Commercial Activity Location Model

JERE FIDLER, Subdivision of Transportation Planning and Programming, New York State Department of Public Works, Albany

•ONE important component of the transportation planning process is the forecasting of future travel demand. Usually, this is closely tied to several land-use forecasts; one of these is a forecast of commercial land. This paper describes a model to predict the most likely locations of future commercial activity in an urban area.

People are consumers. They satisfy their demand for commercial goods and services chiefly by traveling to commercial land. An increasing population will cause a corresponding increase in the demand for commercial goods. It is the magnitude and location of this demand increase which will determine the size and location of future commercial centers.

This model defines a measure of consumer demand for commercial goods. It simulates the movement of people traveling to satisfy this demand. If the locations of future demand are known (forecast independently), the places where this future demand is satisfied can then be found by simulation. The model determines locations where the expected growth in satisfied demand is high; these are potential sites for future commercial development.

DEFINITIONS AND THEORY

The first task is to define an accurate measure of the demand for commercial goods. Because we are dealing with the movement of people to land, one obvious measure of commercial demand is person trips to commercial land; that is, person trips which are measured at traffic origin zones and that are known to have a commercial land use at zone of destination. (For convenience, the traffic analysis zone was chosen as the geographical unit of measurement.) These trips should also be constrained by trip purpose; for example, work trips to commercial land cannot reasonably be included in a measure of consumer demand. Furthermore, these person trips might be weighted by household or family income to add a "spending power" dimension to the measure of demand. Thus, we shall define the demand for commercial goods as a special class of person-trip origins weighted (optionally) by income; the particular trip purposes and land-use types used in applications of the model are described later.

Commercial establishments compete for consumer demand. A measure of the competition that the commercial establishments in one zone exert on the person trips in another zone is defined; the sizes of the establishments are measured by land area. Suppose that D_j units of commercial land exist in zone j. Suppose also that t_{ij} is the trip-driving time between zone i and zone j. Then the competition on the trips in zone i due to the commercial land in zone j is defined by the expression D_j/t_{ij}^x; x is an exponent which measures the relative importance of driving time and will be examined in detail in the next section. Because all zones which have commercial land compete for the trips in zone i, the equation

$$C_i = \sum_{\text{all } j} \left(\frac{D_j}{t_{ij}^x} \right)$$

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defines an expression for the total competition on the trips in zone i, C_i, from all study area zones. The zone table of C_i values is referred to as the competition surface.

The model allocates the trips which originate in a given zone to destination zones according to the proportion of total competition on the origin zone which is due to commercial land in a destination zone. For example, if zone i contains 200 trip origins, if C_i equals 100 units of competition on zone i, and if 25 of these 100 units are due to commercial land in zone j, then (25/100) or one-fourth of the 200 trips will be allocated from zone i to zone j.

In symbols, suppose that T_i trips originate in zone i and that C_i is the total competition on these trips (if the option to weight trips by family income is used, T_i would represent "trip-dollars"). We know that $(D_j/t_{ij}^x)/C_i$ is the fraction of total competition on zone i which is due to commercial land in zone j. Thus, the number of trips allocated to zone j from zone i is the foregoing fraction multiplied by T_i. The total trips allocated to zone j from all study area zones can be calculated in this way. The equation

$$AT_j = \sum_{\text{all } j} \left\{ \left[\left(\frac{D_j}{t_{ij}^x} \right) C_i \right] T_i \right\}$$

is the symbolic representation of the total trips allocated to zone j. This method of trip destribution is the familiar "gravity" formula. The zone table of AT_j values is referred to as the trip surface.

The preceding material describes how the model simulates the movement of people to commercial establishments—people traveling to satisfy their demand for commercial goods and services. This simulation technique is employed in three distinct model phases which are described in the following sections of this paper.

It should be noted that it is not strictly necessary for the demand and competition variables to be defined as they have been. For example, one might wish to use population instead of trip origins as the measure of demand, or airline distance instead of travel time as the measure of spatial separation. In fact, the use of employment instead of land as a measure of commercial establishment size (competition variable) has been examined; the results of this research are encouraging and are given in the next section. The calibration phase of the model is a handy tool for testing the accuracy of particular variables.

THE CALIBRATION PHASE

Description

The purpose of this phase is to check the accuracy of the model using present data. A selected class of zone trip origins is obtained (from survey), and these trips are allocated by the model to zones of destination. This is done according to the simulation technique previously described.

Allocated trips are then compared to the actual trip destinations (from survey). The comparison is made on a district basis (aggregates of zones), and several measures of estimating accuracy are obtained. In this way, the variables which give the best estimates can be selected. For example, one important function of this phase is to determine the "best" value of the travel-time exponent—assuming that the trip class, land-use type, and interzonal travel times have been previously specified and are held constant. This phase proved valuable in examining relationships among variables and in evaluating the usefulness and accuracy of the model.

Application

The first tests of this model were made using 1962 data from the files of the Niagara Frontier Transportation Study. The following base-period inputs are required for the calibration phase:

1. Person trips by zone of origin by land use at zone of destination.
2. Person trips by zone of destination by land use at zone of destination.

