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APPENDIX A

PROGRAMMING CONSIDERATIONS AND PRINTED OUTPUT FROM THE MODEL

A GREAT DEAL OF DEVELOPMENT and testing remains before the NBER model can be used to evaluate programs and policies. Even so, the current version of the NBER model advances the state of the art of building urban simulation models.

In Chapter 9 we described some of our own plans for further development of the model. We hope, however, that others will develop the model along other lines or incorporate some of the model's novel features into urban simulation models of their own design. In this appendix we seek to facilitate this process by providing a brief discussion of the programming of the NBER model.¹

This appendix contains a discussion of the running times of the NBER model and its submodels, followed by a display of illustrative printed output from the program. These sample tables and the supporting narrative provide some of the sense of model operations missing from chapters 3 and 4. However, the final section, a brief description of programming considerations, will probably interest only programmers and computer enthusiasts.

1. We considered including flow charts and program listings but did not provide these materials, which run to 130 pages, because the audience is small and because the NBER Urban Simulation Model is under continuous development. Therefore, persons interested in using the NBER model or in developing it further should contact the authors to obtain program listings of more highly developed and improved versions of the model. We will make every effort to make both up-to-date listings and program decks available to interested parties.

Computer Running Times for the Model

The model has been run on both the IBM 360/67 and the IBM 360/91. A year's simulation requires less than two minutes of CPU (central processing unit) time on the 360/91 and approximately seven minutes of CPU time on the 360/67. Table A.1 shows representative running times by submodel for the two machines. These times depend upon not only the size of the problem but also the compiler and the input data. Considerable variation has been noted between calibration runs and between years within the same calibration run. In Chapter 9 we described a number of changes in program design incorporated into Pittsburgh I that reduced the program's running time while at the same time increasing its dimensions. Running times of Pittsburgh I are about half those of the Detroit Prototype.

Level G compilation of FORTRAN routines results in object programs which generally run much more slowly than Level H (option 2) compilations of the same routine operating on the same data.

		Typical Ru	nning Times ^a
Submodel	Program Subroutines	IBM 360/91 (CPU seconds)	IBM 360/67 (CPU seconds)
Filtering	FILTER, FLTR	0.35	0.87
Industry	NDSTR Y	0.10	0.20
Mover	MOVE, SCOOP	3.40	31.56
Demand	DEMND	1.31	7.73
Supply	SUPPLY, SORTS, SORTH1, SELECT	5.14	26.57
Assignment	MARKET, ENCODE, MATCH,		
-	UPDA TE	77.05	328.45
Price			
formation	PFORM	1.15	3.44
Other	MAIN, TRVLU	9.78	21.77
Total		98.28	420.59

Table A.1 Table of Running Times

Note: Subroutine *INPUT* reads cards for the initial start up, and is not therefore included above. It required 5.15 CPU seconds on the IBM 360/91 and 10.91 CPU seconds on the IBM 360/67.

a. For each year simulated. Problem size: 19 work zones, 44 residential zones, 27 housing types, 72 household types.

Running times for the movers submodel have been reduced 50 per cent by using H-compiled object decks on the IBM 360/91 and 20 per cent by using H-compiled decks on the 360/67 under the same conditions. The H compilation appears to make more difference on a 360/91 because the machine's sequence of operation is frequently quite different from the sequence of steps encountered in the program.

The advances in computer technology cannot be overstated. Five years ago this model would have been so expensive to run that very little, if any, use could have been made of it in testing alternative policies. Today the operating costs of the model are almost trivial by comparison. We have had experience in programming models beginning with the IBM 709 in 1959 and subsequently with the IBM 7090, the 7094, the 360/50, the 360/67, and now the 360/91. Past experience suggests that a single year's simulation run of the Detroit Prototype would have taken from forty-five minutes to an hour of computation time on a 7094 and probably another twenty minutes for tape storage. This assumes, of course, that enough core storage existed on a 7094 to run a model of this size, and that is not true by a factor of two. An IBM 7090 would have required at least four hours, and the old 709 would have taken a whole day for a single year's run. In the late 1950s the Detroit Prototype would have cost at least \$7,200 per simulated year, and today it costs less than \$50 for the same simulation on the 360/91 and \$90 per simulated year on the IBM 360/67. Although these figures are very reasonable, one must remember that the model will typically be run for several simulation periods, so the cost per simulation run is a multiple of the singleperiod cost.

Printed Output from the Program

In the course of a run, the Detroit Prototype of the NBER Urban Simulation Model performs a great many operations in order to simulate the processes of urban growth and development. The quality level of the housing stock is altered, employment levels are changed, moving households are generated, the stock of dwelling units is augmented, and movers are allocated to the available units. In

addition to these primary tasks, many bookkeeping functions are performed as arrays are updated, prices are formed, and trip distributions are revised. Indeed, the model performs so many functions in each time period that a complete reporting of even one time period's activities would produce an indigestible quantity of computer printout. Therefore, it is necessary to have an efficient way of summarizing and controlling the information produced by the model during each run.

Since the model will be used for many purposes, as sensitivity analyses are run and different policy impact studies are carried out, a series of print control options has been incorporated which enable the model output to be varied between different simulation runs as well as between different time periods within a run. The output provided by the model during each time period is controlled by a series of print "switches" that are reset for each model period. At the beginning of a time period the model reads three cards which specify which summary tables are to be produced for that period. This option permits the analyst to obtain a full report of the model's activities in some periods and an abbreviated or summary report of activities for others. The list of reports controlled by the print switch option in the Detroit Prototype is shown in Table A.2.

Although most reports can be controlled by the output option, some are automatically produced during every time period. For example, in each time period the model maps location rents or land prices for each residence zone. Figure A.1, a plot of land prices by residence zone for a calibration run, illustrates these maps. The values are printed in positions which approximate the location of each of the 44 residence zones in the Detroit modeled area. All maps indicate the housing type and the year of the simulation run.

The exhibits included in this appendix illustrate typical output formats for several of the print switch options. Exhibits A.1 and A.2 illustrate two of the five possible tables which summarize the activities performed by the filtering submodel. They show the number of units of each structure group that have filtered between quality levels 1 and 2 in each of the forty-four residence zones. The first six structural groups are single-family detached units. The last three are multiplefamily structures.

The supply submodel also has several summary report options.

