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AN ANALYSIS OF THE ENERGY CONSERVATION POTENTIAL OF VARIABLE WORK HOURS AND ALTERNATIVE TRANSIT POLICIES FOR THE URBAN WORK TRIP

By

James Mitchell Witkowski

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ABSTRACT

AN ANALYSIS OF THE ENERGY CONSERVATION POTENTIAL
OF VARIABLE WORK HOURS AND ALTERNATIVE
TRANSIT POLICIES FOR THE URBAN WORK TRIP

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James Mitchell Witkowski

The primary hypothesis tested by this research was that a reduction in transportation fuel consumption for the urban work trip could be realized through the implementation of a staggered or flexible work hour program. It was also hypothesized that a variable work hour program could be coordinated with the scheduling of a bus transit system to further improve the savings in transportation fuel consumption.

The spatial organization of a hypothetical urban area was generated using data from the literature and a computer simulation program designed to distribute population and employment activities throughout the urban area. With additional data describing the highway and transit network, and the temporal distribution of work travel, the computer program also generated the work trip travel pattern for the urban area and computed the transportation fuel requirements for automobile work trips and the daily transit service. A base case was generated and used as the basis for comparison of the alternative policies.

Several alternative temporal distributions of work travel were used to simulate the effect of variable work hour programs. Tests were designed to determine the influence of the magnitude and location of the work force participating in the variable work hour programs on the reduction in fuel consumption. Experiments were also designed to test the potential for reducing fuel consumption through modifications in the scheduling of transit vehicles during the peak travel period. Other

experiments were designed to test the combined effectiveness of variable work hour and transit scheduling policies. An evaluation was also made to determine whether or not the prevailing fuel environment could influence the policy effectiveness.

The simulation results indicated a high potential for staggered and flexible work hour programs to reduce automobile work trip gasoline consumption. The effectiveness of the variable work hour policies was shown to be influenced by both the number of participants in the program and the dispersion of the participants throughout the urban area. The reduction in fuel consumption increased with the number of participating work travelers. The reduction also increased as the locations of the participating employment centers became more dispersed throughout the urban area. The variable work hour programs also showed a strong negative influence on work trip bus ridership.

The experiments with transit scheduling policies indicated that it would be difficult to reduce work trip fuel consumption through increases in the frequency of service of bus transit. However, this result may be biased by the overall structure of the hypotehtical urban area and the base case used in the analysis. The combined variable work hour and transit scheduling policies showed no further reduction in fuel consumption beyond that achieved by the variable work hour policies.

The experiments also indicated that the policies tested would be less effective at reducing fuel consumption in a fuel environment exhibiting a drastic increase in fuel price or a restriction on fuel availability. This was due to the large mode choice shift to transit, which resulted from the change in the fuel environment. However, a definitive conclusion in this area could not be obtained due to limitations in the modeling system.

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CHAPTER I

Introduction

One of the many effects of the oil embargo of 1973-1974 on the United States has been a surge of interest in the development of better methods of evaluating transportation plans with specific recognition of energy availability. Current capabilities for planning under energy constraints are severely limited by the lack of data. During the embargo, the facilities necessary to collect gasoline supply and consumption data at a disaggregate level were not available. Since the United States has never experienced a long-term fuel shortage, the influence of such a shortage on urban travel and living patterns is unknown.

The influence of transportation system management (TSM) policies to reduce gasoline consumption in urban travel has never been evaluated in an actual urban environment. The only method available for analyzing the potential impact of energy conservation policies or changing fuel environments is extrapolation of observed short-term responses through the use of theoretical models.

1.1 Research Hypotheses

The primary hypothesis tested by this research was that a reduction in transportation fuel consumption for the urban work trip could be realized through the implementation of a staggered or flexible work hour program. It was also hypothesized that for the short-term a staggered or flexible work hour system could be coordinated with the scheduling/frequency policies of a bus transit system to further improve the savings in transportation fuel consumption.

For this research study, transportation fuel consumption is defined as the gasoline fuel consumption of automobile work trips plus the daily total diesel fuel consumption of an urban bus transit system. The phrase "short-term" implies a duration of time short enough such that a significant change in the home to work spatial relationship of urban travel, or the magnitude of urban work travel, would not be realized as a result of the availability or cost of such travel, or as a result of a change in the population in an urban area. In reality, short-term may be several years.

For this research the term "variable work hours" did not include four-day work week programs. The variable work hour programs considered in this study were:

1. Staggered work hours -- a fixed schedule of working hours that normally spreads the employee starting and finishing times over a one to three hour period, with individual groups of employees designated to report at 15 to 30 minute intervals.
2. Flexible work hours -- a program where employees start and finish work at times of their own choosing within the constraint that they work a specified minimum number of hours within a given period, and normally within the additional constraint that they be present during certain "core" hours.

1.2 Goals and Objectives

The goal of this study was to evaluate the impact of selected variable work hour programs and transit scheduling strategies on urban work trip transportation fuel consumption. The work hour programs and transit strategies were tested individually and in combination to allow for the evaluation of the incremental effect of the coordinated policies.

The first objective was to establish an operational modeling system to calculate urban work trip tavel demand and fuel consumption for a hypothetical urban area. The second objective was to design and evaluate (using the modeling system) alternative variable work hour and transit scheduling strategies. The evaluation was primarily based on a comparison to a base case of the transportation fuel consumed. The third objective was to demonstrate the possible effect of the prevailing fuel environment on the success or failure of the various strategies to reduce transportation fuel consumption. With respect to the latter objective, a "normal" fuel environment was defined as a stable or slowly fluctuating retail price for transportation fuel at levels experienced during 1979. A normal fuel environment also implied the unrestricted availability of transportation fuel to the general public.

1.3 Benefits of this Research

The primary benefits of this research were derived from the evaluation of the energy conservation potential of the specific TSM policies tested. The potential for variable work hours or transit scheduling policies to reduce urban work trip energy consumption has never been fully demonstrated, either in the real world or through the use of a modeling system. This demonstration could be a valuable tool to aid in the development of comprehensive transportation plans designed to reduce urban transportation fuel consumption.

1.4 Outline of Report

The remainder of this text is divided into five additional chapters. Chapter II describes previous research on TSM policies with specific reference to the energy conservation potential of variable work hours and transit scheduling policies. Based on the literature review, conclusions are drawn for the justification of this research. Chapter III contains a description of the modeling requirements of the research technique, and a detailed description of the modeling system used in this research effort. Chapter IV describes the process used for the evaluation of the alternatives, and also summarizes each individual policy tested. Also contained in Chapter IV is a description of the hypothesized alternative fuel environments used in the analysis. Chapter V contains a detailed analysis of the research results disaggregated by policy type and policy combination. Chapter VI is a summary of the major conclusions of the research.

Four appendices are also contained in this report. Appendix A includes a detailed description of the modifications required to the computer program used for the research. Appendix B contains a complete data set which describes the base case used for analysis in this research when the data is input to the computer program. Appendix C contains all of the data necessary to describe the policy alternatives tested, and Appendix D contains several charts showing the highway congestion patterns and congestion indices for selected policy alternatives.

CHAPTER II

Previous Research on Variable Work Hours and Bus Transit Strategies Related to Fuel Consumption

2.1 Review of Urban Transportation Energy Conservation Strategies

The most widely accepted theoretical modeling system for urban transportation planning is the Urban Transportation Planning System (UTPS) developed for the Urban Mass Transportation Administration. Hartgen (1976) evaluated the capability of the UTPS models to deal with energy constraints. He concluded that the UTPS process can be used to determine the sensitivity of fuel consumption to certain energy policies (for example, speed reduction, increased vehicle efficiency, carpooling). However, Hartgen concluded the process is generally incapable of analyzing the impacts of such policies as rationing or Sunday driving bans.

Witkowski and Taylor (1979) suggested that the long-term conclusions reached by sensitivity analysis would be suspect because traveler reactions to an extended fuel shortage would most likely be different than during the 1973-1974 embargo. Therefore, the empirical data collected during the 1973-1974 fuel shortage is not necessarily valid for long-term planning, and hence the relationships developed from this data should not be extrapolated. They concluded that the current emphasis in planning under energy constraints should be placed on short-range energy contingency planning, and methods should be developed to test the impacts of energy related transportation policies.

Of particular interest to transportation planners are the evaluation of strategies to reduce automobile fuel consumption in urban areas where approximately 34 percent of the national total transportation energy is consumed (Office of Technology Assessment (1975), p. 3). These trips account for approximately 98 percent of the fuel consumption for urban passenger travel, while supplying transportation for 92-95 percent of the total vehicular person trips (Office of Technology Assessment (1975), p. 17).

A review of the energy conservation potential or urban mass transit by the Office of Technology Assessment (1975) concluded that "pure" transit improvement strategies and economic incentives for transit use (including no-fare transit) can be very effective in attracting increased ridership, but they are ineffective by themselves in substantially reducing national energy consumption. It was reported that the most effective methods of energy conservation involve auto use disincentives coupled with transit use incentives.

Lutin (1976) reports that, given the current work trip patterns in New Jersey, greater savings in energy could be achieved by using automobiles more efficiently than by increasing public transit patronage. His analysis indicated that carpooling (increasing average auto occupancy from 1.2 to 2.0 passengers per vehicle for the work trip) would save the state 40 percent of the journey-to-work energy. The study also indicated that for present transit operations to contribute an 8.8 percent reduction in work trip fuel consumption, 10 percent of all automobile commuters would have to shift to public transit. This would nearly double 1976 ridership levels.

The attractiveness of carpooling and the general ineffectiveness of transit incentives alone to conserve fuel was also demonstrated in a study by Peskin and Schofer (1977). In their study, several hypothetical urban structures were postulated and the impacts of urban transportation and land use policies on transportation energy consumption were evaluated using a simulation model. The results indicated that increasing the work-trip auto occupancy from 1.2 to 1.8 passengers per vehicle would cause a 21 to 42 percent decrease in total urban travel energy consumption depending on the city structure. In contrast to these potential savings, a "free transit" policy resulted in an estimated energy savings of from 4 to 16 percent, while an "express transit" policy did not decrease energy consumption at all. However, under a "no transit" policy, there was as much as a 32 percent increase in total energy consumption, indicating that transit did decrease energy consumption by reducing automobile traffic and congestion. This was based on an estimated 13.3 percent of work trips made by transit for the typical bus system simulated.

The energy conservation potential of carpooling may be over-estimated in these studies, however, because of the assumed value of increased auto occupancy. Other researchers have concluded that the auto occupancy obtainable through carpool incentives is probably in the range of 1.4 to 1.7 passengers per vehicle (Pratt et. al. 1977). In addition, not all carpools represent an energy savings, since, for example, as many as 30 percent of new carpoolers in Portland, Oregon were found to have formerly ridden the bus (Pratt et. al. 1977).

Several other studies (Dupree and Pratt (1973), Voorhees (1974), Remak and Rosenbloom (1976), Gross et. al. (1978)) reviewed the potential of different techniques to reduce urban congestion, and to subsequently reduce gasoline consumption. In each of these studies, staggered work hours was regarded as an effective low-cost action to reduce congestion and gasoline consumption.

Dupree and Pratt (1973) detailed the findings of a survey and analysis of twenty-one low-cost techniques designed to increase the effective processing capacity of fixed capital transportation facilities. A wide range of possible techniques offered promise in satisfying their study objectives. Techniques were rated with particular attention to their potential processing efficiencies (volume increase or time reductions in moving people via existing transportation facilties). In addition, the evaluation considered various cost parameters, impacts on the disadvantaged, environmental and transportation safety factors, technical and institutional viability, and the expected response from travelers.

Techniques were grouped according to their composite ratings and case study analysis candidates were selected from the highest ranked group. The rankings are shown in Table 1.

Dupree and Pratt did not review the effects of these techniques in combination or estimate their energy conservation potential. However, staggered work hours was ranked as one of the most promising techniques for increasing highway effectiveness.

Voorhees (1974) reviewed the potential of ten "action groups" to reduce urban gasoline consumption. This study attempted to define the interrelationships between these action groups and determine which groups assist, are independent, overlap each other, or are counterproductive. The action groups and these interrelationships are shown in Figure 1. Voorhees indicated that the most significant interrelationships identified in this matrix are:

1. Actions to improve total vehicular traffic flow tend to shift travel from non-auto modes to the automobile, and hence tend to be counterproductive to actions designed to decrease auto travel.
2. Carpooling actions and transit actions are both designed to

Table 1. Techniques Designed to Increase the Effective Processing Capacity of Fixed Capital Transportation

1) All Around Most Promising Techniques

- Exclusive Bus Lanes on Urban Arterials (Existing Facilities)
- Exclusive Reserved Lanes on Freeways for Mass Transit (Existing Facilities)
- Exclusive Busways on Specially Constructed Rights-of-Way
- Work Scheduling Changes
- Highway Traffic Engineering System Improvements

2) Less Generally Promising Techniques

- Paved Railroad Rights-of-Way
- High Capacity Transit Buses
- Organized Commuter Car and Bus Pools
- Freeway Metering, Monitoring and Control Systems
- Free or Heavily Subsidized Transit
- Line Haul Feeder System
- Airport Access Improvements
- Automation of Bus Scheduling
- Economic Penalties and/or Incentives
- Urban Goods Movement Improvements
- Para Transit Service (Jitneys, Taxis and Limousines)

3) Least Useful to Achieve Specific Study Objectives

- The Rail Bus
- Demand Actuated Transit Service
- Bus Traffic Signal Preference Systems
- Auto Driver Aids and Directions Systems
- The Minicar

Source: Dupree and Pratt (1973), p. 6.

ACTION GROUP \ ACTION GROUP	1 Measures to Improve Flow of High Occupancy Vehicles	2 Measures to Improve Total Vehicular Traffic Flow	3 Measures to Increase Car and Van Occupancy	4 Measures to Increase Transit Patronage	5 Measures to Encourage Use of Walk and Bike Modes	6 Measures to Improve the Efficiency of Taxi Service and Goods Movement	7 Measures to Restrict Traffic	8 Transportation Pricing Measures	9 Measures to Reduce the Need to Travel	10 Energy Restriction Measures
1. Measures to Improve Flow of High Occupancy Vehicles		C	A	A	A	I	A	I	I	I
2. Measures to Improve Total Vehicular Traffic Flow			I	C	C	I	C	C	C	I
3. Measures to Increase Car and Van Occupancy				O	I	I	I	A	I	A
4. Measures to Increase Transit Patronage					A	I	A	A	I	A
5. Measures to Encourage Use of Walk and Bike Modes						I	A	I	I	A
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement							I	I	I	A
7. Measures to Restrict Traffic								I	I	A
8. Transportation Pricing Measures									I	O
9. Measures to Reduce the Need to Travel										A
10. Energy Restriction Measures										

LEGEND

A = Action Groups which assist each other in reducing energy.
I = Action Groups which are independent of each other in reducing energy.
O = Action Groups which may overlap or preempt each others effectiveness in reducing energy.
C = Action Groups which may be counterproductive to each other in reducing energy.

