Estimating Unmet Travel Needs Using Secondary Data Sources

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This paper presents a set of procedures for estimating transit needs using readily available data sources, applies these procedures to a specific study area, and generates a spatial distribution of transit needs. This distribution of need is used as input to the design of a local transit service for the study area. Ridership data from the implemented transit service is then used to check the reasonableness of the transit need distribution that was generated from the estimation procedures. The results indicate that secondary data sources can be used to develop reasonable estimates of transit needs and to identify specific areas that have high unmet needs; these need estimates can be used to design actual services that are responsive to the travel desires of local residents.

In theory, the design of a public transportation service should be primarily responsive to the needs of the population that will utilize it. In practice, this principle is often more honored in the breach than the observance. Transit service design may reflect historical factors, personal preferences of agency planners or elected officials, or simply conventional wisdom, rather than being the best means of meeting the needs of the transit-using public. One major reason that service design often is not well matched to user needs is the difficulty of determining precisely what those needs are.

Determining unmet travel needs is difficult because it involves several stages, and at each stage considerable data are seemingly required. First, the criteria that establish need must be determined; then these criteria must be applied to the service area population. Second, those with unmet needs must be identified and located in space. Third, the desired destinations of those with unmet needs must be determined. Finally, it is necessary to assess how much of the estimated need may potentially be satisfied by existing transit services. What then remains are the travel needs that attempts are made to meet through new or redesigned services.

This paper presents a set of procedures for estimating transit needs using readily available data sources, applies these procedures to a specific study area, and generates a spatial distribution of transit needs. This distribution of need is used as input to the design of a local transit service for the study area. Ridership data from the implemented transit service are then used to check the reasonableness of the transit need distribution that was generated from the estimation procedures. The results indicate that secondary data sources can be used to develop reasonable estimates of transit needs and to identify specific areas that have high unmet needs; these needs estimates can be used to design actual services that are responsive to the travel desires of local residents.

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A METHODOLOGY FOR ESTIMATING SPATIALLY DISTRIBUTED UNMET TRAVEL NEEDS

An estimation of unmet travel needs can be accomplished on two separate levels:

- a measure of unmet needs based on a comparison of travel behavior under varying levels of mobility and
- a measure of unmet needs relative to current transit service.

Each of these measures is, to some extent, dependent on the trip-making behavior that can be expected from residents of a particular study area. As a preliminary to the analysis of unmet needs, an estimate of the total number of trips currently being generated by study area residents must be made. This is accomplished using a segmentation approach based on characteristics that are accepted as being the primary determinants of trip generation.

In the segmentation approach, households are first disaggregated based on type of dwelling unit (single, multiple) and vehicle ownership (0, 1, 2, or more). Based on this stratification, person trip rates are then obtained for various trip types (home-work, home-shopping, etc.). The trip generation tables are then restratified by income level (high, medium, and low), and a final set of trip generation rates are produced. Using census data to classify the households within the study area, these trip rates are then applied to each group of stratified households in each census block. The result is a spatially disaggregated estimate of trip making within the study area. The geographical distribution of estimates of home-based work and nonwork trips forms the basis for the assessment of unmet travel needs.

These procedures are not intended to be used as a means of forecasting ridership levels, but rather as a tool for locating the areas with highest transit need, both in absolute terms and relative to existing transit services. By developing a spatial disaggregation of estimated unmet needs, it should prove possible to design transit services that will make the greatest possible contribution to mobility. These procedures produce information that permits more rational choices to be made about the type of transit that is most appropriate for an area and the specific configuration (in terms of routing, access points, etc.) of the transit mode utilized.

Measure of Unmet Needs Relative to General Mobility Considerations

A mechanism for uncovering unmet travel needs/desires involves assessing the trip-making behavior of residents as a function of the mobility available to them. It is generally acknowledged that access to the private automobile provides the greatest degree of mobility to urban residents. Thus, households with greater numbers of automobiles tend to travel more; those with a surplus of automobiles ostensibly travel to a degree limited not by mobility but rather by constraints associated with time and money. This principle enables the estimation of unmet travel needs/desires for households relative to comparable (in the socioeconomic sense) households with "ideal" mobility.

This estimation is accomplished for the study area using the segmentation approach already discussed, with households segmented into homogeneous groups relative to income status, type of dwelling unit, and number of automobiles. Trip rates for both work and nonwork trips are then applied to each group to estimate the numbers of trips generated. The variation of these trip rates over the number of automobiles available to the household, in any particular segment with like household structure and income category, is then an estimate of trip needs/desires not met because of mobility limitations.

Two separate measures of unmet needs are estimated:

1. level 1—based on projected trip-making behavior if transit services equivalent to mobility afforded one-automobile households were provided and
2. level 2—based on projected trip-making behavior if transit services equivalent to mobility afforded households with two or more automobiles were provided.

The latter measure represents an estimate of the trips that would be made by residents if mobility restrictions were virtually nonexistent while all other factors remained unchanged (e.g., household income and residence location). The increment of trips that would be generated with removal of mobility constraints over that currently generated thus represents a measure of the trip deficit faced by residents of the study area.

Measure of Unmet Needs Relative to Current Transit Service

A rather different approach is needed to determine unmet travel needs relative to existing transit service. The spatially disaggregated trip deficits obtained by the previous procedure must be transformed into desired trip patterns (at least in terms of direction of travel); then the correspondence between these desire lines and existing transit service must be determined. An estimate of directional travel is developed by using the average daily traffic (ADT) volume measures for the principal roadways within the study area as indicators of desired travel tendencies.

Average volumes along the principal north-south (N-S) and east-west (E-W) roadways in the study area are summed and used to compute probabilities of trips in each of the four compass directions. Thus, if Census Block 100 generated 1,000 home-based trips per day, and 30 percent of the travel in the study area is in a northerly direction, then 300 trips per day from this census block are assumed to flow northward.

