OFF-PEAK HOUR TRANSIT ROUTING

by

Thomas J. Ross

and

Eugene M. Wilson

July 1975

Technical Report #46

Center for Urban Transportation Studies
Institute of Urban and Regional Research
University of Iowa

This report was produced as part of a program of Research and Training in Urban Transportation sponsored by the Urban Mass Transportation Administration of the Department of Transportation.

INTRODUCTION

This research involved the design of an off-peak hour routing methodology for a major, non-CBD, retail center in Cedar Rapids, Iowa. The purpose was to develop, through the flexible-fixed system concept, a technique which allows off-peak hour bus routing to be designed to meet off-peak travel demands associated with an activity center. The technique developed to accomplish this purpose was based on the concept of providing transit service to the trade area of retail center. The premise of this routing scheme is that during the off-peak hour, transit should take on a local style of service providing mobility oriented to the types and locations of trips occuring during this period.

The technique developed contains four basic segments: selection of activity center(s); identification of trip making characteristics to the activity center during the off-peak hours by an on-site survey; identification of spatially significant characteristics of the population and its travel behavior; and the establishment of service levels for route design.

The flexible-fixed transit routing system, on which this technique was based, was developed to service two distinct transportation markets: peak hour travel and off-peak hour travel. This method of routing uses two sets of fixed routes. One set is provided for the peak hour trips (work trips) and the second set operates during the off-peak hours (shopping, medical-dental, and personal business trips). While the system operates on two fixed routings, it is flexible because it changes from peak to off-peak and then back to peak hour configurations. The key element within the flexible-fixed concept is that the routing is oriented toward servicing major urban activity centers which attract off-peak hour trips and employment centers which attract the peak hour work-trips. Conceptually, this simplifies the problem of providing effective transit routing. By recognizing the spatial concentrations of employees and trade areas for retail and other tertiary activity centers, bus routing may be adjusted by time of day to connect major centers of trip attractions with residential trip productions.

ROUTE DESIGN TECHNIQUE

The process-of-elimination technique makes use of survey and census data to identify areas (traffic zones in this case) whose characteristics justify the provision of transit service to an activity center. By systematically eliminating areas of potentially low transit ridership only zones of high ridership potential will remain in the final route determination. The first major step defines the trade area of the retail and tertiary activities. This study analyzes only one such concentration. Those zones outside the trade areas are eliminated from further consideration. The trade area was defined according to trip frequency to the Plaza based on survey data. Those regions with low use were eliminated. Routes were developed on the basis of serving the most "favorable" zones constrained by route operational criteria. The characteristics of the alternate routes were compared and an optimal routing was chosen.

The Field Survey

The site chosen for this research, Lindale Plaza, is located in the northeast corner of Cedar Rapids, Iowa. The center is just west of the intersection of First Avenue (U.S. 151) and Collins Road (Iowa 150). Physically, Lindale is an open mall with two major department stores located at either end of the rectangular mall. Forty-six establishments occupy the main plaza area which has a gross leasable floor area of 44,000 square feet.

To obtain information necessary for the development of this route methodology, personal interviews were conducted at the Lindale Plaza. The objective of this field work was to describe the demographic characteristics of Lindale patrons and the characteristics of their off-peak trips to Lindale Plaza. The questionnaire used in the on-site interview is presented in Figure 1. The first seven questions required a response from the person being interviewed. The last four questions were completed by the interviewer based on observation. During the two day survey, 884 interviews were completed. Of these, 835 interviews were usable. Daily survey sample sizes were about 8.4%, and 7.5% of the total vehicular trips to the Plaza.

Figure 1

LINDALE PLAZA OFF-PEAK TRAVEL SURVEY

1. For this trip to Lindale Plaza today did you:
   (1) ride as an auto passenger (4) ride the bus
   (2) drive (5) use a taxi
   (3) walk (6) other

2. Where were you before coming to Lindale Plaza?
   (1) at home (4) school
   (2) antoher store (5) other
   (3) work

3. How much time will you spend in the Plaza today?
   (1) 15 minutes or less (4) 1 hour or more
   (2) 30 minutes (5) work
   (3) 45 minutes

4. How often do you shop here at Lindale Plaza?
   (1) several times a week (3) once every two weeks or less
   (2) once a week (4) don't know

5. Do you shop in Downtown Cedar Rapids ____________ than you do at Lindale Plaza?
   (1) more (3) less
   (2) the same (4) don't know

6. When you left home today did you plan on stopping at Lindale Plaza?
   (1) yes (2) no

7. What is your home address (or, if you prefer, the street intersection nearest your home)?

   ______________________ (street address) ______________________ (city)

(Following questions completed by interviewer)

8. TIME

9. DAY

10. SEX (1) Female (2) Male

11. AGE
    (1) under 18 (3) 31-45 (5) over 60
    (2) 18-30 (4) 46-60

Urban Trade Area Designation

The purpose of delineating an urban trade area was to reduce the metropolitan area to those traffic zones most directly associated with the activity center. To describe a trade area, the percent of trips originating within travel time contours was used. Figure 2 illustrates the travel time contours and the percent of the 475 urban trips originating within each 5 minute contour. The ten minute contour was chosen as the first cut to delineate the boundary for maximum coverage of a bus service to Lindale Plaza. The ten minute contour contains 75.6 percent of the home residences for urban survey trips and 84.5 percent of the origins to this center from the trip distribution matrix. Also, the ten minute contour does not cross the Cedar River - a natural screen line and travel barrier. The CBD is not included in this area. Zones 61,85, and 87 in Figure 3 were eliminated because addresses in these zones were rural route numbers. Zones 76 and 78 were dropped because no dwelling units existed in these zones. Several zones (73, 74, 79, 81, 84, and 97) were dropped because of the inability to convert addresses to census blocks and then to traffic zones. It should be noted that these zones are primarily rural or else have small residential populations.

Regional Use

The data on the use of Lindale Plaza and probable use of transit service were aggregated into regions. This aggregation of traffic zones to regions was necessary for statistical analysis and to delineate potential route coverage areas. The four regions delineated (see Figure 3) contained 409 survey respondents. Chi squared contingency and Kolmogorov-Smirnov (K-S) tests were employed to evaluate regional differences in the use of Lindale Plaza. The results of these tests are described in the following paragraphs.

The aggregate trip frequencies to Lindale Plaza were 32.8 once every two weeks or less, 30.7% once a week, and 36.9% several times a week. A 3 x 4 Chi square contingency test was used to determine if there were differences in trip frequencies by region. With a Chi square of 17.95 and six degrees of freedom, the hypothesis of independence between region of residence and frequency

