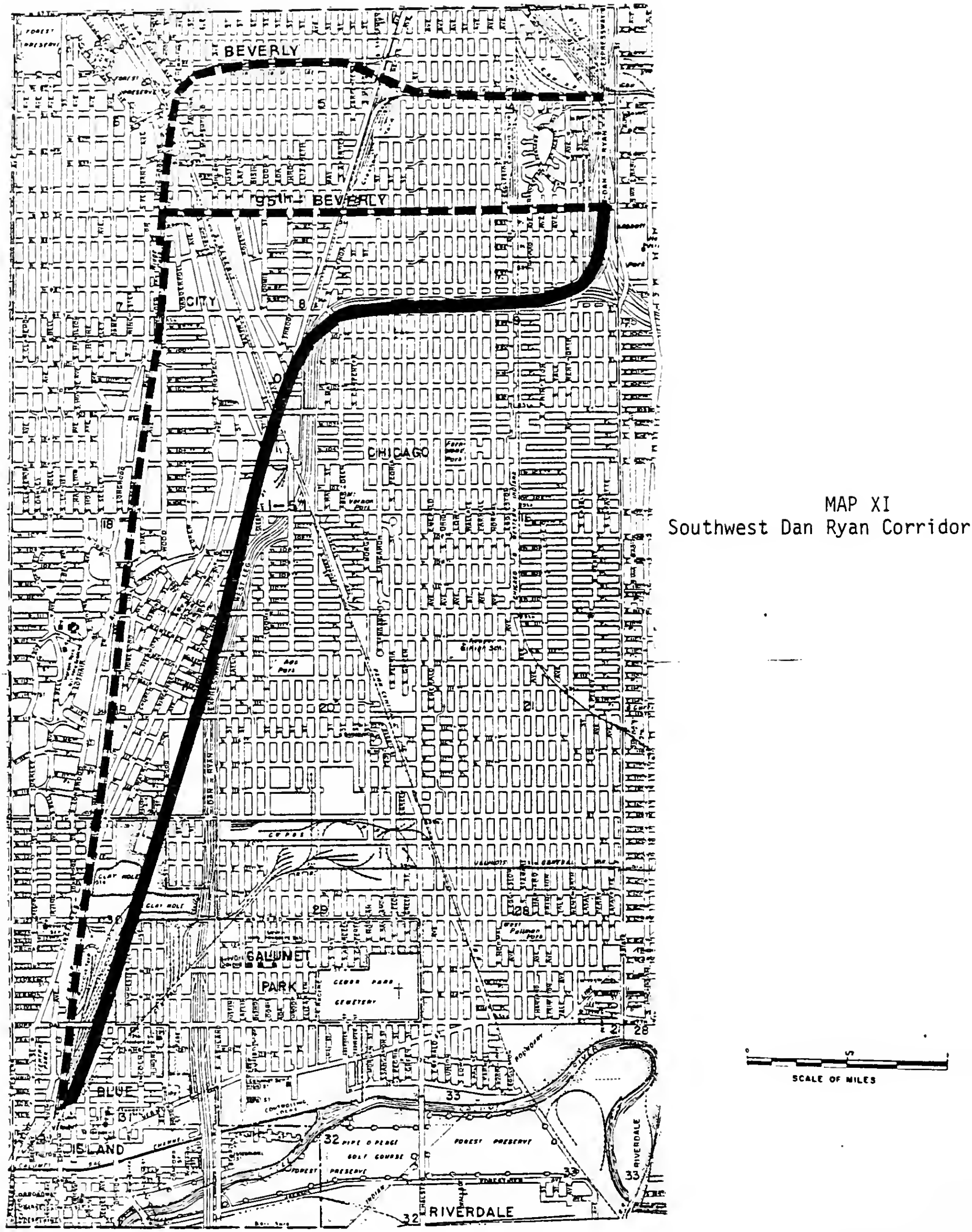
1. 95th Street(Existing Dan Ryan Station)
2. Halsted/I-57
3. 103rd
4. 111th/Rock Island ROW
5. 119th
6. Vermont

B. 95th - Beverly

This facility would connect with the present Dan Ryan line with a subway on 95th Street. From 95th and South Wood Street to Blue Island, the Beverly Branch ROW is used. Stations are located near present Rock Island stations which are heavily used.

Stations:

1. 95th(Existing Dan Ryan)
2. Halsted/95th
3. Ashland Beverly/95th
4. Beverly Branch ROW/103rd
5. 111th
6. 119th
7. Vermont



MAP XI
Southwest Dan Ryan Corridor

Selected Alternative

Other Alternatives

C. Beverly

This facility is similar to the previous alignment except trains would leave the Dan Ryan line at 91st Street. Rock Island Right-of-Way is used until Vincennes Avenue, where the alignment continues along the Rock Island's Beverly Branch.

Stations:

1. Vincennes
2. 95th/Beverly
3. Beverly/103rd
4. 111th
5. 119th
6. Vermont

II. Evaluation

Table I presents a summary of ridership forecasts and performance for the six sketch planning criteria. For proper evaluation, total patronage on the Dan Ryan line is the most important statistic, since evaluation of the extension's ridership would not reveal any diverted flows from the existing Dan Ryan line.

Costs for the three alternatives are presented in Table II. The subsidy required for operation is figured by calculating only the expected net increase in revenue with the opening of the extension and the operating costs for the length of the extension. The 95th-Beverly alternative has the highest costs due its subway alignment along 95th Street.

According to the six sketch planning alternative, the 95th-Beverly alternative is dominated in all categories by the Beverly alternative. The basic choice is therefore narrowed to the lower cost/lower ridership I-57 median strip construction versus the higher cost Beverly alignment which is located along a more populous corridor.

III. Selection of Extension Alternative

Evaluation based on four final criteria is utilized to select the best alternative. Annual riders per subsidy dollar was calculated using the increase in ridership expected on the entire Dan Ryan line and extension. The I-57 shows superiority in three of the four categories and therefore is selected as the Dan Ryan Southwest extension alignment. The I-57 alternative shows superiority in that a higher level of service is provided throughout the Dan Ryan line in contrast to the Beverly alternative which requires branching off of the Dan Ryan line north of the current endpoint at

TABLE I

SOUTHWEST DAN RYAN CORRIDOR EVALUATION

ONE-WAY DAILY PATRONAGE	I-57	95TH BEVERLY	BEVERLY
Extension CBD Trips	22,286	21,448	18,081
Extension Thru Trips	2,786	2,681	2,260
Extension Local Trips	2,430	2,644	2,988
Total Extension Trips	27,502	26,773	23,329
Dan Ryan CBD Trips	23,103	24,638	28,510
Dan Ryan Thru Trips	2,888	3,079	3,563
Dan Ryan Local Trips	4,942	4,942	4,942
Total Trips: Dan Ryan w/Extension	58,435	59,432	60,344

SKETCH PLANNING CRITERIA			
1. Annual Ridership (Dan Ryan and Extension)	17,062,728	17,354,144	17,620,448
2. New Transit Trips (CTA; One-Way CBD Trips Daily)	4,368	4,552	4,724
3. Diverted Auto Trips (One-Way CBD Trips-Daily)	-74	51	168
4. Consumer's Surplus	290,041	320,722	342,010
5. Annualized Capital & Operating Costs	$19,561,000	$28,524,000	$28,112,000
6. Total Households within Noise Impact Band	0	468	461

TABLE II

OPERATING AND CAPITAL COSTS
S.W. DAN RYAN CORRIDOR

	I-57			95th – BEVERLY			BEVERLY		
	(Amount)	Total	Annualized	Amount	Total	Annualized	(Amount)	Total	Annualized
1. Capital Cost									
a) Construction	(5.94 mi)	$63,300,000		(6.8 mi)	$110,100,000		(7.39 mi)	$118,200,000	
b) Station Construction	(5)	16,500,000		(6)	44,400,000		(7)	19,000,000	
c) R.R. Track Relocation		1,400,000			0			700,000	
d) Junctions, difficult construction		2,500,000			4,500,000			2,500,000	
e) Yards		4,803,200			5,836,800			5,836,800	
f) Shops		1,406,200			1,708,800			1,708,800	
g) Rolling Stock	(79 cars)	16,024,000		(96 cars)	43,776,000		(96 cars)	43,776,000	
h) R.R. Leasing (annual)			$ 287,700			$ 448,560			$ 803,640
TOTAL ANNUALIZED CAPITAL			$10,881,000			$18,056,000			$16,904,000
2. Operating (Extension only)									
a) Vehicle Miles			$ 7,903,793			$ 9,536,984			$10,111,679
b) Station Operations			775,900			931,080			1,086,260
ANNUAL OPERATING COSTS			8,679,693			$10,468,064			$11,208,000
3. Total Op. & Cap. Cost			$19,561,000			$28,524,000			$28,112,000
Revenue (Net Increase)			1,373,696			1,519,404			1,652,556
4. ANNUALIZED SUBSIDY			$18,187,000			$27,005,000			$26,460,000

TABLE III

RANKING OF ALTERNATIVES

SOUTHWEST DAN RYAN CORRIDOR

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	HOUSEHOLDS AFFECTED	RANK	CONSUMERS' SURPLUS	RANK
I-57	.151	1	$2,491	1	0	1	290,041	2
Beverly	.125	2	$2,578	2	461	2	342,010	1

95th Street. In addition, the I-57 alternative can be evaluated in system optimization, along with continuing the Beverly Branch commuter rail service.