The second part of the procedure involves estimating the portion of the identified trip deficits that could potentially be served by existing transit services without transfer. Based on accepted principles, it is assumed that transit routes are not readily accessible to households that are located at distances greater than 0.25 mile from the nearest bus route. Thus bands are drawn around transit routes, and only those within the band are considered potential transit users. For all households with transit access, the trip deficits are then distributed in each of the four principal directions, based on the probabilities calculated from the ADT volumes. The number of such desired trips that could possibly be accommodated by any of the existing transit routes without need for transfer is then estimated based on the simple criterion of whether a transit route serving the desired destination is accessible. This produces an extremely liberal estimate of need fulfillment, as many trips by households with home end access to transit will be unable to utilize transit because of its inability to access a desired destination. If more detailed information on destinations is available, it can be used to adjust the potential need fulfillment downward.

DESCRIPTION OF THE STUDY AREA

The methodology described previously was applied as part of a study to determine any unmet transit needs of residents of a small urban community in Southern California. Bell Gardens, California, is an inner suburb of Los Angeles. Located approximately 10 miles from the Los Angeles central business district (CBD), the city encompasses only 2.4 square miles but has a population of approximately 35,000 residents (1980). Despite the high population density of more than 14,000 persons per square mile, the city's housing stock is predominantly composed of detached units; nearly 60 percent of all households reside in single-family units.

In 1981, Los Angeles County voters passed a one-half-cent sales tax increase dedicated to mass transportation; 25 percent of this increase is returned to local cities as a function of population for discretionary use in local public transit projects. Cities such as Bell Gardens have a range of needs that could be addressed by a variety of transit alternatives. Although several specific needs were analyzed as part of a larger project, the focus of this paper is a general-population transit service targeted to improve mobility within the city and to neighboring activity centers.

Figure 1 depicts the relative location of Bell Gardens and various regional activity centers. North-south regional access is provided by Interstate 710, immediately adjacent to the western city limit. East-west flows are partially serviced by Interstate 5, just north of the city, and by a major artery running due east-west across the region through the heart of the city.

Bell Gardens should be expected to have high transit needs, for it is one of the poorest communities in Southern California. The median household income is one-third less than the average for California, and 23 percent of the families have incomes below the poverty level. In fact, 60 percent of all households are considered low income by regional standards. In addition, 15.2 percent of all its households do not own an

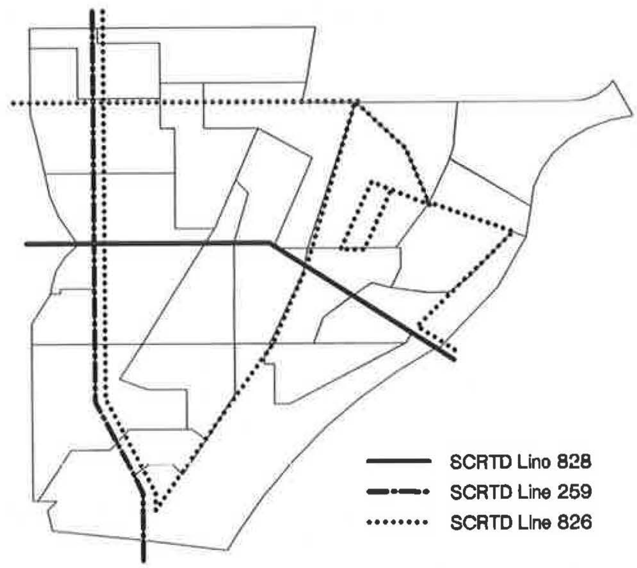

FIGURE 1 Current fixed-route transit service.

automobile, compared to 10.1 percent for California as a whole and 12.7 percent for Los Angeles County. The city also contains a high concentration of youths; 42 percent of the residents are younger than 18 years of age. Although the elderly population is relatively small (only 5.6 percent), more than 30 percent of this group stated that they had a disability that made using conventional fixed-route transit difficult or impossible. This is twice the California average.

Table 1 summarizes salient sociodemographic characteristics of Bell Gardens and also provides similar information for several neighboring cities, Los Angeles County, and the State of California. Overall, the characteristics of Bell Gardens' population are definitely oriented toward high transit needs. Despite this, however, Bell Gardens residents made less than average use of transit for work trips.

Transit service in Bell Gardens at the time of this study consisted of three bus routes operated by the Southern California Rapid Transit District (SCRTD) (Figure 1). SCRTD Route 828 provides service through the city along a major east-west corridor, with transfers to most major SCRTD north-south routes (including routes serving the Los Angeles CBD). SCRTD Route 258/259 provides north-south service with transfers to major east-west routes into downtown Los Angeles and the San Gabriel Valley. Finally, SCRTD Route 826 provides a predominantly local service to neighboring communities in a rather comprehensive, if somewhat tangled, routing scheme. This route provides service to nearby, major commercial activity centers and hospitals and passes within a quarter mile of virtually all residents of Bell Gardens.

Headways for the local service, Route 826, average 30 minutes in the peak periods, 45 minutes off peak, and 60 minutes on weekends. Service is provided from approximately 6:00 a.m. to between 7:00 and 10:00 p.m., depending on the day and bus stop location on the route. Both regional routes, Route 259 and Route 828, provide equivalent service weekdays and weekends, with headways of 40 minutes and 60 minutes, respectively, constant over the full service period (approximately 6:30 a.m. to 7:00 p.m. for both routes).

APPLYING THE METHODOLOGY TO THE STUDY AREA

Data and Procedures

The socioeconomic data used in the study were derived principally from the 1980 census. To facilitate the analysis of the possible variation of transit needs within the city, data were disaggregated to a level of 22 census block groups that comprise the city.