Figure 1. Interrelationship of TSM Action Groups.
Source: Voorhees (1974), P. 29.

reduce the travel of the single occupant vehicle, and hence these two actions may overlap and reduce some of each other's effectiveness.

3. Energy restriction actions and transportation pricing actions act to reduce travel or impose mode shifts in a similar manner and tend to overlap each other's effectiveness.
4. Auto travel disincentives, such as traffic restriction actions, transportation pricing actions, and energy restriction actions, tend to complement and assist incentive actions, such as transit improvements, walk and bike actions, and carpooling programs.

Voorhees presented groups of transportation fuel conservation actions for small, medium and large urban areas, with an estimated range of savings for each action individually and for each group as a whole. Measures to improve total vehicular flow were estimated to be most effective at reducing fuel consumption for larger urban areas (1,000,000 persons or more), where, for example, staggered work hours were estimated to reduce work trip energy consumption from 1 to 2 percent. Although no figures were given, staggered work hours is suggested to be less effective for medium or small size cities.

Characteristics of the implementation of staggered work hours are:

1. Decreased travel time.
2. Minor lifestyle changes.
3. Minor economic impact.
4. Decreased air pollution, noise and congestion.
5. Requires considerable coordination.

The energy conservation estimates presented by Voorhees were based on an estimate of the impact of each action on highway congestion and vehicle miles of travel. For the staggered work hours program, estimates were made based on the assumed change in average cruising speed, the number of acceleration/deceleration cycles per mile, the number of stop and go cycles per mile, and the amount of time spent idling. Most of the fuel economy data were taken from a report by Claffey (1971).

Remak and Rosenbloom (1976) reviewed the effectiveness of twenty-two techniques for reducing peak period traffic congestion. Actions to reduce congestion would also reduce energy consumption. Five techniques were estimated to be the most effective in reducing congestion in the central business district of large cities: (1) parking controls; (2) road pricing; (3) priority expressway transit treatment; (4) staggered work hours and (5) auto free zones.

None of the techniques was found to offer more than marginal reductions in peak period traffic congestion when applied individually. However, packages of effective combinations of congestion-reduction techniques were presented as shown in Figure 2. The staggered work hour package combined five individual techniques:

1. Staggered work hours.
2. Road pricing.
3. Parking controls.
4. Transit marketing.
5. Extended-area transit.

The combination of the staggered work hours policy and the transit policies in this package is very similar to the policies tested by this research. Remak and Rosenbloom indicated that, when coordinated with the needs of an existing transit system, staggered work hours have been able to make significant improvements in transit system operating efficiency and increase ridership.

	Carpooling	Zoning and building codes	Planned neighborhoods	New Towns	Communications	Traffic cells	Auto-free zones	Staggered work hours	Parking controls	Road pricing	Circulation	Transit priority: arterials	Transit priority: highways	Extended-area services	Transit incentives	Maximum use of existing facilities	Freeway surveillance and control
Road pricing	+	0	0	0	+	+	0	+	+	+	+	+	+	+	+	-	-
Parking controls	+	+	0	0	+	+	0	+	+	+	+	+	+	+	+	-	-
Staggered work hours	-	0	0	0	0	0	0	+	+	+	+	+	+	+	+	-	-
Auto-free zones	0	+	+	0	0	+	+	0	0	0	+	+	+	+	+	0	0
Traffic cells	0	+	+	0	0	+	+	0	+	+	+	+	+	+	+	+	+
Maximum use of existing facilities	-	+	+	0	-	+	0	-	-	-	-	-	-	-	-	+	+
Freeway surveillance and control	-	0	0	0	0	+	0	-	-	-	-	-	-	-	-	+	+
Zoning and building codes	+	+	+	+	0	+	+	0	+	0	0	0	0	0	0	+	0
Planned neighborhoods	0	+	+	+	0	+	+	0	0	0	+	0	0	0	0	+	0
New Towns	-	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0
Communications	-	0	0	+	+	0	0	0	+	+	-	-	-	-	-	-	0
Carpooling	+	+	0	-	-	0	0	-	+	+	+	-	-	-	-	-	-
Transit incentives	-	0	0	0	-	+	+	+	+	+	+	+	+	+	+	-	-
Circulation system	+	+	+	0	-	+	+	+	+	+	+	+	+	+	+	-	-
Transit priority: arterials	-	0	0	0	-	+	+	+	+	+	+	+	+	+	+	-	-
Transit priority: expressways	-	0	0	0	-	+	+	+	+	+	+	+	+	+	+	-	-
Extended-area services	-	0	0	0	-	+	+	+	+	+	+	+	+	+	+	-	-

Figure 2. Matrix Showing Mutually Supportive TSM Techniques Arrayed to Suggest Program Packages.
Source: Remak and Rosenbloom (1976), p. 18.

In the study by Gross et. al. (1978) techniques are presented to estimate the potential gasoline "net" savings due to several transportation system management (TSM) actions for New York State. The general categories of TSM actions are:

1. Actions to ensure efficient use of road space.
2. Actions to reduce vehicle use in congested areas.
3. Actions to improve public transit service
4. Actions to improve transit management efficiency.

These general categories of TSM actions were broken down into thirty-three specific actions, and the statewide energy conservation potential of each was estimated. The results are shown in Table 2. These actions were estimated to reduce the gasoline consumption within New York State by 37.1 million gallons annually.

Staggered work hours, flex-time, and the four day work week ranked eighth with an estimated annual gasoline savings of 1.8 million gallons. This figure was based on an assumed fleet average fuel economy of 15.8 miles per gallon (mpg), and an estimated reduction of 0.00022 gallons per mile (gpm) per vehicle. The latter estimated was based on the work by Tannir (1977) which is discussed in the section on the impacts of staggered work hours.

The procedure used to estimate the net energy savings of each TSM action was based on the estimated impact of the action on vehicle-miles of travel (VMT), and traffic congestion. This was then converted into an energy savings using the assumed fleet mpg.

Gross assumed that these actions impact independently on gasoline consumption and that the results of each were additive. In reality this is highly unlikely, as discussed by Voorhees (1974) and Remak and Rosenbloom (1976). Gross also showed a relatively large potential saving from

Table 2. Preliminary Estimates of Gasoline Savings from TSM Actions

Strategy	Tri State	Cap. Dist.	U-R	Syr.	Roch.	Buff.	Bing.	Chem.	Total	Construction and Maintenance Energy (annual gallons of gasoline equiv.)
TOPICS,etc.	588,987	65,443	2,094,176	130,886	1,177,974	523,544	65,443	--	4,646,453	1,022,400
Comput. Traff. Cont.	--	--	--	--	--	--	--	--	--	--
Ramp Metering	--	--	--	--	--	--	--	--	--	--
Oneway Street	--	--	--	--	--	--	--	--	--	--
Exc. 1, Reversed Contra Flow Lanes	105,070	--	--	--	--	--	--	--	105,070	2,000
Toll Plazas	--	--	--	--	--	--	--	--	--	--
Pref. Access Ramps	--	--	--	--	--	--	--	--	--	--

Table 2 (continued)

Strategy	Tri State	Cap. Dist.	U-R	Syr.	Roch.	Buff.	Bing.	Chem.	Total	Construction and Maintenance Energy (annual gallons of gasoline equiv.)
Spec. Turn Lanes, etc.	--	--	--	--	--	--	--	--	--	1,380
Pedes-trians	110,380	19,747	--	17,797	22,127	44,370	--	--	214,604	89,600
Bicycles	5,726,392	666,457	270,684	--	--	788,297	--	--	7,451,830	2,760
Reduced Pkg. Sp.	--	--	--	--	--	--	--	--	--	--
Inc. Pkg. Rates	--	--	--	--	--	--	--	--	--	--
Diff. Pkg. Rates	--	--	--	--	--	--	--	--	--	--
Pks. Permit System	--	--	--	--	--	--	--	--	--	--
Limit New Pkg.	--	--	--	--	--	--	--	--	--	--

Table 2 (continued)

Strategy	Tri State	Cap. Dist.	U-R	Syr.	Roch.	Buff.	Bing.	Chem.	Total	Construction and Maintenance Energy (annual gallons of gasoline equiv.)
Transp. Cor. Pkg.	See Transit	71,067	--	4,255	121,970	--	--	--	197,292	450
Stagg, etc. Hours	423,663	594,100	--	550,940	--	--	243,360	--	1,812,063	--
Tolls	--	--	--	--	--	--	--	--	--	--
Red. Off-Pk. Fares	4,665,277	44,543	9,689	51,637	81,079	118,534	11,096	191	4,982,046	--
Ride-sharing	--	--	--	--	676,559	--	--	--	676,559	--
Auto Res. Zones	--	222,152	90,228	--	--	--	--	--	312,380	520
Truck Rest.	--	--	--	--	--	--	--	--	--	--
Rout., Sch., etc.	560,515	7,768	3,884	3,884	1,942	1,942	5,826	1,942	587,703	20,560
Express Bus	37,648	--	--	28,236	--	--	--	--	65,884	2,672

Table 2 (continued)

Strategy	Tri State	Cap. Dist.	U-R	Syr.	Roch.	Buff.	Bing.	Chem.	Total	Construction and Maintenance Energy (annual gallons of gasoline equiv.)
P & R	195,804	--	--	65,268	261,072	--	--	--	522,144	48,000
Shuttle Transit	601	601	--	18,482	--	--	--	--	19,685	25,000
Amenities	7,922,647	57,567	8,725	55,342	92,191	143,988	--	--	8,280,460	36,510
Fare Coll.	--	--	--	6,516	--	--	--	--	6,516	9,600
Pass. Info.	2,992,824	23,374	6,107	--	33,557	62,490	3,176	--	3,121,528	N/A
Demand Resp. System	220,926	1,072	--	6,432	7,797	--	--	--	236,227	937,610
Bus Maintenance	--	--	--	--	--	--	--	--	--	390,000
Monitoring	--	--	--	--	--	--	--	--	--	--
Marketing	6,338,117	--	--	44,274	--	115,190	6,980	--	6,504,561	3,600
TOTAL (M gal.)	29.80	1.7	2.5	0.96	2.42	1.76	.3	.002	39,743,005	2,625,000

SOURCE: Gross et. al. (1978), p. 8.

NET = 37,117,943

increased pedestrian activity and bicycling which contradicts statements made by Voorhees (1974).

Although some of the studies have addressed the combined impact of several actions, as a whole these efforts made only gross approximations of the impacts of staggered work hours and transit incentives on gasoline consumption. The previous studies did not define the relationships between the size of the participating work force and the impact on fuel consumption, nor did they indicate the magnitude of the temporal redistribution of the work trip required to effect a significant reduction in gasoline consumption. There is also little evidence to suggest how transit schedules could be coordinated with the variable work hour programs to reduce energy consumption.

2.2 Local Bus Supply and Urban Travel Demand

It is unfortunate that mechanisms were not available during the oil embargo (1973-1974) to capture the information necessary for an extensive analysis of the relationships between transit demand and supply under energy constraints. Therefore, by default, the relationships used in this research were those determined during the more prevalent non-embargo periods. The elasticities between local bus supply and urban travel demand under normal conditions probably represents the minimum obtainable headway elasticities under energy constrained conditions, and thus would produce conservative estimates of potential fuel savings. Headway elasticity is defined as the percent change in ridership resulting from a one percent change in headway.

In general, most of the literature that evaluated the effectiveness of improvements in bus transit system operations to induce ridership and/or to reduce work trip energy consumption have drawn conclusions based on conventional operation strategies. Actions to improve transit operations consist of scheduling/frequency changes and bus routing/coverage changes. Scheduling and frequency improvements include:

1. Increasing the number of scheduled transit vehicles.
2. Reducing headways and passenger wait times.
3. Lengthening the hours of service.
4. Rescheduling to provide convenient departure times, or to match regularly scheduled activities, or to provide better coordination at transfer points.

An in-depth review of the state-of-the-art of traveler response to transportation system changes has been performed by Pratt et. al. (1977). Traveler response to service frequency changes can vary markedly, however significant conclusions from the Pratt review included:

1. Limited evidence suggests that the median response to frequency improvements is approximately a one half of 1 percent patronage gain per 1 percent frequency increase.
2. Middle and upper income areas are the most sensitive to headway changes provided the prior service was relatively infrequent, (three buses or so per hour) and the trips served are predominantly short.
3. Lower income groups are generally more sensitive to fare changes than to frequency changes, particularly when headways are already short.
4. Sensitivity analysis of bus service to short, suburban trips, done with a mode choice model calibrated for the northern Chicago suburbs, indicated the middle-to-upper income population to be about 40 percent more sensitive to frequency than to fares in the 10 to 20 minute headway range, and over two times more sensitive

to frequency than to fares in the 20 to 40 minute headway range (Pratt and Bevin (1971)).

5. Travel demand modeling suggests that transit wait time, plus transfer time, plus walk time may be two to two and one half times as important in mode choice as an equal time spent in the transit vehicle (Quarmby (1967), Shunk and Bouchard (1970)).

6. In various experiments by the Mass Transportation Commission of the Commonwealth of Massachusetts (MTCCM (1964)), bus riders attracted from other travel modes by increased frequency were distributed as follows:

Trips Made Previously	
in own car	18 to 67%
in carpool	11 to 29%
by train	0 to 11%
by taxi	0 to 7%
by walking	0 to 11%

Headway elasticities determined from individual Massachusetts demonstration projects (MTCCM (1964)) are shown in Table 3 along with the elasticities implied by other reported findings (Holland (1974)). The median headway elasticity among those calculated from the Massachusetts experiments is -0.4, or -0.6 omitting depressed urban areas.