Table A.2 Print Control Options

Option Number	Causes the Printing of:
1	Report on filtering activities performed
2	List of profit scores too low to be used
3	Table of structural conversions performed; by zone and type of conversion made (prohibitions by zoning ordinances are included in this list)
4	Option 3 including impossible but potentially profitable conversions (impossible because required inputs do not exist in the zone).
5	Summary of conversions which were performed in each zone (input and output housing type omitted)
6	List of unfilled demands, numbers created as outputs, and numbers consumed as inputs for each house type (zone of activities is omitted)
7	Report of employment updates which attempt to cause negative totals within a work zone (nonnegativity is maintained whether reported or not)
8	Report of new employment totals by work zone and employment group
9	Report of net change in employment by work zone and employment group
10	Report of prices of all housing types and land types by residence zone which were in effect at the beginning of the simulation year
11	Report of initial estimates of prices for all housing and land types in each residence zone resulting from the market
12	Report of shadow prices (location rent) on all housing types in each residence zone
13	Report of adjusted prices on all housing and land types, which reflect a blend of initial estimates and old prices; will be used as next year's prices
14	Report of net change in prices between this year's prices and next year's prices
15	Report of household totals by residence zone and income class after movers have been located
16	Report of net change in household totals by residence zone and income class
17	(Unused at this time)
18	(Unused at this time)
19	List of inputs to each market problem for each housing type: number of families by workplace and income, and number of dwelling units available by resi- dence zone
20	List of average perceived travel cost for each solution of the market problem; one per housing type
21-70	List of solutions to the market problem for house-types 1 through 50.
71-120	Matrix of perceived travel costs used in the market problem for house-types 1 through 50

Exhibit A.3 is the first page of the list of conversion activities which were considered by the supply submodel in the sample calibration run. The activities, listed in their order of profitability, consist of all transformations for which inputs were available at the beginning



26.5

of the supply submodel's operation. The column labeled "SCORE" indicates the profitability of each activity.

Supply activities in Exhibit A.3 are described by residence zone, ZN; by input housing type, IN; and by output housing type, OUT. Activity levels associated with each possible transformation are described by the number of output structures produced, STRUT OUT; the number of output dwelling unts produced, D. U. OUT; and the number of dwelling units used as inputs, D. U. IN. For

UNITS FILTERING DOWN LEVEL 1 TO LEVEL 2 STRUCTURE GROUP NUMBER ZONE 2 3 4 5 6 , 0.0 8 9 1 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 123 0.0 0.0 3.0 0.0 0.0 0.0 0.0 8.0 0.0 5.0 29.0 0.0 0.0 0.0 0.0 0.0 0.0 99.0 3.0 5.0 456789011234567 1011234567 2.0 0.0 0.0 0.0 0.0 0.0 265.0 50.0 85 . 0 0.0 0.0 0.0 0.0 817.0 84.0 0.0 833.0 0.0 30.0 2 . 0 0.0 39.0 0.0 0.0 984.0 16.0 285 . 0 0.0 0.0 0.0 0.0 0.0 776.0 \$1.0 102 . 0 0.0 0.0 0.0 0.0 0.0 180.6 17.8 106.0 25.0 0.0 23.0 194.0 0.0 0.0 0.0 371.0 0.0 161.0 44.0 Ĭŏ 0.0 0.0 303.0 0.0 0.0 0.0 377.0 65.0 43.0 14.0 0.0 ŏ. Ō 0.0 0.0 62. 0 0.0 0.0 0,0 0.0 4 0 0.0 0.0 10.0 0.0 0.0 0.0 0.0 18.0 ó.ŏ 2.0 0.0 0.0 0.0 ō.ō 0.0 0.0 0.0 0.0 0.0 0.0 0.0 n Ó, O 0.0 0.0 0.0 0.0 0.0 C. 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 19 20 21 22 23 24 25 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 103.0 0.0 124.9 0.0 ō.ó 0.0 0.0 0.0 0.0 0.0 0.0 0.0 171.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 6.0 Ż .0 29.0 0.0 0.0 44.0 54.0 26 27 28 0.0 6.0 0.0 0.0 0.0 0.0 0.0 0.0 30.0 0.0 0.0 • 0.0 0.0 0.0 0.0 0.0 29 0.0 0.n ō.ŏ 0.0 0.0 Ő . 0 0.0 0.0 0.0 34.0 30 31 32 33 0.0 11.0 0.0 1.0 0.0 0.0 0.0 0.0 2.0 12.0 0.0 0.0 0.0 0.0 . 0 0.0 0.0 ō 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 34 35 36 38 39 40 0.0 0.0 0.0 0.0 12.0 0.0 0.0 0.0 0.0 ō, ō 119.0 0.0 10.0 0.9 0.0 0.0 0.0 42 0.0 0.0 0.0 0.0 0.0 0.0 0.0 43 0.0

Exhibit A.1 Number of Units Filtering Down from Level 1 to Level 2, Classified by Structural Group

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 example, the first and most profitable supply activity in Exhibit A.3 occurred in residence zone 22 and involved the conversion of one type-18 dwelling unit (a large, low-quality, single-family unit on a half-acre lot) into two type-23 structures (small multifamily buildings of medium quality with medium-sized apartments). The constraint which determined the level of activity is indicated by the column labeled CONSTRAINT? Three possible constraints could be binding: the input constraint, IN; the demand constraint, DMD; and

the zoning constraint, ZN. An asterisk indicates which constraint is effective for each supply activity. For example, the asterisk in the column headed IN indicates that the level of the first supply activity is limited by the number of type-18 units that are available for use

Exhibit A.2 Number of Units Filtering Up from Level 2 to Level 1, Classified by Structural Group