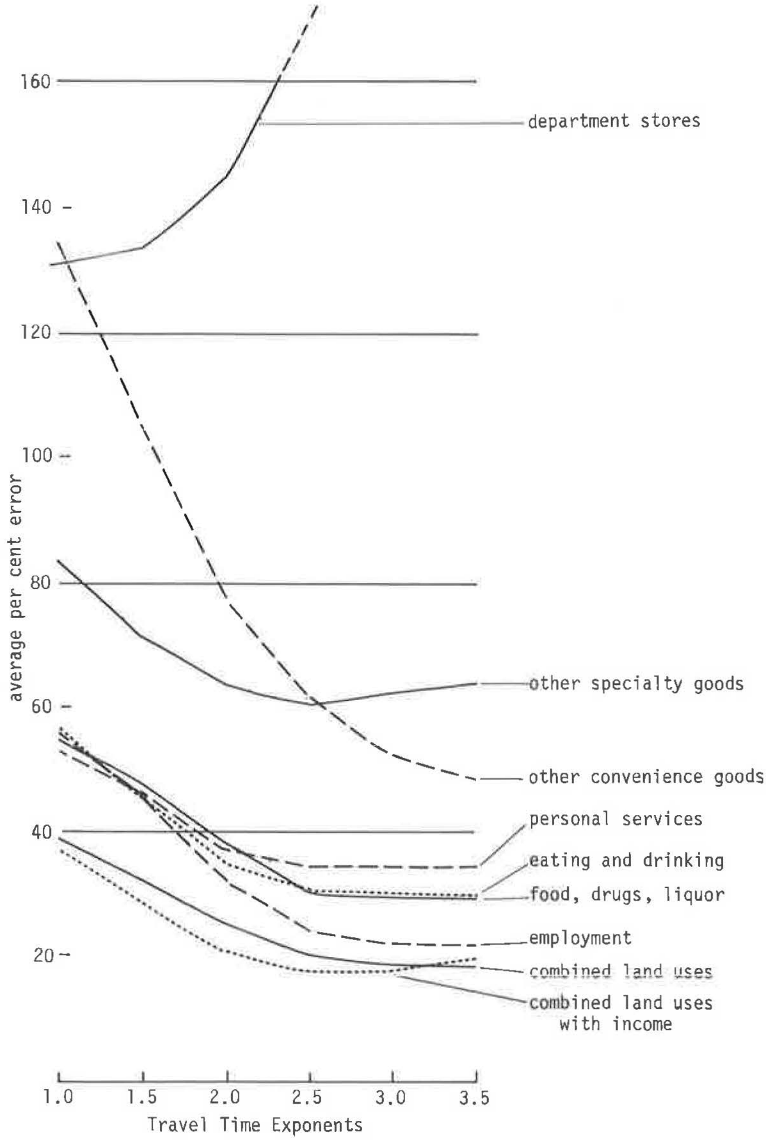

Figure 1. Simulation of nonwork trips to commercial land, using 1962 travel times.

3. Commercial land use by zone.
4. Interzonal travel times for all possible pairs of traffic zones.
5. Income factors (optional) by zone.

Land-use data were available by detailed categories, the following of which were selected for extensive testing: (a) food, drug, and liquor stores; (b) eating and drinking places; (c) department stores; (d) other specialty goods (shopping goods) stores; (e) other convenience goods stores; and (f) stores providing personal services. These data did not include large parking areas.

Person-trip information was obtained by origin and destination zone and was separated into categories according to the land uses just mentioned (at zone of destination). Moreover, all work-purpose trips (purpose at destination) were excluded from these tests; the trip purposes remaining included the following: (a) shopping, (b) social-recreation, (c) eat meal, (d) personal business, (e) serve passenger, and (f) ride as a passenger. For the selected land-use categories, most of the trips were shopping trips.

Inter-zonal travel-time data for the 1962 highway network were obtained from the Schneider traffic assignment program, using the capacity restraint feature. This input was constant for all tests of the calibration phase. For the zone income factors, U. S. Bureau of the Census data for 1960 were used. The median incomes of families and unrelated individuals were obtained by census tract and were converted into zone factors.

With travel times invariate, tests were made to determine the responsiveness of the model to land-use type, travel-time exponent, and income. In general, all of these factors were significant. As was mentioned previously, the calibration phase compares model-allocated trip destinations with actual trip destinations on a district basis; the average absolute percentage difference of actual trips vs estimated trips is one criterion used to measure accuracy.

Figure 1 shows some of the results of these tests. Model accuracy is plotted against the travel-time exponent for different land-use types. As an example, consider the curve for the food, drug, and liquor stores category. The points for this curve were obtained by running the calibration phase for this land-use type for the six travel-time exponents. In particular, person trips at zone of origin (known to have a food, drug, or liquor store at destination) were allocated by the model to destination zones, using food, drug, and liquor store land as the competition variable. There were 195, 584 nonwork trips in this category.

As Figure 1 shows, the accuracy of simulation improves as the travel-time exponent increases—average percent difference declines from 56 percent for exponent 1. 0 to 30 percent for exponent 3. 5. The fact that simulation accuracy improves as the exponent increases is a meaningful result. Higher exponents increase the importance of driving time; therefore, model accuracy should improve for higher exponents if the trip type under consideration was one for which driving times are relatively significant. Previous research (1) has indicated that driving times are more significant for shopping trips to convenience goods land than for shopping trips to specialty goods land (convenience goods are those purchased frequently and are usually low-cost items).

Because the food, drug, and liquor store category is one of the convenience goods land uses, the model responds in a reasonable way for this category. Indeed, the same statement can be made for other categories. All of the so-called convenience goods land uses have simulation accuracies which improve as the travel-time exponent increases. These include: (a) eating and drinking places (88, 246 trips); (b) person services land (23, 818 trips); and (c) other convenience goods stores (9, 954 trips). Specialty goods land uses exhibit an opposite effect. The simulation of trip movements to department stores (99, 043 trips) decreases in accuracy as the travel-time exponent increases; this is to be expected, since driving times are less significant for these trips. The "other specialty goods" category (44, 466 trips) appears to be an intermediate category with respect to the importance of driving time.

One disturbing element of these results is the uniformly low accuracy in simulating department store trips. Two possible explanations can be put forward: (a) the model is inappropriate for these trips, or (b) survey sampling may have been ineffective for these trips, since Saturday was not included as a sampling day in this study area. The importance of Saturday as a shopping day is well-known. If most department store trips are made on this day, commercial trips may be underrepresented in this category. Since the model did respond in a reasonable way to the travel-time exponent for these trips, there is some justification for claiming the second explanation instead of the first.

The high inaccuracy in the other convenience goods category has little significance, for the trips in this group constitute only 3 percent of all convenience goods trips.

Considerable improvements in the accuracy of simulation occur when the model is run for combinations of land-use categories. One example is presented here: the demand variable used is person trips to convenience goods land uses (food, drugs, and liquor; eating and drinking; person services; and other convenience goods) while the competition variable is total commercial land (convenience goods land plus specialty goods land). There was a total of 317, 602 nonwork trips in the combined group. This particular combination implies that specialty goods land has a role in attracting convenience goods trips—an assumption which is not unreasonable for large clusters of commercial activity. By making this choice of categories, we are able to make forecasts of commercial activity which include specialty goods land; moreover, this eliminates the large amount of error due to department store trips. Of course, the trips to specialty goods land uses will then have to be predicted by some other method.