Figure 2 TRAVEL TIME CONTOURS

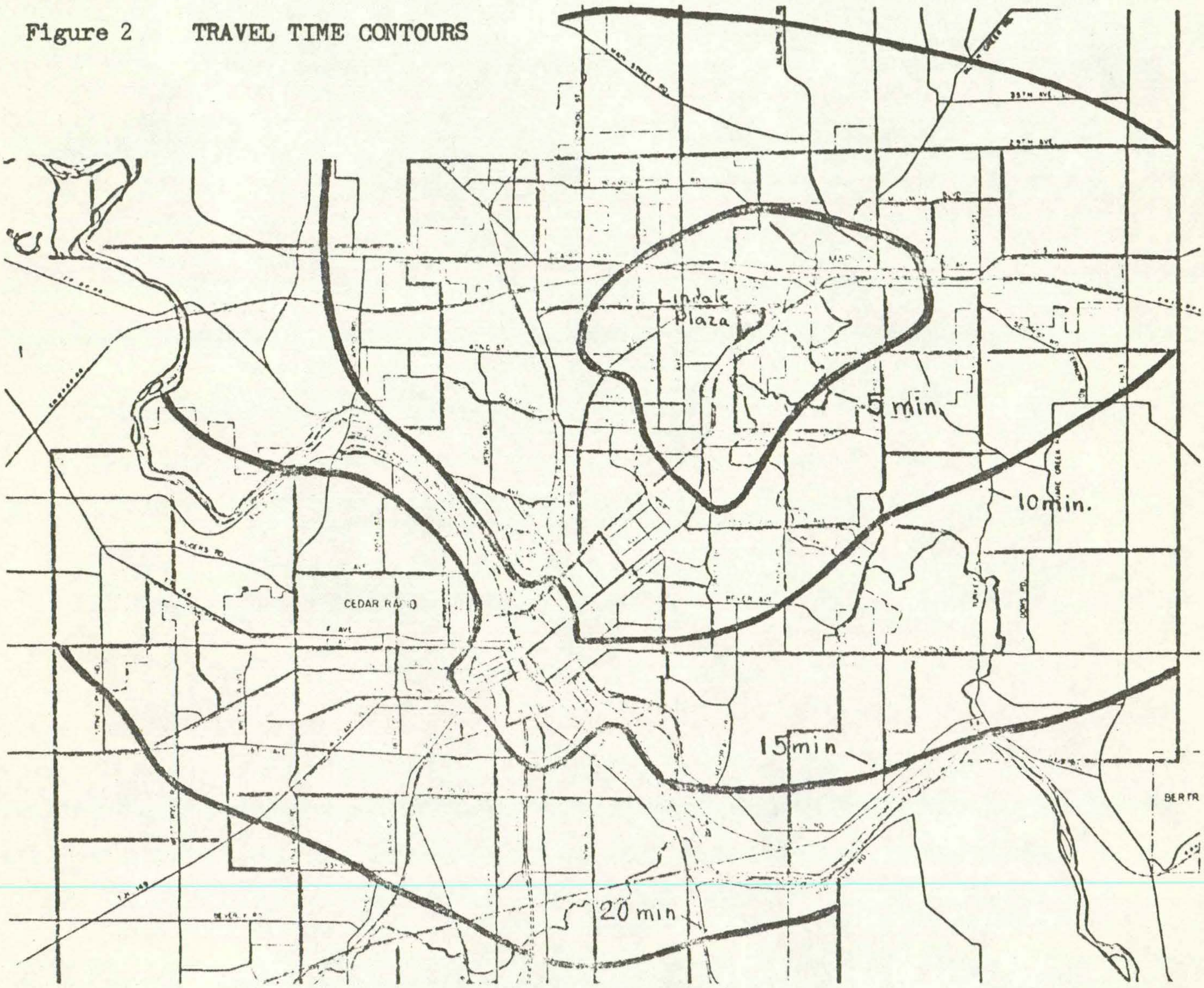
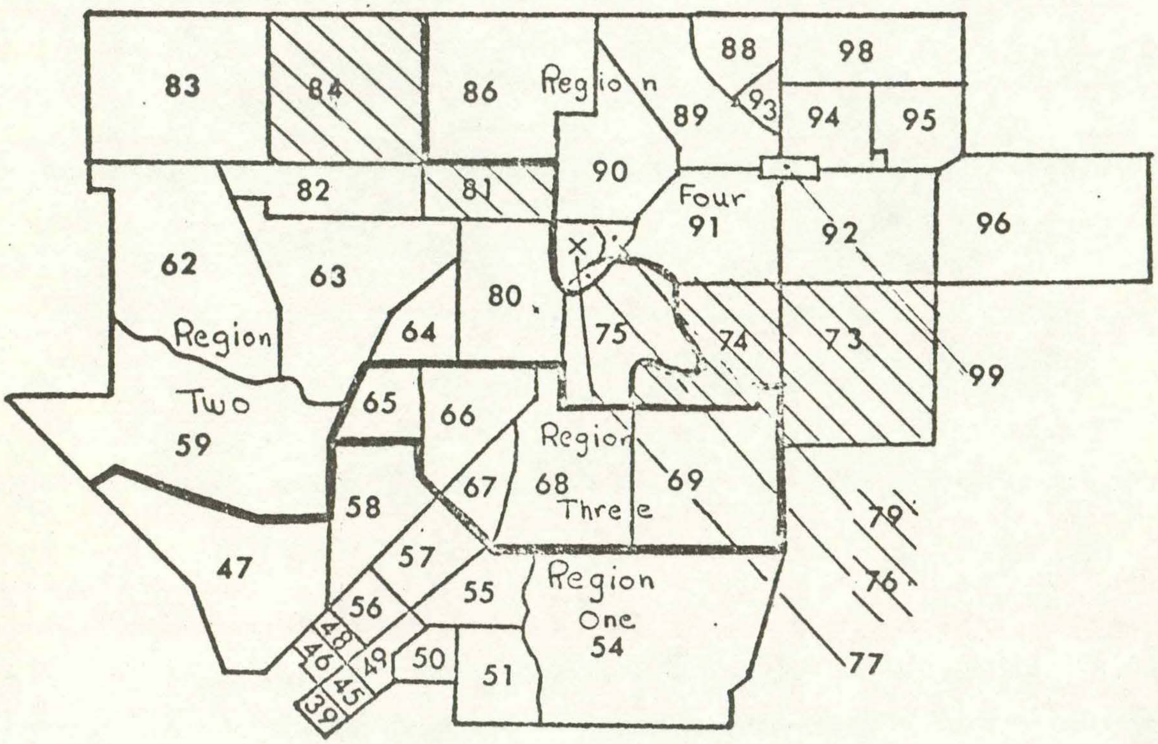


Figure 3 REGIONS USED IN ANALYSIS



of trip making was rejected at the d = .01 level of significance.

The next test evaluated whether there were regional preferences for Lindale Plaza when compared to the CBD. A 3 x 4 contingency test was again employed to analyze the relative frequency of shopping in the CBD and Lindale Plaza. This hypothesis of regional independence was rejected with an x^2 = 50.7 at the .01 significance level.

Tests were then performed to determine if there was a significant difference in trip frequency between regions.

A summary of these paired tests is contained in Table 1. As shown in Table 1, Region One had a lower frequency than any other region to both Lindale and to the CBD compared to Lindale. There was no significant difference in frequency of use between regions two and three and regions three and four. Region four, however, had the least preference for the CBD when compared to Lindale Plaza.

Potential Transit Ridership

Testing potential transit ridership was the intent of two of the survey questions. Question 2 asked where the individual was prior to coming to the Plaza and was based on the premise that home-based trips are more easily served by transit than non-home based trips. The other question asked if the person planned to visit Lindale when he/she left home (Question 6). This was premised on the belief that trips with planned destination comp ise a majority of transit trips. If a spatial relationship existed between planned and unplanned trips, bus routing could be devised to concentrate on "planned trip areas".

A 4 x 5 contingency table was constructed for Question 2 by regions. The null hypothesis stated that the proportion of trips coming to Lindale from different places is not significantly different for all regions. This hypothesis could not be rejected at a significance level of α .70, Chi square = 8.98 with 12 degrees of freedom. Generally, no region had a higher proportion of trips for any "where before" category. The results for the planned trip question versus regions showed that the proportion of planned or unplanned trips was independent of region at a significance level of α = .58, Chi square = 1.9,

Table 1

SUMMARY TABLE OF TEST RESULTS ON
USE OF LINDALE BY REGIONS

Frequency of Use		$\propto$	CBD vs. Lindale*		$\propto$
H_i^A	$R_1 < R_2$	$<.01$	H_i^E	$R_1 > R_2$	$<.01$
H_o^B	$R_2 \leq R_3$	$>.13$	H_o^F	$R_2 \geq R_3$	$>.50$
H_o^C	$R_3 \geq R_4$	$>.15$	H_i^G	$R_3 > R_4$	$<.07$
H_i^D	$R_4 > R_1$	$<.02$	H_i^H	$R_4 < R_1$	$<.01$

*> in this case indicates a higher use of the CBD than Lindale and the converse.