A limited range of sociodemographic factors was purposefully chosen both to streamline analysis and interpretation and to make use of available regional databases (e.g., trip generation rates). Clearly, a range of alternative classification variables is available—in particular, household role and lifestyle factors that in several studies have been shown to be significant determinants of variation in travel behavior Unfortunately, the effort required to conduct such analyses precludes the inclusion of such variables in a simplified estimation procedure. Furthermore, variations across lifestyle variables typically lead to indeterminant classifications of individuals and households. What is important, however, is to determine if the lifestyles of the study area's population are not so dissimilar from those of the surrounding area as to introduce potential errors by using regional trip rates.

In addition to census data, several regional databases were used to develop the estimates of unmet transit needs for Bell Gardens. The original Los Angeles Regional Transportation Study (LARTS) Transportation Model, which was based on the 1967 origin-destination study, incorporated a two-dimensional stratification based on type of dwelling unit and vehicle ownership (0, 1, 2, or more) to forecast daily person trip rates for five trip types (1, home-other; 2, other-other; 3, other-work; 4, home-work; and 5, home-shopping). An update of the original origin-destination study was conducted by the Southern California Association of Governments (SCAG) and the California Department of Transportation (CALTRANS) in the *1976 Urban and Rural Travel Survey* (*1*). Based on these 1976 data, the Santa Ana Transportation Corridor study (*2*) updated the LARTS trip generation rates and restratified the trip generation tables to include an income stratification (low, middle, high) in addition to the original stratifications based on housing unit type and vehicle ownership. The resulting trip generation table, which is displayed in Table 2, was judged to represent current Southern California conditions accurately and was considered an acceptably reliable forecasting tool for estimating the number of trips currently generated by residents of the study area.

Use of the trip rate table (Table 2) requires stratification of the households in Bell Gardens by type, income, and vehicle ownership. This was accomplished using a three-step procedure. First, households in each block group within the study area were classified by income level and type of housing unit using 1980 census data. This included detail on the number of households of each particular type (single, multiple) and the number of families in each particular income category (low, middle, high). These were used in conjunction with the distribution of household income (adjusted to 1979 values) by housing type for Los Angeles County obtained in the 1976 SCAG/CALTRANS survey. This resulted in estimates of the number of families, by income category, that live in each housing unit type. Second, the Los Angeles County statistics

TABLE 1 SUMMARY OF SOCIODEMOGRAPHIC CHARACTERISTICS

	CITY	POPULATION	ELDERLY (65+) POPULATION: TOTAL	ELDERLY (65+) POPULATION: %	MEDIAN AGE	WORKERS 16+ YEAR	WORK TRIPS BY PUBLIC TRANSIT %	WORKERS PER POPULATION %	ELDERLY PUBLIC TRANSIT DISABILITY %	HOUSEHOLD INCOME: MEAN	HOUSEHOLD INCOME: MEDIAN	PER CAPITA INCOME	FAMILIES BELOW POVERTY LEVEL %	HOUSEHOLDS ZERO AUTOS %	AREA (SQUARE MILES)	POPULATION DENSITY PER/MILE
1	Bell Gardens	34117	1914	5.6	22.0	9817	4.5	29	30.1	13745	12137	3796	23.1	15.2	2.4	14200
2	Bell	25450	2574	10.1	27.0	9306	6.1	37	16.0	15103	12636	5302	17.0	14.1	2.8	9100
3	Cudahy	17984	868	4.8	NA	5343	7.1	30	20.6	11900*	13900*	NA	NA	17.9	1.1	17000
4	Downey	86602	9142	10.6	34.0	40297	1.7	47	14.6	23510	20191	9339	5.3	5.5	12.8	6800
5	Huntington Park	46223	4057	8.8	25.2	16911	15.6	37	14.6	13858	11345	4498	20.4	25.7	3.0	15400
6	Los Angeles	2966850	312580	10.5	30.3	1351616	10.8	46	16.9	21715	15746	8422	13.0	17.2	463.7	6400
7	Lynwood	48548	3218	6.6	24.1	17190	5.6	35	18.2	16772	15099	4931	18.3	11.0	5.0	9700
8	Maywood	21810	1530	7.0	NA	7351	7.7	34	18.4	14700*	18900*	NA	NA	18.3	1.2	17700
9	Montebello	52929	5676	10.7	29.5	23483	5.9	44	18.3	21129	7731	7153	10.3	11.3	8.2	6500
10	Norwalk	85286	5171	6.1	26.8	35249	2.1	41	21.7	20915	19467	6276	8.3	5.2	10.9	7800
11	Pico Rivera	53459	3708	6.9	26.7	21106	3.6	39	18.4	20271	18401	5878	8.9	7.3	8.2	6500
12	South Gate	66784	7110	10.6	27.7	25215	6.2	38	15.4	17523	14825	6002	12.1	12.7	7.5	7800
13	L.A. County	7477503	738565	9.9	29.9	3373997	7.0	45	16.5	22518	17563	8317	10.5	12.7	-	-
14	California	23667902	2401006	10.1	30.0	10585675	5.8	45	14.9	22436	18248	8303	8.7	10.1	-	-

NA = Not Available
* = Estimate

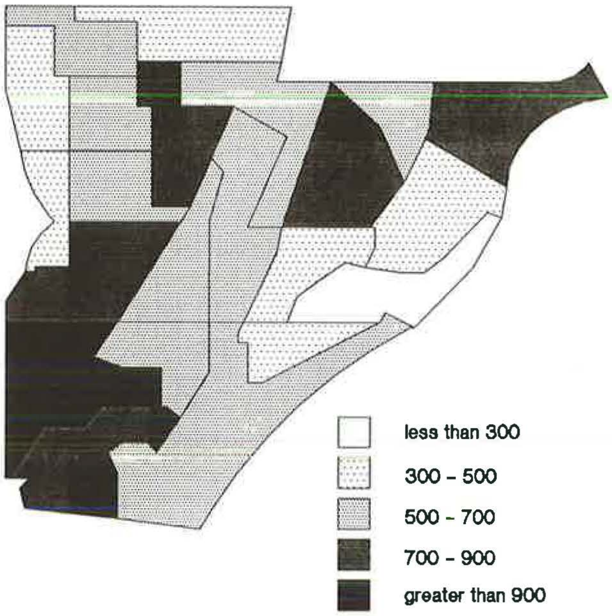

FIGURE 2 Spatial distribution of home-based work trip ends.