Figure 1 shows that average percentage error of simulation is reduced to 19 percent for this combination of categories (lowest unbroken curve). The combining of land-use categories in this way appears to have a strong effect on simulation accuracy; this is probably due to smaller errors of sampling variability.

The effect of weighting trip origins by income was also tested, using the above combination of categories. The result was a small reduction in percentage error for most travel-time exponents. Most of this improvement in accuracy occurred in central business district zones, where the model was overestimating trips significantly; one general effect of income weighting in these tests was to remove trips from the downtown area and allocate them elsewhere.

On the basis of the calibration tests, it was decided to produce a forecast of commercial activity using the preceding combination of categories. Trip origins were weighted by incomes and a travel-time exponent of 3. 0 was chosen. Figure 2 shows a comparison of model-estimated trips with actual (survey) trips for this choice of parameters. This simulation has a 17. 5 average percent error.

Employment as Competition Variable

Some preliminary tests of the model were made using employment as the competition variable. Employment was measured by the number of work trips having particular commercial land uses at zone of destination. These trips replace commercial land as the "attractor" of nonwork trips in the model.

A dashed curve in Figure 1 shows the results of these tests. In this case, the work trips used were those having any convenience goods or specialty goods land use at destination. The demand variable (trip origins) was nonwork trips having convenience goods land at destination; these trips were also weighted by income. Again, the accuracy of simulation improves as the travel-time exponent increases: 57 percent error for exponent 1. 0 to 23 percent error for exponent 3. 0.

We conclude from this that employment appears to be an accurate alternative to land as the competition variable. Of course, if it is desired to use the model for land-use forecasting, an additional step would be required to make the conversion from employees to land. Otherwise, commercial activity could be forecast in units of employment instead of in land units. However, it will be assumed in the remainder of this paper that land is the competition variable.

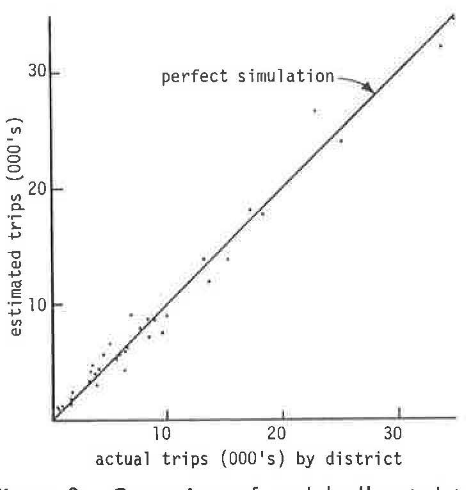

Figure 2. Comparison of model-allocated trips with actual trips for combined land-use categories.

THE INITIALIZATION PHASE

Description

In this phase of the model, the region is examined under "present" conditions to determine whether additional commercial land can be supported. Every zone is considered as a possible location for new land. An initial allocation of trip origins is made to zones using the present land-use pattern and traffic network; this determines the base or initial trip surface. Next, an independently defined commercial activity center size is selected; this commercial center, or "commercial unit," may be defined in terms of floor area or site area. This amount of commercial land is then temporarily added to the existing land in a particular zone i, and a second allocation of trips to destination zones is performed. If the trips attracted to zone i in the second allocation are compared to those attracted in the initial allocation, the number of trips which have been drawn to the zone because of the new commercial center can be measured. We shall refer to the difference between the two allocation values as the trip potential of this size commercial center in zone i.[1] The trip potential is then determined independently for each zone.

The foregoing procedure yields a set of numerical values representing a trip-potential surface. Zones having high trip-potential values represent possible sites for the commercial center in question. From this trip potential surface, the "best" zone in which to locate the new center can be determined. In this connection, the zone trip-potential values are first aggregated into districts, and an average trip-potential value is calculated for each district; the best zone is then chosen to be the zone with the highest trip potential within the district having the highest average potential. This technique was used to overcome possible inaccuracies due to sampling variability.

This selection process guarantees that a best zone is determined. However, the best may not be good enough. Some criterion is needed to determine whether the new trips attracted to the zone justify the new center. Accordingly, a minimum trip-generation rate for the specified size of commercial center is required as an independent input. The minimum rate represents the smallest number of new trips required to travel to a zone on an average travel day in order for the new center to be established; it is specified in units of trips per 1000 sq ft of land and is referred to in this paper as the trip sufficiency rate. If the trip potential in the selected best zone equals or exceeds this minimum rate, the center may be located there. If not, another zone will be tried.

Other criteria may be used to determine the feasibility of locating a new commercial center in the selected zone. The zone may be required to contain a sufficient amount of vacant usable land. Also, zoning laws or land cost may be such as to prohibit commercial development in certain locations. These criteria may be tested as options.

If a selected zone satisfies all of the preceding requirements, commercial land corresponding to this size commercial center is then assumed to exist in that zone. This zone has therefore become more competitive—its ability to attract trips is greater. The surface of competition must then be changed to account for this new land. Also, the new trips attracted to this zone are added to the initial trip surface. After a new commercial center is located and the competition surface is revised, the entire process is repeated. A new trip potential surface is obtained, again assuming that new land exists in each zone.

Three commercial center sizes are permitted; each size may have a distinct trip sufficiency rate and travel-time exponent. In this phase, the model will locate all possible commercial units which satisfy the trip- and land-sufficiency criteria. It operates iteratively and will continue until no additional satisfactory sites can be found. Because we are dealing with present conditions, it is possible that new commercial land cannot be supported anywhere in the region. The model determines if this situation exists; if it does, the final or "forecast" phase is begun immediately. Commercial centers which are located in the initialization phase are "permanently" added to the present land-use pattern before the forecast phase is executed.

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[1]The model does not attempt to distinguish between persons traveling to the new center in a zone and those traveling to previously existing land in the zone. Conceivably, new commercial development in a particular zone could induce more trips to existing land. Furthermore, some new commercial developments might consist of additions to previous commercial centers. For these reasons, this model is not referred to as a "shopping-center" model.

Figure 3. Trip-potential surface, 1962 (each dot equals 150 trips).