H_i^A $x^2=13.21$, df=2, D=21.4

H_o^B $x^2=4.15$, df=2, D=17

H_o^C $x^2=3.516$, df=2, D=14.3

H_o^D $x^2=7.82$, df=2, D=18.7

H_i^E $x^2=13.4$, df=2, D=24.1

H_o^F $x^2=1.04$, df=2, D=7.7

H_o^G $x^2=6.7$, df=2, D=19.6

H_i^H $x^2=14.4$, df=2, D=36.0

with three degrees of freedom. Therefore, it was not possible to distinguish higher or lower potential transit ridership between the regions with the results of the two survey questions.

Based on the above analyses, Region One was dropped from further consideration. Region One consistently had the lowest use of Lindale Plaza when compared to the other regions. Also it could not be shown to have any special trip making characteristics which would demand its inclusion. On this basis, no further information was analyzed for Region One.

Zonal Data

Additional data were compiled on a zonal code for the three remaining regions before the alternate routes were developed. The data included a measure of trip density, and two socio-economic variables.

To test for additional differences between regional trip making rates, it was first necessary to determine if the internal structure of each region characterized by the occupied dwelling units (ODU) per residential acre affected trip production. To test this, a one-sample K-S test was employed. Zones within a region were ranked by occupied dwelling units per acre. The theoretical distribution used for testing purposes was the cumulative percent of occupied dwelling units in a zone for the region. None of the regions had an increase in trip density with a corresponding decrease in occupied dwelling unit density (Region Two: D(for α =.05, n = 123) = .126, D (actual) = .09; Region Three: n= 116) = .12, D (actual = .11). This led to the conclusion that there was no difference within regions in trip production to Lindale due to variance in residential density.

A one-sample Chi square test to determine if different regions have different trip rates per occupied dwelling unit densities was performed. The expected trip frequency for each region was computed by multiplying the percent of the occupied dwelling units in a region (number of dwelling units in region over total number of dwellings in all regions) by the total number of trips for all three regions. The null hypothesis tested was that there was no difference between the number of trips per region and the expected number of trips. The Chi

	Region Two	Region Three	Region Four
Expected Number of Trips	118.95	61.9	122.08
Number of Trips (Total, 303)		64	116

$df = 2, X^2 = .516, \alpha > .70$

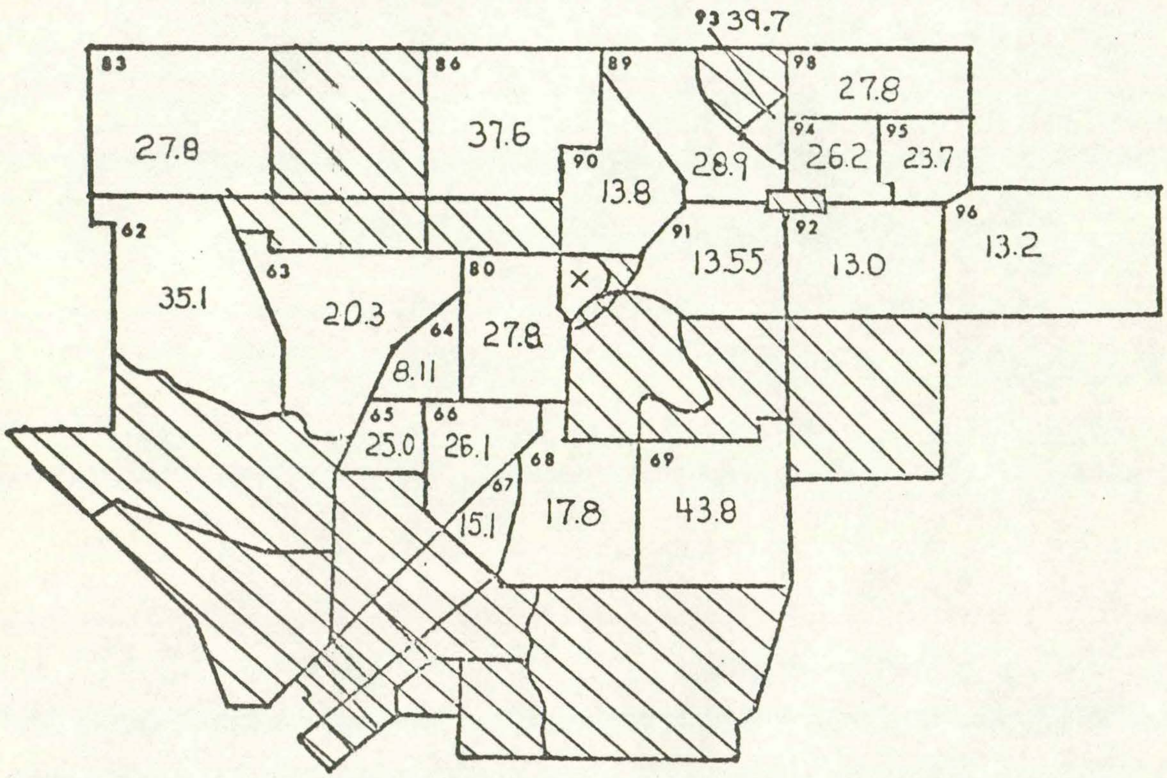
square for the one-sample test was .516 with two degrees of freedom. The null hypothesis (no difference) was rejected at an α >.70. The regions produce trips in proportion to the number of occupied dwelling units.

This necessitates determining whether zones within a region also produce trips in proportion to the number of occupied dwelling units in that zone. To make the micro analysis more reliable, all zones with one or less survey trips were eliminated from the analysis. The zones deleted were 59, 84 and 82 from Region Two and zones 88 and 99 from Region Four. No zones were deleted from Region Three.

Once again a one-sample Chi-square test was applied with the expected number of trips determined by the proportion of occupied dwelling units (ODU) in each zone divided by the number of ODU in the region. For Region Two, the null hypothesis that zones produce trips in proportion to the number of dwelling units in the zone was rejected at a significance level of .001 with a Chi square of 19148 and 4 degrees of freedom. For Region Three the null hypothesis could not be rejected and $.30 > \alpha > .20$, with a $X^2 = 5.67$ and df = 4. The null hypothesis for Region Four was rejected at a significance level of $\alpha = .05$.

In Figure 4 the trips per 1,000 ODU ratios for each of the 20 zones remaining in the analysis are illustrated. Within the figure several patterns exist. In Region Four a tier of zones (90, 91, 92, 96) exists which has trip rates of lower values than the tier above it (zones 86, 89, 93, 94, 95, 98). Within Region Two, zone 62 has a relatively high trip rate when compared to the other zones in the region. Region Three appears to have great variations in trip making rates but it should be observed that zone 69 contains only four percent of the ODU in Region Two. Zones 66 and 65 take on trip rate values which are in the same range as zones 80 and 63 in Region Two.