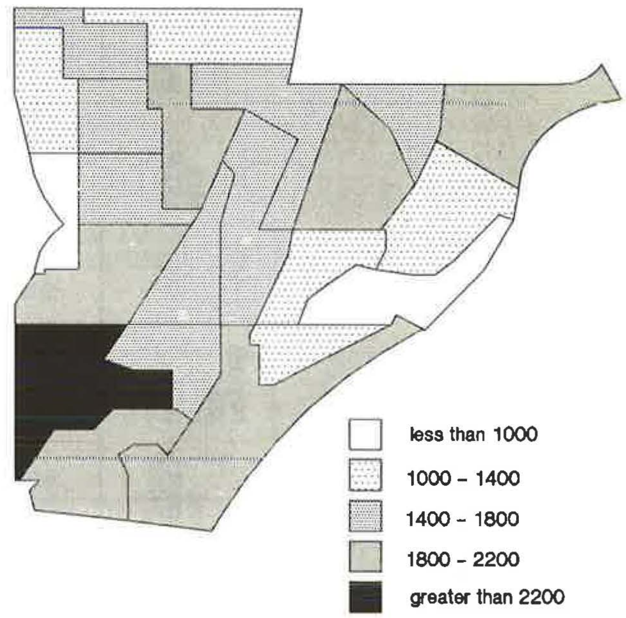

FIGURE 3 Spatial distribution of home-based nonwork trips.

TABLE 2 HOUSEHOLD TRIP GENERATION RATES (24-HOUR PERSON TRIPS)

	Income Level	S0	M0	S1	M1	S2+	M2+
Home Based	Low	0.261	0.192	0.717	1.192	1.521	1.467
Work	Middle	0.641	0.779	1.530	1.372	2.180	2.244
Trips	High	0.803	1.178	1.695	1.833	2.534	2.176
Home Based	Low	0.978	0.923	3.677	2.327	5.371	4.767
Non-Work	Middle	1.464	1.779	3.470	3.093	5.927	4.067
Trips	High	2.613	2.723	5.500	4.002	7.055	4.941
Non-Home Based	Low	0.370	0.712	1.949	1.221	2.790	3.167
Non-Work	Middle	0.669	1.573	2.214	2.372	3.140	2.911
Trips	High	1.487	2.354	2.450	2.983	4.133	3.765

where:

S0 = Single Family, Housing Units Zero Auto
M0 = Multiple Family, Housing Units Zero Auto
S1 = Single Family, Housing Units One Auto
M1 = Multiple Family, Housing Units One Auto
S2+ = Single Family, Housing Units Multiple Auto
M2+ = Multiple Family, Housing Units Multiple Auto

Source: OCTC, 1981

for households stratified by vehicle ownership and housing unit type from the 1976 SCAG/CALTRANS survey were used in conjunction with the household type and automobile ownership census data for the study area to estimate the distribution of vehicles by household type. Third, vehicle-income stratification ratios drawn from the 1976 SCAG/CALTRANS survey were used in conjunction with results from the first two steps of the procedure to produce the estimated stratification of households within the study area.

Application of the trip rates to the market segments determined by the foregoing procedure produced estimates of the trips generated by residents of the study area for various trip purposes. The geographical distributions of estimates of home-based work and nonwork trips are shown in Figures 2 and 3, respectively.

In estimating trip distribution by direction, local traffic data were used. The average ADT volumes along the four principal arteries through Bell Gardens (Gage, Florence, Eastern, and Garfield) were used to compute probabilities of trips along each of the major directions. Admittedly, this is an imprecise procedure, subject to two major sources of potential bias. First, relative ADT levels on principal roadways may primarily reflect the directional distribution of through traffic, not of Bell Gardens residents. Second, the directional distribution of automobile trips may not reflect the desired directional pattern of transit dependents. Despite these potential problems, the use of ADT data was considered to be the most reasonable approach to generating the needed directional distribution.

This assumption is somewhat ameliorated by the following considerations. Local freeways route virtually all north-south through traffic and much east-west through traffic around the study area; thus, identified ADT levels can be considered fair estimates of local demands. Examination of Figure 1 shows regional activity centers near Bell Gardens that lie along major arteries passing through the city. Interviews with several community groups identified usage of such centers that supported the directional estimate based on ADTs. No general public survey was attempted, although a small sample phone or mail-out survey could identify primary destinations outside the city proper. Finally, a more elaborate examination of traffic counts can lead to a better assessment of origin-destination flows. Such an approach is becoming a standard technique in travel modeling and forecasting.