UNITS FILTERING UP LEVEL 2 TO LEVEL 1

				ST	RUCTURE	GROUP NUMBE	R		
ZONE	1	2	3	4	5	6		8	9
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	42.0	37.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
3	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
4	0.0	0.0	743,0	187.0	122.0	26.0	0.0	0.0	0.0
5	35.0	0.0	0.0	0.0	247.0	68.0	0.0	0.0	0.0
6	82.0	79.0	368.0	29.0	369.0	67.0	0.0	0.0	0.0
7	213.0	0.0	575.0	88.0	82.0	0.0	0.0	0.0	0.0
8	380.0	0.0	38.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	123.0	0.0	0.0	80.0	0.0	0.0	0.0
10	379,0	66.0	0.0	224.0	97.0	91.0	0.0	0.0	0.0
11	51.0	0.0	18.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	661.0	44.0	204.0	327.0	156.0	133.0	0.0	0.0	0.0
14	471.0	662.0	0.0	230.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	408.0	0.0	49.0	0.0	0.0	0.0
16	319.0	398.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	106.0	280.0	0.0	110.0	0.0	10.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	130.0	0.0	0.0	0.0
21	857.0	133.0	0.0	299.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0,0	377.0	0.0	42.0	1.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	360.0	156.0	49.0	0.0	28.0	0.0	0.0	0.0
25	0.0	111.0	0.0	0.0	214.0	59.0	0.0	0.0	0.0
26	0.0	253.0	141.0	593.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	204.0	595.0	0.0	191.0	0.0	0.0	0.0	0.0	0.0
21	1/2.0	980.0	0.0	122.0	0.0	4.0	0.0	0.0	0.0
24	154.0	1.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0
33	0.0	180.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0		0.0	*1 0	0.0	0.0	0.0
35	20.0	16.0	0.0	02.0	*5.0	51.0	.0.0	0.0	0.0
30	20.0	260.0	110.0	1.1.0	33.0		0.0	0.0	0.0
19	/0.0	200.0	110.0	141.0		0,0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	
60	0.0	0.0	0.0	0.0	ň. ň	0.0	0.0		0.0
61	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	0.0	ñ n	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	ñ ñ	0.0	0.0	0.0
<u></u>	0.0	0.0	0.0	0.0	0,0	0.0	0.0	0.0	0.0
					~ ~ ~ ~	~ ~ ~		~ ~ ~	

as inputs in residence zone 22 during the modeled period. Similarly, from inspection of the constraints column it is apparent that the next two activities are constrained by available input units as well but that the fourth most profitable activity is limited by the demand constraint. The fifth and sixth most profitable activities are again constrained by the number of input units available for transformation while the seventh is limited by both a demand constraint and a zoning prohibition.

All activities in Exhibit A.3 are listed according to their profit score with the exception of the activity which follows the message "SEARCHING *ITEMP* LIST FOR 17 CAUSED BY 5 17 24 4.143."

Exhibit A.3 List of Supply Submodel Activities Classified by Profitability

'CONVERSIONS' MADE BY CONSTRUCTION INDUSTRY FOR YEAR 17

						CONSTRA	\1NT ?	
ZN I	IN OUT	STRUT OUT	D. U. OUT	D. U. IN	SCORE	IN DMD) ZN	
22 1	18 23	2.0	12.0	1.0	10.6	1 * -	1	
22 1	7 22	166.0	996.0	83.0	10.0	· • •	• • • •	
22 2	20 23	3.0	18.0	12.0	9.7	i • •	· -i	
22 1	16 22	1744.0	10464.0	872.0	8.7	i- •	• -i	
22 1	16 23	1082.0	6492.0	541.0	7.1	i	i	
22 1	11 23	1460.0	8760.0	730.0	7.1	i • -	· -i	
36 1	8 22	2 0.0	0.0	0.0	6.8	i	r ∎İ	
22 1	2 23	22.0	132.0	11.0	6.1	i	i	
<u> 20 1</u>	18 23	5 0.0	0.0	0.0	5.8	1.	i	
35 1	18 20		0.0	0.0	5.7	- i	- i	
<u> </u>	8 22	0.0	0.0	0.0	5.7			
22	10 23	280	168.0	16.0	5.6	1. 1		
36	18 27	s 0.0	0.0	11.0	5.6	12.		
36 1	18 20	n 0.0	0.0	0.0	5.4			
36 1	17 22	, n n	0.0	0.0	5.7			
36	18 21		0.0	0.0	5 1		: 1	
30		,	0.0	0.0	. á			
3 1	18 27	. 28.0	168.0	16.0	4.5			
30	18 20	20.0	100.0	14.0	4.5		:]	
35	18 10		0.0	0.0	4.7			
61 1	18 21	0.0	0.0	0.0	4.0			
71	18 20	, <u>, , , , , , , , , , , , , , , , , , </u>	0.0	0.0	4.0			
36 1	18 20	0.0	0.0	0.0	4.7		: -	
38	16 19		0.0	0.0	1.7		. 21	
36	19 19		0.0	0.0	4.6			
35	18 21	í ñ ñ	0.0	0.0	4.6			
36	17 20	0.0	0.0	0.0	4.5			
39	16 19		0.0	0 0	4.5	- i - i		
36	16 22		0.0	0.0	4 3	1.		
LÕ I	18 20		ຄູ່ດໍ	0.0	4.2			
36 1	16 19		0.0	0.0	4.2			
Š	17 24	466.0	2796.0	233.0	4.1	1 • 1	1	
SEARCHI	NG *1TE	MP+ LIST FOR 17	CAUSED BY 5	17 26 6 163				
38 1	18 17	7 31.0	31.0	31.0	5.2			
36	17 19	0.0	0.0	0.0	ú. î	1 - 1	• -1	
36 1	7 2	5 0.0	0.0	0.0	L .O	i - 1		
40	18 19	à ô,ô	0.0	ă ă	<u> </u>	i - 1	1	
39 1	17 19	0.0	0.0	0.0	3 9			
41 1	18 10	0.0	0.0	0.0	3.8	1. 2		
38	17 19	0.0	0.0	0.0	3.7			
38	17 20	0 0	0.0	0.0	3 6		_	
37	17 22	0.0	ດັດ	0.0	3.6			
27	16 19	0.0	0.0	0.0	3.6		1	
40 1	18 21	0.0	0.0	0.0	3.6	i - 1		
		***	~	0.0	~ ~ ~ ~			

Until the activity preceding this message was encountered, currentperiod expected demand for type-17 units had been satisfied for the entire modeled area. The preceding activity, however, used 233 units of housing type 17 as an input to produce 2,796 units of type 24. In this case, reducing the available number of type-17 units also relaxed the demand constraint for that housing type. At this point the submodel re-examines the list of profitable activities, called the *ITEMP* list, to determine whether an earlier, more profitable activity that produces type 17 had been passed over because of the

demand constraint. In this case one such activity was found and reported under the message.