Figure 4 TRIPS PER 1,000 ODU



Based on the above analysis, three important generalities are made about trips to Lindale. In this case it is not necessary to consider dwelling unit per acre densities as affecting trip rates to Lindale: There appears to be no aggregate effect. Second, all three regions appear to be producing trips to Lindale as a function of the number of occupied dwelling units in the regions. Finally, in Regions Two and Four, at least one zone in each region produces trips at a rate different than would be expected if all trip rates were equal.

Two variables were calculated for each of the remaining 20 zones. These variables, autos per-occupied dwelling unit and per-age variable, were to serve as guides to differentiate the socio-economic difference between the zones. The autos per occupied dwelling unit ratios are presented in Figure 5. While the range of the rates is only from 1.10 to 1.8., some extreme values are worth noting. Zone 69 in the southeast corner has the highest value (1.8.). Zones 83 and 62 on the west side have rates greater than zones to their east. Zone 67 has the lowest ratio of autos per occupied dwelling unit.

The percent of the zonal population which is either male and over 59 years of age or female over 44 years of age is shown in Figure 6. The average percent of persons in a zone meeting the age and sex criteria is 17.07 percent. The zones with above average percentiles appear to cluster to the south of Lindale (zones 80, 65, 66, 67, 68 and 69). Another clustering appears in the city of Marion in zones 91, 89, 93, 94 and 95.

Zones with low autos per occupied dwelling unit ratios and high percentage of males over 59 years of age or females over 44 years of age are good candidates for transit service. Data would indicate that these zones have low trip/ODU ratios.

ALTERNATE ROUTES

Delineating specific routing alternatives is the final step in the flexible-fixed off-peak route methodology. The technique uses initial route operational criteria. The operational criteria were also used to develop alternate routes for the remaining zones. These alternate routes then were compared on the basis of zonal characteristics to determine the "best" route.

Figure 5 . AUTOS PER ODU

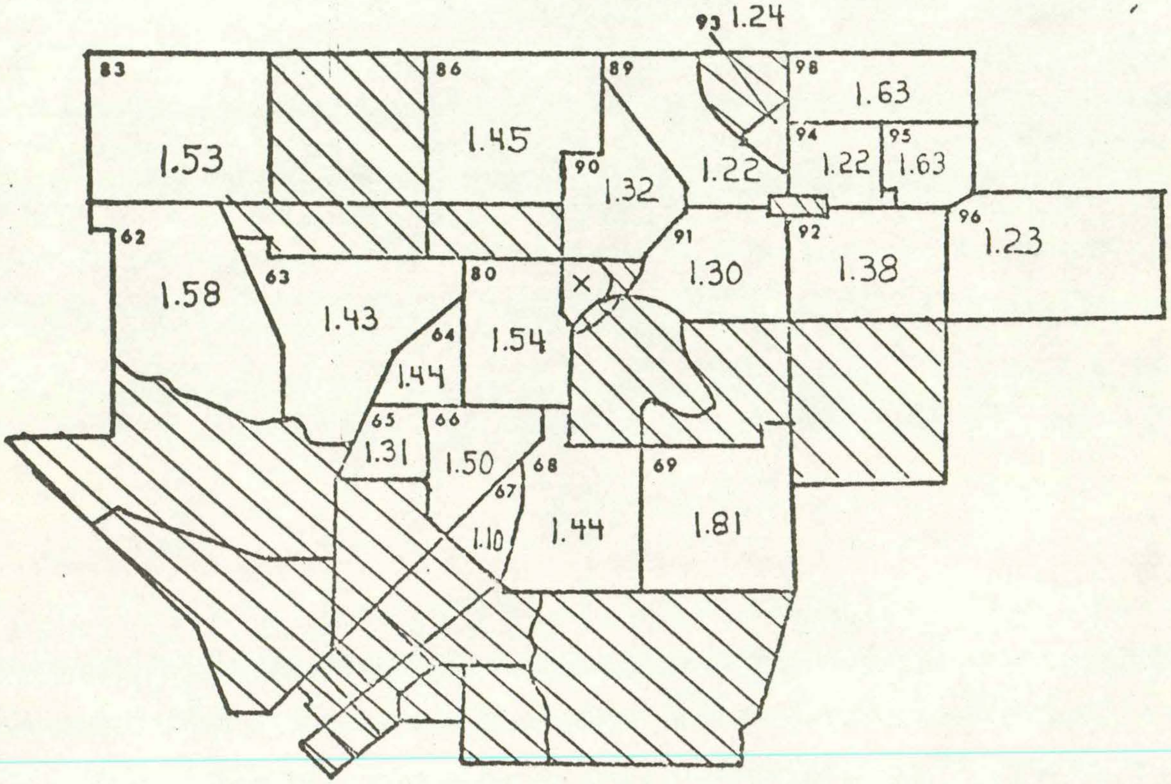
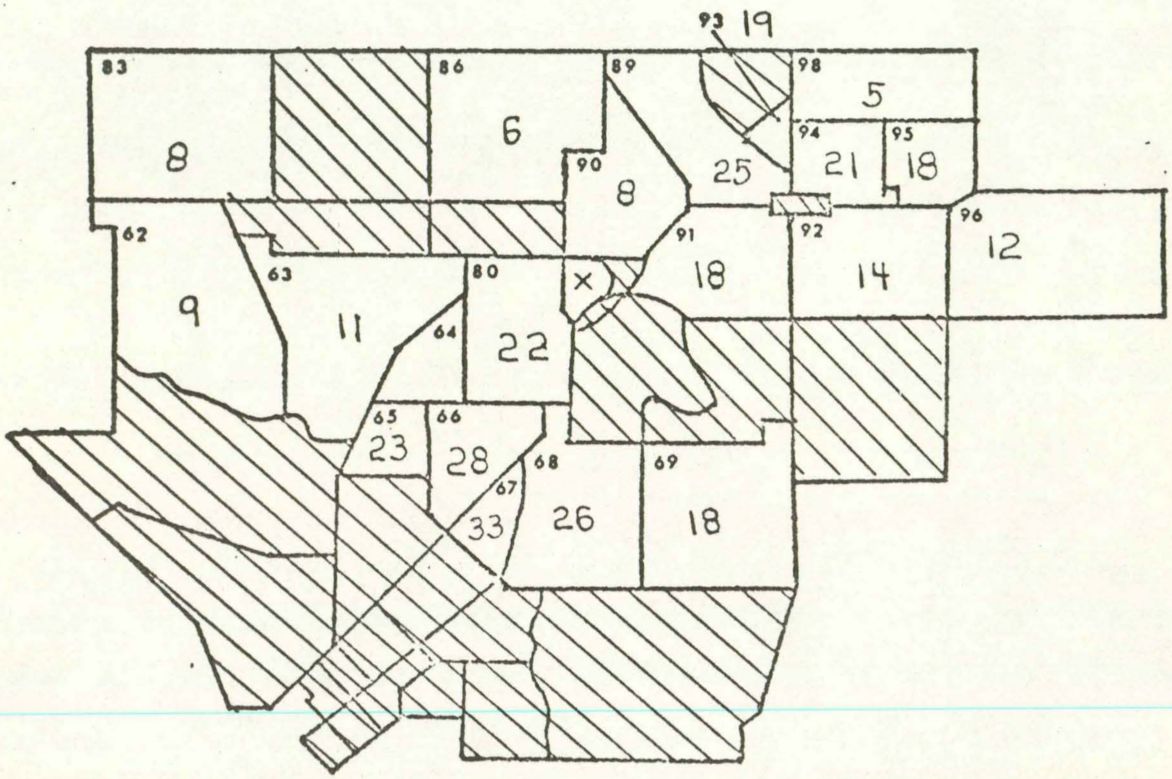


Figure 6 PERCENT OF ZONAL POPULATION MEETING AGE AND SEX CRITERIA



The criteria were developed with the primary purpose of providing service for home to Lindale Plaza trips; Financial constraints and the present bus service were not considered. The route operational criteria used to designate zones for possible routing were:

(1) No route may serve both the Cedar Rapids and Marion areas. (see Figure 7)

(2) No route may have a headway greater than 30 minutes.