Transit service and ridership data were obtained from the regional transit agency, the Southern California Rapid Transit District (SCRTD). The routes were plotted with 0.25-mile bands surrounding them, and all residents within the routes' catchment area were considered potential transit users. An additional factor was employed for potential trips using the 826 route. Route 826 is confined to an approximate 4- to 5-mile east-west reach, and a 1-mile north-south reach. The majority of the route is within 1 mile of the city limits and can be considered to service trips with an average distance less than or equal to 1 mile. Those parts of Route 826 beyond this distance are predominantly "covered" by either Route 828 or Route 259. Based on trip length distributions for work (1980 census) and nonwork (1976 CALTRANS/LARTS survey data) trip purposes, the 1 mile distance restriction would service 1 percent and 30 percent of work and nonwork trips, respectively. These percentages were used to adjust the "eligible" trips that could be accommodated by Route 826. Service levels for the 828 and 259 routes were adjusted to prevent double counting.

Table 3 summarizes the results of this procedure, indicating the percentage of trips that could potentially be served by transit in each zone. Estimates for nonwork trips may be quite liberal since many restrictions on mode choice (such as carrying packages for shopping trips) have been ignored. Nonetheless, proximity to transit lines is a basic determinant of transit potential.

Estimating Travel Deficits

Based on the data presented above and the procedures outlined previously, trip deficits were computed for each census block in Bell Gardens. These trip deficits (both level 1 and level 2) are displayed in Table 4 for work and nonwork trips. The numbers in this table refer to trip ends (i.e., the number of round trips between home and an activity would be equal to one-half of the totals displayed). Note that these measures represent coarse approximations to increased demand that might be achieved through provision of high-level transit service that approaches characteristics of the automobile. Such service is typically associated only with demand-responsive systems with a high density of service. The geographical distributions of these trip deficits are displayed in Figures 4 and 5.

The results indicate that the level 1 deficit for the city amounts to approximately 3,600 person trips/day, which corresponds to approximately 1,800 daily activities (or about 0.20 daily person trip per household in the city), that are foregone because of mobility restrictions associated with the absence of any automobile in the household. The level 2 deficit, which corresponds to the difference between estimated actual travel and the amount of travel that would occur if automobile availability constraints essentially were eliminated, is in excess of 18,000 person trips/day, or more than 9,000 daily activities (or 1.0 daily person trip per household).

These aggregate figures have more meaning when distributed among the households according to automobile ownership. The level 1 deficit, which impacts only those households with zero automobiles, corresponds to approximately 2.6 person trips per day for each household with zero automobiles. This, in turn, represents at least one activity per day per household impacted. Similarly, the level 2 deficits impact both zero- and one-vehicle households. These deficits correspond to approximately 5.2 and 2.6 daily person trips per household for zero- and one-vehicle households, respectively (roughly, 2 and 1 activities, respectively, per day per household impacted).

The preceding estimates of travel needs do not reflect the potential ability of existing transit services to provide mobility to Bell Gardens residents. A zone with high needs may be situated favorably relative to transit service, which would enable residents of this zone to satisfy some of their mobility needs with transit. In contrast, other zones may be poorly situated to transit, in which case their residents lack transit mobility regardless of the theoretically estimated level of needs. Thus a mechanism is needed to adjust the travel needs for the quality of transit service supplied to a zone. This adjustment procedure simply entailed determining, for each census block, the trip deficits that could not be accommodated on transit. That is, the values in Table 4 were multiplied by the

TABLE 3 TRIPS POTENTIALLY SERVED BY EXISTING TRANSIT SERVICE

Analysis Zone	Work Trips Potentially Served	Non-Work Trips Potentially Served
A1	4.0%	32.1%
A2	10.9	37.0
A3	33.0	52.4
A4	36.2	31.2
A5	26.6	38.2
A Total:	23.2	38.5
B1	0.4	10.0
B2	10.9	37.0
B3	7.2	34.2
B4	41.1	58.0
B5	13.1	38.4
B6	1.0	30.0
B Total:	10.2	31.6
C1	21.0	44.0
C2	18.1	30.0
C3	55.7	50.5
C4	53.7	50.9
C5	61.0	72.0
C6	21.1	44.0
C Total:	38.2	48.1
D1	21.0	44.0
D2	9.9	31.8
D3	19.9	40.3
D4	5.9	32.0
D5	17.9	38.9
D Total:	15.5	37.1
AREA TOTAL:	**21.6%**	**38.7%**

values in Table 3, and the results were subtracted from Table 4. The result is Table 5, a spatially disaggregated estimate of travel deficits that could or could not potentially be served by existing transit service. Figures 6 and 7 show these results graphically.

USING UNMET NEEDS ANALYSIS TO DESIGN TRANSIT SERVICE

No single transit alternative is likely to meet every transportation need identified. The more diverse the unmet needs of various user groups are, the greater will be the resulting range of necessary service alternatives. The characteristics of any proposed system must clearly fit the needs of particular markets. The purpose of the Bell Gardens transit service was to provide improved local intracommunity service and to facilitate access to the existing regional transit system. Two primary concerns were to provide better transit for work trips and to improve the mobility of elderly members of the community. Thus the elderly market and the commuter market received especially high priority. Alternate transit services are defined not only by the technology employed (e.g., bus transit, taxi, dial-a-ride, etc.), but also, and perhaps more importantly, by the level of service that technology provides. The service alternatives that were considered for Bell Gardens included:

- some form of conventional fixed-route, fixed-schedule transit (FRT),
- some form of demand-responsive transit (DRT), potentially dial-a-ride, route deviation, point deviation, or taxi (regular or shared-ride), and
- a jitney service (fixed route but variable schedule).

Various applications of fixed-route, demand-responsive, and jitney technology had the potential to satisfy portions of the total travel demand. Given this choice of feasible alternatives, the next step was to match carefully the elements of transit service options to identified needs and priorities of specific markets.