In addition to the list of individual supply activities shown in Exhibit A.3, the supply submodel reports the summaries shown in exhibits A.4 and A.5. As shown in Exhibit A.4, the detail about housing types has been suppressed. The printout is a summary of the



	C	CONVERSIONE FOR	NE40 13
70/15 /10	AUTE OUTOUT	INTE LIDET	LAUD ANDUT
LUNE NO			0.0
;	AS 70 0000	A65 0000	0.0
;	3083 0000	183 0000	
	1002.0000	103.0000	0.0
2	6356 0000	A18 0000	0.0
2	5256.0000		
9	1495.0000	160.0000	0.0
	0.0	0.0	
10	0.0		
	1956 0000	163 0000	0.0
	335 0000	90.0000	0.0
	223.0000	80.0000	
12	40.0000	0.000	0.0
17	0.0		
16	0.0	0.0	
13	155 0000	155 0000	0.0
	333.0000	230.0000	0.0
10		0.0	0.0
19	12,0000	1.0000	0.0
20	0.0	0.0	4.0
1		1111 0000	0.0
#	\$4225.0000	2341.0000	
52	0.0		8.8
	8.8	0.0	
26	1736 0000	101 0000	
	685 0000	685 0000	
36	990 0000	990,0000	0.0
20	1091 0000	1091 0000	0.0
30	105 0000	N7 0000	
÷.	118 0000	118.0000	0.0
12	108.0000	99.0000	0.0
	0.0	0.0	0.0
ü	620.0000	\$10,0000	0.0
ii	0.0	0.0	0.0
16	0.0	0.0	0.0
37	179.0000	179.0000	0.0
18	0.0	0.0	0.0
39	653,0000	653,0000	0.0
60	0.0	0.0	0.0
6 Ï	0.0	0.0	0.0
42	0.0	0.0	0.0
	0.0	0.0	0.0
	782.0006	782 0000	

Exhibit A.5 Summary of Supply Activities Classified by Housing Type

SUI HARY	OF CONVERSIONS BY	TYPE	
HOUSE TYPE	UNFILLED DEMAND	UNITS INPUT	UNITS OUTPUT
1	-15205.000	0.0	0,0
2	-6656.000	0.0	0.0
3	-4965,000	93.000	0.0
	-1988.000	77.000	0.0
5	-2494.000	0.0	0.0
•	-2818,000	\$364.000	0.0
,	-15774.000	0.0	0.0
8	-5939.000	0.0	0.5
•	-4837.000	0.0	0.0
10	-6941.000	14.000	0.0
11	-1051.000	730.000	0.0
12	-5321.000	2686.000	0.0
13	-6057.000	0.0	0.0
15	61.000	0.0	0.0
15	D.D	0.0	93.000
16	-4.000	1417.000	0.0
	0.0	h19.000	\$194.000
10	0.0	569.000	328.000
19	-4068.000	0.0	0.0
20	-4382.000	12.000	0.0
21	-15724.000	0.0	0.0
11	-11,000	102.000	11568.000
25	-6,000	48.000	15798.000
24	0.0	0.0	16776.000
25	-22.000	0.0	1095.000
26	-2.000	0.0	1590.000
17	-6517,000	0.0	0.0
28		0.0	0.0

total number of dwelling units used as inputs, and the number of acres of land used for new construction in each residence zone. For example, no units are produced by the model in the first zone; as a result, no existing units were used as inputs nor was any vacant land used. In the second zone, however, 4,579 dwelling units were produced during the period by transforming 463 input units.

In contrast, in Exhibit A.5 the zonal detail is suppressed, and the supply activities are summarized by housing type. The summaries indicate how many units of each type were produced as outputs and how many were used as inputs during the time period. The printout also shows the level of unfilled demand for each housing type during this time period, with negative numbers indicating a surplus of the given type and positive numbers indicating a shortage. Housing type 14 is the only one with positive unfilled demand. From Exhibit A.5, then, it is apparent that there was a surplus of all but five types of unit at the end of the period. Since these "surpluses" include an allowance for normal vacancies, the unfilled demand figures listed in Exhibit A.5 will usually be negative.

Several other reports are available which describe each housing submarket in detail, but they are too lengthy to display for any of our actual simulations. A smaller version of the model—10 (residence) by 10 (workplace)—used to debug the program, can be used to illustrate these more detailed tables. Exhibit A.6, which presents sample output from the market-clearing submodel of one of these 10 by 10 examples, illustrates the format used in the Detroit Prototype. The first section of the exhibit contains a list of the demanders of housing type 1 by work zone and income class. Households in which the primary wage earner is employed in zone 1 and belongs to income class 3 are identified by the mnemonic 1-3^{*}.

Exhibit A.6 Sources and Sinks for Market-clearing Submodel: 10×10 Version

SOURCE-	SINK PI	ROBLER	4 TO BE	SOLVE	D FOR	HOUSE	TYPE 1												
SOURCES 1-1* 1-3* 0. 140.	(FAHI) 2-1+ 2-3+ 0. 0.	3-1+ 3-3+ 0, 20,	SEEKING 4-1+ 6-3+ 0. 5UM +	HOUSE: 5-1- 5-3- 0. 0. 340.	8) 6-1+ 6-3+ 0. 0.	7-1• 7-3• 8. 0.	8-1* 8-3= 0. 8,	9-1• 9-3• 0. 0.	18-1• 10-3• 9. 9.	1-2+ 1-4+ 40. 50.	2-1• 2-4• 0. 0.	3-2• 3-4• 0. 5.	4-1. 4-1. 0. 40.	5-2. 5-4. 0, 0,	6-2• 6-4• 0. 0.	7-20 7-40 0. 40,	8-2• 8-4• 0. 8.	9-2. 9-1. 0. 3.	10-2. 10-4. 0. 0.
81NK\$ (37.	HONISES 2. 4.	AVA11 3. 20.	62.	Y ZONE 51 27.) 12.	7. 26,	8. 58.	9. 18.	18+ 78.										

In the example shown in the exhibit there are 140 households in group 1-3* who demand housing of type 1 in the current model period. Altogether 340 households demand type 1 housing in this period. The second section of Exhibit A.6 contains a list of the number of type-1 units available in each of the ten residence zones in this period. In all, 347 type-1 units are available. In this section zone 1 is represented as 1*, and so on.

The transportation cost matrix, shown in Exhibit A.7, contains entries only for those rows and columns with nonzero inputs. For example, since there are no families in income class 1 who work in zone 1 and demand a type-1 house, the row labeled 1-1* is omitted from the problem. Similarly, if type-1 houses had been unavailable in one or more residence zones, these columns would have been omitted.

In order to solve a transportation algorithm the number of SOURCES must equal the number of SINKS. The example shown in exhibits A.6 and A.7 has more SINKS (units available total 347) than SOURCES (households total 340). Therefore, the number of SOURCES has been increased by adding 7 households to the model in the class 1-5*. These fictitious households have no transportation costs, and when they occupy a dwelling unit, it is actually vacant. If there had been more demanders than available units, a fictitious zone (11*) would have been created with enough capacity to house the excess demanders.