(3) An average bus speed of 12.0 miles per hour to Cedar Rapids and 14.0 miles per hour in the Marion area were used.

(4) Routes were to be looped where possible, but inbound and outbound portions of the route may not be separated by more than two blocks (approximately 1,250 feet) except near the residential end point of the route.

(5) Convoluted routes were to be avoided.

(6) Fringe zones will not be serviced at the expense of high potential close-in zones.

Criterion one basically was neccesitated by the spatial separation of the two areas. A maximum headway of 30 minutes was established from a subjective viewpoint. The two different bus operating speeds were based on present operational data. Basically traffic operation differences between the two cities causes the difference in bus operating speeds. Criterion four and five were necessary to minimize the problem of short inbound trips and long outbound trips or vice versa. The last criterion is consistent with the trip distance-decay premise. Shopping trips are basically short trips; sacrificing the short trip to service fringe areas would be inconsistent.

The preceeding criteria were based on the assumption that only one bus was available for any single route. Thus, given criterion 2 and 3, the maximum route length standard was six miles for a Cedar Rapids route and seven miles for a Marion route. Furthermore, routes must pass through the high potential close-in zones. Distances to each zone in the Cedar Rapids and Marion areas are presented in Table 2. For both areas the distances were developed as right angle measures with access modifications. As shown

Figure 7 RESIDENTIAL LAND USE

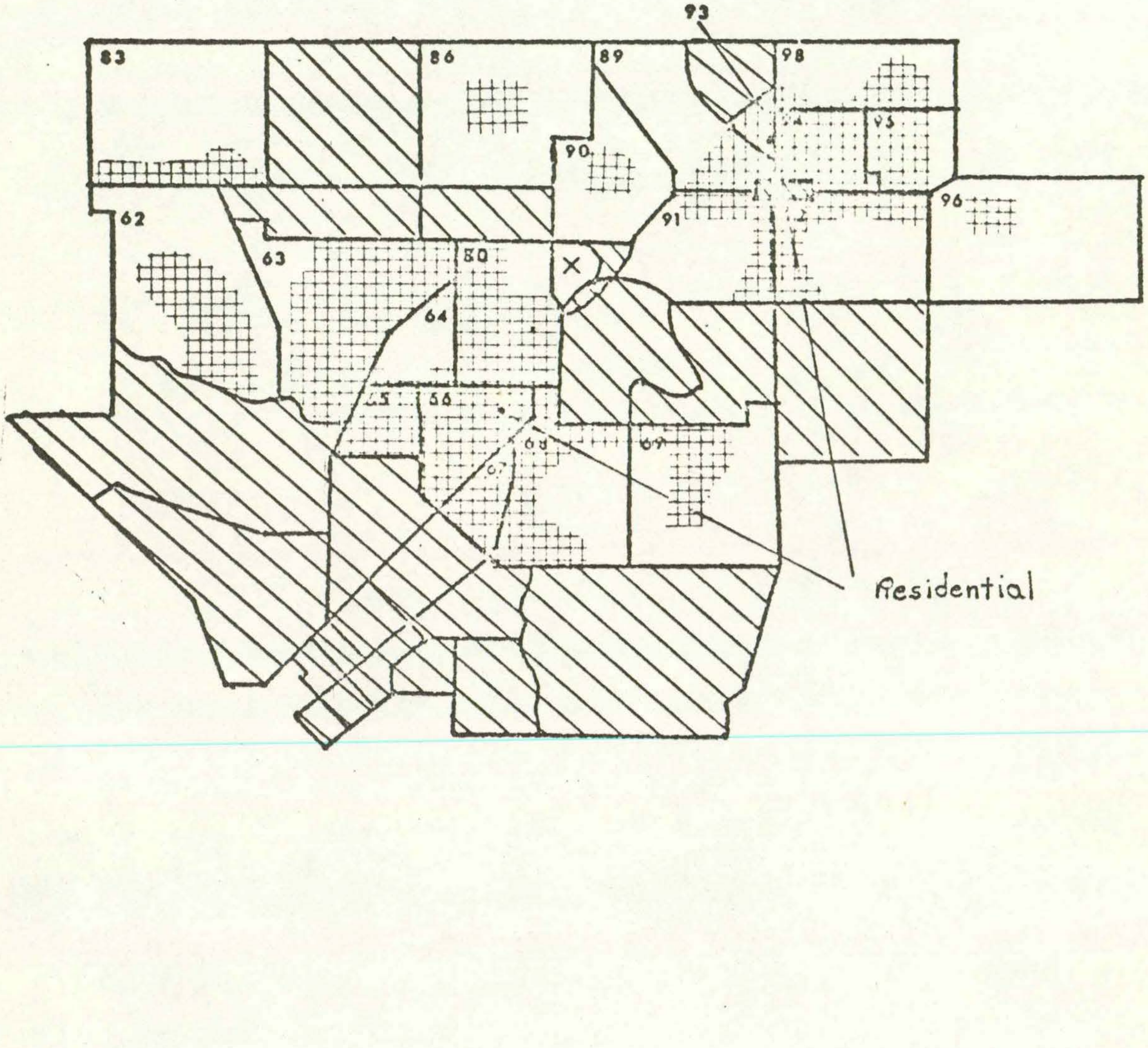


Table 2

DISTANCES TO ZONES FROM LINDALE PLAZA

	62	7	4.00
	63	5	3.50
	65	6	2.55
Cedar	66	4	2.13
Rapids	67	6	2.41
Area	68	5	2.35
	69	7	3.57
	80	3	1.27
	83	7	4.60
	86	4	2.80
	89	3	1.34
	90	2	1.02
Marion	91	3	1.34
Area	92	5	1.79
	93	5	1.76
	94	5	2.04
	95	6	2.50
	98	7	2.90
	96N	7	3.26
	96W	7	2.92

in Table 2, all zones in the Marion area fell within the seven mile limit (3.5 miles one way). Due to interzonal accessibility problems and their relative isolation, zones 86 and 90 were dropped from consideration.

Within the Cedar Rapids area there are only four possible routing configurations. These are shown in Figure 8. These four routes service the following sets of zones:

Route A = 80-66-65

Route B = 80-66-67

Route C = 80-66-67-68

Route D = 80-66-65-67

Routes for the Marion area are illustrated in Figure 9. Because of the looping criterion, it was not possible to service one route with the inbound leg of a route and another zone with the outbound leg. The six routes service the following sets of zones:

Route Z = 89-91-92-96

Route Y = 89-94-95

Route X = 89-94-95-98

Route W = 89-93-94-95

Route V = 89-93-94-95-96

Route U = 89-93-94-95-98

Summarized in Tables 3 and 4 are all the zonal data developed earlier. On the basis of these two tables the sets of zones for each route were compared. Survey date indicated that routes, A, B, C and D cannot be shown to be significantly different. As previously indicated, trip-making rates for zones 65-68 could not be shown to be significantly different. The only differences that can be shown are those in relation to the percent of the zonal populations fitting the age and sex criteria, residential and auto density, the number of occupied dwelling units, and route operational criteria. In Table 3 the non-survey data show only two major differences between zones in the area. Zone