CHAPTER VIII

Lake Street Corridor

Sketch planning is undertaken in the Lake Street corridor in order to determine the best improvement or replacement for the Lake Street elevated line. The alternative selected in this evaluation will serve as the single corridor improvement or 'do-something' alternative that will compete in system optimization with retaining the present Lake Street service.

I. Alternatives

Two alternatives are evaluated, both of which would allow for the abandonment of the existing Lake Street Elevated east of Laramie Avenue. Both alternatives would therefore save the capital cost of maintenance for the existing 'L' structure. Although it is not necessary to include these savings in this evaluation, capital maintenance savings are an important benefit with the implementation of either of these options.

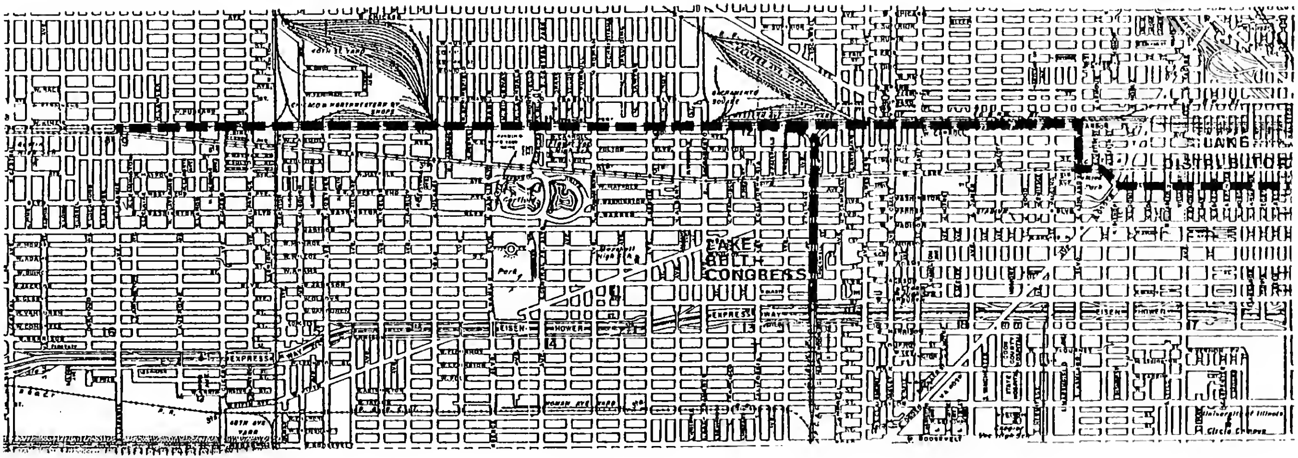
A. Lake-Belt-Congress

This alternative consists of replacing the Lake Street Elevated east of Laramie with a line following the Chicago C&NW right of way, turning south along the Belt Railroad until it meets with the Congress line on the Eisenhower Expressway. Lake trains share the existing tracks with the Congress trains and enter the CBD via the Dearborn subway. This alternative would require the construction of only one new station on the Belt right of way.

Stations:

1. Harlem(Oak Park)
2. Oak Park
3. Ridgeland
4. Austin
5. Central
6. Cicero (New)

Line joins with Congress



MAP XII
Lake Street Corridor

B. Lake Distributor

This alternative would allow the replacement of the existing 'L' by utilizing the C&NW right of way (elevated grade) starting at Laramie. At Ashland Avenue, the facility would require the construction of a subway east along Randolph Street until Des Plaines Avenue. This alternative assumes that the Lake service is routed through the Monroe Distributor line. The costs of constructing the subway until Halsted and Randolph are included in the capital costs for this evaluation, the remainder of the subway facility is therefore allocated to the Distributor subway.

Stations:

1. Harlem (Oak Park)
2. Oak Park
3. Ridgeland
4. Austin
5. Central
6. Cicero (New)
7. Pulaski (New)
8. Homan (New)
9. Western (New)
10. Ashland/Ogden (New)
11. Halsted (New)

II. Evaluation

The performance of the two alternatives is summarized in Table I. Ridership reflects total patronage on a Lake service. Since the Lake-Belt-Congress alternative joins with the Congress line at Cicero Avenue, patrons no longer have access to the Lake service east of Cicero Avenue. Lake trains could either run express or pick up additional passengers on the Congress line but this component of Congress ridership is not reported here. Since the market area of the Lake service is diminished with a Lake-Belt connection, a decrease in patronage occurs. The number of automobile trips increase and there is a slight decline in total CTA ridership. In contrast, the Lake-Distributor alternative increases the existing Lake line's patronage by five percent.

Since the Belt option is a low-cost alternative, no domination across all six sketch planning criteria occurs. Both alternatives therefore have to be compared on the basis of cost-effectiveness criteria in order to select the corridor optimal line.

TABLE I

LAKE STREET CORRIDOR EVALUATION

ONE WAY DAILY PATRONAGE	LAKE-BELT-CONGRESS	LAKE-DISTRIBUTOR
1. CBD Trips	14,153	19,899
2. Thru Trips	1,274	1,791
3. Local Trips	1,967	3,973
TOTAL DAILY ONE-WAY TRIPS	17,394	25,663
SKETCH PLANNING CRITERIA		
1. Annual Ridership	10,158,096	14,987,192
2. New Transit Trips (CTA; One-Way Daily CBD)	-370	226
3. Diverted Auto Trips (One-Way Daily CBD Trips)	-247	151
4. Consumer's Surplus	-40,886	14,966
5. Annualized Capital and Operating Costs	$ 7,958,051	$14,392,000
6. Total Households Within Noise Impact Band	0	0

TABLE II

CAPITAL AND OPERATING COSTS

	LAKE-BELT-CONGRESS			LAKE-DISTRIBUTOR		
	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST						
. Construction, right of way	(1.1 mi)	$7,000,000		(4.6 mi)	$44,300,000	
. Station construction	(1)	3,300,000		(6)	44,400,000	
. R.R. track relocation		600,000			2,400,000	
. Junctions, difficult construction	(1)	2,500,000		(1)	2,500,000	
. Yards		-			-	
. Shops		-			-	
. Rolling stock		-			-	
. R.R. leasing (annual)			$ 108,600			$ 499,560
TOTAL ANNUALIZED CAPITAL			1,204,000			8,150,000
. Vehicle miles			5,512,695			4,534,849
. Station operations			1,241,440			1,706,980
TOTAL OPERATING COSTS			$6,754,135			$ 6,241,829
. Revenue			-5,079,000			-7,494,000
ANNUAL OPERATING SUBSIDY			$1,675,000			$(1,252,000)
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$2,879,000			$ 6,898,000

III. Selection of Corridor Alternative

Table III is a full presentation of all of the capital and operating costs for the two alternatives. Since there is no increase required in the number of cars currently assigned to the Lake Street line, additional vehicle procurement is not necessary. The storage facilities at the terminal station in Oak Park will remain in use, thus no expenditures for yards or shops are listed. Operating costs are totaled for Lake Street trains to the CBD, therefore this includes the vehicle miles operated over the Congress line in the Lake-Belt alternative (Operation of Congress line stations are not included).

Table III is the comparison of performance associated with the final four criteria for each alternative. The Lake-Belt Congress is a low cost alternative that would decrease total subsidy, but would have less patronage. The final ranking therefore favors the Lake-Distributor option due to its favorable impacts on level of service (consumer's surplus) and new transit trips. The Lake-Belt alternative would represent a decrease in service and will not be selected as the single improvement alternative for this corridor. However, since the Lake-Distributor alternative depends upon the completion of a downtown distributor line (Monroe Street), the selection of a corridor optimal line is highly dependent on the future scheme for the proposed Central Area Transit Project. Therefore, the Lake-Distributor line will be selected as the corridor optimal line, but the following conditions will be noted:

1. Assuming that the Distributor is not built, the Lake-Distributor alternative will be dropped and only the Lake-Belt alternative will be compared to the existing Lake Street line in system optimization.