The solution of the assignment problem and the zonal assignments of the various households are summarized in Exhibit A.8. The matrix in the exhibit is bordered on its top and left sides by the shadow prices associated with the solution. These shadow prices on residence zones (columns) are the location rents of house type 1 in each of the zones. The shadow prices on the workplaces for each income group

Exhibit A.7 Interzonal Transportation Costs

1	RAUSP	ORTATION C	OSTS FOR	SEEKERS O	OF HOUSE	TYPE 1					
		1+	2.	3+	4.	5+	5+	7.	8 *	9+	10
	1 2.	0.0	8.0	8.5	49.6	61.8	109.0	100.4	90.7	100.0	111.3
	13+	ŏ.ŏ	8.8	9.2	54.1	67.5	118.9	109.6	99.0	109.1	121.
	3 3+	9.2	5.3	0.0	44.4	87.1	110.9	95.3	88.4	105.6	77.1
	1 4 .	0.0	9.5	10.0	58.6	73.1	128.8	118.7	107.2	118.2	131.
	5 60	10.0	5.7	0.0	48.1	94.4	120.1	103.2	95.8	114.4	84.
	4 4.	58.6	33.0	48.1	0.0	75.8	95.1	85.8	64.3	59.1	84.9
	7	118.7	113.0	103.2	85.8	15.7	11.0	0.0	24.3	14.3	27.
	8 4.*	107.2	93.7	95.8	64.3	18.0	39.6	24.3	0.0	19.0	24.
	9 6 *	118.2	117.3	114.4	59.1	28.3	27.2	14.3	19.0	0.0	12.
	1 5+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.

	Exhi	ibit A	A. 8	
Solution	Matrix	and	Shadow	Prices

	OPTIM	AL SOLUTION	AND	SHADO	W PRICES	HO	USE TYPE	1				
z	Y	ZO NE SHOW	1* 122.	112.	112.	67.	5. 54.	6• 2.	7• 13.	8* 22.	9. 12.	10.
,	2.	m. ⁻	0.	0.	0.	0.	0.	0.	0.	۰٥.	0.	40.
1	3+	121.	٥.	٥.	6.	22.	27.	8.	۰.	56.	15.	6.
3	3+	77.	٥.	0.	٥.	۰.	٥.	٥.	۰.	٥.	٥.	20.
ı	4.	122.	52.	۰.	14.	0.	0.	٥.	۰.	٥.	0.	٥.
5	4.	84.	٥.	۰.	٥.	٥.	٥.	٥.	٥.	٥.	٥.	5.
4	6 -	67.	٥.	٥.	٥.	40.	٥.	٥.	٥.	٥.	٥.	٥.
7	4+	13.	٥.	٥.	٥.	0.	۵.	14.	26.	٥.	e.	٥.
8	4.	22.	٥.	٥.	٥.	٥.	0.	0.	٥.	2.	٥.	0.
9		12.	٥.	0.	٥.	٥.	٥.	0.	0.	0.	5.	0.
1	5•	٥.	o.	٥.	٥.	٥.	٥.	е.	0.	٥.	0.	,

(rows) may indicate a wage gradient among work zones. Currently we make no use of these wage gradients, but we find them intriguing and plan further investigation of their properties.

Another series of reports describes the price formation section of the market-clearing submodel. Approximately the first half of each of the four possible price matrices is shown in exhibits A.9 through A.12. These price matrices have the dimensions 28 (27 unit types

Exhibit A.9

Current Year's Expected

Prices for Dwelling Units and Land, Housing Types 1-28, Year 1

	26	27	3 28	•	5	6	,	8	٩	10	11	17	13	15	15	16	17	18	19	20	21	29	23	25	25
ZONF							105			765	100		100												
.,	106	61.	110.	107.	192.		144.	140.			104.		300.	198.	100.	204.	×54.	184.	ψ υ).	279.	142.	270.	175.	122.	110.
21	121.	140.	74.	267.	218.	90.	506.	221.	108.	400.	267.	116.	482.	506.	140.	620.	€00.	218.	250.	168.	87.	250.	135.	75.	135.
51	168.	154.	76.	182	160.	95.	256.	168.	110.	272.	182.	127.	328.	255.	134.	422.	272.	160.	196.	135.	89.	155.	135.	71.	135.
41	117.	108.	56.	.13	166.	M).	157.	117.	90.	245.	150.	90.	295.	157.	108.	380.	245.	144.	157.	115.	78.	135.	95.	63.	95.
51	127	48.	65.		110	90.	16.6	127.	96	177.	118.	110.	251	168.	110.	274.	177.	110.	167.	118.	35	135.	95.	75.	99.
	95.	59.	80.																						
01	79.	57.	65.	134.	110.	40.	162.	122.	64.	160.	130.	90.	257.	162.	105.	400.	180.	110.	152.	105.	7.	135.	85.	65.	89.
71	150.	110.	50.	169.	124.	70.	167.	150.	95.	211.	160.	110.	558.	163.	110.	328.	211.	124.	151.	106.	82.	135.	95.	65.	95.
31	116.	63.	54.	150.	120.	61.	142.	116.	40.	160.	130,	86.	187.	142.	65.	516.	160.	120.	141.	89.	20.	95.	20.	20.	62.
91	107.	87.	40.	130.	ш.	75.	165,	107.	77.	189.	150.	80.	261.	165.	87.	293.	189.	ш.	125.	61.	44.	85.	55.	20.	69.
101	121	20.	70. 40.	150.	110.	91.	165.	121.	94.	191.	130.	97.	258.	165.	88.	\$56.	191.	110.	156.	10).	20.	116.	47.	20.	74.
111	130.	110.		". 132.	128.	110.	160.	130.	110.	175.	132.	74.	186.	160.	170.	271.	175.	128.	142.	98.	69.	110	85.	55.	86.
121	81.	45.	80.	116	110	80	166			34.0	186		244			116	160	110	77	5.					20
	18.	11.	50.												43.	313.	140.					20.			
151	81.	25.	40. 34.	160.	130.	102.	173.	132.	105.	257.	160,	40.	318.	173.	107.	40C.	232.	150.	209.	121.	70.	175.	85.	47.	87.
141	144.	110.	65.	174.	125.	96.	159.	144.	85.	208.	174.	110.	352.	159.	110.	522.	208.	123.	191.	119.	78.	175.	9 5.	56.	95.
151	81.	110.	64.	139.	341.	95.	165.	81.	98.	240.	139.	101.	289.	165.	110.	372.	240.	141.	173.	120.	79.	105.	67.	48.	63.
161	148.	103.	40.	174.	121.	74.	172.	145.	92.	225.	174.	95.	271,	172.	105.	349.	225.	121.	194.	123.	79.	175.	95.	54.	95.
171	87.	25.	25. 60.	162.	200.	65.	185.	130.	120.	295.	162.	117.	232.	183.	127.	360.	298.	200.	250.	132.	30.	250.	91.	20.	73.
	73.	20.	14.		1.00			-	100	76.0															
	91.	40.	12.		100.	/•.		204.	140.	208.		123.	204.	255.	110.	524.	265.	100.	224.	152.	95.	150.	114.	eu.	91.
191	46.	125.	61.	196.	204.	83.	267.	359.	122.	505.	196.	146.	237.	267.	125.	367.	505.	204.	248.	168.	98.	171.	135.	56.	45.
201	243.	151.	64.	203.	215.	95.	280.	245.	109.	320.	205.	177.	249.	280.	131.	386.	320.	215.	296.	201.	105.	221.	175.	55.	55.
211	130.	06.	53.	154.	117.	40.	165.	150.	82.	182.	134.	85.	230.	161.	86.	310.	182.	117.	196.	125.	70.	148.	85.	29.	94.
221	215.	20.	57.	328.	190 .	83.	249,	215,	110.	230.	128.	136.	221.	24 S	115.	342.	730.	190.	220.	38.	94.	374.	796.	150.	227.
231	228.	100.	32.	188.	160.	86.	204.	224.	118.	295.	188.	147.	250.	204.	121.	356.	795.	160.	152.	103.	52.	50.	40.	20.	45.