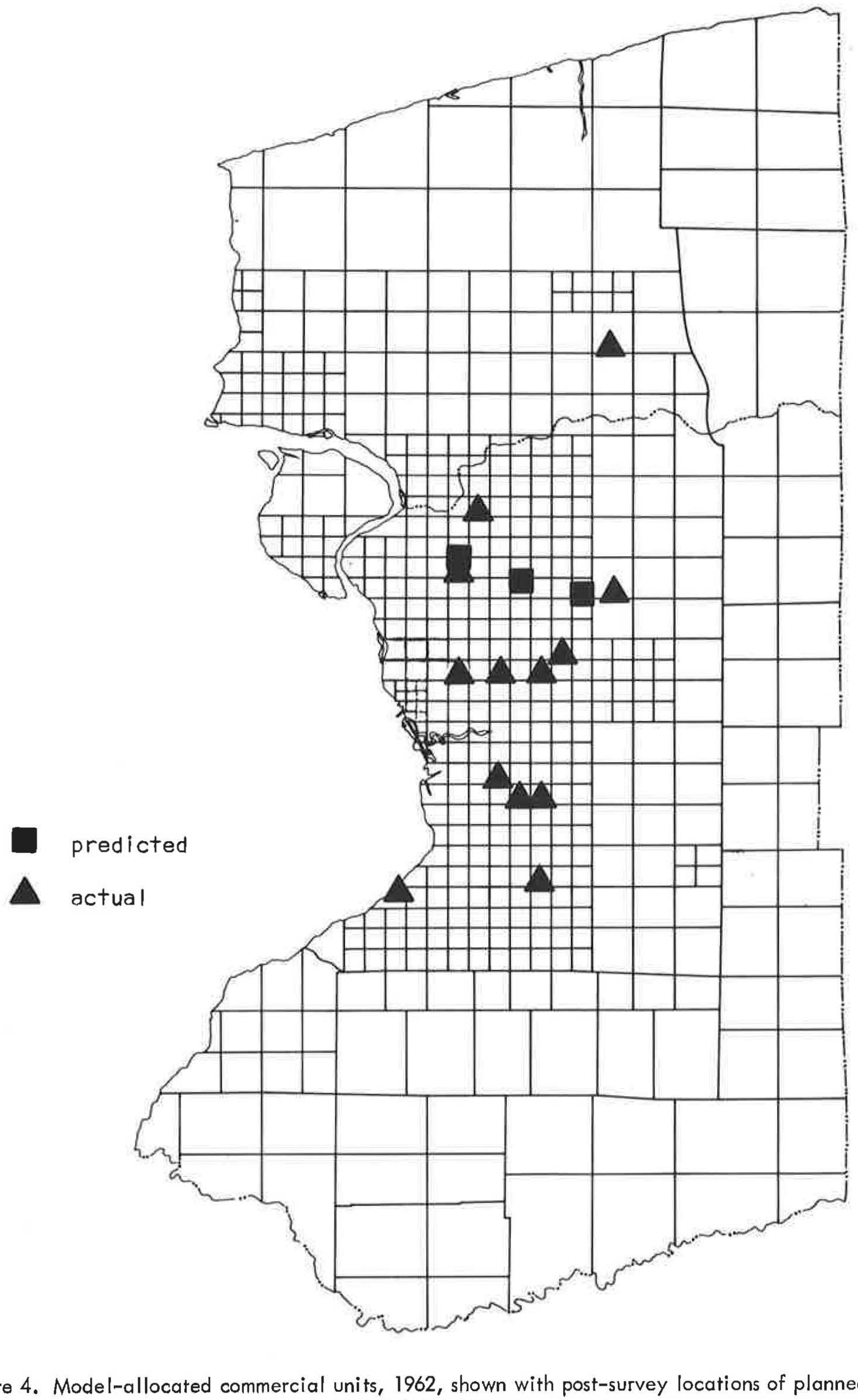

Figure 4. Model-allocated commercial units, 1962, shown with post-survey locations of planned commercial development.

TABLE 1

SEQUENCE OF THIRTY BEST ZONES FOR COMMERCIAL UNIT LOCATION, 1962 CONDITIONS

Rank	Zone	Trip Potential	Sufficient Land
1	57	3, 004	No
2	115	2, 565	Yes
3	200	2, 556	Yes
4	64	2, 502	No
5	104	2, 445	Yes
6	109	2, 254	Yes
7	66	2, 145	Yes
8	103	2, 129	No
9	54	2, 073	No
10	106	2, 061	Yes
11	170	2, 052	Yes
12	63	2, 045	Yes
13	169	2, 026	Yes
14	62	2, 014	No
15	116	1, 966	Yes
16	105	1, 894	Yes
17	52	1, 892	No
18	102	1, 881	No
19	111	1, 778	Yes
20	123	1, 732	No
21	26	1, 674	No
22	117	1, 658	Yes
23	53	1, 642	No
24	110	1, 634	Yes
25	122	1, 623	Yes
26	27	1, 596	No
27	87	1, 543	Yes
28	98	1, 506	Yes
29	118	1, 481	Yes
30	171	1, 471	Yes

Application

The initialization phase was run for the Niagara Frontier Area (for 1962) using the trip-class, land-use combination, exponent, etc., chosen from the results of the calibration phase. A commercial center size of 500, 000 sq ft (not including parking) was selected. Twelve study area traffic analysis zones, known to contain major commercial activity clusters, were examined to obtain the trip sufficiency rate for this center size. This rate was 7. 3 trips (nonwork trips to convenience goods land) per 1000 sq ft of land (convenience goods land plus specialty goods land). Under this assumption, no satisfactory zones for additional commercial land could be found. Table 1 shows the 30 zones having highest trip potentials for this run and Figure 3 shows the trip potential for all zones within the Niagara Frontier cordon area (2). It is apparent from Figure 3 that the downtown area possesses little potential for further commercial development.

Since the surveys for this study area were completed, several major commercial developments have been planned. As a further test of the model, it was decided to reduce the trip sufficiency rate to a level which would permit the location of new centers. This rate was 4. 0 trips per 1000 sq ft, which is approximately the study area average rate for the class of trips in question. Using this rate, three commercial centers of 500, 000 sq ft were located. Figure 4 shows the locations of these centers and also the locations of the actual planned developments. The results are quite reasonable; one unit is within a zone where development is planned and another is located in a zone adjacent to planned development.