2. Assuming that the Distributor will be built, but at a later time; the Lake-Belt alternative could serve as a short-term improvement enabling early abandonment of the Lake Street elevated and thereby avoiding necessary capital maintenance costs.

TABLE III

RANKING OF ALTERNATIVES

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	HOUSEHOLDS AFFECTED	RANK	CONSUMERS' SURPLUS	RANK
Lake-Belt-Congress	3.53	1	No new trips	2	0	1	-40,886	2
Lake-Distributor	2.15	2	$35,062	1	0	1	14,996	1

CHAPTER IX

New Grand Avenue Line

A key question relating to the construction of a new Grand Avenue line is the best alignment for such a facility east of Cicero Avenue. Sketch planning is undertaken to select the best alignment for this new line.

I. Alternative Alignments

Two alignments are evaluated; both use the Milwaukee Road right of way from Cicero to the terminus at Franklin Park. From Cicero, either the Milwaukee Road right of way can be used until a connection with the Lake Street line near Ashland, or the Cicero Belt right of way could be used for an earlier connection to the Lake Street service. In both cases, trains would continue to the CBD sharing the Lake Street line with the existing service. The existing Milwaukee Road service is changed so that commuter trains make no stops east of Franklin Park. All of the alternatives assume that the Distributor subway would be built.

A. Milwaukee ROW

This facility would run from Franklin Park along the Milwaukee Road right of way until the intersection of the C&NW Railroad at California Avenue. From there, it would join a rebuilt Lake Street line (or could join the existing Lake Street service at Ashland/Lake) into a subway along Ashland Avenue, east along Randolph until its connection with the Distributor subway at Des Plaines Avenue.

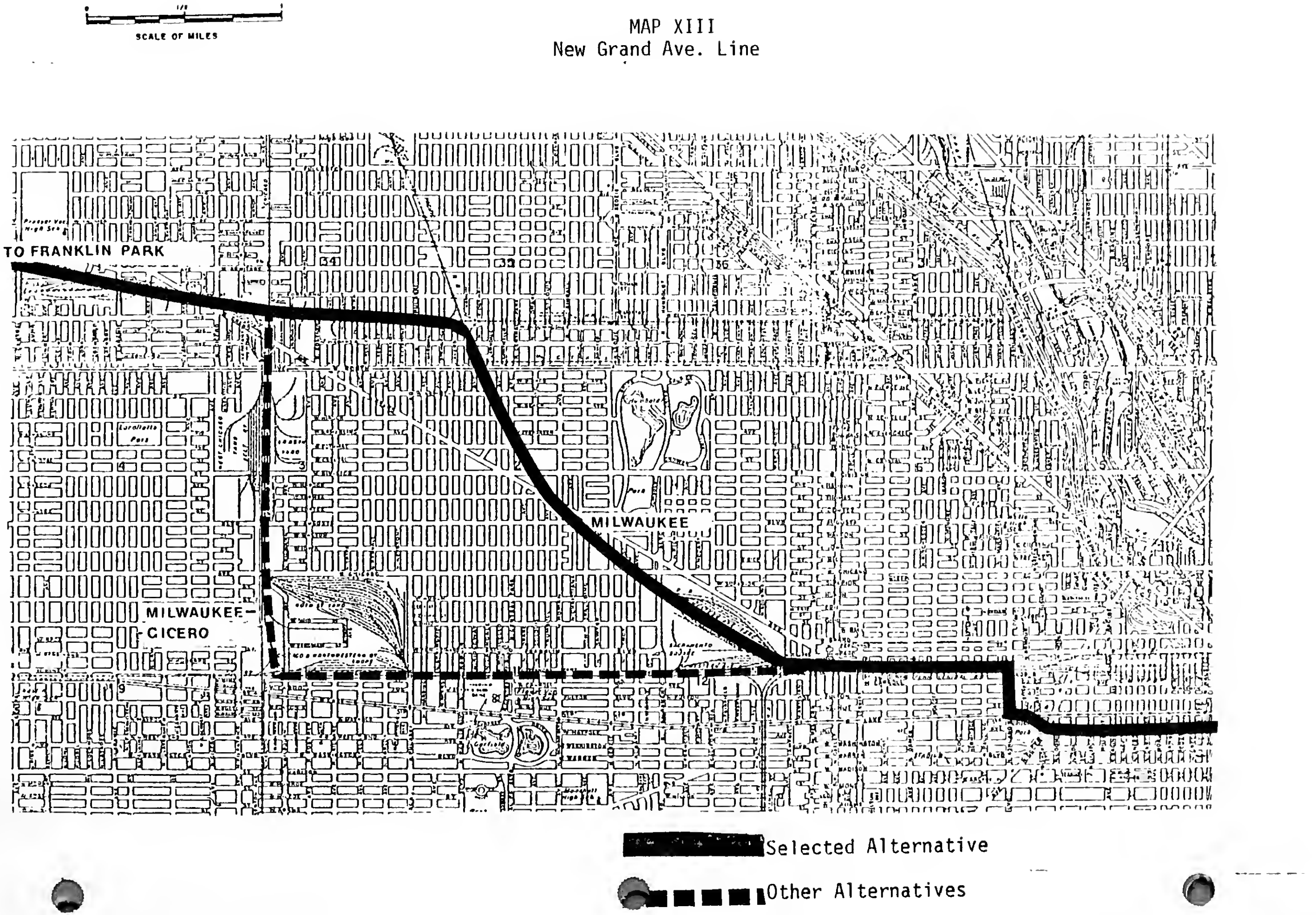
Stations:

1. 25th/Belmont(Franklin Park)
2. Pueblo/Cumberland
3. Grand/Harlem/Fullerton
4. Narragansett
5. Central
6. Cicero
7. Pulaski
8. Chicago/Kedzie/Grand
9. Western(Shared with a rebuilt Lake Street line)
10. Ashland/Ogden (Shared with a rebuilt Lake Street line)

B. Milwaukee ROW - Cicero

This facility would run from Franklin Park along the Milwaukee Road right of way to Cicero, where the Belt Railway right of way would be used to connect with either the existing or rebuilt Lake Street Line.

MAP XIII
New Grand Ave. Line



Stations:

1. 25th/Belmont(Franklin Park)
2. Pueblo/Cumberland
3. Grand/Harlem/Fullerton
4. Narragansett
5. Central
6. North/Chicago
7. Division/Cicero
8. Chicago/Cicero
9. Line joins Lake Street line (either rebuilt or existing) at Cicero.

II. Evaluation

The performance of the two alternatives is summarized in Table I. Ridership for stations on the shared portion of the Lake-Grand services is not totaled for the new Grand Avenue line. Capital and operating costs for both alternatives is given in Table II. Ridership on a Milwaukee service into the Lake-Distributor is greater than on the Milwaukee-Cicero alternative. Much of this ridership increase can be attributed to better coverage in the area near Humboldt Park. There might be some overprediction of trips from this area, however, due to this area's actual diminished orientation of trips to the CBD. However, the Milwaukee ROW alternative still offers a higher level of service in providing better travel time to the CBD. No domination occurs between the low-cost Cicero alternative and the high ridership Milwaukee ROW alternative. Both alternatives therefore have to be compared on the basis of the final four criteria in order to select the corridor alternative.

III. Selection of Corridor Alternative

Table III is a comparison of performance with respect to the selected criteria. The Milwaukee ROW alternative to connect with the Distributor subway is superior in all categories. This alternative will therefore be selected as the best alignment for a new Grand Avenue line. It should be noted that the future of this line is not dependent on the future of the Lake Street line, (since it can join either the existing or a rebuilt Lake Street facility) but it will be dependent on the construction of the Distributor subway.