Figure 8 POSSIBLE ROUTES - CEDAR RAPIDS AREA

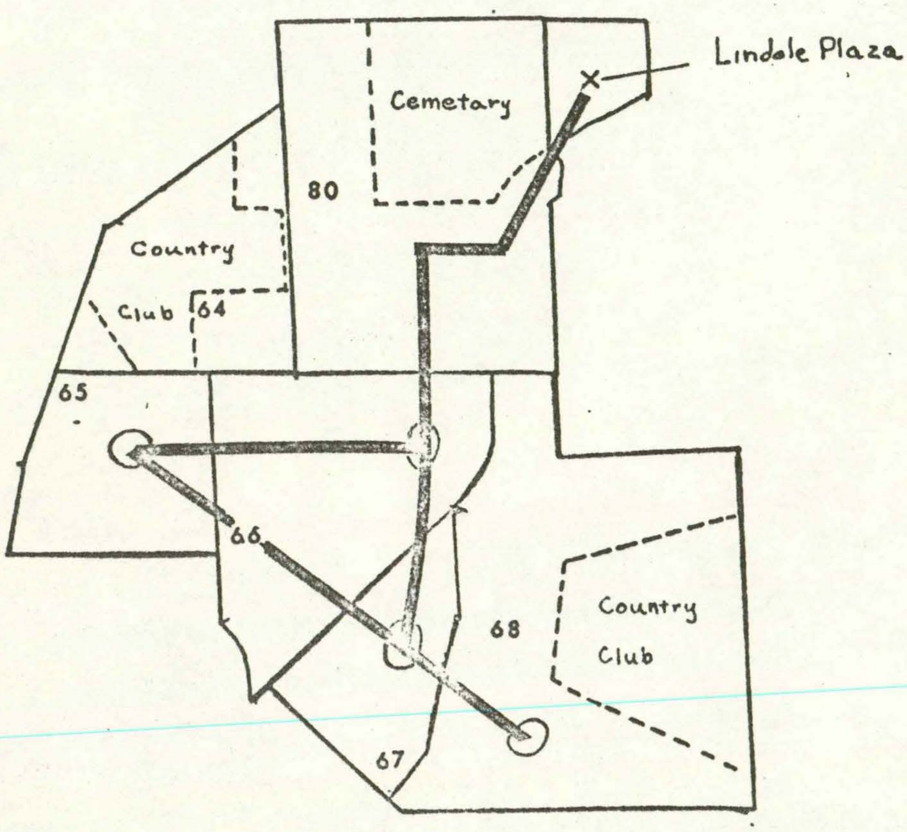


Figure 9 POSSIBLE ROUTES - MARION

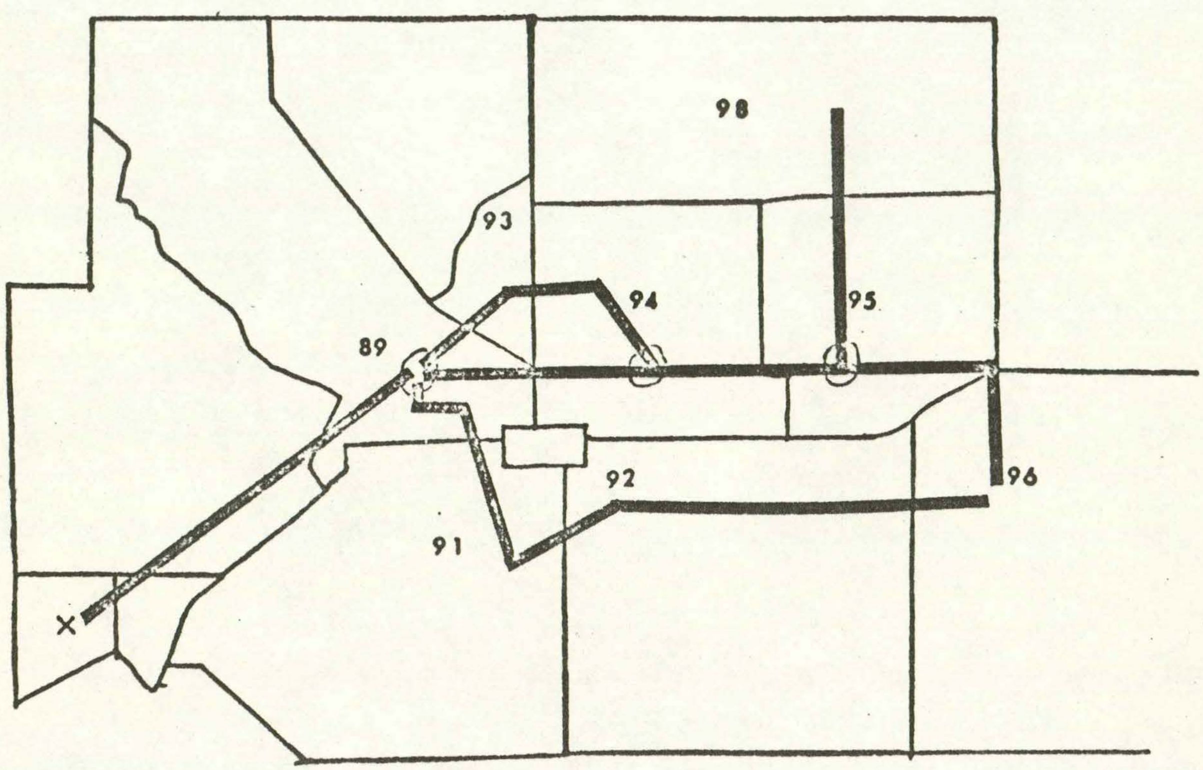


Table 3

ZONAL DATA AND TESTS FOR CEDAR RAPIDS AREA

Legend

TZ = Traffic zone

Data

R = Region of which zone is a member
TS = Survey trips from zone
ODU = Occupied dwelling units
TR = Trips per 1,000 ODU
D = ODU per acre
AD = Autos per ODU
SA = Percent of zone's population male and over 65 years of age or female and over 45 years of age

Tests

F = Frequency of trip making to Lindale Plaza test between regions
P = CBD/Lindale preference test between regions
WB = Where before coming to Lindale test between regions
PL = Planned or unplanned trip test between regions
DW = ODU per acre effect on trip making within region test
TRB = Trip per 1,000 ODU difference between region test
TRW = Trip per 1,000 ODU difference within region test

Results

NC = not calculated
INP = Independent of Region
NO = No difference
YES = Difference exists

Table 3

TZ	R	TS	ODU	TR	D	AD	SA	F	F	WB	PL	DW	TRB	TRW
59	2	4	662	4.53	2.1	NC	NC							
62	2	37	1055	35.1	4.7	1.58	9	$<R_3$	$>R_3$	INP	INP	NO	NO	YES
63	2	33	1627	20.3	5.9	1.43	11	"	"	"	"	"	"	"
64	2	3	370	8.11	4.5	1.44	17	"	"	"	"	"	"	"
75	2	3	50	NC	1.4	NC	NC							
80	2	22	792	27.8	4.6	1.54	22	$<R_3$	$>R_3$	INP	INP	NO	NO	YES
82	2	1	214	4.7	14.0	NC	NC							
83	2	16	575	27.8	3.4	1.53	8	$<R_3$	$>R_3$	INP	INP	NO	NO	YES
84	2	0	200	NC	5.6	NC	NC							
65	3	14	561	25.0	4.4	1.31	23	$>R_3$	$<R_3$	INP	INP	NO	NO	YES
66	3	23	884	26.1	5.5	1.50	28	"	"	"	"	"	"	"
67	3	9	596	15.1	7.8	1.10	33	"	"	"	"	"	"	"
68	3	13	731	17.8	3.9	1.44	36	"	"	"	"	"	"	"
69	3	5	114	43.8	.85	1.81	18	"	"	"	"	"	"	"