THE FORECAST PHASE

Description

In the forecast phase it is assumed that a certain time period has elapsed and that some regional growth has occurred. Thus, the pattern of demand for commercial goods and services will have changed. Because commercial demand is measured in units of person-trip origins, this phase requires an independent forecast of this variable by zone. The changes in traffic network travel times and zone household income factors should also be predicted, but these are optional.

The magnitude of growth in commercial demand (trip origins) controls the number of new commercial centers that can be located in this phase. For example, if there are 300, 000 trip origins in the present year and if 500, 000 trip origins are forecast for the future year, then 200, 000 trips are available to be distributed to new commercial centers.

The allocation technique for these future trip origins is the same as is used in the initialization phase. Again, three commercial center sizes are permitted, each having a distinct trip sufficiency rate and travel-time exponent. The first center size is selected, and a trip potential surface is obtained for this size (the final trip surface obtained from the initialization phase is used as the base trip surface in determining trip potential in this phase). A best zone is chosen and is tested for trip sufficiency and vacant land availability. The process of locating new commercial units is then repeated as before. Moreover, each time a new unit is located, the new trips attracted to its zone are removed from the pool of available trips.

TABLE 2

ZONES RECEIVING COMMERCIAL LAND, 1985

Zone	Land Area (000's sq ft)	Added Trips
204	500	14, 720
234	500	6, 236
137	500	10, 059
372	500	5, 340
163	500	6, 604
203	500	7, 189
180	250	6, 710
119	250	3, 388
183	250	6, 126
117	250	3, 200
248	250	3, 964
Total	4, 250	73, 535

This phase operates until one of the following conditions occurs: (a) the supply of trip origins to be distributed is exhausted; (b) any additional commercial centers will not attract a sufficient number of trips; or (c) an independent estimate of the number of new centers to be located during the forecast period has been made, and this number of centers has been located. In practice, condition (a) is very unlikely to occur since some of the growth in trips will probably be absorbed by existing commercial land.

One important option available in this phase is known as the "planned centers option." If it is known that a certain amount of land is committed for commercial development at some future date, this information may be communicated to the model before it locates any additional future units. In this way, the competitive effect of the planned center will be a factor in any subsequent choice of commercial center location (by the usual model procedure). This option also provides a measure of the trip potential of these planned centers and may therefore be used to test the feasibility of such locations. The option may be used in conjunction with the usual forecast, or independently of it.

Another option in this phase locates "neighborhood" commercial centers in high-potential zones which did not receive new centers during the standard run. The purpose

TABLE 3

1985 FORECAST SUMMARY BY DISTRICT

District	Commercial Land		Trip Destinations Allocated				Trip Density	
	1962	1985	1962	1985	Diff.	Rate	1962	1985
0	1, 880	1, 880	4, 047	3, 605	-443	0. 89	2. 2	2. 0
10	7, 761	7, 761	17, 707	15, 435	-2, 273	0. 87	2. 3	2. 0
20	1, 838	1, 838	5, 579	5, 144	-435	0. 92	3. 0	2. 8
21	1, 758	1, 758	8, 444	9, 976	1, 532	1. 18	4. 8	5. 7
22	3, 097	3, 097	11, 727	11, 531	-196	0. 98	3. 8	3. 7
23	3, 179	3, 179	7, 013	7, 058	45	1. 01	2. 2	2. 2
24	2, 121	2, 121	8, 614	7, 976	-639	0. 93	4. 1	3. 8
25	227	227	1, 277	1, 692	416	1. 33	5. 6	7. 5
30	2, 521	2, 521	7, 630	8, 260	631	1. 08	3. 0	3. 3
31	3, 283	3, 283	26, 654	25, 658	-996	0. 96	8. 1	7. 8
32	2, 696	2, 696	24, 090	31, 396	7, 306	1. 30	8. 9	11. 6
33	728	728	4, 257	8, 273	4, 016	1. 94	5. 8	11. 4
34	1, 324	1, 324	7, 269	16, 453	9, 185	2. 26	5. 5	12. 4
35	1, 362	1, 362	6, 433	8, 513	2, 080	1. 32	4. 7	6. 3
40	647	647	4, 064	9, 345	5, 281	2. 30	6. 3	14. 4
41	3, 415	3, 415	32, 274	37, 443	5, 169	1. 16	9. 5	11. 0
42	1, 692	2, 192	13, 749	30, 227	16, 478	2. 20	8. 1	13. 8
43	834	834	2, 308	8, 613	6, 304	3. 73	2. 8	10. 3
44	1, 526	2, 026	5, 825	24, 734	18, 909	4. 25	3. 8	12. 2
45	800	800	2, 934	10, 104	7, 170	3. 44	3. 7	12. 6
50	279	779	1, 525	10, 977	9, 452	7. 20	5. 5	14. 1
51	3, 540	4, 040	17, 924	52, 093	34, 168	2. 91	5. 1	12. 9
52	2, 939	3, 939	8, 833	31, 737	22, 904	3. 59	3. 0	8. 1
53	1, 514	1, 514	8, 761	24, 013	15, 252	2. 74	5. 8	15. 9
54	230	230	766	7, 263	6, 497	9. 49	3. 3	31. 6
55	1, 145	1, 895	4, 467	19, 478	15, 011	4. 36	3. 9	10. 3
60	7, 790	7, 790	34, 768	53, 055	18, 287	1. 53	4. 5	6. 8
61	1, 154	1, 154	5, 104	22, 260	17, 156	4. 36	4. 4	19. 3
62	1, 628	1, 628	3, 235	13, 457	10, 222	4. 16	2. 0	8. 3
63	153	153	555	5, 013	4, 458	9. 03	3. 6	32. 8
64	1, 521	1, 521	6, 012	21, 631	15, 620	3. 60	4. 0	14. 2
65	1, 042	1, 042	5, 406	17, 288	11, 883	3. 20	5. 2	16. 6
66	216	716	1, 043	5, 435	4, 391	5. 21	4. 8	7. 6
70	1, 111	1, 111	3, 653	11, 399	7, 746	3. 12	3. 3	10. 3
71	5, 675	5, 675	13, 655	36, 761	23, 106	2. 69	2. 4	6. 5
Total	72, 626	76, 876	317, 602	613, 294	295, 692	1. 93	4. 4	8. 0