TABLE I

Franklin Park-Grand Avenue Line

ONE WAY DAILY PATRONAGE	MILWAUKEE ROW	MILWAUKEE ROW - CICERO
1. CBD Trips	23,750	15,285
2. Thru Trips	4,750	1,305
3. Local Trips	5,459	2,817
Total Daily One-Way Trips	33,959	19,407

Sketch Planning Criteria		
1. Annual Ridership	19,832,056	11,333,688
2. New Transit Trips (One-Way Daily CBD Trips)	2,463	1,350
3. Diverted Auto Trips (One-Way Daily CBD Trips)	1,291	546
4. Consumer's Surplus (Time Savings; Daily one-way Equivalent Minutes-CBD Trips)	212,396	99,485
5. Annualized Capital and Operating Costs	$32,493,000	$24,259,000
6. Total Households within Noise Impact Band	0	0

TABLE II

CAPITAL AND OPERATING COSTS

GRAND AVENUE LINE

	MILWAUKEE ROW			MILWAUKEE ROW-CICERO		
	(Amount)	Total	Annualized	(Amount)	Total	Annualized
CAPITAL COST						
. Construction, right of way	(10.1 mi)	$105,900,000		(8.3 mi)	$94,400,000	
. Station construction	(10)	57,600,000		(8)	26,400,000	
. R.R. track relocation		5,400,000			4,300,000	
. Junctions, difficult construction	(2)	5,000,000		(2)	5,000,000	
. Yards		7,502,000			5,350,400	
. Shops		2,207,000			1,566,400	
. Rolling stock	(124)	56,544,000		(88)	40,128,000	
. R.R. leasing (annual)			$ 1,096,850			$ 901,380
TOTAL ANNUALIZED CAPITAL			21,197,000			15,715,000
. Vehicle miles			9,744,000			7,302,000
. Station operations			1,551,000			1,241,000
ANNUAL OPERATING COSTS			$11,296,000			$ 8,543,000
. Revenue			-9,916,000			-5,667,000
ANNUAL OPERATING SUBSIDY			$ 1,380,000			$ 2,876,000
TOTAL ANNUALIZED SUBSIDY (Capital and Operating)			$22,577,000			$18,591,000

TABLE III

RANKING OF ALTERNATIVES

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	HOUSEHOLDS AFFECTED	RANK	CONSUMERS' SURPLUS	RANK
Milwaukee ROW	.878	1	$8,606	1	0	1	212,396	1
Milwaukee-Cicero	.610	2	$11,640	2	0	1	99,485	2

CHAPTER X

North Lakefront Area

The final application of the sketch planning methodology is undertaken to screen alternatives for the North Lakefront area. However, due to the complexity of options available for the Howard and Ravenswood lines, this corridor has to be treated in a different fashion. The complexity of the North Lakefront sketch planning evaluation is caused by the following characteristics:

- Since this corridor contains two existing lines, a single do-something alternative for each line will not suffice. The performance of a new Ravenswood line, for example, will be impacted heavily by an action taken for the Howard line.

- A large number of alternatives have been proposed for replacing the existing shared right of way for the Ravenswood and Howard. These options include all possible combinations of replacing one line to a completely new right of way, or two entirely new facilities.

Given these conditions, it is necessary to evaluate every possible combination of alternatives for the North Lakefront Area. Then, in system optimization, only the non-dominated alternatives will be compared to the existing situation (present Howard and Ravenswood lines). Since any action taken for this corridor will still involve retention of both the Howard and Ravenswood services (or their equivalent), operating and equipment costs have not been included in this analysis. In addition, due to the great number of possible alignments, the computation of households within the noise impact band was not undertaken. However, since most of the new alignments specified for this corridor are subway facilities, the loss of this evaluation criterion is not significant.

I. Alternative Alignments

Each of the alternatives evaluated for the Howard and Ravenswood lines consists of a series of links or alignment segments. In addition, evaluation is undertaken for each conceivable combination of the Howard and Ravenswood alternatives. However, the listing of stations and alignment is presented by each link and not by the entire length of each alternative.

A. Ravenswood Alternatives

1. New Lincoln Avenue Line

Several of the options for improving the Ravenswood service include a new subway facility to run from the existing Ravenswood elevated structure, down Lincoln Avenue to Belmont and Ashland.

Stations:

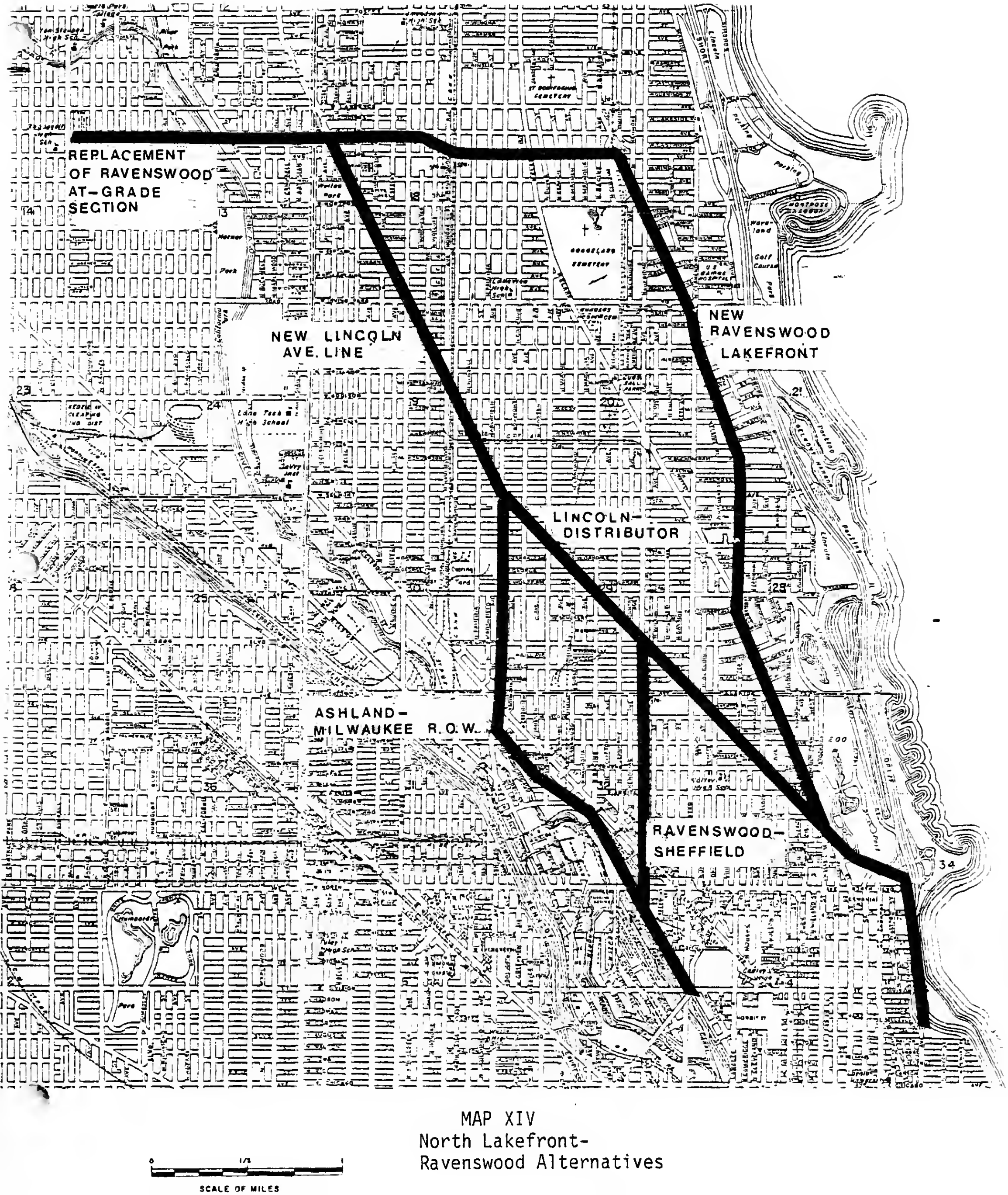
1. Wilson/Lincoln
2. Irving Park/Lincoln
3. Addison/Lincoln
4. Belmont/Ashland

2. Ashland-Milwaukee ROW

This facility would serve as a new connection from a new Lincoln Avenue subway to the Franklin Street line. The alignment would be a subway from Belmont and Lincoln and continue south on Ashland Avenue until Clybourn. At that point, the facility would emerge and use the Milwaukee Road right of way until its connection with the proposed Franklin Street subway.

Stations:

1. Ashland
2. Armitage/Clybourn



MAP XIV
North Lakefront-
Ravenswood Alternatives

3. Ravenswood-Sheffield

This subway would continue the Lincoln Avenue line from Belmont and Ashland, turn south on Sheffield (under the existing North-South elevated) until its connection with the proposed Franklin Street line.

Stations:

1. Diversey
2. Fullerton

4. Lincoln-Distributor

This facility would be a subway connecting the proposed Lincoln Avenue line north of Belmont to the northern terminus of the proposed downtown Distributor Subway. From Belmont and Ashland the subway would continue on Lincoln to Wells and Clark, and then connect with the Distributor via LaSalle and Lake Shore Drive.