Actions to improve transit through bus routing and coverage changes include:

1. Introduction of bus service where there was none perviously, or elimination of service where it exists.

2. Major systemwide realignment so as to significantly alter system coverage.

3. Extension of existing routes to provide service to new developments, or other previously unserved areas.

Table 3. Transit Service Headway Elasticities

Massachusetts Demonstrations, (MTCCM, 1964) A/	Headway Elasticity	Months After Implementation
Boston-Milford suburban route (new headway approximately hourly)	-0.4	10-12
Uxbridge-Worchester suburban route (new headway hourly)	-0.2	7- 9
Adams-Williamstown city route (new headway approximately hourly)	-0.6	1- 3
Pittsfield city route (raised from 3 to 8 round trips daily)	-0.7	1- 3
Newburyport-Amesbury (depressed area) city route (new headway 30 min. peak/60 midday) B/	-0.4	6- 8
Fall River (depressed area) city service (overall 20 percent service increase)	nil	4- 6
Fitchburg-Leominster city route (new afternoon headway 10 minutes, to match morning) B,C/	-0.3	6- 8
Boston downtown distributor, Phase 1 (new headway 5 minutes, to match peak) C/	-0.8	5- 7
Boston downtown distributor, Phase 2 (new headway 4 minute base, 8 minute midday) C/	-0.6	8-10
Boston rapid transit feeder route (new midday headway 5 minutes, to match peak) C/	-0.1	4- 6
Other Reported Findings (Holland, 1974)		
Study of Milwaukee transit (1955-1970)	-3.8	--
Detroit city route (new headway 2 minute base, 3-1/2 minute midday) D/	-0.2	--
Chesapeake, Virginia, suburban service D/	-0.9	--

A/ Arc elasticity calculated by the Handbook authors on the basis of revenue.

B/ Includes impact of minor route extension.

C/ Approximate elasticity computed for full service day by using an unweighted average of peak and off peak (or morning and afternoon) headway improvements.

D/ Arc elasticity calculated by the Handbook authors on the basis of ridership.

SOURCE: Pratt, et. al. (1977), p. 160.

4. Initiation of special purpose bus routes to serve specific, inadequately serviced, existing or potential travel demands.

5. Restructuring of a bus system to reationalize service, to accommodate new travel patterns and to reduce circuitry and the number of transfers required for bus travel.

The summary of traveler response to changes in bus routing/coverage by Pratt et. al. (1977) indicated:

1. That the elasticity of patronage to system coverage has been estimated to be in the range of 0.3 to 0.8 percent per 1 percent increase in bus miles of service.

2. Travel models calibrated for Boston indicated transit work trip elasticities of -0.39 for line-haul bus and subway travel time, and -0.71 with respect to changes in transit access time, including walk, wait and applicable feeder bus travel times.

3. The ability of new or modified bus routes to attract patronage is strongly a function of how a route relates to the local development, transportation system, and travel patterns. New bus routes have been found to take 1 to 3 years to reach their full patronage potential.

4. The shorter the walk to transit service, the higher the probability that transit will be used. A 1968 survey of the Buffalo metropolitan area showed that among workers residing 1/10 of a mile from a bus, 20 percent used transit, while among those 1/8 of a mile from a bus, 10 percent used transit.

5. A major component of riders attracted to new or revised bus routes may be riders diverted away from other routes, as shown in Table 4.

Table 4. Source of Riders Attracted to New or Revised Bus Routes

Source of New Riders	Radial Routes to Suburbs St. Louis (97)	Circumferential Route @ 3 Miles Boston (176#)	Circumferential Route @ 5 Miles Boston (176#)
Other Transit Routes	60%	94% A/	87% B/
Auto	28% C/	4%	13%
Walk and Other Means	12%	2%	D/
New Trips	D/	less than 1%	D/

A/ 81% of this diversion was from other routes on the same streets.

B/ 44% other bus routes and 43% rail rapid transit.

C/ 16% single auto driver and 12% carpool.

D/ Not reported.

Source: Pratt et. al. (1977), p. 182.

2.3 Variable Work Hour Programs

The objective of staggered or flexible work hour programs is to shift work trip travel away from the peak transportation system demand periods. The desired results are a reduction in peak highway and transit system loading, improved transportation levels of service, and reductions in energy consumption and vehicle emissions.

Traveler response to staggered work hour programs has been measured at both terminal facilities, such as parking lots or transit stations, and on through facilities, such as highway or transit links. In both cases, the shift in peak period travel demand has been shown to be significant provided the employee participation rate is high.

2.3.1 Impacts on Work Starting Times

In April, 1970 the Port Authority of New York and New Jersey in cooperation with the Downtown Lower Manhattan Association (D-LMA), initiated a staggered work hours program to determine the impact of spreading out travel demands of workers on public transportation. Prior to the initiation of the program a survey of employee starting times was conducted by the D-LMA. The results shown in Figure 3 indicate that for the 113 firms surveyed (representing 136,000 employees out of a work force of 480,000) 66 percent of the employees were scheduled to start work at 9:00, and 64 percent left work at 17:00 (O'Mally and Selinger (1973)). Initially, 46,000 employees shifted their starting times from 9:00 to 8:30 and left at 16:30 instead of 17:00. Another 4,000 began later, at 9:30 and left at 17:30. The program stressed a shift of at least 30 minutes so as to require a definite change in commuting habits. A dramatic flattening of the peak period arrival pattern occured as exemplified by the diagram of the temporal distribution of persons entering

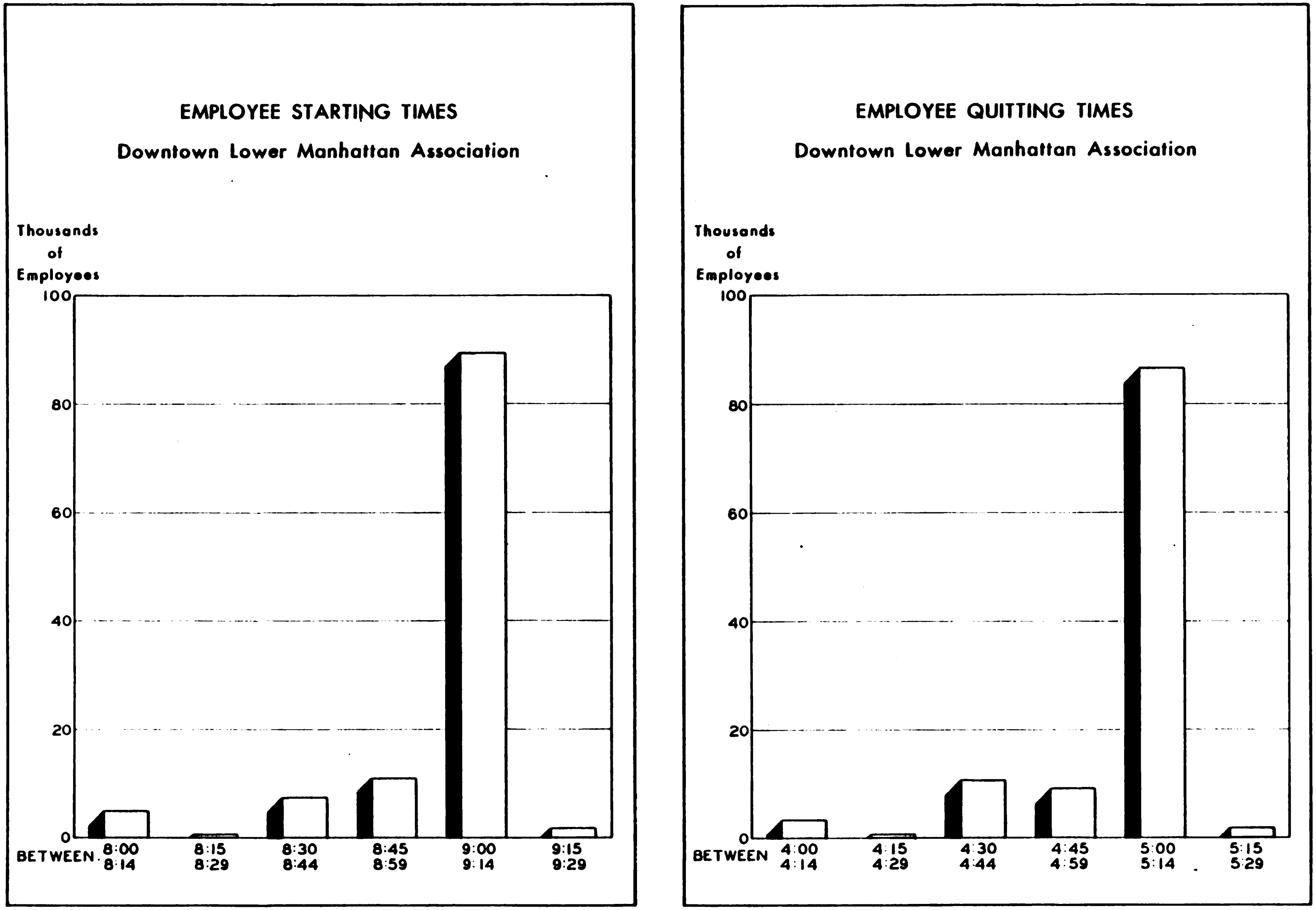


Figure 3. Employee Starting and Quitting Times, Downtown Lower Manhattan.
Source: O'Malley (1974), Exhibit 17 and 18.

the Port Authority Building lobby shown in Figure 4. The number of arrivals in the peak five minutes was reduced 29 percent (Port Authority of New York and New Jersey (1977)).

Of particular interest is the marked resemblance of the "before" starting times in Figure 3 to a normal distribution shifted approximately 15 minutes prior to the 9:00 starting time. This distribution corresponds closely to the statistics collected by Santerre (1966) on work arrival times in Houston, Texas.

In the Queen's Park area of Toronto, a variable work hours demonstration involving approximately 11,000 government employees was implemented in October, 1973 (Greenberg and Wright (1975)). In this program, 68 percent of the employees were assigned to staggered work hours and another 23 percent were placed on flexible work hours. Figure 5 shows the effect of the variable work hour programs on work starting times. The peak hour arrivals and peak 15 minute arrivals were cut in half. For the employees on flexible work hours, 40 percent chose to commence work before 8:00, whereas only 9 percent arrived after 9:00 -- an indication of a preference for earlier working hours.

Similar results were obtained in Ottawa, Ontario where half of the central area workers (35,000 employees) participated in a variable work hours program. All of the participants were federal government employees. Figure 6 shows a 50 percent reduction in the peak 15 minute period arrivals for government employees using transit. The AM peak hour to peak period ratios of work place arrivals for employees using transit and for vehicles entering and leaving parking lots were reduced 16.9 percent and 13.5 percent respectively (Safavian and Mclean (1975)).

Figure 4. Arrival Time and Number of Persons Entering the Port Authority Building Lobby.
Source: Port Authority of New York and New Jersey (1977), p. 321.

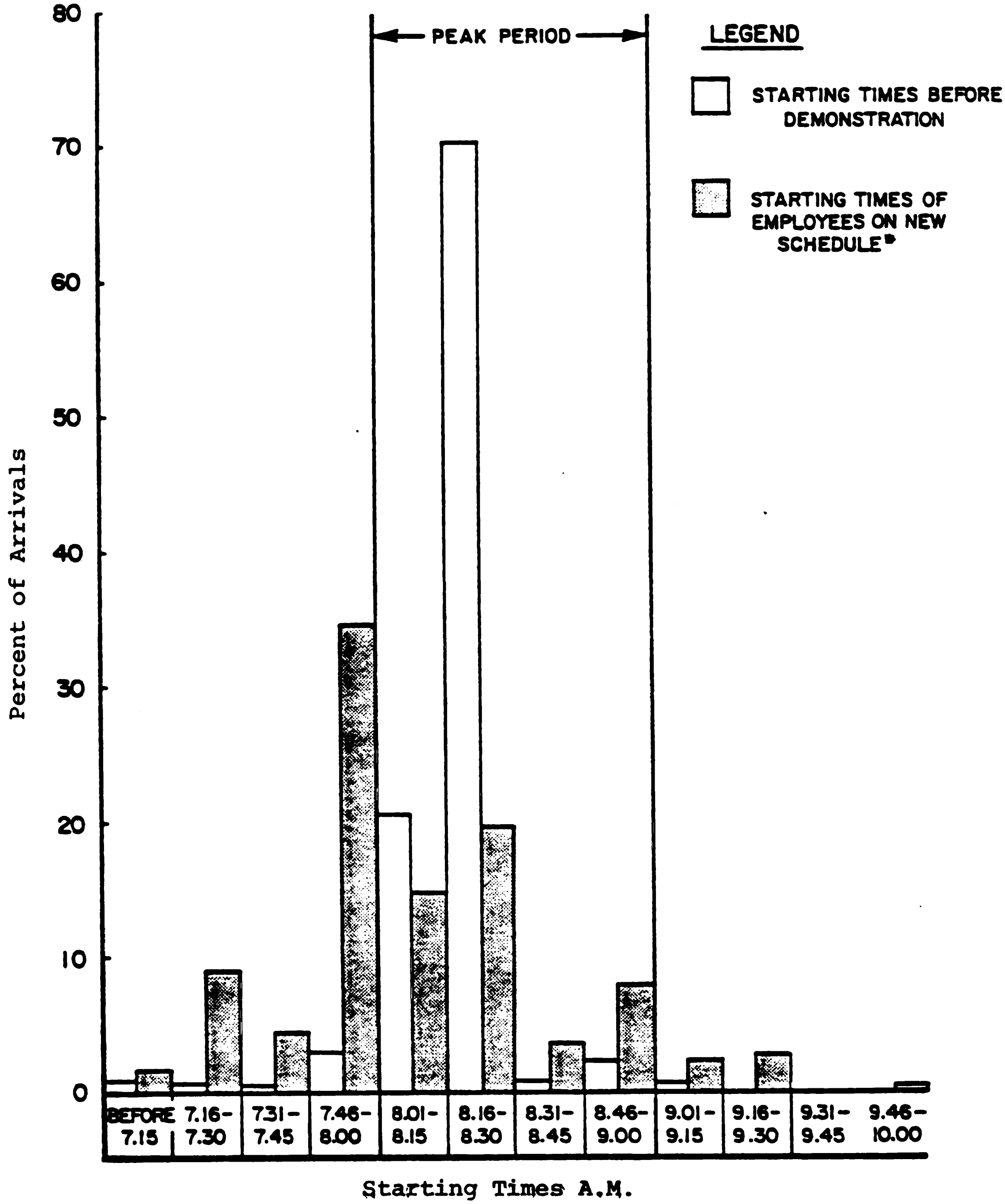


Figure 5. Starting Times of All Government Employees in Queen's Park Prior to October 29, 1973 Compared to the Starting Times of Employees on New Work Schedules.

Source: Greenberg and Wright (1975), p. 13.