The spatial distribution of travel deficits was such that a fixed-route service did not appear capable of adequately meeting all important transit needs. As Figures 6 and 7 indicate, the zones of highest transit service adjusted trip deficits do not group along any corridor, but instead are distributed

TABLE 4 TRIP DEFICITS

CENSUS BLOCK TRACT GROUP	LEVEL 1 DEFICITS WORK TRIP DEFICIT	LEVEL 1 DEFICITS NON-WORK TRIP DEFICIT	LEVEL 1 DEFICITS TOTAL TRIP DEFICIT	LEVEL 2 DEFICITS WORK TRIP DEFICIT	LEVEL 2 DEFICITS NON-WORK TRIP DEFICIT	LEVEL 2 DEFICITS TOTAL TRIP DEFICIT
A1	25	62	87	72	231	303
A2	55	126	181	197	625	832
A3	51	123	174	189	597	786
A4	38	82	120	183	599	783
A5	122	211	333	319	1,044	1,363
TOTAL A	292	611	903	961	3,113	4,074
B1	24	53	77	159	529	688
B2	27	68	95	105	338	443
B3	9	27	36	51	161	212
B4	19	39	58	88	282	370
B5	71	135	206	268	901	1,169
B6	27	55	82	120	386	506
TOTAL B	178	377	555	791	2,595	3,386
C1	44	69	113	191	665	856
C2	71	152	223	219	708	927
C3	78	154	232	231	761	992
C4	47	97	144	213	704	917
C5	47	113	160	166	524	690
C6	63	133	196	151	633	784
TOTAL C	348	716	1,064	1,216	4,175	5,391
D1	26	49	75	140	579	719
D2	49	111	160	243	786	1,029
D3	83	174	257	277	902	1,179
D4	92	180	272	236	761	999
D5	135	259	394	471	1,568	2,039
TOTAL D	386	770	1,156	1,368	4,502	5,870
TOTAL:	**1,204**	**2,474**	**3,678**	**4,336**	**14,385**	**18,721**

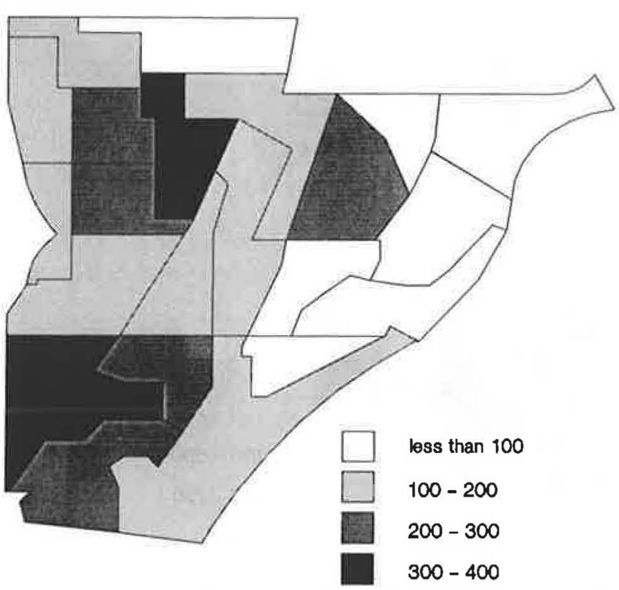

FIGURE 4 Total level 1 trip deficits.

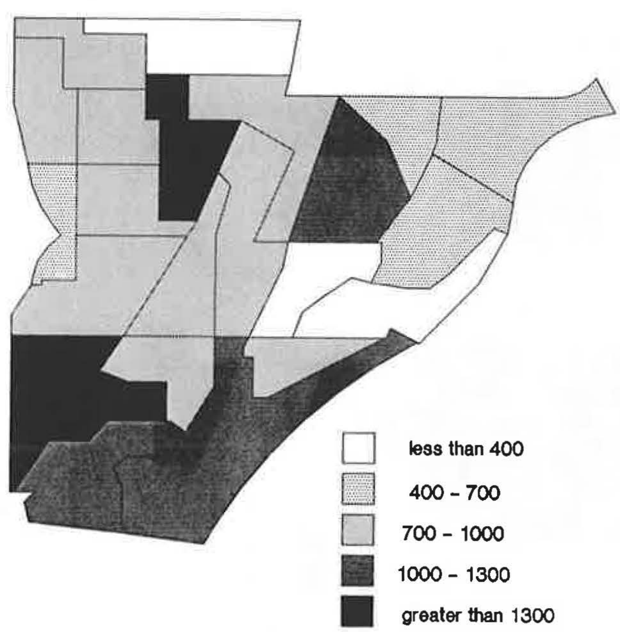

FIGURE 5 Total level 2 trip deficits.

TABLE 5 TRIP DEFICITS AND TRANSIT SERVICE

CENSUS BLOCK TRACT GROUP	LEVEL 1 DEFICITS			LEVEL 2 DEFICITS		
		POTENTIALLY SERVED			POTENTIALLY SERVED	
	NOT SERVED	Work	Non-Work	NOT SERVED	Work	Non-Work
A1	66	1	20	226	3	74
A2	128	6	47	580	21	231
A3	93	17	64	411	62	313
A4	80	14	26	530	66	187
A5	220	32	81	879	85	399
TOTAL A	587	70	238	2,626	237	1,204
B1	72	0	5	634	1	53
B2	67	3	25	307	11	125
B3	26	1	9	153	4	55
B4	27	8	23	170	36	164
B5	141	9	52	788	35	346
B6	66	0	16	389	1	116
TOTAL B	399	21	130	2,441	88	859
C1	74	9	30	523	40	293
C2	164	13	46	675	40	212
C3	111	43	78	479	129	384
C4	70	25	49	445	114	358
C5	50	29	81	212	101	377
C6	125	13	58	464	32	278
TOTAL C	594	132	342	2,798	456	1,902
D1	48	5	22	435	29	255
D2	120	5	35	755	24	250
D3	170	17	70	760	55	364
D4	209	5	58	741	14	244
D5	269	24	101	1,345	84	610
TOTAL D	816	56	286	4,036	206	1,723
TOTAL:	**2,396**	**279**	**996**	**11,901**	**987**	**5,688**