Stations:

1. Diversey/Lincoln
2. Lincoln/Sheffield
3. Fullerton/Lincoln
4. Clark/Lincoln
5. North/Lake Shore Drive
6. Division/Michigan

5. Replacement of Ravenswood At-Grade Section

This alignment would consist of a completely new elevated structure to replace the existing Ravenswood at-grade section of track from Western to Kimball.

Stations:

1. Kimball
2. Kedzie
3. Western

6. New Ravenswood Lakefront

This line would be a completely new alignment for the entire Ravenswood Service east of Western Avenue. From the existing Ravenswood alignment, it would run as an elevated structure on Wilson Avenue. Near the existing Howard elevated it would become a subway and turn south on Broadway. The subway would continue to Diversey, then to Lincoln and Wells via Clark, and then use LaSalle and Lake Shore

Drive until its connection with the northern terminus of the proposed Distributor subway on Michigan Avenue.

Stations:

1. Wilson/Clark
2. Montrose
3. Sheridan/Clarendon
4. Addison
5. Belmont/Broadway
6. Diversey/Broadway/Clark
7. Fullerton/Clark
8. Armitage
9. North/Lake Shore Drive
10. Division/Michigan

B. Howard Alternatives

1. Sheffield-Clark

This would be a completely new facility for the Howard line south of Lawrence. From Lawrence to Addison, the Milwaukee Road right of way would be used for a new elevated structure. At Roscoe, the line would be a subway under Clark to Division where it would then connect with the existing State Street subway.

Stations:

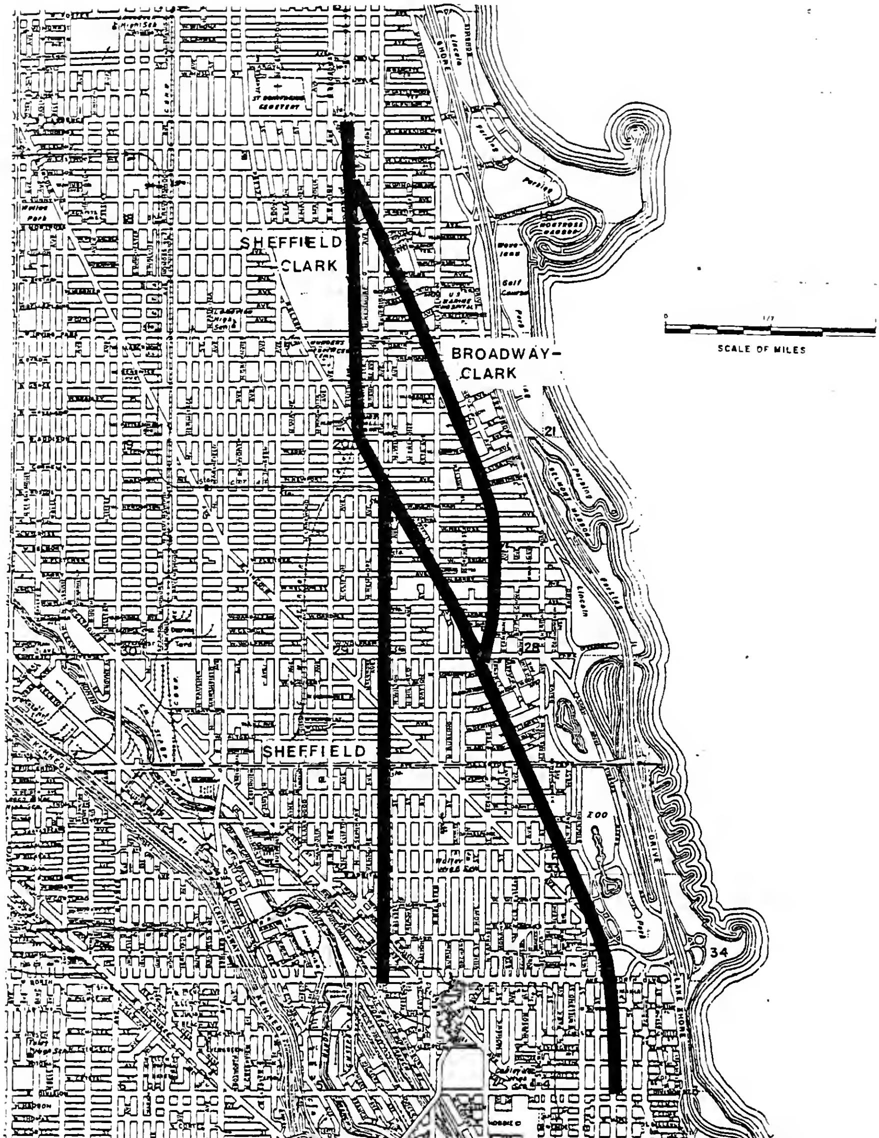
1. Irving Park
2. Addison
3. Belmont/Halsted
4. Fullerton
5. Armitage
6. North
7. Clark/Division (existing)

2. Broadway-Clark

This facility would also be a completely new subway for the Howard line. From Wilson to Diversey it would run under Broadway, then continue the rest of the way via Clark to Division where it would connect with the existing State Street subway.

Stations:

1. Wilson
2. Sheridan/Clarendon
3. Addison/Broadway
4. Belmont/Broadway
5. Diversey/Broadway
6. Fullerton
7. Armitage
8. North
9. Clark/Division (existing)



MAP XV
North Lakefront-
Howard Alternatives

3. Sheffield

This facility would be a new subway under Sheffield, therefore located along the same route as the existing elevated structure. A new elevated structure would be built along the Milwaukee right of way south of Lawrence to Clark and Roscoe. From there, the facility would be a subway under Sheffield connecting to the existing portal for the State Street subway.

Stations:

1. Wilson	3. Addison	5. Fullerton
2. Irving Park	4. Belmont	

C. Corridor Alternatives

The complete set of all possible combinations for the north lakefront area is presented in Table I. Each of these combinations is treated as a single alternative. The alternative for retention of both the existing Howard and Ravenswood facilities is not evaluated in sketch planning but instead will be treated as an alternative in system optimization. The alternatives for a Lakefront Ravenswood line with either a Sheffield-Clark or Broadway-Clark alignment for Howard will not be evaluated because such an alternative would have both of these lines within too narrow a band along the eastern edge of the area.

II. Sketch Planning Evaluation

Since improvements to both lines are being evaluated, performances measures for all categories are developed for the entire corridor (both lines). Table II presents ridership broken down by component for each of the corridor alternatives. Demand for the two lines as a whole increases when at least one of the services is relocated to the eastern edge of the area. The Ravenswood service performs poorly when placed further west along the Ashland-Milwaukee ROW alignment.

Table III is a full presentation of the sketch planning criteria for each of the seventeen corridor alternatives. Capital costs were estimated and annualized for construction, stations, and necessary railroad right of way leasing. In addition, the cost of maintaining the existing North-South

TABLE I

North Lakefront Alternatives

Combination #	Ravenswood Alternative	Ravenswood Link #	Howard Alternative	Howard Link #
A-1	Existing	-	Existing	-
A-2	"	-	Sheffield	3
A-3	"	-	Sheffield-Clark	1
A-4	"	-	Broadway-Clark	2
B-1	Ashland-Milwaukee Row	1,2,5	Existing	-
B-2	"	1,2,5	Sheffield	3
B-3	"	1,2,5	Sheffield-Clark	1
B-4	"	1,2,5	Broadway-Clark	2
C-1	Sheffield	1,3,5	Existing	-
C-2	"	1,3,5	Sheffield	3
C-3	"	1,3,5	Sheffield-Clark	1
C-4	"	1,3,5	Broadway-Clark	2
D-1	Lincoln	1,4,5	Existing	-
D-2	"	1,4,5	Sheffield	3
D-3	"	1,4,5	Sheffield-Clark	1
D-4	"	1,4,5	Broadway-Clark	2
E-1	Lakefront	5,6	Existing	-
E-2	"	5,6	Sheffield	3

TABLE II

Daily One-Way Ridership

Corridor Alternatives	A-2	A-3	A-4	B-1	B-2	B-3
Ravenswood Ridership	Existing	Existing	Existing	Ashland-Milwaukee Row	Ashland-Milwaukee Row	Ashland-Milwaukee Row
CBD	12,454	11,590	11,600	11,164	11,137	11,091
Thru	1,401	1,303	1,305	1,255	1,253	1,248
Local	4,669	4,669	4,669	3,500	3,500	3,500
Total	18,524	17,562	17,574	15,919	15,890	15,839
Howard Ridership	Sheffield	Sheffield-Clark	Broadway-Clark	Existing	Sheffield	Sheffield-Clark
CBD	44,119	51,398	47,653	41,798	43,915	52,930
Thru	8,700	10,135	9,397	8,243	8,660	10,438
Local	5,860	5,907	7,524	5,860	5,860	6,159
Total	58,679	67,440	64,574	55,901	58,435	69,527
Corridor Total	77,203	85,002	82,148	71,820	74,325	85,366