Exhibit A.10

Estimated Prices for Market Simulation (Dwelling Units and Land), Housing Types 1-28, Year 1

	26	27	3 2 R	•	5	6	,		9	18	11	12	15	16	15	15	17	18	19	20	21	21	23	24	25
11	131.	120.	80,	183.	181.	43.	167.	119.	113.	247.	203.	99.	188.	168,	126.	361.	315.	259.	166.	115.	20.	386.	317.	88.	100.
21	127.	ıı.	67.	182.	171.	69.	152.	116.	97.	240.	192.	88.	187.	165.	109.	358.	30%.	247.	162.	103.	78.	381.	305.	69.	95.
31	129.	53.	67.	135.	174.	69.	155.	····	\$7.	243.	194.	85.	139.	164.	111.	361.	307.	266.	164.	105.	78.	384.	303.	70.	97.
41	122.	107.	58.	176.	163.	70.	148.	106.	95.	234.	185.	81.	151.	157.	113.	352.	301.	245.	163.	101.	78.	376.	298.	84.	98.
51	114.	100.	67. 36.	17).	167.	\$5.	146.	106.	97.	221.	189.	85.	168.	151.	9 9.	341.	38%.	266.	150.	101.	78.	373.	303.	87.	87.
81	116.	61.	67. 32.	165.	160.	76.	146.	106.	103.	226.	186.	81.	172.	152.	118.	345.	305.	242.	158.	101.	78.	367.	296.	75.	80.
71	92.	99. 61.	69. 36.	170.	166.	72.	146.	106.	97.	222.	190.	85.	172.	156.	115.	360.	310.	244.	152.	101.	78.	373.	303.	74.	90.
81		99. 80.	67.	162.	159.	<i>"</i> .	146.	106.	106.	222.	149.	83.	168.	157,	139.	334.	306.	232.	150.	104.	89.	360.	286.	95.	83.
71	96.	67.	11.	174.	172.	<i>n</i> .	148.		101.	225.	194.	91.	165.	162.	124.	346.	307.	269.	150.	107.	54.	378.	308.	78.	94.
101	100.	83,	54.	159.	155.		196.	107.		219.		81.		156.	155.	342.	305.	237.	183.	109.	95.	355.	285,	107.	¥7.
111	97.	73.	39.		105.	83. 89	134.		1.41	231.	197.	92.		102	123.	347.	317.	242.	157.		**	3714	300.	83. ••	90.
131	100.	67.	42.	167	160.	7.	1.10.	106	115	239. 217	1		168.	155	151	350	105	240.	171.	101	•••		799	104	107.
141	109.	81.	52.	158.	151.	66.	165.	106.	182	216.	173.	81.	168.	161.	166.	339.	788.	235.	377.	161.	78.	372.	301.	18.	113.
151	115.	85.	41.	156.	161.	76.	166.	115.	100.	216.	182.	81.	186.	171.	150.	360.	299.	23 5.	181.		87.	382.	311.	112.	123.
161	126.	97.	51.	156.	151.	66.	16.	106.	109.	216.	184.	82.	180.	155.	151.	345.	297.	234.	173.	101.	8D.	362.	290.	107.	114.
171	115.	92.	52.	188.	179.	75.	146.	106.	123.	216.	180.	81.	20).	186.	166.	359.	292.	260.	192.	101.	91,	364.	307.	103.	130.
181	116.	86.	50. 36.	.175.	165.	\$6.	146.	106.	112.	216.	177.	81.	187.	176.	131.	360.	Z92.	231.	180.	101.	79.	364.	295.	93.	116.
191	108.	79. 108.	36.	165.	160.	75.	169.	114.	113.	222.	188.	81.	183.	179.	150.	349.	30%.	240.	180.	110.	87.	382.	310.	109.	123.
201	125.	95.	5i.	172.	162.	78.	153.	116.	97.	234.	192.	81.	191.	171.	160.	348.	294.	248.	182.	116.	88.	\$83.	311.	117.	124.
211	126.	59.	85.	169.	154.	73.	146.	122.	109.	222.	145.	89.	168.	171.	150.	332.	303.	243.	158.	115.	92.	361.	z90.	90.	103.
221	129.	106.	51. 81.	163.	158.	74.	160.	117.	127.	232.	185.	\$8.	183.	170.	151.	349,	317.	246.	169.	123.	109.	337.	267.	108.	92.
231	121	99. 91.	67.	166.	153.	68.	146.	106.	110.	228.	18G.	81.	178.	163.	143.	332.	105.	231.	167.	110.	92.	367.	296.	185.	108.

plus land) by 44 (residence zones), but because of space limitations the sample tables present information for only 23 of the zones.