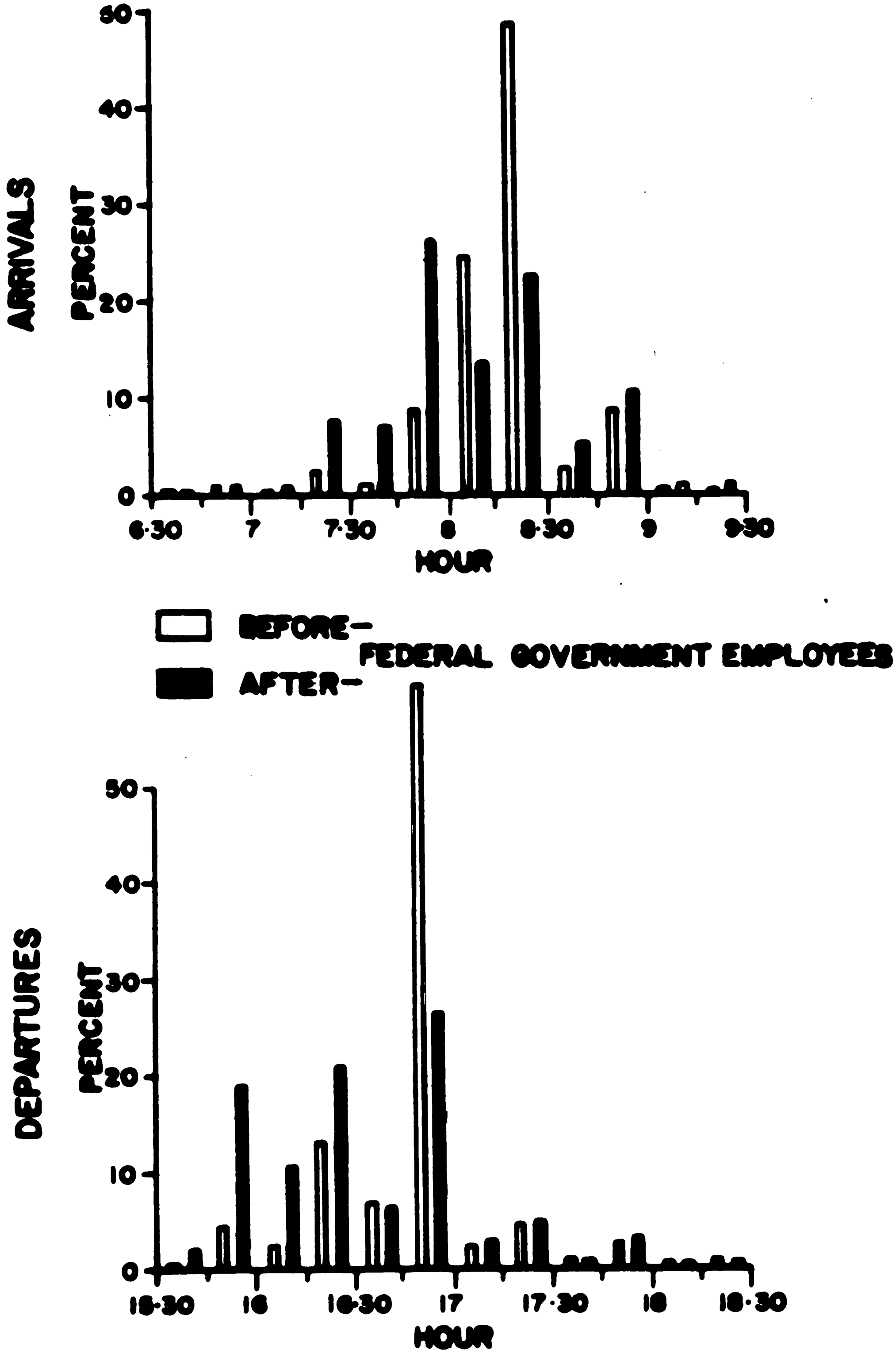


Figure 6. Changes in Work Arrivals and Departures for Bus Passengers.
Source: Safavian and Mclean (1975), p. 22.

2.3.2 Impacts on Peak Period Transit Demand

The lower Manhattan variable work hour program resulted in a combined 26 percent reduction in the peak 15 minute passenger volume at three of the busiest subway stations. During the 8:30 to 8:45 period, just prior to the peak period, passenger volume increased 24 percent at the same three stations (O'Mally and Selinger (1973)). This compares with a 29 percent reduction in the peak for workers arriving at the Port Authority Building lobby as shown earlier. Figure 7 shows the shifts in passenger volume at these three major stations after the implementation of the program.

In the Ottawa demonstration, the peak hour transit passenger volumes were reduced 8.4 percent and 19.2 percent as a percentage of the AM and PM peak periods respectively. Transit passengers in the peak 15 minutes were reduced by 21 percent in the morning and 29 percent in the afternoon (Safavian and Mclean (1975)).

For the Toronto program (Greenberg and Wright (1975)), data were not collected to show the impact of the variable work hour program on total subway ridership. However, as shown in Figure 8, the peak distribution of government employees riding in the Yonge street subway line was shifted significantly following the beginning of the program in the Queen's Park government center. The peak 15 minute government employee volume was cut in half and the peak was shifted to an earlier time period which may have resulted in some flattening of the overall demand distribution on the subway line.

2.3.3 Impacts on Peak Period Automobile Demand

One of the most detailed studies of the impacts of a variable work hours program on traffic volumes was performed on the Ottawa demonstration

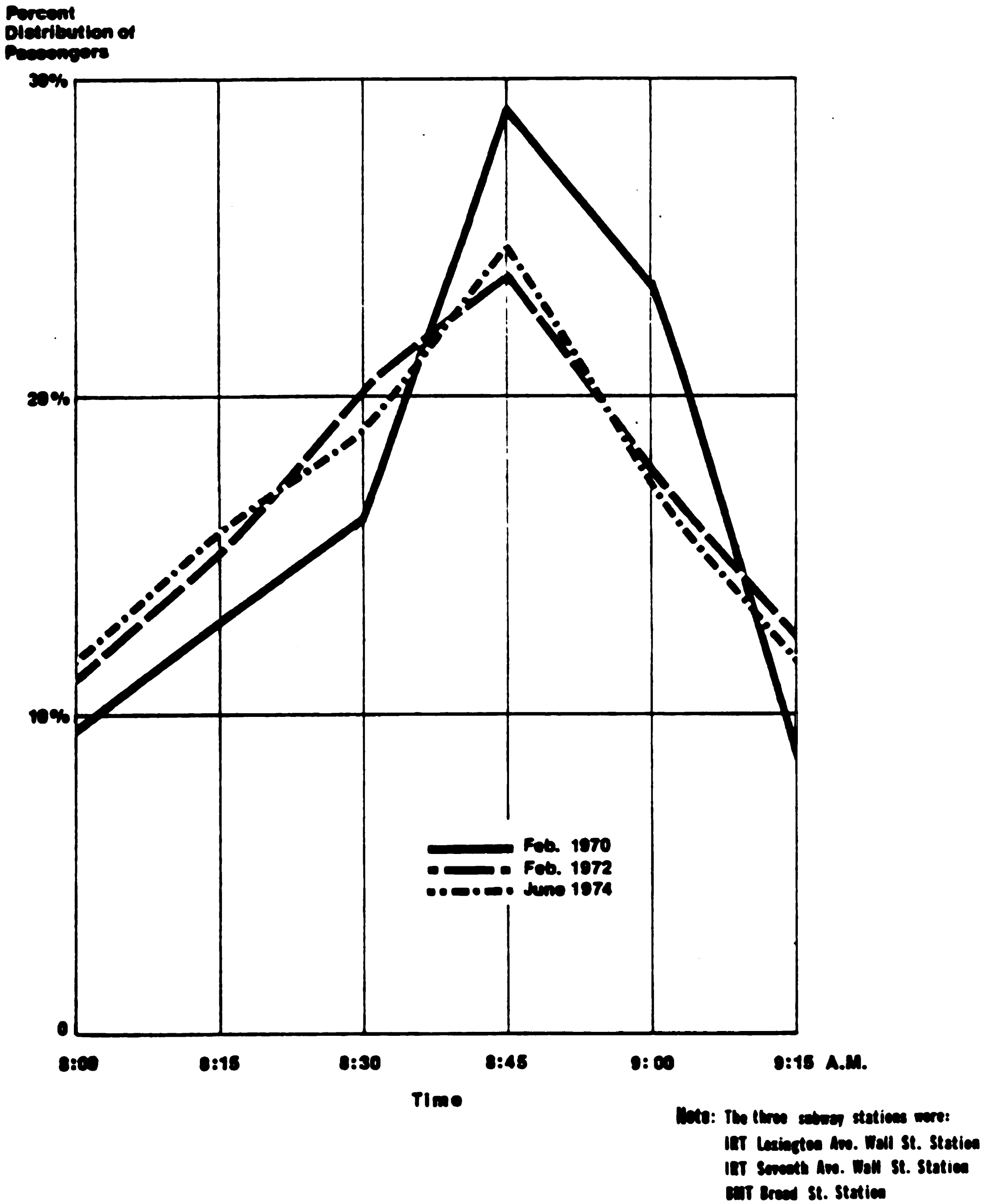


Figure 7. Staggered Work Hours -- Passenger Counts at Three Major Downtown Stations.
Source: Port Authority of New York and New Jersey (1977), p. 298.

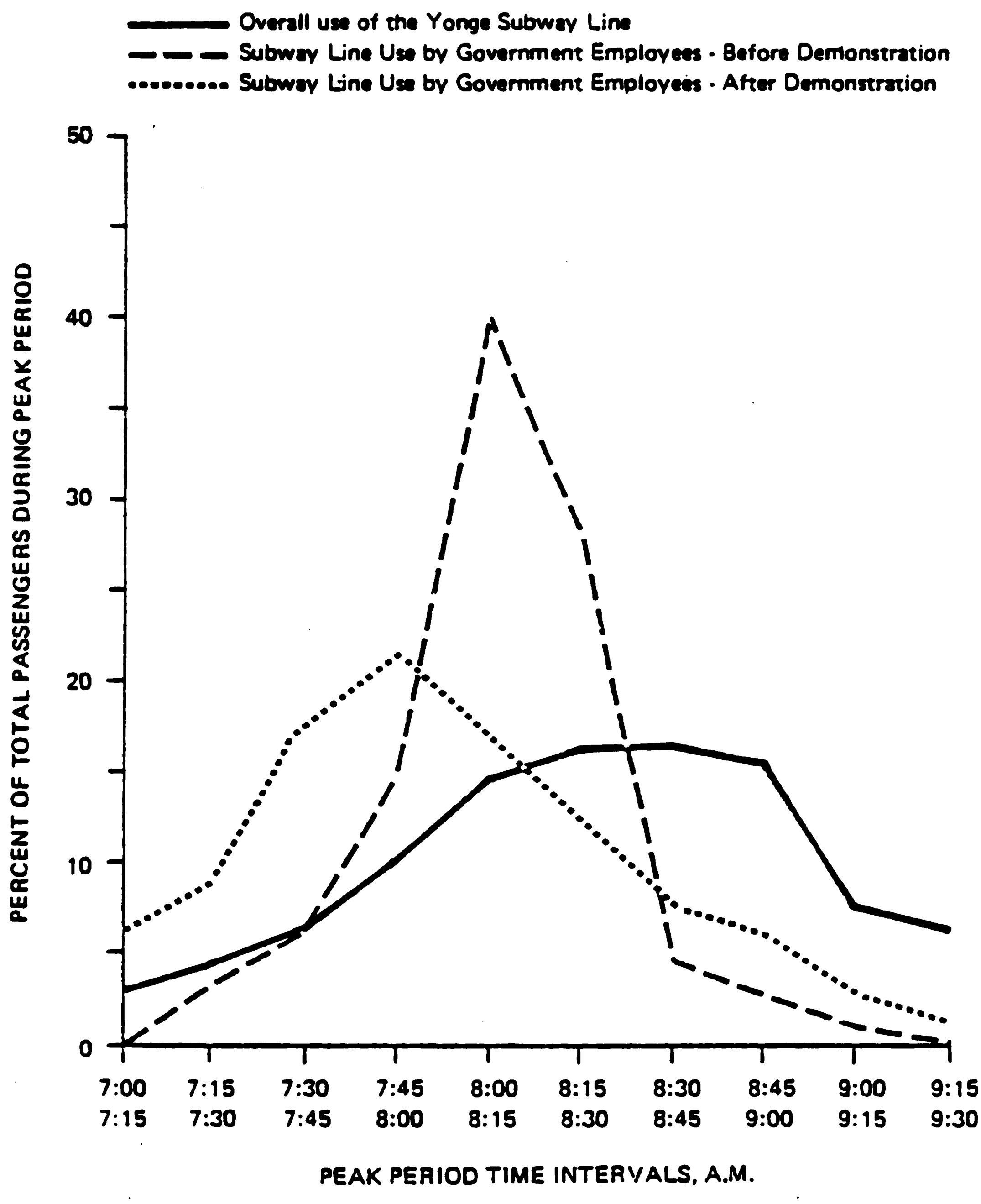


Figure 8. Variations in Subway Ridership on the Yonge St. Subway Line in the A.M.
Source: Greenberg and Wright (1975), p. 2.

(Safavian and Mclean (1975)). This study is particularly interesting in that 50 percent of the total central area work force participated.

In this study, peak period traffic counts were made at a screenline (Screenline B) which encompassed the majority of the Ottawa central business district (CBD), and at six CBD parking facilities. Figure 9 depicts the temporal distribution of automobile volumes crossing Screenline B entering the CBD area in the morning and departing from the area in the evening before and after the beginning of the variable work hour program. Figure 6 reveals that there was a slight decrease in the AM peak 15 minute volume and the peak period was shifted 15 minutes earlier than before. The total AM volume increased by 10 percent between the before and after periods, hence the complete impact of the program may have been surpressed.

The change in PM traffic distribution was more defined. The distribution became more uniform and the peak 15 minute period was shifted 60 minutes earlier. The PM peak 15 minute volume decreased 17 percent, even though the three hour total volume increased by six percent.

The traffic count data taken from the six CBD area parking facilities showed a change similar to, yet more distinct than, that exhibited at Screenline B. The AM and PM distributions of arrivals and departures are shown in Figure 10. Stated as a percent of the peak period totals, the program resulted in a 13.5 percent and 21.6 percent decrease in the AM and PM peak hour arrivals and departures respectively. The peak 15 minute periods in the AM and PM realized a 13 percent and 30 percent decrease respectively. These decreases are greater than measured at the screenline because these traffic counts contain a higher percentage of work trips involved in the program.