Table 4

ZONAL DATA AND TESTS FOR MARION AREA

Legend

TZ = Traffic zone

Data

R = Region of which zone is a member
TS = Survey trips from zone
ODU = Occupied dwelling units
TR = Trips per 1,000 ODU
D = ODU per acre
AD = Autos per ODU
SA = Percent of zone's population male and over 65 years of age or female and over 45 years of age

Tests

F = Frequency of trip making to Lindale Plaza test between regions
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DW = ODU per acre effect on trip making within region test
TRB = Trip per 1,000 ODU difference between region test
TRW = Trip per 1,000 ODU difference within region test

Results

NC = not calculated
INP = Independent of Region
NO = No difference
YES = Difference exists

Table 4

86	4	17	452	37.6	4.0	1.45	6	$>R_1, <R_3$	$<R_3, \leq R_1$	INP	INP	NO	NO	YES
88		1	38	NC	1.8	NC	NC							
89		10	345	28.9	5.7	1.22	25	$>R_1, <R_3$	$<R_3, <R_1$	INP	INP	NO	NO	YES
90		9	652	13.8	5.2	1.32	8	"	"	"	"	"	"	"
91		8	590	13.5	5.0	1.20	28	"	"	"	"	"	"	"
92		13	997	13.0	5.8	1.28	24	"	"	"	"	"	"	"
93		7	176	39.7	3.9	1.24	29	"	"	"	"	"	"	"
94		19	941	26.2	5.7	1.22	32	"	"	"	"	"	"	"
95		14	590	23.7	5.6	1.63	28	"	"	"	"	"	"	"
96		4	302	13.2	5.6	1.23	23	"	"	"	"	"	"	"
98		13	467	27.8	4.5	1.63	5	"	"	"	"	"	"	"
99		1	53	NC	2.1	NC	NC							

68 has a relatively low ODU/acre value and zone 67 exhibits a low (1.1 autos/ ODU) value. From an operational viewpoint the residential population of zone 68 would be difficult to service while also servicing zone 67. Zone 68's residential population is located along the north, south, and west edges of the zone. Also, serving this area would require crossing First Avenue (the major arterial) which adds to these difficulties. When comparing the two routes, A and B, with end points in zones 65 and 57, respectively, zone 65 is more attractive because the zone does not contain commercial or shopping facilities. Zone 67's east border is First Avenue and retail services are located along it. Residents within zone 67 may walk to retail facilities whereas persons in zone 65 cannot. It is primarily on this basis that Route A is chosen from the Cedar Rapids group.

Because there was a significant difference in trip making by zones in the Marion area, the selection of the best route is more clearcut. Referring to Table 4, zones 89,93, and 94 have both high trip making rates as well as lower autos per ODU ratios and a higher percent of the population meeting the age and sex criteria. This effectively eliminates routes Z and Y because the former services neither zone and the latter services only one of the zones. A field evaluation of Route W showed it would prove to be too long for 20-minute headways and too short for a 30-minute loop. The choice that remains between Routes V and U is primarily one of serving zone 96 or zone 98. Even with zone 98's high auto density and low number meeting the age and sex criteria, the high trip making rate makes zone 98 a better candidate for transit service than zone 96. The higher trip making rate as well as the residential population of zone 96 having walking access to minor retail facilities support this choice. Zone 98 is isolated from retail facilities much the same as zone 65. The "best" route from the Marion area was therefore Route U.

The final two routes are shown in Figures 10 and 11. Field testing proved the routes to be within the length limits. If only one of these routes could be implemented, the choice would be the Marion route due to its greater reliance on Lindale Plaza as a shopping center rather than the Cedar Rapids area. The final route design in the case of Cedar Rapids is highly dependent on the existing

Figure 10 PROPOSED ROUTE - CEDAR RAPIDS AREA

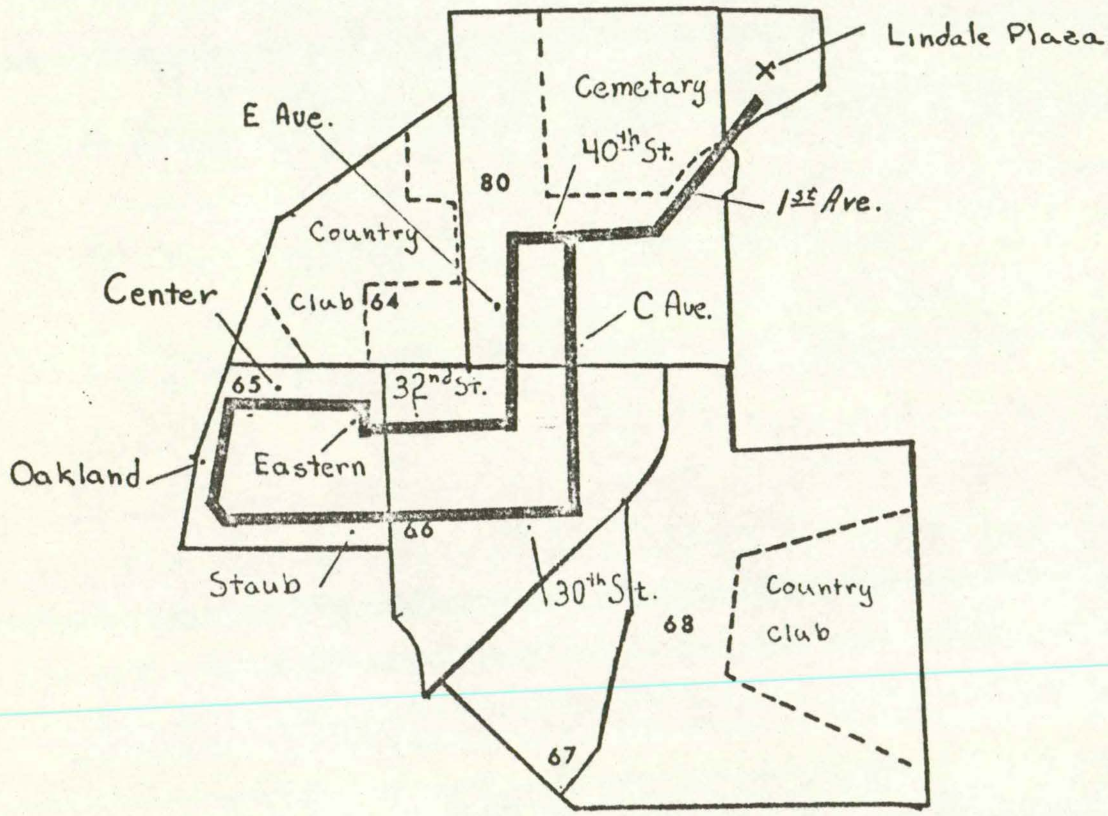
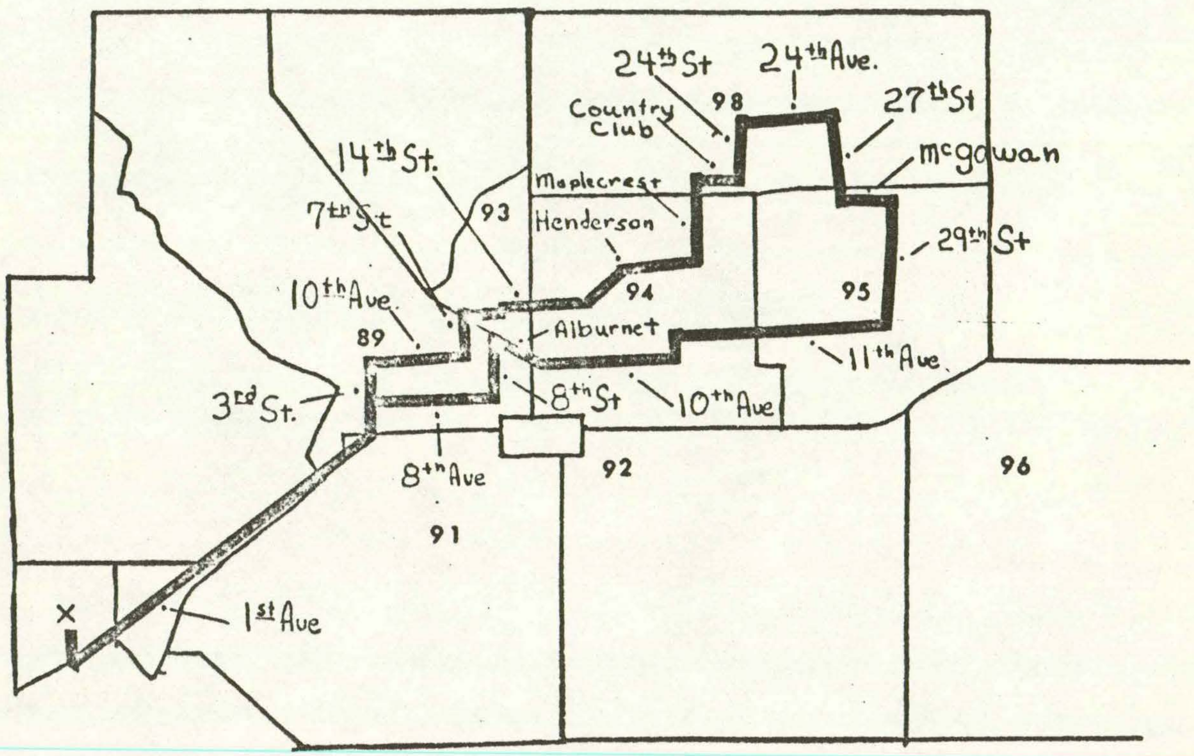