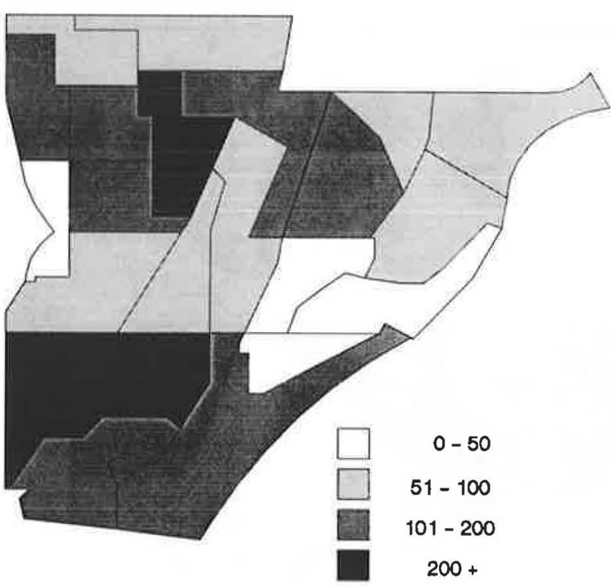

FIGURE 6 Spatial distribution of transit service adjusted level 1 trip deficits.

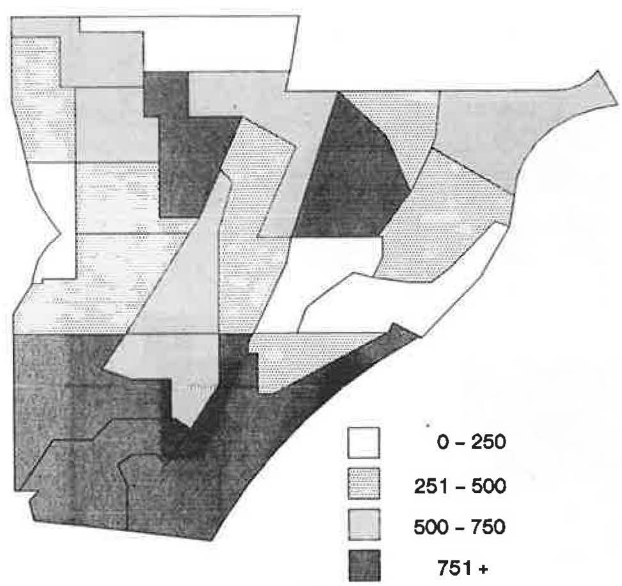

FIGURE 7 Spatial distribution of transit service adjusted level 2 trip deficits.

throughout the city. The only mode judged capable of serving this dispersed distribution of need was some form of demand-responsive transit. DRT also had the advantage that, as a flexible transit service, it could serve both work trips during the peak period (primarily as a feeder to SCRTD regional routes) and intracommunity travel by low-income and elderly persons during off-peak.

Based on these considerations, a point deviation DRT system was recommended for implementation. In this modified DRT service, on each vehicle tour, the vehicle is always routed by several fixed points in the city. Residents can request pick-up and delivery to any point in the city; alternatively, those whose origin is near the fixed points can simply walk to these locations for pick-up. The fixed points were placed in the residential areas of greatest unmet need, as determined by the previous analysis, and at a major center of community activity. Figure 8 shows the location of these points superimposed on the spatial distribution of daily transit service adjusted level 2 trip deficits, as well as an example routing of a DRT vehicle on a particular excursion.

The pricing rationale employed was to maximize social benefits derived from increased transit use. Such public benefit fares account for incremental benefit to nonusers as well in establishing a fare policy. This justifies the use of sales tax funds from Proposition A on a citywide basis. As the service is a general benefit, any fares derived should be expected to pay for only a small portion of the cost. A nominal ($0.25) flat fare was selected to (1) avoid equity problems, (2) reflect the short trip lengths of the demands to be served, (3) facilitate implementation and operation, and (4) discourage unnecessary travel that might result from a no-fare operation.

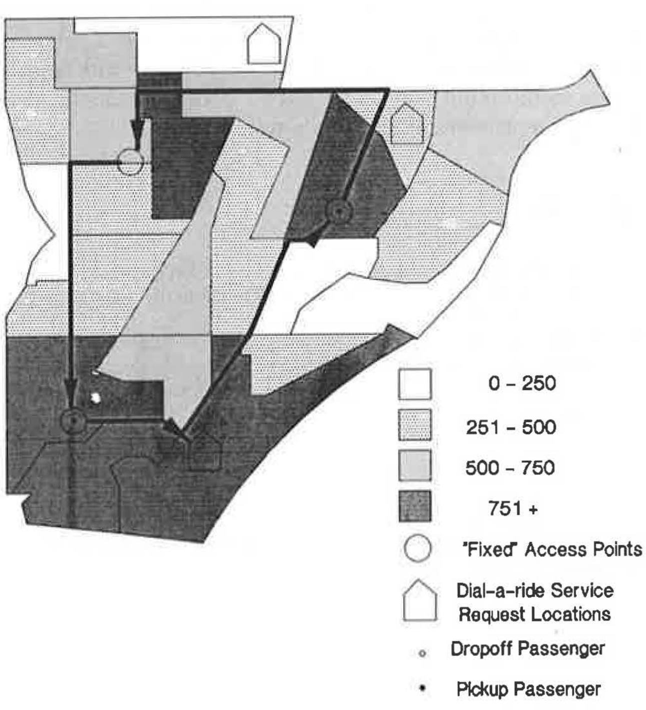

FIGURE 8 Routing of DRT service relative to distribution of transit service adjusted level trip deficits.