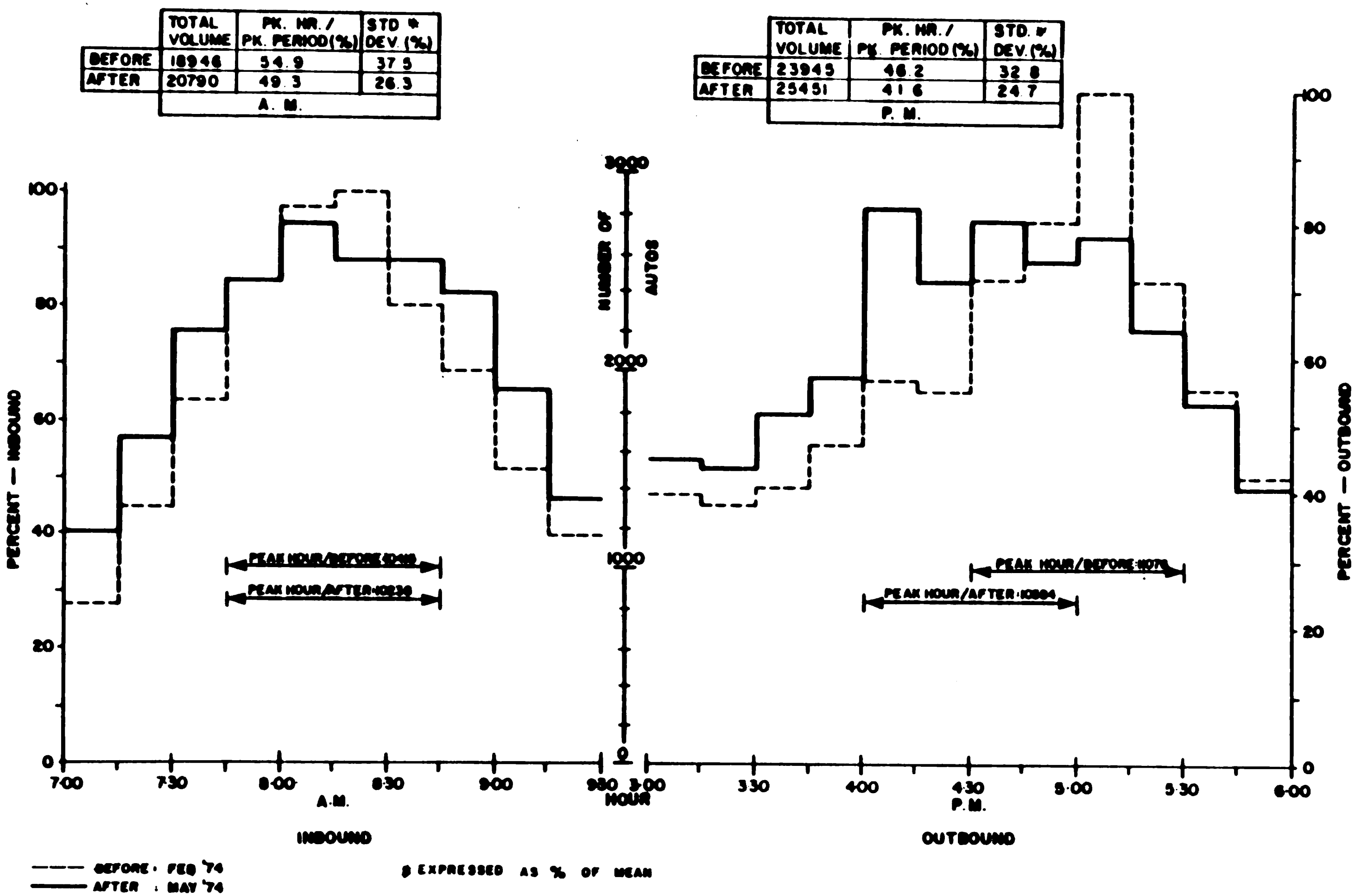


Figure 9. Automobile Volumes at Screenline B in Ottawa CBD.
Source: Safavian and Mclean (1975), p. 21.

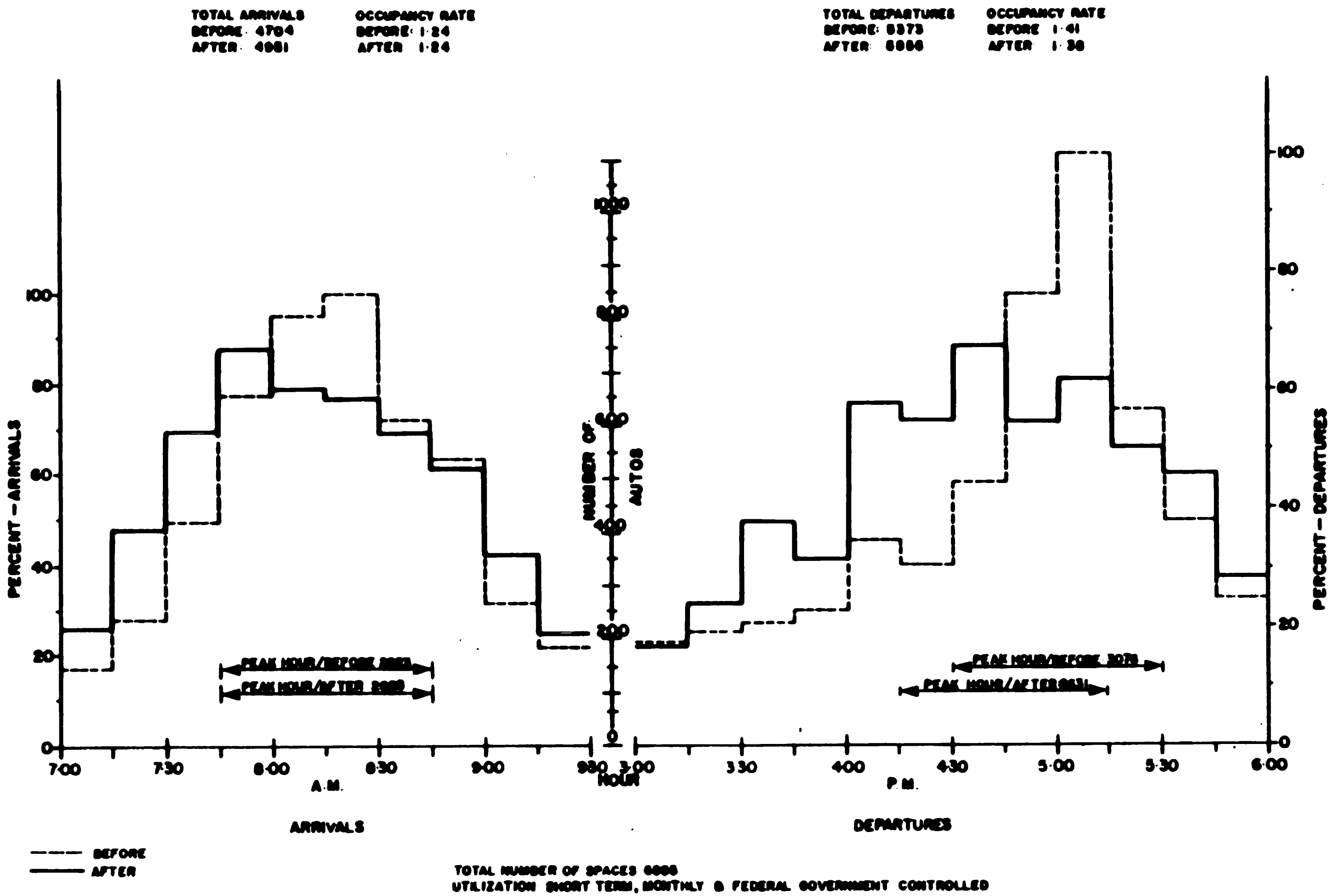


Figure 10. Automobile Volumes at Six Ottawa CBD Parking Facilities.
Source: Safavian and Mclean (1975), p. 21.

A staggered work hour program at the 3-M company headquarters in St. Paul, Minnesota was evaluated as being highly successful in reducing peak period traffic volumes at the company industrial complex (Owens and Van Wormer (1973)). Expressed as a percent of the average daily traffic (ADT), the AM peak 15 minute traffic volume entering the complex was reduced 34 percent, and the AM peak hour volume dropped 25 percent after the program was introduced. During the PM peak period, the 15 minute peak period and peak hour volumes decreased 20 percent and 13 percent respectively, when expressed as a percentage of the ADT. The effect was significantly diluted on the highways in the surrounding area. For example, the AM peak 15 minute period and peak hour traffic volumes were reduced nearly 2 percent and 7 percent respectively when expressed as a percentage of the ADT on major highways adjacent to the 3-M complex.

The implementation of staggered work hour programs has not always been successful. Notably, a staggered work hours plan was adopted by 145 firms throughout the London, England central business district. Only 2 percent of the district work force participated in the program as a result of opposition from business due to anticipated losses in business efficiency. This, coupled with dispersed geographical locations of the participating firms, resulted in a negligible impact on traffic or transit congestion (Dupree and Pratt (1973)).

The experience in Atlanta, Georgia (Dupree and Pratt (1973)) demonstrated the potential problems inherent in the planning and implementation of a staggered work hours plan. Even though the Atlanta Chamber of Commerce obtained furing for planning and implementing a staggered work hours plan in 1968, no plan has been implemented to date due to strong opposition from business management and employees. Also, failure on the part of the proper authorities to affect transit schedule changes prompted many low-income employees to resist changes in their work schedules.

Traveler response to flexible work hour programs is more difficult to analyze because the timing of work trips is more at the discretion of the employee. The literature review revealed little concrete information concerning the real impact of flexible work hours on actual work trip travel behavior.

However, one study did reach several relevant conclusions concerning the impact of flexible work hours on commuting behavior. The California Department of Water Resources (DWR) introduced a flexible work hour program in 1974. Based on the responses to a survey of 576 DWR employees, Jones et. al. (1977) concluded that flex-time is predominantly used to improve the match between personal schedules, travel schedules, and work schedules, rather than as an opportunity to change travel mode. However, the responses indicated that flex-time increases the opportunity for trial use of buses and carpools, and the direction of experimentation was "positive" in terms of the frequency of ride-sharing. It appeared that flex-time allowed transit riders and potential riders to match work and bus schedules more closely, absorb a greater degree of unreliability in bus service without suffering the penalty of being late to work, and schedule bus commuting so as to avoid the crush loads and seatless rides of the peak period. The authors also concluded that while flex-time did not appear to be a powerful incentive for carpooling, its marginal effect did seem to be positive due to an increase in husband-and-wife carpools.

Flex-time seems to have improved the quality of the commute trip experienced by many DWR employees regardless of mode. Sixty percent of the respondents reported a favorable impact and 43 percent reported "a major positive impact" in their ability to avoid peak period congestion.

2.3.4 Summary of Impacts on the Temporal Distribution of Transit and Automobile Traffic

Change in work schedules result in corresponding changes in the peak period travel demand. The changes in the temporal distribution of travel demand appear to vary in magnitude depending on the percent of the work force involved in the variable work hour program, and the proximity of the transportation facilities to the participating employment centers, although neither relationship has been developed quantitatively. The flattening of the distribution of peak period arrivals and departures tends to become less as the distance from the participating employment centers increases. This effect appears due to the increase of "non-participants" in the travel demand patterns with increased distance from participating employment centers.

It has been shown experimentally that the percent change in the observed magnitude of the peak period automobile and transit demand resulting from a staggered work hour program will not exceed the percent change in work trip arrivals or departures (Safavian and Mclean (1975)).

2.4 Previous Studies on the Simulation of Staggered Work Hour Programs

There have been only a few studies which attempt to determine the impact of staggered work hour programs through simulation of the redistribution of work trips during the peak period. None of these studies attempted to translate the results into reduction in fuel consumption.

Betz and Supersad (1965) studied the impact of staggered work hours on highway congestion in the central business district (CBD) of a hypothetical city. Only the PM (work-to-home) peak period was considered as the authors suggest that the evening movement is the more critical of the two daily traffic peaks.

Their method of analysis consisted of an all-or-nothing assignment in five-minute time intervals, the identification of problem intersections (volume/capacity (v/c) ratio greater than 1) and the determination of a possible staggered work hour schedule to eliminate problem intersections. First, the intersection with the highest v/c ratio was selected, and the largest employment center contributing traffic to this approach was identified. Then the finishing time of this employment center was adjusted within a feasible range to lower the intersection v/c ratios along the paths of the origin-destination pairs for the given employment center. This process was continued for each employment center until all intersection approaches had a v/c ratio less than 1.

The base case assumed all employment centers finished work at the same time. The analysis attempted to determine the total amount of stagger necessary (in five-minute periods) to reduce congestion at intersection approaches.

The traffic assignment in the research by Betz and Supersad did not include capacity restraints. The authors define the "net capacity" of an approach to be the residual from practical capacity after accounting for the non-work peak hour trips, and those trips from small employment locations where quitting times could not be staggered. The "net capacity" was used to calculate the v/c ratio.

The results indicated that variations in land use and highway network patterns directly affect the efficiency of a staggering system. The dispersed land use pattern showed significantly more intersections with a v/c ratio greater than one when compared to the concentrated land use pattern tested. However, the dispersed pattern showed a lower average v/c ratio. Each pattern required a stagger of seven periods (35 minutes) to relieve congestion for the no-freeway case. The addition of freeways increased the required stagger to 14 and 13 periods for the dispersed and concentrated patterns respectively. The introduction of freeways tended to increase the problem at those intersections which were already critical, and increased the number and intensity of critical intersections for both land use patterns. It appears that a limiting factor in the efficiency of staggering to relieve urban highway congestion is the operation of expressway ramps and intersections.

A study by Santerre (1966) examined the feasibility of implementing a staggered work hour program in Houston, Texas and evaluated the potential reduction in freeway traffic as a result of various levels of participation. Santerre surveyed various employment centers to determine the number of employee vehicles using freeway exit ramps near their destination. The employee arrival time was also sampled. Using only two employment centers, it was estimated that by removing all of their arrivals from the peak hour (7:00 AM to 8:00 AM), the average volume measured during ten-minute intervals on the freeway near these locations would be reduced 9.5 percent for the inbound lanes. Santerre concluded that the magnitude of change required to achieve an optimum staggered work hours plan to alleviate morning peak period traffic congestion was not excessive.

Tannir (1977) attempted to simulate the effects of a staggered work hour/four day work week program on the operational efficiency of a highway network serving a high-density employment area in a medium-sized city. In this study only a very small portion (0.2 percent) of the total vehicle trips using the highway network are included in the simulated staggered work hour program. These trips all had the same work destination. The results indicated the influence of the staggered work hour program was confined to within a two-mile radius of the destination.

Given the small number of trips involved in the staggered work hour simulation and several shortcomings in the technique used, the conclusion by Tannir that the staggered work hour program realized only marginal benefits is less than definitive.

2.5 Justification for the Research

The intent of variable work hour programs, from the urban transportation point of view, is to reduce the vehicular traffic congestion and the transit passenger peaking that occurs during the average work day. The objective of lowering and spreading the peak period demand over a longer time period is to increase the efficiency of existing transportation facilities.