The first price table, Exhibit A.9, shows the expected prices of each housing type in each residence zone for the current period of the simulation model. These expected prices are used by the model to determine current-period supply activities and demand allocations. Exhibit A.10 shows the one-period equilibrium price determined by the model for the current period. Since it is assumed that market prices do not adjust instantaneously, the expected prices for the next period are a weighted average of current-period expected and oneperiod equilibrium prices. The differences between this period's and next period's expected prices are shown in Exhibit A.11. The final summary, Exhibit A.12, shows the location rents calculated for each housing type and each zone.

Although many types of reports are available within the Detroit Prototype, additional tables can easily be added for special purposes. New options can be added to the print control vector fairly easily, or this feature can be bypassed, and output can be printed by incorporating additional statements into the program.

Exhibit A.11 "Increases" in Expected Prices (Next Year Minus This Year), Housing Types 1-28, Year 1

	26	2 27	3 28	٠	5	6	,	8	9	18	11	12	13	14	15	16	17	86	19	20	21	22	23	24	25
ZONE		•					-13	-8			14.	-1		-10		-11.	28.		-01	-86	-18		\$7.	-18.	-6.
.,	1	- 52	-2																-33.	-000					
21	-38.	-11:	-18	-34,	-19.	-9.	-61.	-42.	-4.	-64.	-30.	-11	-118.	-36.	-12	105.	-38.		-35.	-34.	-3.	\$5.		-2.	-16.
31	-16.	-8.	-19.	١.	6.	-11.	-49.	-22.	-5.	-12.	5.	-17.	-55.	-56.	-9.	-24.	16.	33.	-15.	-12.		100.	67.	-0.	-15.
41	2.	-1.	3.	18.	9.	-4.	-4.	-5.	۰.	-4.	22.	-4.	-46.	-0.	2.	-11.	22.	48.	3.	-3.	۰.	96.	81.	9.	۰.
51	- 5		3.	21.	25.	-9.	-1.	-9.	۱.	18.	28.	-18.	-37.	٦.	-+.	27.	51.	54.	-7.	• 7.	-2.	95.	85.	-5.	-5.
61	3:	-2.	-17.	13.	28.	13.	-6.	-6.	-16,	18.	28.	-4,	-34.	-4.	6.	-22.	50.	53.	-1.	-2.	3.	93.	85.	۰.	-4.
21	-6.	-1.	~13:	۰.	17.	١.	-8.	-10.	۱.	۰.	12.	-10.	-66.	-+-	2.	5.		48.	e.	-2.	-1.	95.	83.	۰.	-2.
	-1-	3	-16.		16		•					-1	•7		30	,						196	106	30	
•	30.	19.	-6.																				1		
31	16.	15.	-12		24.	-1.	-*-	2.		14.	20.	•.	-38.	-1.	13.	21.	47.	35.	10.		10.		101.	17.	10.
191	-3.	17:	11.	12.	18.	-7.	-8.	-6.		η.	22.	-6.	-36.		26.	-6.	45.	51.	5.	3.	30.	96.	93.	35.	
111	-3.	-1-		16.	16.	-16.	-2.	-7.	2.	22.	26.	,	-3.	۱.	۶.	31.	57.	46.	6.	5.	۰.	104.	86.	12.	2.
121	33.	6.	10.	15.	20.	۱.	٥.	30.	10.	36.	26.	۰.	-25.	۰.	11.	10.	72.	51.	35.	23.	21.	141.	116.	30.	29.
131	-7:	3:	3	3.	13.	-10.	-11.	-10.	۰.	-6.	10.	18.	-68.	-7.	18.	-20.	26.	45.	-15.	-8.	8.	78.	86.	23.	8.
161	+12.	23.	:	-6.	11.	-12.	-5.	-15.	7.	3.	-8.	-12.	-65.	١.	12.	7.	52.	h\$.	-8.	-7.	۰.	79.	82.	12.	7.
	8.	23.	6.							-14		-	-											**	
151	27.	26.	<u>1</u> 1.		•••										10.	-134	24.	3/.		-,.	,				
161	10.	27.	12.	-7.	12.	-5,	-10.	-17.	7.	-3.	٩.	-,.	-36,	-7.	19.	-1.	29.	45.	-8,	-9.	ο.	75.	78.	21.	
171			16. 18.	10.	-8.	۹.	-15.	-10.	١.	-53.	7.	-14.	-12.	١.	9.	-0.	-3.	16,	-23.	-12.	25.	45.	86.	33.	23.
181	-28.	3.	13.	2.	-6.	-5.	-36.	-39.	2.	-21.	5.	-19.	-9.	-25.	9.	۰.	9.	20.	-17.	-20.	-7.	86.	70.	13.	18.
191	-18.	-7:	6.	-11.	-18.	-3.	-47.	-90.	-4.	-33.	-2.	-26.	-22.	-39.	10.	-7.	-0.	14.	- 27.	-23.	-4.	84.	78.	21.	31.
201	32. -46.	30.	16.	-12.	-21.	-6.	-51.	-51.	-5.	-34.		-38.	-23.	-10.	12.	-15.	-10.	10.	-86.	-34.	•7.	65.	55.	26.	27.
	28.	31.	18.	1.	15		-1		11	16	78	,	- 78						-15						
	12.	29.											- 43.			•••	49.		-0.0						
221	-53.	-2.	8.		-13.		-33.	-39.	۶.		25.	-19.	-15.	-31.	14.	3.	35.	22.	-21.	34.	•.	-13.	-12.	-17.	-24.
231	-41. 26.	28.	-12:	-9.	-3.	-7.	-25.	-47.	-3.	-27.	-1.	-26.	-20.	-16.	9.	-10.	۰.	28.	6.	5.	16.	127.	183.	34.	25.