TABLE II - Continued

Daily One-Way Ridership

Corridor Alternative	B-4	C-1	C-2	C-3	C-4	D-1	D-2
Ravenswood Ridership	Ashland-Milwaukee ROW	Sheffield	Sheffield	Sheffield	Sheffield	Lincoln	Lincoln
CBD	11,964	14,519	9,933	10,592	11,258	21,769	22,125
Thru	1,346	1,633	1,117	1,192	1,267	2,449	2,489
Local	3,500	4,411	4,411	4,411	4,411	5,704	5,704
Total	16,810	20,563	15,461	16,195	16,936	29,922	30,318
Howard Ridership	Broadway-Clark	Existing	Sheffield	Sheffield-Clark	Broadway-Clark	Existing	Sheffield
CBD	48,291	40,571	43,988	52,729	48,282	36,662	38,473
Thru	9,523	8,001	8,676	10,398	8,700	7,230	7,587
Local	7,524	5,860	5,860	5,907	7,524	5,860	5,860
Total	65,338	54,432	58,524	69,034	64,506	49,752	51,920
Corridor Total	82,148	74,995	73,985	85,229	81,442	79,674	82,238

TABLE II - Continued

Daily One-Way Ridership

Corridor Alternative	D-3	D-4	E-1	E-2
Ravenswood Ridership	Lincoln	Lincoln	Lakefront	Lakefront
CBD	18,822	18,810	31,909	31,044
Thru	2,117	2,116	3,589	3,492
Local	5,704	5,291	5,606	5,291
Total	26,643	26,217	41,104	39,827
Howard Ridership	Sheffield-Clark	Broadway-Clark	Existing	Existing
CBD	49,824	50,356	32,322	37,342
Thru	9,825	9,930	6,374	7,364
Local	5,907	6,430	5,860	5,860
Total	65,556	67,016	44,556	50,566
Corridor Total	92,199	93,233	85,660	90,393

TABLE III

North Lakefront Corridor Evaluation

Sketch Planning	A-2	A-3	A-4	B-1	B-2
1. Annual Ridership	45,087,000	49,641,000	47,974,000	41,943,000	43,406,000
2. New Transit Trips (One-Way Daily)	744	2,029	1,773	-186	584
3. Diverted Auto (One-Way Daily)	497	1,356	1,185	-124	390
4. Consumer's Surplus (Time Savings: Daily One-Way Equvalent Minutes-CBD trips)	45,208	107,227	98,245	-19,517	-33,527
5. Annualized Capital Costs	$11,156,000	$17,345,000	$17,852,000	$16,794,000	$27,952,000

TABLE III

North Lakefront Corridor Evaluation

Sketch Planning Criteria	A-2	A-3	A-4	B-1	B-2
1. Annual Ridership	45,087,000	49,641,000	47,974,000	41,943,000	43,406,000
2. New Transit Trips (One-Way Daily)	744	2,029	1,773	-186	584
3. Diverted Auto Trips (One-Way Daily)	497	1,356	1,185	-124	390
4. Consumer's Surplus (Time Savings: Daily One-Way Equivalent Minutes-CBD trips)	45,208	107,227	98,245	-19,517	-33,527
5. Annualized Capital Costs	$11,156,000	$17,345,000	$17,852,000	$16,794,000	$27,952,000

TABLE III - Continued

North Lakefront Corridor Evaluation

Sketch Planning Criteria	B-3	B-4	C-1	C-2	C-3
1. Annual Ridership	49,854,000	47,974,000	43,797,000	43,207,000	49,773,000
2. New Transit Trips (One-Way Daily)	1,908	1,651	-204	-179	1,966
3. Diverted Auto Trips (One-Way Daily)	1,275	1,103	-136	-120	1,314
4. Consumers Surplus (Time Savings: Daily One-Way Equivalent Minutes-CBD trips)	91,578	80,836	-62,799	-569,270	92,521
5. Annualized Capital Costs	$34,139,000	$34,646,000	$16,283,000	$27,219,000	$33,632,000

TABLE III - Continued

North Lakefront Corridor Evaluation

Sketch Planning Criteria	C-4	D-1	D-2	D-3	D-4	E-1	E-1
1. Annual Ridership	47,562,000	46,530,000	48,027,000	53,844,000	54,273,000	50,025,000	52,790,000
2. New Transit Trips (One-Way Daily)	1,705	2,328	2,847	4,063	4,249	3,305	3,920
3. Diverted Auto Trips (One-Way Daily)	1,139	1,556	1,902	2,715	2,839	2,208	2,619
4. Consumer's Surplus	81,345	129,345	155,341	214,833	230,261	174,019	207,394
5. Annualized Capital Costs	$34,139,000	$26,596,000	$34,706,000	$40,895,000	$41,401,000	$27,643,000	$33,202,000

structure from Armitage to Lawrence was annualized over a fifty year period and added to those corridor alternatives which necessitate retention of this segment.

Based on the five sketch planning criteria, the following nine corridor alternatives listed in Table I are dominated and therefore rejected: A-4, B-1, B-2, B-3, B-4, C-1, C-2, C-3, C-4, D-2. The alternatives that remain consist of the following combinations for the Howard and Ravenswood lines:

Ravenswood	Howard
1. Existing	Sheffield
2. Existing	Sheffield-Clark
3. Lincoln	Existing
4. Lincoln	Sheffield/Clark
5. Lincoln	Broadway-Clark
6. Lakefront	Existing
7. Lakefront	Sheffield

Adding the situation for retention of both the existing Howard and Ravenswood services results in eight alternative combinations to be evaluated in system optimization. This will be accomplished by having three alternatives for the Ravenswood service (Lincoln, Lakefront, and existing) and four alternatives for the Howard service (Sheffield, Sheffield-Clark, Broadway-Clark, and existing). Constraints will be developed to restrict the combination of alternatives to the seven situations above.

APPENDIX A

The following is a summary of estimation methods for the relevant criteria in sketch planning. Sources with further explanation are noted wherever necessary.

I. Patronage

A. CBD Trips

CBD trips are obtained from the SONARRTA Network Evaluation Package. This is a computer coded network that represents the existing and all possible future configurations for the regional commuter rail and rapid transit system. Integrated with the network is a CBD trip demand model. The network has the capability of providing line by line entering volumes for commuter rail and rapid transit in addition to total automobile trips to the CBD. Further information regarding the network and the CBD demand model is contained in Part 1 of the SONARRTA Phase I Final Report.

B. Local Trips

This is a linear model that predicts local trips (trips not destined for the CBD) for rapid transit lines on the basis of population and line length. The basic rationale and validation of the model is contained in Lee, Permut, Methods of Predicting Local Demand for New Rapid Transit Services, RTA Technical Report 75-03. Using 1975 population and ridership volumes, the model was recalibrated for the sketch planning evaluation;

$$Y = 129.76 + 0.015X \qquad R^2 = .97$$

Where Y = Number of local trips per mile

X = Population density in a service area band within one mile of a rapid transit service.

C. Thru Trips

Thru trips are those trips on the rapid transit system that originate on a line and pass through the CBD for a destination on another rapid transit line. Calculation of these trips assume that a constant ratio of CBD trips to thru trips within a corridor. For entirely new lines, the system-wide ratio for CBD to thru trips is used. The validation of the thru trip factor is given in SONARRTA Working Paper #5.

II. New Transit Trips, Diverted Auto Trips

These totals are calculated based on the SONARRTA Evaluation Package. A base figure for total CTA trips and automobile trips to the CBD is obtained for the existing commuter rail and rapid transit system. Changes in the total number of trips for automobile and CTA is then attributed to an alternative by subtracting the alternative system's totals from the base system figures.