It is apparent from the literature review that variable work hour programs can be a successful alternative for reducing the congestion of peak period travel. However, the degree to which the reduction in congestion can be translated into a savings of transportation fuel is unknown. There are also some contradictory statements made about the potential capabilities of combining variable work hours with improvements in transit service to further enhance the overall level of effectiveness of the TSM strategies.

The level of effectiveness of variable work hours appears to be dependent on several factors, including:

1. The level of participation in the work force;
2. the relative location of the employment centers participating;
3. the degree of coordination of transit scheduling with the work hours programs; and
4. the highway network configuration.

The relationship between these factors and the potential for energy conservation is unknown. If variable work hour programs are to be given serious consideration as a potential means of reducing fuel consumption for the urban work trip, these relationships must be investigated. This research concentrated heavily on factors one through three listed above. The investigation of factor four was not a part of this research effort.

CHAPTER III

The Modeling System

3.1 The Model Requirements

Since the objectives of this research did not include the development of a modeling system, it was necessary to identify and utilize a modeling system which was capable of accurately simulating the travel impact of the transportation system management (TSM) policies tested and of estimating the energy requirements of the resultant travel patterns. The minimum requirements of the modeling system are shown in Figure 11.

The broken flow lines in Figure 11 represent the feedback mechanism necessary to evaluate the impacts of traffic congestion on mode choice, network assignment, and energy consumption. The capability to evaluate the impacts of congestion or reductions in congestion is the heart of the modeling system. It was assumed that the overall work travel demand patterns were fixed and were unaffected by fluctuations in the cost or time required for travel.

The research required a modeling system that included a mode choice model that incorporated the elements of travel time or cost, such as in-vehicle travel time, walk time, and, for transit passengers, waiting time. It was necessary, especially for automobile travel, that in-vehicle travel time be related to highway congestion. In this way the impact on mode choice of increases or decreases in congestion could be shown.

It was also necessary that the model be capable of relating changes in mode choice to changes in the frequency of transit service. In this way the effects of frequency changes could be tested along with the variable work hour programs. It was anticipated that the simulation

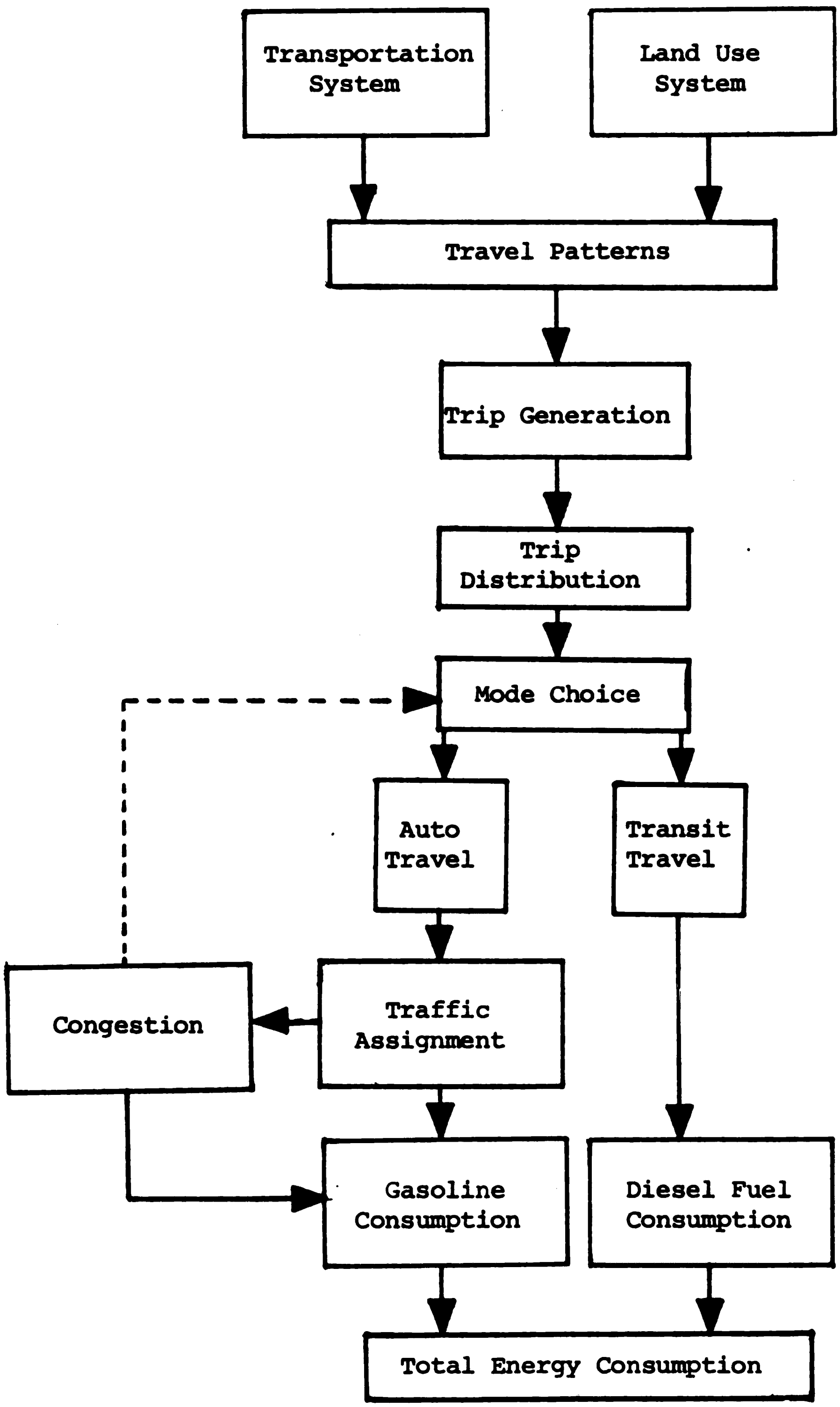


Figure 11. Basic Requirements of Modeling System.

of variable work hour programs and coordinated variations in bus scheduling would result in lower fuel consumption.

This research also required a model in which the energy consumption for automobile and transit travel were computed separately. This permitted the evaluation of policies affecting both modes, and allowed for the simulation of coordinated transit policies and variable work hour programs.

The last major requirement of the modeling system was the capability to simulate the variable work hour programs. That is, the model had to be capable of simulating work travel over several distinct time elements so that the impact of a change in the proportion of travelers during each time element could be tested.

The MOD3 modeling techniques used by Peskin and Schofer (1977) satisfied most of the requirements of this research, and fit within the limitations of the available computer system. The program utilizes an aggregation of generally accepted techniques for transportation and land use planning, and was deemed acceptable for use in this research.

3.2 The MOD3 Model

MOD3 is based on the modeling structure developed by Edwards (1975) and later extended and modified by Bowman et. al. (1975), and by Peskin and Schofer (1977). Only those portions of MOD3 that are considered relevant to this research effort are discussed. More detail can be obtained by referring to earlier research reports cited above.

MOD3 is a large-scale computer model which simulates the spatial development of an urban area, forecasts the passenger travel that takes place during a single day, and computes the energy consumption resulting from that travel. A flow diagram for MOD3 is shown in Figure 12. In effect, the model combines the elements of land use distributions, mode choice, and network assignment with an energy consumption module for

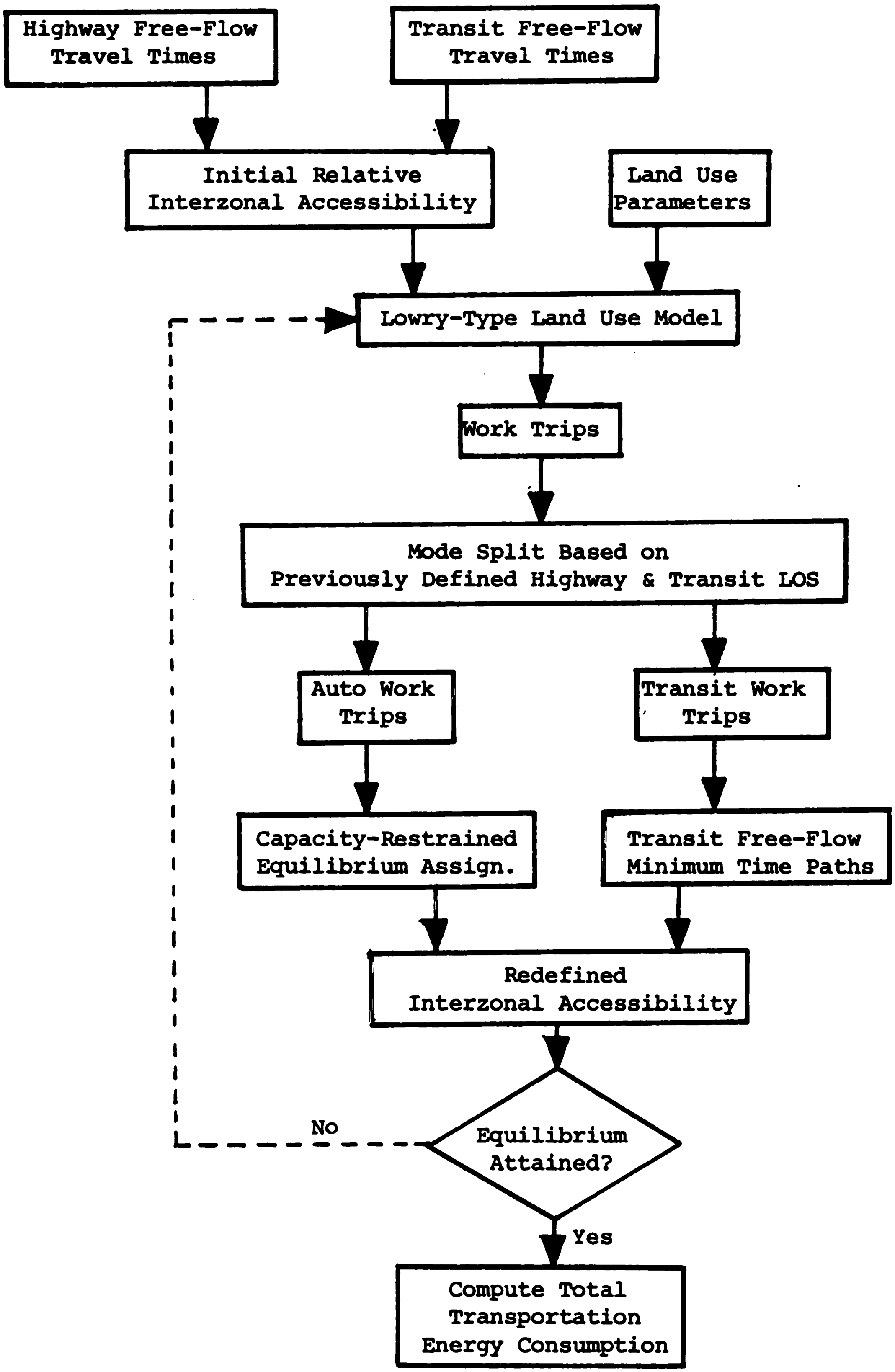


Figure 12. Operation of MOD3.
Source: Peskin and Schofer (1977), p. 16.

work trips. The model can also be used to predict energy consumption for non-work trips, but these trips are not part of this research study.

The land use portion of this model interacts with the travel portion in three distinct stages to sequentially develop incremental "layers" of land use. The first stage, the base run mode, is the description of the base or existing land use patterns. This description is accomplished by exogenously defining the basic employment statistics at the zonal level and the highway and transit network configuration. MOD3 uses a land use model to establish the population and service employment distribution pattern, and then proceeds to develop the initial stage travel patterns and energy consumption. In this stage, changing the values of the input parameters representing travel time or cost, or altering the highway or transit network configuration will impact the resulting population, service employment and travel distribution for a fixed zonal level of basic employment and a fixed set of land use parameters.

The second stage, the incremental run mode, involves the generation of an incremental layer of growth representing the distribution of additional population and employment for some future date. At this stage, a change in the values of the transportation variables impacts the distribution of population, employment, and travel of only the additional growth layer. The distribution of those elements generated in the base stage remain fixed. However, the mode choice and network assignment is affected by changes in the values of the transport parameters at the incremental level. The final stage represents the future state of the urban area, and is defined by the combination of the base and incremental layers.

As originally developed, the policy testing capabilities of MOD3 are at the incremental level. That is, changes in policy are made at the additional growth level to test the impacts on the future development of the urban area. The relationship between the base and incremental stage of MOD3 is shown in Figure 13. Each stage is defined in a separate computer run, with the combination of the base and incremental stage made during the incremental run to produce the future state.

3.2.1 MOD3 Program Availability and Computer Requirements

The Fortran version of MOD3 used in this research and sample data sets were obtained on magnetic tape from the Department of Civil Engineering at Northwestern University in Evanston, Illinois. A printed listing of the program and complete documentation is available in the Doctoral Dissertation by Peskin (1977).

MOD3 is a rather large computer program having approximately 3,500 lines of Fortran coding. A typical data set for an incremental run is approximately 1,130 lines in length. Peskin (1977) indicates that the execution time of MOD3 for a typical incremental run was under 65 seconds on an IBM 370/195 computer, with central processor storage requirements under 61,000 decimal words. For this research, MOD3 required approximately 170,000 octal words of centeral processor storage on a CDC Cyber 750 computer, with an execution time under 45 seconds.

As a result of the large size of the program and data sets, data manipulation and program execution were performed using a remote terminal. A compiled version of the program and the data sets were stored on magnetic disks. Printed output was received through a high speed line printer.