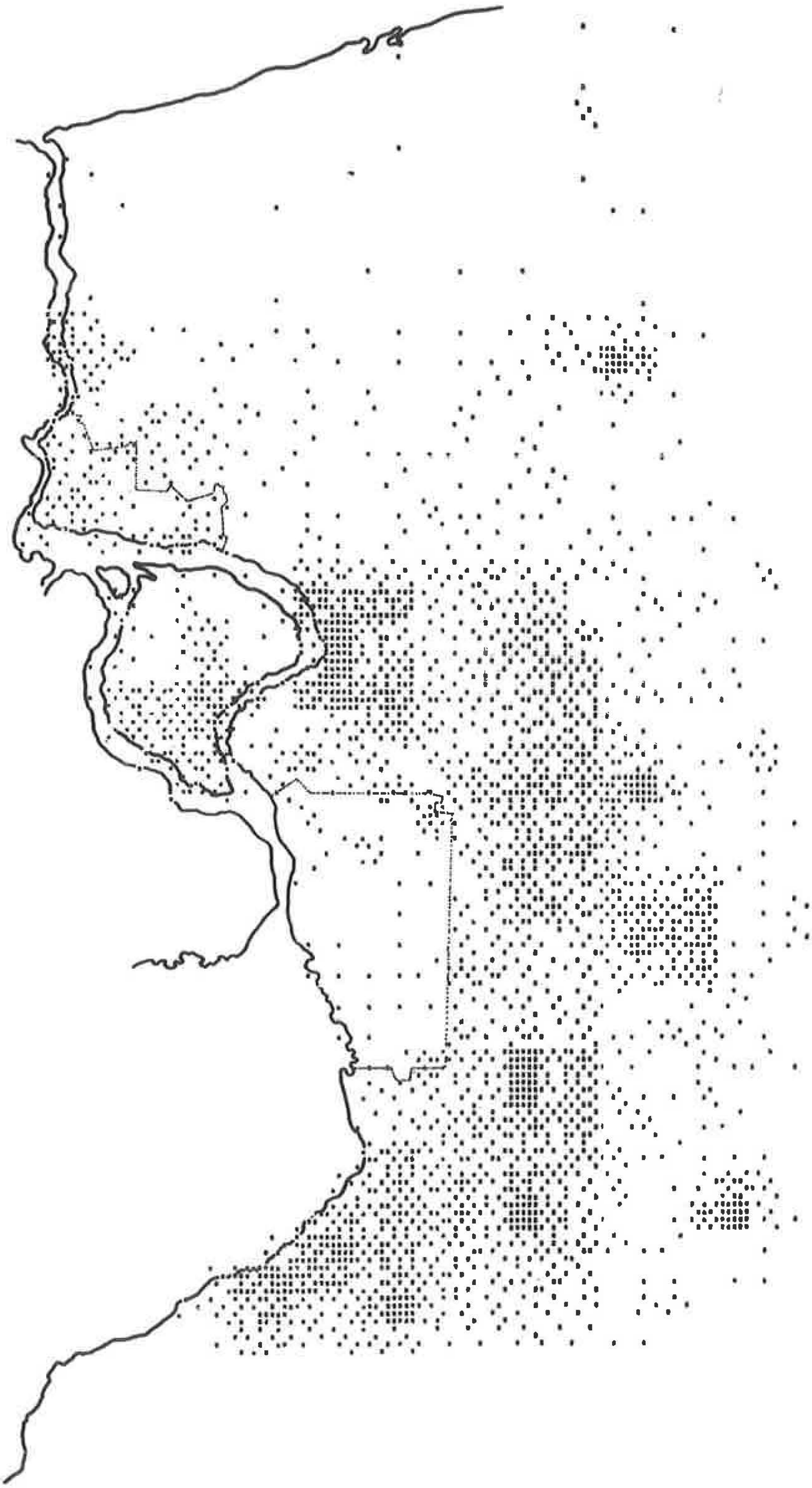

Figure 5. Trip-potential surface, 1985 (each dot equals 300 trips).