Figure 11 PROPOSED ROUTE - MARION



street network. Alternate configuration are greatly limited when routes of a linear or closely looped design are attempted. The next routing option of large route loops with two buses running in opposite directions on the loop would leda to significant problems due to primarily to the physical structure of Lindale Plaza's trade area. The loop would need a one direction headway of 40 or 60 minutes. This would mean some trips of 20 to 30 minutes. Auto travel time ratios to Lindale Plaza would be boosted due to the necessity of staying within the trade area and also increasing route mileage. The principle of supplying auto competitive service to high trip generation areas would be effectively destroyed. Within the Marion area the survey data proved most useful in the selection of a route within that area. The northern half of the city proved to be a high trip generation area. Because of this it was possible to justify placing a route directly through this area. The present route effectively surrounds this area without penetrating it with both inbound and outbound legs.

SUMMARY OF ROUTE DESIGN TECHNIQUES

Provision of transit service from one end of the urban area to the other should not be a primary goal in the off-peak hour but rather transit service should take on a local style of service providing mobility oriented to the types and locations of off-peak hour trips. Development of this local service can be accomplised by servicing trips made to a major activity center from that center's associated trade area.

The technique developed for analysis in this research contains the following four basic elements: (1) choice of activity center(s); (2) identification of trip making characteristics to an activity center during the off-peak hours by an on-site survey method; (3) identification of spatially significant characteristics of trips and population and; (4) establishment of service levels and design routes.

The choice of an activity center for possible service during the off-peak hours is dependent on the volume of trips and the function of the center. This type of information is readily available in urban areas.

The identification of trip-making characteristics to an activity center by an on-site survey method is the heart of this route design technique. A flexible-fixed system is an activity centered system; consistency in the data collection techniqe is essential. This demands that the survey techniqe be activity center based. Off-peak travel is positively identified, which allows bus routes to be designed to serve these trips.

Further examination of the trip characteristics from a spatial viewpoint provides information on the activity center's service area. Subsections of this area with greater trip densities, special trip making characteristics, and special demographic characteristics are identified through simple non-parametric statistical testing. A search is made not only for those subsections with a greater propensity towards trip making but also towards transit ridership.

The service criteria were developed to be competitive with auto travel. This constrains the route design.

A fully operational flexible-fixed off-peak hour routing system would be a coordinated system of local neighborhood routes which service activity centers and their associated residential areas. As the travel patterns to activity centers change and activity centers are added to or deleted from the urban area, routing would be added or deleted.

CONCLUSIONS

This research substantiates the hypothesis that the technique developed orients bus routing to off-peak hour travel. Conclusions include:

(1) The on-site survey technique operated satisfactorily for the purpose of identifying spatial trip-making differences to Lindale Plaza.

(2) The spatial distribution of the urban residential location of Lindale Plaza falls off with distance from the center. The primary areas of trip origins are the northeast sector of Cedar Rapids and the city of Marion. The competitive function of the CBD as well as the screenline effect of the Cedar River appear to effectively dampen travel to Lindale Plaza from areas south of the river.

(3) The proposed transit routing in the Cedar Rapids area would serve zones of high travel to Lindale Plaza. Bus oriented street improvements are needed before transit routing can be considered as an auto competitive mode for the highest travel zones (specifically zones 63 and 62).

(4) The proposed transit routing for the Marion area would serve zones of the highest travel to Lindale residential areas. This route would improve transit service to Lindale and compete favorably with the automobile travel time.

Further Research Needs and Ramifications of Implementation

Before this technique would be applicable to peak hour routes, there is a need for further study. Spatial competition between activity center necessitates the use of a multi-activity center type of survey. Paired comparisons for similar technique would be necessary to identify the spatial interaction of similar activity centers. The design of such a survey could be simplified by maximum transit distance constraints. This would eliminate certain pairs of activity centers. Seasonal effects on travel require further study to allow additional routes to be scheduled as demand requires. Examples of this type of routing would be Christmas shopping shuttles or summer time recreational routes. Also, if a strict set of route operation criteria is followed, which makes fixed routing as auto competitive (from a travel time standpoint) as possible, then impractical routes can be eliminated. By eliminating over-extended routes and orienting fixed route service to demand areas the prospect of a higher level of service in relation to cost of operation appears logical.

Politically, off-peak hour routing would be a volatile issue. Central business district merchants and other interests view city transit operations as a service they require. Cutting off sections of the city from direct service to the CBD would be a difficult proposal to sell the downtown merchants. To decrease opposition it would be necessary to demonstrate the higher level of service CBD patrons would enjoy due to the reorientation of transit services.

The selection of which activity centers to service will be a matter demanding close study. It will be necessary to develop a classification system based on the size, function, spatial relationship to like facilities, and spatial arrangement of the activity center's patrons. Basically this will be a political decision with the planner responsible for determining the effect of the alternatives.

Another problem which demands further study is the possibility that segments of the population (the transportation deprived) will not be served or will actually become more deprived. Also, if an urban area is sufficiently segregated along economic and/or ethnic lines, the routing patterns could possibly reflect this segregation. This problem was not a concern of this research but the matter deserves attention. Latent demand also was not measured. The establishment of the relationship between trip making and auto availability would be instrumental in identifying areas of low trip making due to low autos per family ratios. Weekend trip making shoud be characterized as an expansion of this research. Special weekend routing may be required if substantial travel differences are present.