3.2.2 The Land Use Model

In MOD3, the allocation of land use, population, and service-type employment is based on a Lowry-type (Lowry (1964)) land use model, which

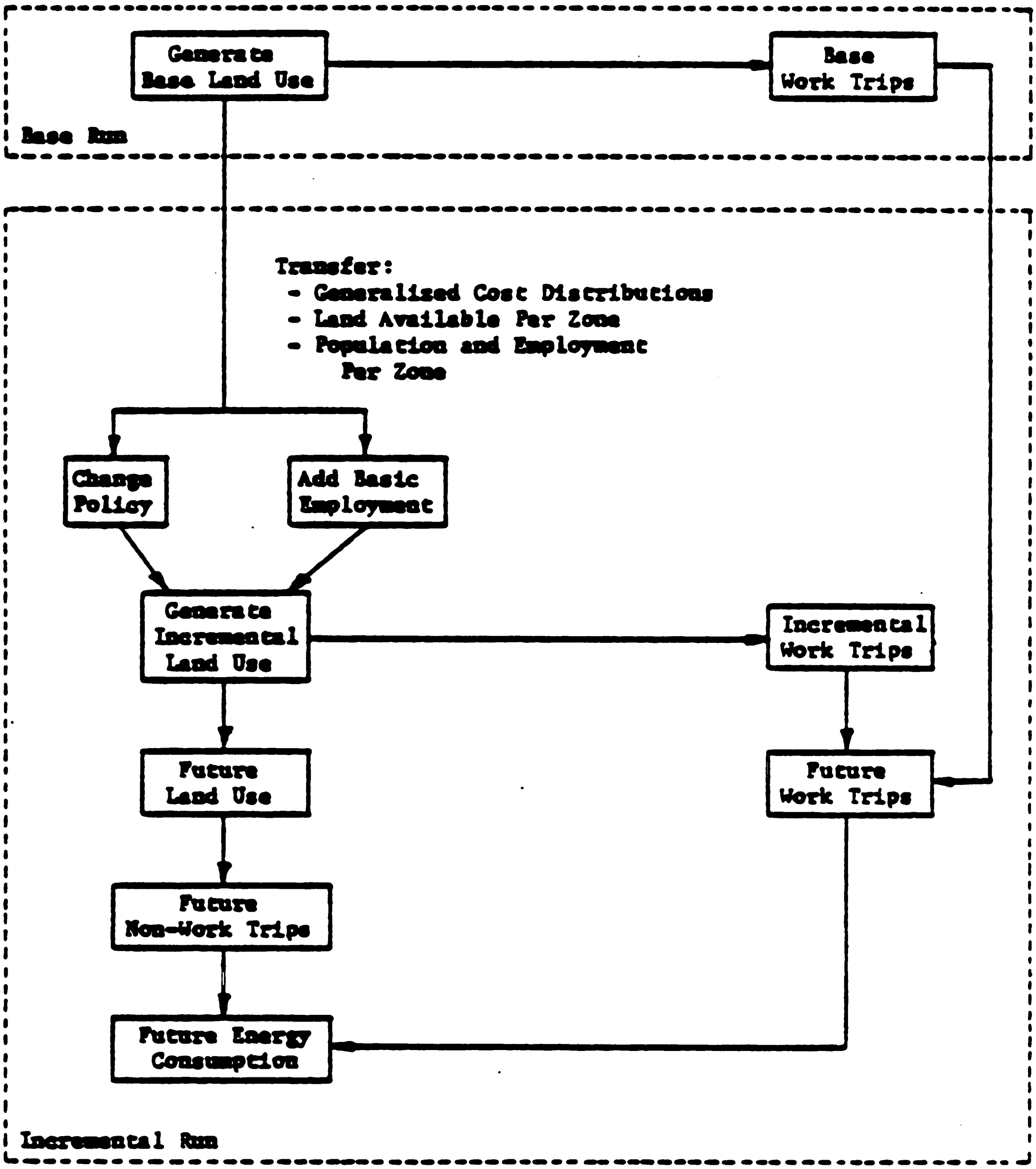


Figure 13. Relationship Between the Base and Incremental Stage of MOD3.
Source: Peskin and Schofer (1977), p. 50.

was developed and calibrated in conjunction with the Pittsburgh Regional Economic Study using data assembled in the Pittsburgh Area Transportation Study. With an exogenously specified set of constraints on available land, acceptable residential densities, and minimum sizes of employment, the Lowry-model allocates the spatial distribution of urban activities.

Figure 14 shows the basic structure of the Lowry-type model and depicts the iterative nature of the activity allocation process. The process initially apportions the exogenously specified zonal basic employment to residences based on the relative accessibility of each zone to all other zones. Basic employment is defined as employment in those industries whose products or services depend on markets external to the region under study. Typical of industries that might be considered as basic are manufacturing, national financial institutions, and university employment.

The population of each zone is then established by factoring in the labor force participation rate. The level of service employment in each zone is a function of the population of the zone and the relative accessibility. The service employment is allocated to residences and the associated population is again calculated. The resultant increase in population requires more services, and the iteration process continues until the incremental population and service employment approach zero.

The relative accessibility from zone i to zone j for trip type k is used to allocate population and service employment, and is defined by a gravity model of the form:

$$A_{ij}^{k} = \frac{U_j \, G_j^k \, f_{ij}^{\;k}}{\sum_j U_j \, G_j^k \, f_{ij}^{\;k}} \; r^k \tag{1}$$

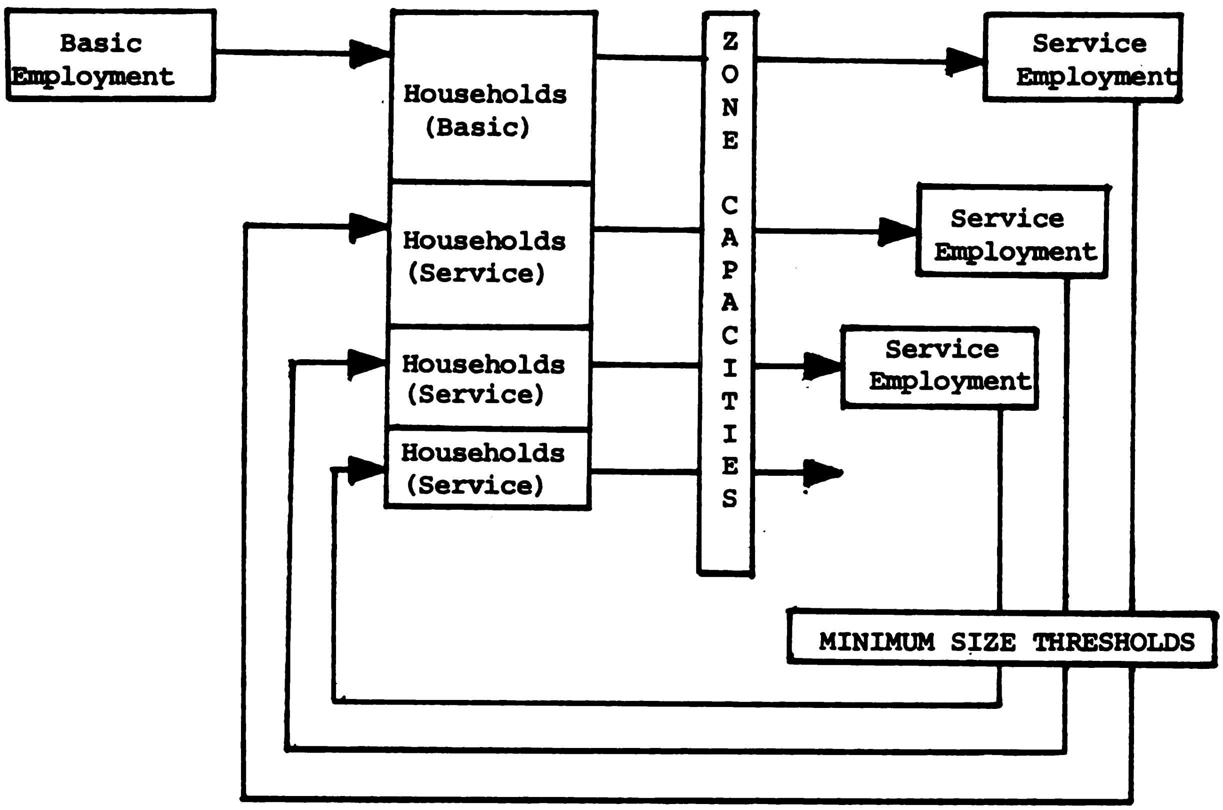


Figure 14. Causal Structure of Lowry-Type Land Use Model.
Source: Goldner (1971), p. 101.

where

A_{ij}^{k} = the relative accessibility from zone i to zone j for trip type k,

U_j = a balance factor in the iterative structure of the Batty (1972) version of the Lowry model, used to prevent over-allocation of workers to residences in zone j,

G_j^k = the exogenously specified utility or location attraction of zone j for receiving population (for work trips) or service workers (for service trips),

f_{ij}^{k} = the interzonal friction factor, a relative measure of the impedance to travel from zone i to zone j for trip type k, a function of the travel time and the dollar cost of travel (including gasoline costs for automobile trips), and

r^k = the trip generation rate per household for trip type k, assumed equal to 1.0 for work trips and exogenously specified for service trips.

The denominator in equation 1 is the cummulative interzonal accessability from zone i to all other zones. Therefore, a_{ij} can be interpreted as the probability of travel between zones i and j from work to home or from home to a service site.

The trip interchanges are based on the attractiveness of each zone relative to all other zones in terms of the allocated zonal activities and are computed using a gravity model with all friction factors equal to 1.0, based on the work by Voorhees (1968) for work, social-recreational, and nonhome-based trips. The relationship has the form:

$$T_{ij}^{k} = \frac{P_i \; A_j}{\sum_j A_j} \qquad (2)$$

where

T_{ij}^{k} = the trips from zone i to zone j for trip category k,

P_i = total population in zone i, and

$$A_j = \begin{cases} \text{for work trips: total employment in zone j.} \\ \text{for service trips: service employees in zone j.} \end{cases}$$

This computation only represents half of the total trips. That is, either the work-to-home portion or the home-to-service site portion of the trip is simulated. The model multiplies the computer trip interchange by a factor of two to estimate the total daily travel.

The interzonal impedance factor, f_{ij}, in equation 1 is an integral element in the relationship between transportation and land use. An interative computation of land use is used by MOD3. The highway network congestion depends on the arrangement of land uses which are distributed based on relative accessibility. The essence of the transportation/land use feedback is shown in Figure 15.

The generalized cost of travel is defined by a composite of the dollar cost of travel and the dollar value of travel time. The linear function used to compute the generalized cost of travel is defined by:

$$GC_{ij} = t_{ij} + \frac{C_{ij}}{V} \tag{3}$$

where

GC_{ij} = the generalized cost of travel from zone i to zone j,
t_{ij} = travel time between zone i and j in minutes,
C_{ij} = dollar cost of travel between zones i and j, and
V = value of travel time in dollars per minute.

The generalized cost of travel is used to compute friction factor values and to define the minimum cost paths on the highway network.

3.2.3 Mode Split

The MOD3 program uses a binary logit mode split mode of the form:

$$P_{ij} = \frac{e^G}{1 + e^G} \tag{4}$$

where

P_{ij} = the probability of a trip from zone i to zone j by automobile, and

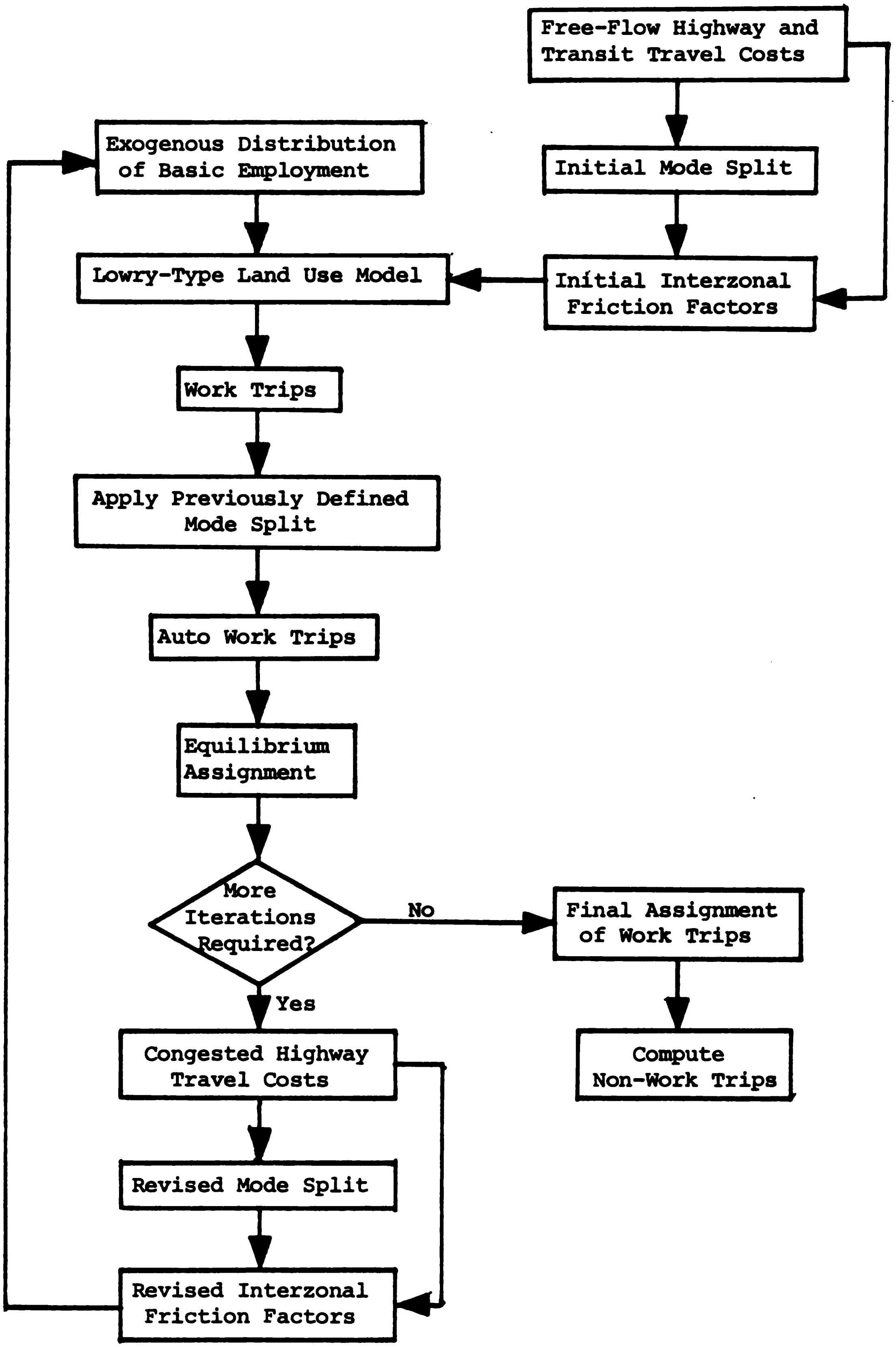


Figure 15. Details of MOD3 Transportation/Land Use Feedback.
Source: Peskin and Schofer (1977), p. 41.

e = the base of the nautral logrithm.

The exponent G has the form:

$$G = q + r(W_A - W_T) + s(T_A - T_T) + t(C_A - C_T) + u(\text{Own}) \qquad (5)$$

where

q, r, s, t, u = coefficients from model calibration for each trip type,

W_A, W_T = automobile and transit walk times,

T_A = automobile in-vehicle travel time, including parking,

T_T = transit in-vehicle travel time, including waiting time,

C_A = automobile out-of-pocket costs (gasoline and parking),

C_T = transit out-of-pocket costs (fare and transfer fees),

Own = average automobile ownership per household.