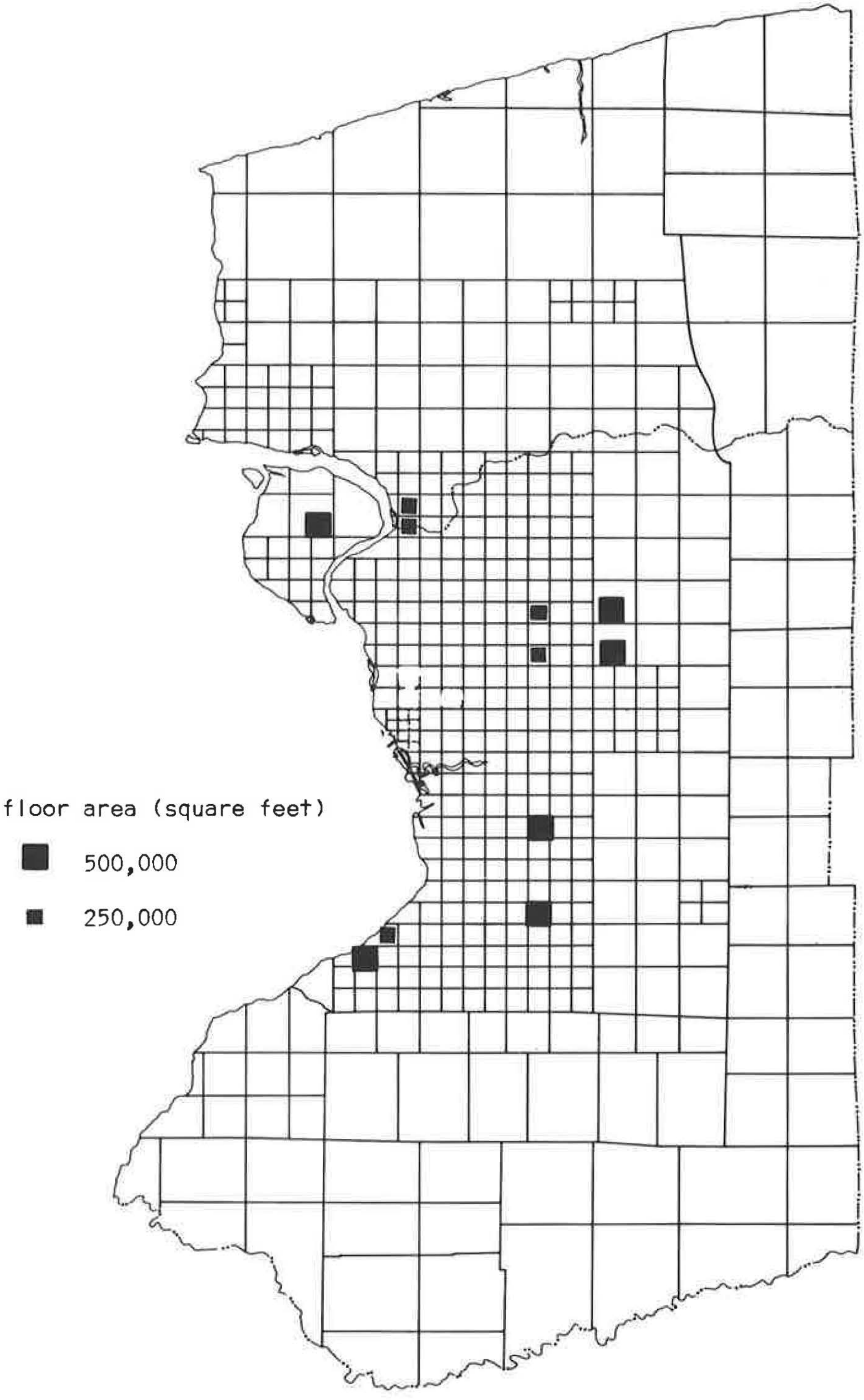

Figure 6. New commercial unit locations.

of this option is to allocate a token amount of land to zones having considerable "unused" potential. A trip sufficiency rate is also required for these centers, but the updating procedure of the model is not used.

After the forecast for one time period has been completed, this phase may be repeated for another time period—provided that the required set of inputs is available. Thus a 20-year forecast could be produced in as many cycles as desired.

The primary output of the model (all phases) is a list of traffic zones receiving new commercial land, the amount of additional land in these zones, and the relative trip-attracting potential of each. Other intermediate outputs are available, as well as the option to produce study area maps of commercial land and trips in both present and future periods.

Application

This phase was also applied to the Niagara Frontier Area to produce a forecast for 1985. The change in the pattern of commercial demand is measured by the change in the distribution of person-trip origins. This variable was forecast by using the regional-growth model developed by the staff of the Subdivision of Transportation Planning and Programming (3). Appropriate trip-origin growth rates were obtained on a district basis and were then applied by zone to the special class of 1962 commercial trip origins used in this particular forecast (nonwork trips to convenience goods land). This technique produced an increment of 296, 000 trip origins.

An approximation of 1985 median family incomes by zone was also prepared by performing a district trend analysis on U. S. Census data. These income factors were then used to weight the preceding trip origins. Travel-time data for this forecast were again obtained from the traffic assignment program, using the 1962 highway network plus committed additions or improvements. The three centers located as a test of the initialization phase of the model were not included in this run.

Two commercial center sizes were defined—500, 000 and 250, 000 sq ft. Figure 5 shows the zone-trip potentials for the first iteration. The trip sufficiency rates assumed for these sizes were 7. 5 and 8. 5 trips per 1000 sq ft.

Eleven centers were located. Table 2 gives a list of the zone locations of the centers; Figure 6 shows their location within the study area. It will be observed that seven of these eleven centers are within or adjacent to zones in which known commercial development has been planned since survey time (Fig. 4). Also, a comparison of the 1962 and 1985 trip potential in Figures 3 and 5 reveals the apparent shift of commercial development potential as the region grows.

Table 3 gives the final district summary of this forecast. Figures 7 and 8 are computer-printed maps of commercial land and commercial trip destinations as of 1985. The planned centers and neighborhood centers options were not exercised in this forecast.

SUMMARY AND CONCLUSIONS

This paper describes a model to predict future locations of commercial activity in any urban area. Figure 9 shows the model components in block diagram form. The model uses a gravity formula to simulate the movement of persons to commercial land. Consumer demand for commercial goods and services is defined as a special class of person-trip origins; person-trip destinations represent satisfied consumer demand. The model allocates person-trip origins to their commercial destinations, using an existing distribution of commercial land and highway network travel times.

The calibration phase compares model-estimated trip destinations with actual trip destinations for the purpose of measuring predictive accuracy. This phase has also been used to demonstrate the reasonable behavior of the model to the following variables: travel-time exponent, land-use type, and family income.

The initialization and forecast phases predict future zone locations of commercial activity. In the initialization phase, commercial units are added to the present land-use pattern—assuming that no regional growth has occurred. This phase answers the

Figure 7. Commercial land, 1985 (each dot equals 100,000 sq ft).