Exhibit A.12 Location Rents for Housing Types 1-28 and Land, Year 1

	1 26	:7	3 28	٠	5	6	,	•	•	18	11	17	13	14	15	16	17	18	19	28	21	22	23	24	25
ZOINE												••													
н	16.	14.	50.	27.	29.	17.		14.	10.	29.	31.		18.	19.	27.	»».	<i>.</i> ,	48.	10.	14.		49.	50.	20.	20.
21	12.	12.		26.	20.	2.	7.	10.	٥.	24.	20.	7.	18.	16.	10.	30.	26.	36.	12.	2.	0.	44.	38.	2.	15.
31	15.	15.	0.	28.	23.	2.	9.	9.	٥.	27.	22.	۹.	21.	15.	12.	33.	29.	53.	18.	۰.	٥.	47.	36.	2.	16.
41	;:	8.	1:	28.	16.	5.	2.	Ð.	2.	19.	14.	8.	12.	7.	14.	24.	23.	35.	13.	۰.	٥.	39.	32.	17.	18.
51	15.	13.	39.	19.	16.	е.	e.	0.	0.	5.	17.	s.	٥.	2.	0.	13.	26.	34.	e.	e		36.	36.	۰.	7.
61	0.	0.	36.	12		,	•			18	14.			•	10.	17.	• 7			6	8	50	3.0	,	
	ö.	<i>ï</i> .	32.				•																		
1	6.	7.	36.	14.		۶.	θ.	٥.	υ.	•.	18.		3.	7.	10.	17.	32.	33.	2.		υ.	30.	×.	<i>'</i> .	۰.
#1	8	26.	0. 10.	6.	4.	10.	θ.	θ.	9.	6.	17.	1.	e.	1.	40.	5.	28.	21.	€.	3.	μ.	23.	10.	27.	3.
91	0.	6.		18.	21.	5.	e.	7.	۰.	9.	22.	10.	۹.	13.	25.	18.	29.	39.	۰.	6.	5.	41.	41.	п.	14.
101	ō.	0,	θ.	3.	۰.	7.	θ.	۱.	16.	5.	15.	0.	۰.	7.	54.	13.	25.	27.	13.	8.	17.	18.	18,	48.	17.
111	1	29. 8.	34.	16.	16.	18.	9.	8.	17.	15.	25.	п.		14.	38.	19.	39.	32.	1.	16.	۹,	34.	33.	17.	10.
121	11.	19. 10.	39.	17.	17.	15.	18.	10.	10.	15.	28.	10.	13.	17.	22.	12.		35.	10.	10.	10.	36.	36.	16.	13.
	15.	14.	42.		19																				
131	23.	28.	52.								12.				941		20.	···				24.	54.		
141	29,	32.	•1.	2.	0.	θ.	е.	0.	۶.	e.	۰.	σ.	θ.	11.	41.	11.	10.	25.	22.	۰.	e.	35.	ж.	я.	55.
15)	D.	10.	11.	۰.	10.	9.	θ.	۰.	2.	0.	10.	θ.	17.	21.	51.	12.	20.	22.	31.	10.		45,	44.	44.	43,
168	0.	0.	0.	0.	٥.	0.	٥.	θ.	12.	٥.	12.	۱.	n.	6.	52.	17.	19.	24.	25.	θ.	2.	25.	23.	39.	59,
171	33.	33.	35.	32.	28.	8.	۰.	0.	25.	n.	8.	θ.	33.	36.	45.	30.	15.	30.	42.	θ.	13.	27.	٩ θ.	35.	\$0.
181	19.	35. 19.	30. 19.	19.	15.	θ.	0.	e.	15.	۰.	6.	0.	14.	24.	52.	16.	13.	20.	30.	e.	۱.	27.	28.	26.	36.
191	22.	25.	36.		9.	۰.	3.	8.	16.	6.	16.	ο.	14.	21.	51.	21.	76.	30.	30.	9.	۰.	45.	43.	42.	42.
101	39.	42.	51.	14			,	14		18	20	•			41	10	14	78			16.			50.	
	41.	49.	61.										••••												
211	22	40.	51.	13.	2.	7.	۰.	17.	12.	7.	11.		۹.	22.	51.	٩.	25.	52.	•.	14.	14,	26.	24.	23.	22.
221	10:	12.	52.	7.	7.	7.	14.	n.	30.	17.	13.	7.	14.	21.	52.	21.	38.	36.	19.	22.	30.	6.	٥.	40.	12.
231	25:	39:	÷.	10.	2.	۶.	σ.	0.	в.	12.	14.	0.	10.	16.	46.	۰.	27.	20.	17.	۹.	н,	30.	29.	38.	28.

Program Description

The computer program is mostly written in FORTRAN IV, for the IBM 360 series. The few assembly language routines used are selfcontained subroutines which perform specialized functions such as manipulating characters for creating plots and reading elapsed CPU time. The program is a composite of many subroutines. This allows convenient local modifications to be made with generally good assurance of a successful subsequent run. On the other hand, the program makes extensive use of the overlay option in order to economize on restricted core space. The use of this option demands considerable sophistication about data storage on disks and its subsequent retrieval. Experienced programmers who are knowledgeable about these methods should find it relatively easy to modify the program. However, inexperienced programmers will discover that modifications appear to be simple, but that somehow subsequent simulation runs are never successful.

Submodel	Subroutines	Block Common
Employment	NDSTRY	/LIMITS/,/CORFAX/,
location		/BODIES/,/CSIC/,
		/TRAVL/,/UPDAT/
Movers	MOVE, SCOOP,	/CORFAX/,/UPDAT/,
	ENHANS	/BODIES/,/TRAVL/,
		/MOVER/,/DMOV/,
		/DETAL/,/HOUY/
Demand	DEMND	/CORFAX/,/BODIES/,
allocation		/TRAVL/,/MOVER/,
		/BETA/
Filter	FLTRS, FILTER	/FILTR/,/LIMITS/,
:		/CORFAX/,/SCALE/
Supply	SUPPLY, SORT,	/CORFAX/,/SUPLY/,
	SORTS, SELECT,	/CSTMN/,/SCOP/,
	PACK	/VREQ/
Market-	MARKET, ENCODE,	/TRAVL/,/SPLY/,
clearing	MATCH, UPDATE,	/MOVER/,/ANSWR/,
	PFORM	/TRANS/,/SHDOW/,
		/PRLAG/,/MNTHLY/

Table A.3	
Submodels and Subroutin	es



Figure A.2 Overlay Map of Program

The operational model consists of a main program and eleven overlay segments. These eleven segments in turn comprise 26 subroutines and 25 named block common storage areas. Table A.3 shows the relation of the seven submodels to the subroutines and block common areas. Figure A.2 is a schematic of the model's overlay structure. The relative positions of overlays alpha, beta, and delta depend on the size of the problem being attacked. In the Detroit Prototype program, alpha is located about 71,000 bytes from the origin; beta, about 120,000 bytes; and delta, about 191,000 bytes.

Maximum core requirements vary according to the compiler used, but the maximum core size is determined by the end of *DEMND* in the Detroit Prototype, and it is about 229,000 bytes from the origin. Generally, additional amounts of core are required for various system-monitoring and program-linking routines; so the Detroit Prototype program requires approximately 250K bytes of nonsystem core.