III. Consumer's Surplus

Consumer's surplus is used to measure user benefits for transportation services. It is based on the "willingness to pay" concept from welfare economics, whereby the net benefit which accrues to the actual consumers from their consumption of a good is the difference between what they are willing to pay and what they actually pay. The basic theory and rationale for use in SONARRTA along with further background sources are included in SONARRTA Working Paper #3. The formula that is the basis of calculation is integrated into the SONARRTA Evaluation Package;

$$CS = \frac{1}{2} \sum_{\substack{\text{all} \\ \text{zones}}} \sum_{\substack{\text{all} \\ \text{modes}}} (T^1 + T)\ (C - C^1)$$

Where
CS = Consumer Surplus
T = Total trips on rapid transit on the base (existing) system
T^1 = Total trips on rapid transit on the new (alternative) system
C = Travel cost (time and fare) under the base system
C^1 = Travel cost under the alternative system

Travel cost includes all components of a trip time (access to a station, waiting, line haul, downtown station egress) and is obtained by valuing time at four cents a minute and adding to the fare. The calculation of consumer surplus is achieved by obtaining T^1 and C^1 by zone for each alternative system and then calculating the above formula using T and C obtained from the base system. The totals given in the sketch planning tables are in time units (equivalent minutes).

IV. Capital Costs

Capital cost figures are based on Permut, Zimring, Capital and Operating Costs for the Replacement and Expansion of the Chicago Rapid Transit System, RTA TR-75-02. The following is a summary by each category:

A. Construction Type / Per-Mile Unit Cost ($Millions, 1975 dollars)

Construction Type	Per-Mile Unit Cost ($Millions, 1975 dollars)
Tunnel	28.7
Cut and Cover	16.6
Elevated	16.0
At-Grade	6.4

B. Stations / Unit Cost ($Millions, 1975 dollars)

Stations	Unit Cost ($Millions, 1975 dollars)
Underground	15.6
Elevated	3.3
At-Grade	3.3

C. Right of Way Acquisition

City owned rights of way over streets are considered free. Estimated cost of relocating railroad track in order to provide rapid transit service on the same right of way is estimated at $264,000 per track mile.

D. Junctions, Difficult Construction

Major junctions that require interlocking system's are estimated at $2.5 million dollars. Subway crossings under depressed expressways require an additional $2.0 million. Junctions between depressed expressway median lines and subway lines cost $4.5 million. Replacing an operating elevated structure with another elevated structure on the same right of way while continuing operation has been roughly estimated at doubling the construction cost due to the necessity for staging.

E. Yards

The cost of a yard is based on the following formula:

1) $\frac{2x50}{5280}$ = .019 miles of track required for each car stored.

2) Per mile cost of single at-grade track = $3.2 million per mile.

3) .019 x $3.2 million = $60,800 per car.

F. Shops

Capital cost is $17,800 per car serviced on the line.

G. Rolling Stock

$456,000 per rapid transit car.

H. Railroad Right of Way Leasing

Annual cost, based on the 1975 cost of CTA leasing the C&NW right of way in Oak Park, is $108,600 per mile.

V. Annualization of Capital Costs

Capital costs are annualized by multiplying capital cost expenditures by the appropriate capital recovery factor;

$$\frac{i\ (1+i)^n}{(1+i)^n - 1}$$

Where i is the interest rate (8% for sketch planning) and n is equal to the service life of the facility. The service lives for the appropriate facility are as follows;

a) Station facilities, subway, steel elevated structure and at-grade track - 50 years.

b) Shops, yards, rolling stock - 35 years.

VI. Operating Costs

Determination of operating costs is completed on a line specific basis. In order to develop vehicle mileage estimates, the equipment needs (number of rapid transit cars) must be estimated.

A. Equipment Needs Model

Estimation of required rolling stock is necessary for the calculation of operating cost in addition to the capital cost for vehicle procurement. The following model, developed by Hurter, is utilized;[1]

Definitions

f = peak unidirectional one hour flow at CBD cordon
k = vehicle capacity
R = round trip travel time (endpoint-CBD-endpoint) in hours

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[1] Hurter, A.P. "Mass Transit Cost" - Appendix B, Zerbe, Croke editors, Urban Transportation for the Environment, Cambridge, 1975.

n_p = number of cars per train in peak

N_c = number of cars required by line

Trains required $= N_t^1 = f \cdot R/_{knp}$ (N_t^1 is an integer and always rounded up)

If round trip time is greater than an hour, an additional train is needed to make sure peak service is provided on all parts of the line throughout the rush hour period.

Therefore;

Total trains required $= N_t^* = N_t^1 + 1$ if $R > 1$

$$N_t^* = N_t^1 \text{ if } R \leq 1$$

Total peak vehicle needs is calculated by the number of cars per train multiplied by the trains required, with a 10% reserve fleet of spares;

$$N_c = (1.1)\ (N_t^*)\ (n_p)$$

For all new lines, number of cars per train was set at eight and vehicle capacity was estimated at 70 passengers per car.[2]

Round trip time to the CBD and back is half the actual round trip time for a connected line. Use of this trip time is approximately half of what an actual connected line's round trip time is through the CBD and back (since most rapid transit lines are connected to another radial line). Use of only a single line's travel time to the CBD and back will under-estimate a total connected line's equipment needs by approximately one-half. However, on a connected line basis, half of the equipment is allocated to each matched line. Therefore, this method can be used to calculate car requirements for individual lines. (It is assumed that all proposed radial lines will be connected through the CBD with another radial line).

Peak unidirectional one hour flow was estimated from the SONARRTA network. A factor was developed for the ratio of one hour flow to total CBD and thru trips (The SONARRTA CBD cordon area includes actual CTA max load points). For most

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[2] Zimring, Marda - Study of the Impact of Staggered Work Hours on Public Transportation, RTA Technical Report - 75-05.

radial lines, this ratio was found to be twenty five percent, i.e., one hour max flow is generally one quarter of total one way daily CBD and thru destined trips.

B. Vehicle Miles

Once rolling stock requirements were calculated, vehicle mileage per year by line was estimated. This was completed by assuming eight car trains to be operated at the rush hour headway four hours daily and off-peak two car train operation for the rest of the day assuming eight minute headways. Daily vehicle mileage was annualized by assuming Saturday and Sunday together equal to one average weekday. A $1.36 per vehicle mile cost was used for the 1975 cost of rail operations (not including station operations).[3]

C. Station Operations

Cost of annual station operations was estimated at $155,180 per station.[4]

VII. Revenue

Revenue was calculated by assuming that ninety percent of the patrons would pay a full fare (50¢) and the remainder would pay half fare (student, senior citizens, and handicapped). Daily one way ridership was doubled and annualized in order to calculate annual revenue for a rapid transit line.

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[3] Permut, Zimring, Capital and Operating Costs.

[4] Ibid.

APPENDIX B

The sketch planning results as reported in the previous chapters were distributed as a separate working paper to representatives of the regional planning agencies and rail operators. Comments were received from the Northeastern Illinois Planning Commission, Chicago Area Transportation Study, City of Chicago Department of Public Works, Illinois Department of Transportatation, and the Chicago Transit Authority. Based on the comments received, further analysis was undertaken for some of the selected alternatives. A summary of this subsequent analysis is summarized in this appendix.

Chapter IV: Douglas Corridor

The selected alternative for this corridor was further investigated due to its alignment through Douglas Park along Ogden Avenue. Because of difficulties in justifying new transportation facilities through urban parkland and requirements of the environmental impact review, some of the agencies expressed concern that such an alignment was not realistic.

Based on discussions with Environmental Protection Agency staff, no change in the selected alternative for this corridor will be made. The retention of this alternative is based on the following observations:

1) Since the alignment would be built over an existing avenue that already cuts through Douglas Park, the environmental aspects of the facility will not be subject to as detailed scrutiny as an entirely new separate right of way.

2) Subway construction through the park would be perfectly acceptable from an environmental standpoint. Since the costs of cut and cover construction are approximately equal to elevated construction (without stations), the basic analysis is not affected.

3) If it is determined that the facility can not be placed in Douglas Park, an alternate alignment that avoids the park but is placed in the same general vicinity would have approximately equal patronage and cost figures as the Ogden alignment.

Chapter V: Southwest Corridor

Two major comments were made concerning the selection of an alternative for this corridor: 1) An elevated facility along Archer Avenue was not considered and 2) With respect to the choice of alignments between Stevenson and Archer, since the costs and patronage are so different, one alignment can not possibly serve as representative of a new facility for this corridor.

Based on discussions with City of Chicago Department of Public Works staff, it was found that an elevated alignment for Archer Avenue is being considered as part of the Southwest Corridor Study. However, the feasibility of constructing such a facility is still very much in doubt due to the narrow width of Archer Avenue in certain critical locations. An elevated alternative will therefore not be a likely representative of a future rapid transit facility for this corridor.

With respect to the second observation, it is apparent that one alternative cannot serve as the do-something alternative for this corridor. The selection of an alternative for this corridor would be heavily influenced by available funding. Since the consideration of budget levels is undertaken only in system optimization (Phase II of the study), the sketch planning alternatives should consist of a wide range of capital projects with respect to costs and benefits.