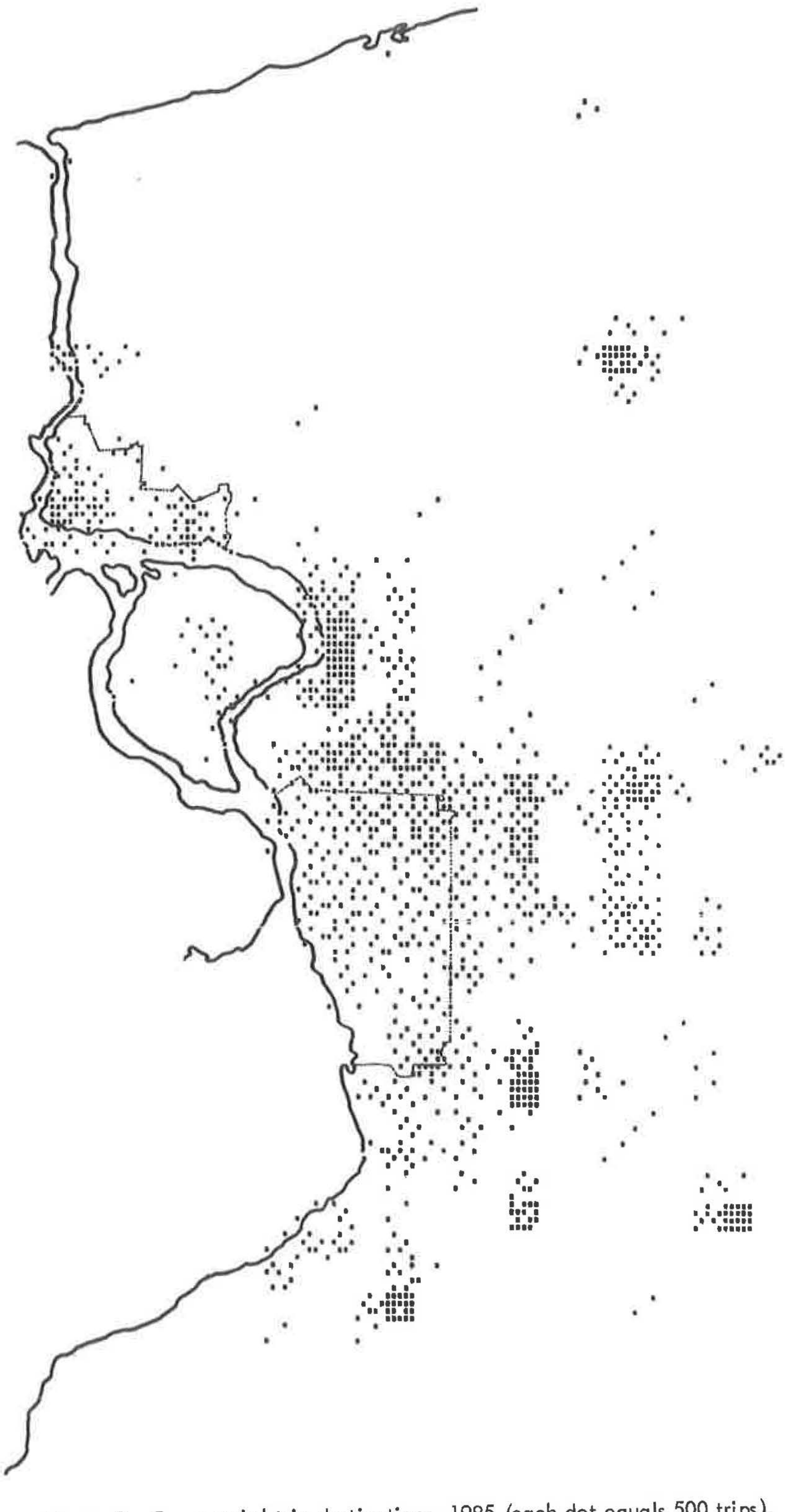

Figure 8. Commercial trip destinations, 1985 (each dot equals 500 trips).

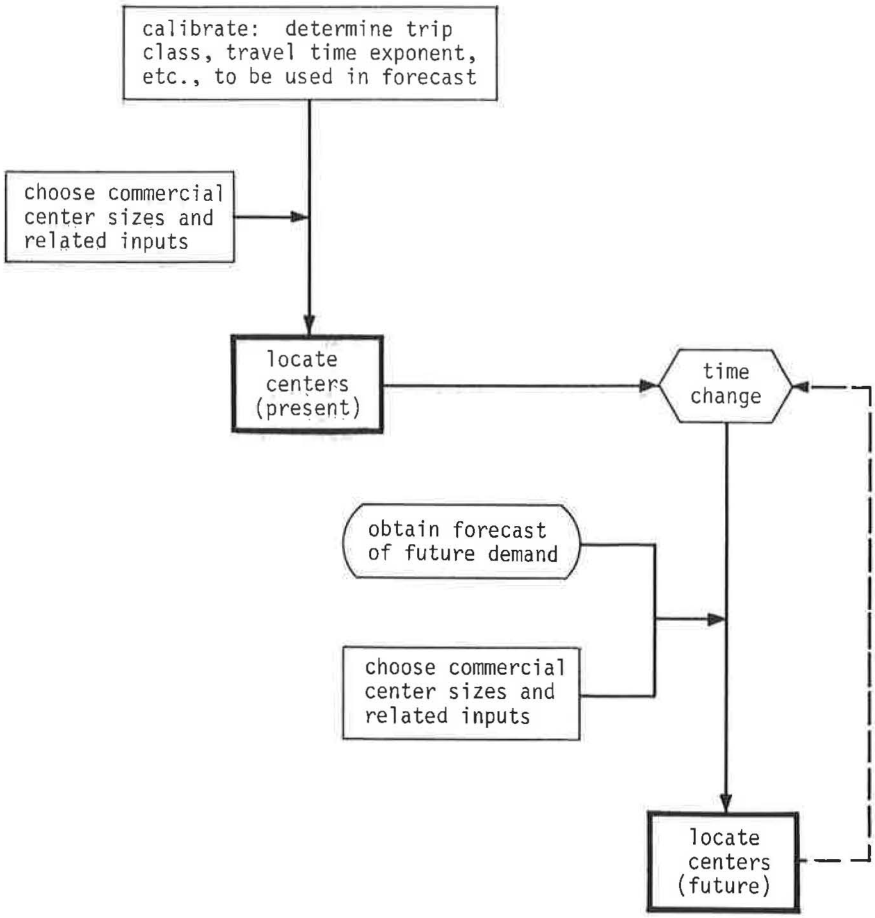

Figure 9. Diagram of commercial activity location model.

question: Can additional commercial development be supported in the region, given the current distribution of commercial activities?

In the forecast phase, it is assumed that a certain time period has elapsed and that the distribution of the demand for commercial goods will have changed. This change, specified in terms of future person-trip origins, is an input to this phase.

In the latter two phases, three sizes of commercial centers (in land area) are permitted. Each size requires a trip sufficiency rate to determine the adequacy of selected sites. The examination of selected sites for available vacant land and zoning or land cost restraints is also a feature of the model. In the forecast phase, plans for commercial sites which develop after study area land-use data are obtained can be used as inputs. This phase may be repeated for successive time periods.

Initial applications of the model have been encouraging. Sites selected for future commercial unit locations in the initialization phase have been very near to known commercial developments in the one study area tested. The sites selected by the forecast phase also compare favorably with known developments and are in areas where regional growth is expected to be intense. The model appears to be a very useful transportation planning tool.

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