EVALUATION OF THE PROCEDURES

To determine whether the procedures developed previously are useful in designing transit services that respond to actual needs, a comparison between projected needs and manifest behavior is needed. This comparison was accomplished by using the geographical distribution of demand for the point deviation DRT service. For this comparison, drivers' logs for a single month were analyzed to determine the locations of all residential trip origins for the month (school trips were excluded, but they represented a small portion of all trips). This distribution of monthly rider origins (Figure 9) was then compared to both the spatially disaggregated unadjusted and transit-adjusted trip deficits.

The use of a full month of daily driver logs avoids problems associated with periodic fluctuations in demand. These monthly figures are to be correlated with unmet travel needs estimated on a daily basis, since no simple analysis can provide accurate assessments of day-to-day variability in travel demand. Standard correlation techniques, of course, properly account for the difference in scale of the estimated deficits and observed ridership.

As a means of assessing the quantitative agreement between the spatially disaggregated estimates of travel need and actual rider origins, Spearman rank-order correlations were performed. Conventional product-moment correlations (Pearson) assess the degree of linear relationship between two continuous, interval scaled variables, assuming bivariate normal populations. Rank order correlations (Spearman) avoid this burden of population distribution assumptions by converting raw data to ordinal values. On the other hand, Spearman correlations are a weaker statistic than are Pearson correlations. Neither method, however, necessarily reflects a causal relationship between the correlated variables. Specifically, the block group zones were ranked by ridership origins, level 1 travel deficit, and level 2 travel deficit, respectively; and rank-order correlations were computed. The results are shown in

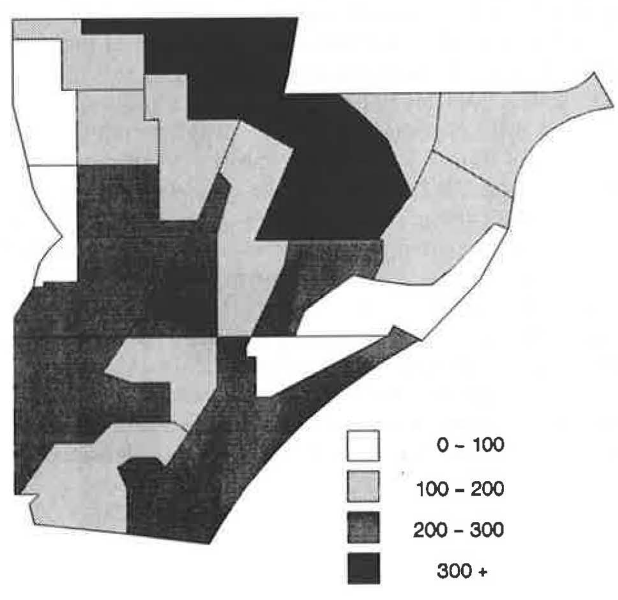

FIGURE 9 Spatial distribution of observed DRT trip origins.

TABLE 6 SPEARMAN RANK-ORDER CORRELATIONS BETWEEN RIDERSHIP AND TRIP DEFICITS

	Correlations Between:	
Ridership	Unadjusted Level 1 Trip Deficits	Unadjusted Level 2 Trip Deficits
All zonal origins	.56	.66
Excluding B1	.63	.74
Ridership	Transit Service Adjusted Level 1 Trip Deficits	Transit Service Adjusted Level 2 Trip Deficits
All zonal origins	.66	.80
Excluding B1	.72	.79

All correlations significant at .01 level

Table 6. Two sets of correlations were computed, one with all zones included, the other excluding zone B1. This zone had unexpectedly high ridership, and further analysis of the data revealed that 40 percent of all trips originated at two residential addresses. As no other zone exhibited a similar phenomenon of a few households marking such intensive use of the service, the ridership level of zone B1 may be an abnormality.

The results of the rank-order correlations generally support the validity of the approach to unmet travel need estimation presented here. The correlation of 0.80 between the transit service adjusted level 2 trip deficits and actual ridership indicates that the procedures result in reasonably good predictions of the spatial distribution of transit demand. It is noteworthy that adjusting the travel deficits for access to transit uniformly increased the rank-order correlations. This indicates that the extra work necessitated by this adjustment is worthwhile. A Pearson correlation of 0.73 between transit adjusted level 2 trips deficits and ridership indicates that variations in the level of absolute trip deficit explain about 53 percent of the variation in absolute zonal demand for the service.

The service implemented is primarily a demand-responsive operation, with door-to-door service. The exception is the placement of three fixed points—thus the classification as a point-deviation DRT system. As these points were selected on the basis of the needs assessment, there is some bias in the resulting evaluation, although this is somewhat tempered by the observed data that indicate trip rates comparable to similar zones without the fixed points. It is possible, but not verified, that the individuals using the fixed-point locations may be quite different from the other users of the system (e.g., individuals with English language problems).

The DRT service was designed to reflect the distribution of the identified deficits, and although aggregate demand estimates for the service closely matched actual ridership, overall ridership does not match, nor is it expected to match, needs identified relative to automobile-equivalent mobility. Although analyses of variance in other factors related to need, such as income or population density, could lead to a similarly designed and effective service, this technique also provides an assessment of residual unmet need—that is, automobile-equivalent mobility not met by implemented services.

The statistical results indicate that the procedures outlined here produce reasonably reliable estimates of the spatial distribution of need and demand for transit service. This conclusion must be qualified to the extent that the service in question was of relatively uniform quality throughout the study area, whereas fixed-route transit produces major quality differentials depending on the location of the route relative to origin and desired destination. A useful area for additional research would be the testing of these procedures, with appropriate modification to reflect service access differentials, with a newly implemented fixed-route transit service.

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