For this reason, two mutually exclusive alternatives will be specified from this corridor for system optimization. In addition to the Franklin-Stevenson alignment that has already been selected, the Franklin-Archer-Harlem alternative will also be kept as a do-something alternative for this corridor. Franklin-Archer-Harlem has the second best ranking of all of the alternatives in this corridor and is representative of the alternative for subway construction along Archer Avenue. The inclusion of these two alternatives in system optimization will have these important benefits:

1) In evaluating alternatives for capital rail projects, the selection of an alternative for the Southwest Corridor will not be strictly decided by a high or low funding level.

2) The Franklin-Stevenson and Franklin-Archer-Harlem alternative represent the full range of inexpensive median strip to expensive subway construction for this corridor, thereby permitting evaluation on a more realistic basis.

In addition, one other observation was made for improving the Archer alignment so that better access would be provided to the Midway Airport terminal. This can be accomplished by subway construction under the airport instead of elevated construction to the north of the airport. This would increase the cost of an Archer facility by approximately 25 million dollars. Since this is only a marginal increase in the cost of an Archer subway, an airport terminal subway station will be considered a feasible option for the Southwest Corridor but need not be explicitly evaluated in Phase II of the study.

<u>Chapter VI</u>: Lakefront Corridor

An observation was made that a new South Lakefront line would increase ridership on the existing Dan Ryan line which is currently operating near capacity at the present time. In the patronage analysis for a new South Lakefront line, it was found that the Dan Ryan line would experience a ten per cent increase in peak hour ridership. However, assuming two and a half minute headways (Dan Ryan currently operates at three minute peak headways) and present loadings, the Dan Ryan could absorb a twenty per cent increase in peak hour ridership. The trade-offs of increasing volumes on the Dan Ryan must be evaluated along with the benefits of increased service to the southeast with a new line. Therefore, the ICG-Penn alignment will be retained as the do-something alternative. It should also be noted that the option of retaining the existing Jackson Park-Englewood line will also be evaluated in system optimization.

Chapters VII and IX: Grand and Lake Street Corridors

Concern was raised about the evaluation of both the Lake Street and proposed Grand Avenue lines without accounting for the interdependence of benefits and capital costs between these lines. Although the issue of interdependence among all lines will be explicitly evaluated in Phase II of the study, it has a significant impact with respect to the choice of alternatives for these two corridors. For this reason, further analysis was undertaken for alternatives in these two corridors.

Instead of evaluating each corridor individually, patronage and costs were estimated for all possible combinations of alternatives. The feasible combinations of alternatives consist of a Grand-Milwaukee right of way alignment with either an existing, rebuilt (Distributor), or relocated (on the Belt R.R.) Lake Street service or a Grand-Belt alternative with an existing or rebuilt Lake Street service. The option of a Grand-Belt and Lake-Belt combination was not evaluated since it is not possible to have both of these services on the Congress line.

Tables I and II summarize the results of the combined corridor evaluation. Costs and patronage were estimated for both facilities. Capital maintenance savings for the existing Lake Street line were subtracted from alternatives that involve abandonment of the Lake Street elevated structure east of Laramie. Operating costs and the costs of vehicle procurement was not calculated for this analysis.

The Grand-Milwaukee, Lake-Belt alternative is dominated within the five sketch planning criteria so that the performance rankings are only completed for the four remaining alternatives in Table II. As can be seen, a Grand-Milwaukee alternative performs better than the Grand-Belt alternative when combined with the existing Lake Street service (as proven in Chapter 9) but is fairly even in rankings with a Grand-Belt alternative with respect to a rebuilt Lake Street line. Since the Grand-Milwaukee alternative shows slight superiority over a Grand-Belt alignment in combination with the Lake service alternatives, it will be retained as the do-something alternative for this corridor. Furthermore, the Lake-Belt alternative is found to be inferior to the Lake-Distributor alternative so that the conclusions of Chapter VII remain unchanged.

Chapter X: North Lakefront Area

An observation was made that all of the new Ravenswood alternative would use the distributor subway as a connection to the CBD while the Franklin line would be unused. This was found to be unrealistic since it is likely that a Franklin Street subway would be built before the Monroe distributor subway. Several solutions to this problem were investigated.

TABLE I

EVALUATION OF GRAND AND LAKE ALTERNATIVES

ONE-WAY DAILY PATRONAGE (Total, Grand and Lake Lines)	GRAND-MILWAUKEE EXISTING LAKE	GRAND-MILWAUKEE LAKE-DISTRIBUTOR	GRAND-MILWAUKEE LAKE-BELT-CONGRESS
1. CBD Trips	33,627	33,857	32,250
2. Thru Trips	5,593	5,533	5,614
3. Local Trips	7,702	8,036	6,796
Total Daily One-Way Trips (Grand and Lake)	46,922	47,426	44,660

SKETCH PLANNING CRITERIA	GRAND-MILWAUKEE EXISTING LAKE	GRAND-MILWAUKEE LAKE-DISTRIBUTOR	GRAND-MILWAUKEE LAKE-BELT-CONGRESS
1. Annual Ridership	27,402,448	27,696,784	26,081,440
2. New Transit Trips (One-Way Daily CBD Trips)	2,463	2,605	2,304
3. Diverted Auto Trips (One-Way Daily CBD Trips)	1,291	1,386	1,184
4. Consumer's Surplus	212,396	220,512	201,583
5. Annualized Capital Costs	$17,338,000	$19,670,000	$17,628,000

TABLE I

EVALUATION OF GRAND AND LAKE ALTERNATIVES
(Continued)

ONE-WAY DAILY PATRONAGE (Total, Grand and Lake Lines)	GRAND-BELT EXISTING LAKE	GRAND-BELT LAKE-DISTRIBUTOR
1. CDB Trips	25,647	32,155
2. Thru Trips	3,377	4,623
3. Local Trips	5,725	5,485
Total Daily One-Way Trips (Grand and Lake)	34,749	42,263

SKETCH PLANNING CRITERIA	GRAND-BELT EXISTING LAKE	GRAND-BELT LAKE-DISTRIBUTOR
1. Annual Ridership	20,293,416	24,681,592
2. New Transit Trips (One-Way Daily CBD Trips)	1,350	980
3. Diverted Auto Trips (One-Way Daily CBD Trips)	546	655
4. Consumer's Surplus	99,485	220,621
5. Annualized Capital Costs	$11,535,000	$16,792,000

TABLE II

RANKING OF ALTERNATIVES

ALTERNATIVE	ANNUAL RIDERS / ANNUAL SUBSIDY DOLLAR	RANK	CAPITAL DOLLARS (Ann) / DAILY NEW TRANSIT TRIPS	RANK	CONSUMERS' SURPLUS	RANK	SCORE
Grand-Milwaukee Existing Lake	1.580	2	$ 7,039	1	212,396	3	6
Grand-Milwaukee Lake-Distributor	1.408	4	$ 7,551	2	220,512	2	8
Grand-Belt Existing Lake	1.759	1	$ 8,544	3	99,485	4	8
Grand-Belt Lake-Distributor	1.470	3	$17,135	4	220,621	1	8

One solution would be to consider a three line north lakefront system (i.e., Howard, Ravenswood, and Lakefront). However, after studying previous proposals for this corridor, it was found that a lakefront line was never considered as a third, independent service but only as a new alignment for either the Ravenswood or Howard (Broadway-Clark alignment).

Instead of analyzing a three line system, the option of splitting the Howard service into the Franklin and State Street tubes was studied. This would be an option only when the Ravenswood would be routed through the Distributor subway. Capital costs would increase only marginally (cost of inter-locking) since the cost of the Franklin subway below North Avenue is allocated to the CUTD project. Patronage would also be approximately equal for a split Howard service.

The specification of alternatives for the North Lakefront area was checked again to insure that splitting of the Howard service would be feasible. The Lincoln-Sheffield Clark and Lincoln-Broadway Clark alternatives were rejected because these alternatives would necessitate two separate tunnels for the Howard service north of North Avenue. Since costs and patronage for the remaining alternatives are the same as reported in Chapter X, the same set of non-dominated solutions (without the two rejected alternatives) is presented below:

Ravenswood	Howard
1. Existing	Sheffield
2. Existing	Sheffield-Clark
3. Lincoln	Existing(Howard split service)
4. Lakefront	Existing(Howard split service)
5. Lakefront	Sheffield(Howard split service)

Adding the retention of both the existing Howard and Ravenswood services results in six alternative combinations to be evaluated in system optimization.