Talvitie (1972) indicated that the logit formulation yields results comparable to other forms of probabilstic modal choice models. Stopher and Lavender (1972) concluded that the logit formulation was preferrable to other forms of probabilistic mode choice models because the model is less time-consuming to calibrate and less cumbersome to use.

The model formulation was ideal for this research because it individually incorporated several aspects of travel time and cost which relate to mode choice. With this formulation the mode choice was sensitive to both out-of-pocket costs and to the indirect costs of transportation such as congestion and passenger wait time.

The values of q, r, s, t and u included in the MOD3 package and used in this research are those from a study by Charles River Associates (1972) for Pittsburgh, Pennsylvania. These values were used in this research primarily because they represent the required coefficients calibrated to this model structure for a single metropolitan area. It was decided that this consistancy was more important to the modeling process than selecting coefficients from several different studies of smaller urban areas. The values for the calibration coefficients are shown in Table 5.

Table 5. Calibration Coefficients for the Mode Split Model

Trip Type	g	r	s	t	u
Work Trips	-4.8	0.11	-0.04	-2.2	3.8

Source: Peskin (1977).

Included in the transit in-vehicle travel time is a factor representing the average passenger waiting time. This factor is a function of the frequency of transit service and is expressed as:

$$\text{Wait} = \begin{cases} 0.5(60/\text{FREQUENCY}), & \text{Frequency} < 4 \text{ vehicles/hr.} \\ 3.25 + 0.25(60/\text{FREQUENCY}), & \text{Frequency} > 4 \text{ vehicles/hr.} \end{cases} \quad (6)$$

This represents the wait time distribution shown in Figure 16. It was through this wait time factor that the mode split was made sensitive to transit frequency.

3.2.4 Network Assignment

The assignment of automobile trips to the highway network is accomplished within MOD3 using a capcity-restrained equilibrium assignment algorithm first developed by LeBlanc (1973) and applied by Bowman, et. al. (1975). The computation begins with an all or nothing assignment of automobile trips to the minimum time (or generalized cost) path between zones. These flows are adjusted by evaluating each link volume and the speed-volume curve to determine the combination of flows which yields the lowest value for the objective function of travel time or cost.

The equation used to describe the volume/travel time relationship is given by:

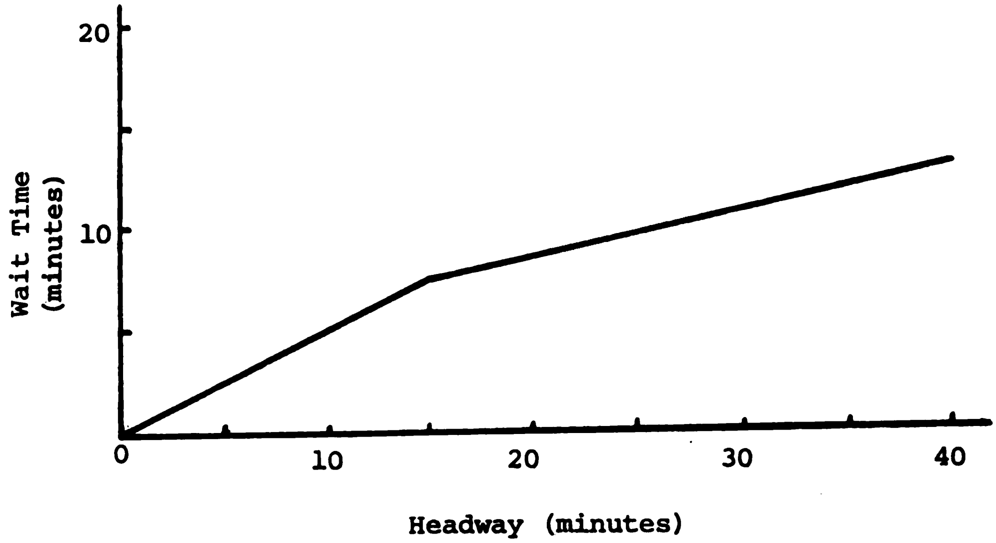


Figure 16. MOD3 Average Passenger Wait Time as a Function of Transit Vehicle Headway.

$$T_i = T_{oi} \ (1 + 0.15 \ (V_i/C_i)^4) \qquad (7)$$

where

T_i = actual link travel time,

T_{oi} = link free flow travel time,

V_i = assigned link volume, and

C_i = link free flow capacity (the volume at which congestion begins).

This relationship is the formula used by the Federal Highway Administration for capacity restrained network assignments (COMSIS Corporation (1973)). It is strictly convex increasing, which results in an increase in travel time for each additional unit of volume.

The objective function employed by this algorithm to evaluate the optimality of the automobile assignment has the form:

$$\min Z = \sum_i [(T_{oi})(V_i)+(0.2)(T_{oi})(B_i)(V_i^5)] \qquad (8)$$

where

T_{oi} and V_i are defined as before,

$B_i = 0.15/C_i^4$, and

C_i is also defined as before.

The first term in equation 8 represents the vehicle-minutes of travel on the network at the free flow link travel speeds. The second term represents a portion of the additional vehicle-minutes of network travel that result from the increase in congestion as vehicles are added to the network links.

Equation 8 is the integral of equation 7 with respect to link volume, and is evaluated at the assigned link volume, V_i. This algorithm represents a system-optimization technique, as opposed to an individual user-optimization, in the sense that the average travel time is minimized

(Wardrop (1952)). With an individual user-optimization algorithm, travel times on alternative routes between each pair of intersections are equal and are less than the travel time that any individual vehicle would experience by selecting any of the unused routes (Wardrop (1952)). Wardrop (1952) indicated that user-optimization is likely in practice since each driver will tend to select a route that will reduce his travel time to a minimum, while system-optimization is the most efficient in that it minimizes the total vehicle hours spent. This algorithm ignores the influence of intersections and transit vehicles on traffic congestion, and is only a static assignment technique in the sense that vehicles entering the network during different time elements do not interact. The length of the time segment being simulated must be exogenously specified in terms of the free flow capacity per unit of time for each link of the highway network.

For this research the assignment algorithm employed by MOD3 was used to identify the congested traffic links during the peak period. This information was used in turn to identify transit routes where the addition of transit vehicles would result in the greatest reduction in congestion.

Transit trips are not specifically assigned to transit routes by MOD3. All transit trips between zone pairs are assumed to travel on the transit minimum time path. Changes in demand on each route can be traced by examining zone pair mode split values, provided there is a unique transit connection between zone pairs.

The transit minimum time path algorithm used was developed by le Clerq (1972) and modified by Bowman et. al. (1975). The algorithm determines interzonal transit travel times by combining parallel route service and weighting the differing route times by their respective frequencies of service. The time spent waiting is based on the combined frequencies of the parallel route services. The resulting travel time includes in-vehicle time, wait time, transfer time, walking time in transfering between routes, and walking time between zones. Walk time to and from transit at the destination is not included.

The algorithm does not include the impacts of automobile congestion nor the time required for passengers to board and alight in determining the minimum transit paths. However, these were not considered to be major weakness for this research.

3.2.5 Non-Work Trips

MOD3 simulates the total travel for an urban area for an entire day. In doing so, MOD3 generates and distributes trips for four non-work trip categories including non-home based trips, social trips, and two types of service trips. Work trips are computed considering the effects of congestion on the highway network while non-work trips are not. Hence, only work trips are assigned to the network using the capacity restrained assignment technique.

The simulation of non-work trips was not an integral part of this research. Therefore, the reader is referred to the work by Peskin and Schofer (1977), for details on the formulation of these trip categories. However, the existence of non-work trips in the traffic stream is acknowledged through adjustements in the available highway capacity for work trips (see the discussion in Section 3.3).

3.2.6 Automobile Fuel Consumption

The computation of automobile fuel consumption in the MOD3 program is processed for each link of the network based on a specified speed/ fuel consumption relationship for both automobiles and transit vehicles.

The relationship for automobile gasoline consumption used by Peskin and Schofer (1977) was discarded because the fleet gasoline consumption rates had changed enough to warrant the re-evaluation of the relationship. A relationship that not only considered the effect of congestion on fuel consumption, but also reflected the current automobile fleet distribution was more desirable.

Using data collected by driving instrumented vehicles in urban traffic, Evans et. al. (1976) and Chang et. al. (1977), showed that the fuel consumed per unit distance could be expressed as a linear function of the trip time per unit distance. The relationship is expressed as:

$$\phi = k_1 + k_2 \bar{t} \; ; \; (\bar{v} < \approx 60 \text{ km/hr}) \tag{9}$$

or

$$1/E = k_1 + \frac{k_2}{\bar{v}} \; ; \; (\bar{v} < \approx 60 \text{ km/hr}) \tag{10}$$

where

ϕ = fuel consumped per unit distance,

E = fuel economy (km/1 or mi/gal),

$\bar{t}$ = average trip time per unit distance (T/D)
where D = trip distance
T = trip time,

$\bar{v}$ = average trip speed D/T, and

k_1 and k_2 are calibration constants.

Hence the total fuel consumed, F, for a trip of distance D in time T can be expressed as:

$$F = k_1 D + k_2 T \tag{11}$$

for T in seconds or minutes,

D in kilometer or miles, and

F in milliliters or gallons.

Chang et. al. (1976) calibrated equation 9 to data collected for a series of "microtrips" (travel between consecutive stops) for a single vehicle. This yielded k_1 and k_2 values of 112 ml/km (0.048 gal/mile) and 1.05 ml/s (0.0166 gal/min) respectively. With these values, equation 11 can be rewritting as:

$$\phi = 112 + 1.05\ \bar{t}\ (\bar{t} \text{ in seconds per km})$$

or (12)

$$\phi = 0.048 + 0.0166\ \bar{t}\ (\bar{t} \text{ in minutes per mile})$$

although the correlation coefficient value was not given, the graphical approximation of equation 11 to the actual data appears excellent (see Figure 17).

This relationship was used by Chang to predict the fuel consumption of 26 "mactotrips" (trips starting and ending at a specific location made up of a series of microtrips) ranging in length from 8 to 36 kilometers. The predicted fuel consumption differed from the observed by -6.3 to 9.3 percent, with a root mean square value of 3.8 percent. The mean error in the prediction was not reported.

Similar tests were run with vehicles of various weights and engine sizes, with calibration done to determine the values of k_1 and k_2 for each vehicle. Chang reports that the results appear to be independent of roadway type, traffic conditions, and the driver. For the vehicles tested, k_1 was found to be approximately proportional to vehicle mass in kilograms (k_1 = 0.0484(mass)), and k_2 was approximately proportional to the fuel idle flow rate in ml/s (k_2 = 1.21(idle flow rate)).

Atherton and Suhrbier (1979) used the results of field tests conducted by the Union Oil Company (West (1976)) to compute the coefficients k_1 and k_2 for the 1976 composite automobile in the United States. Union Oil tested 106 vehicles (all 1975 model year) of various sizes and weights. Fuel consumption under three types of driving cycles was measured:

- Urban cycle with 15.6 mph average speed and 4 stops per mile,

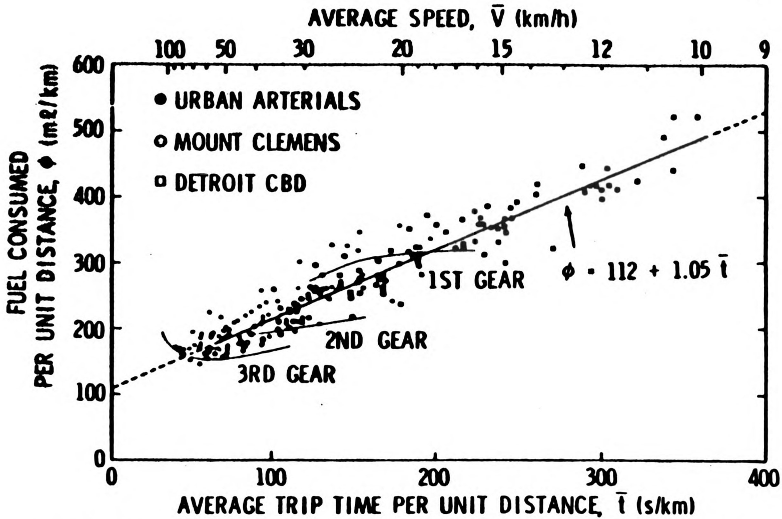


Figure 17. Average Fuel Consumption per Unit Distance versus Average Trip Time per Unit Distance. The curves represent constant speed fuel consumption per unit distance.

Source: Chang et. al. (1976), p. 28.

- Suburban cycles with 41.1 mph average speed and 0.4 stops per mile, and

- Interstate cycle with 55 mph average speed and zero stops per mile.

All vehicles were fully warmed-up before testing. Using the linear relationship for fuel consumption rate in equation 8, the values of k_1 and k_2 were determined for each automobile. The data from the urban and suburban cycles were combined to approximate the range of speeds used in the study of Chang. The interstate cycle fuel consumption rates were outside the range of linearity. The coefficients k_1 and k_2 computed for nine automobile weight classes are shown in Table 6.

Atherton and Suhrbier (1979) used the results of the Union Oil study to develop a fuel consumption rate estimate for a composite vehicle representing the average automobile on United States highways in 1976. The resulting values of k_1 and k_2 are shown in equation 13.

$$\phi = 0.0425 + 0.01\ \bar{t} \text{ gal/mi.} \qquad (13)$$

where

k_1 is in gal/mi,

k_2 is in gal/min, and

$\bar{t}$ is in min/mi.

This relationship is plotted in Figure 18 along with the relationship used by Peskin and Schofer (1977) in MOD3.

Another technique used to compute the energy consumption of urban traffic is used in the network simulation model (NETSIM) developed by Lieberman et. al. (1977). The NETSIM simulation program is one step higher in level of sophistication for the calculation of fuel consumption rates in that the procedure incorporates the influence of vehicle acceleration directly into the fuel consumption estimate. The fuel

Table 6. Coefficients for Fuel Consumption Estimating Relationships for Automobiles of Various Weights

$$\emptyset = k_1 + k_2\bar{t}$$

Number of Vehicles Tested	Weight Class (lbs)	Class Mark (lbs)	k_1 (gal/mi)	k_2 (gal/min)
3	1875 - 2125	2000	0.0273	0.0024
5	2126 - 2375	2250	0.0269	0.0039
7	2376 - 2875	2625	0.0313	0.0046
17	2876 - 3250	3000	0.0337	0.0075
17	3251 - 3750	3500	0.0398	0.0086
12	3751 - 4350	4000	0.0454	0.0090
20	4251 - 4750	4500	0.0456	0.0124
16	4751 - 5250	5000	0.0504	0.0137
9	5251 - 5750	5500	0.0565	0.0152

Source: Atherton and Suhrbier (1978), p. A-6.

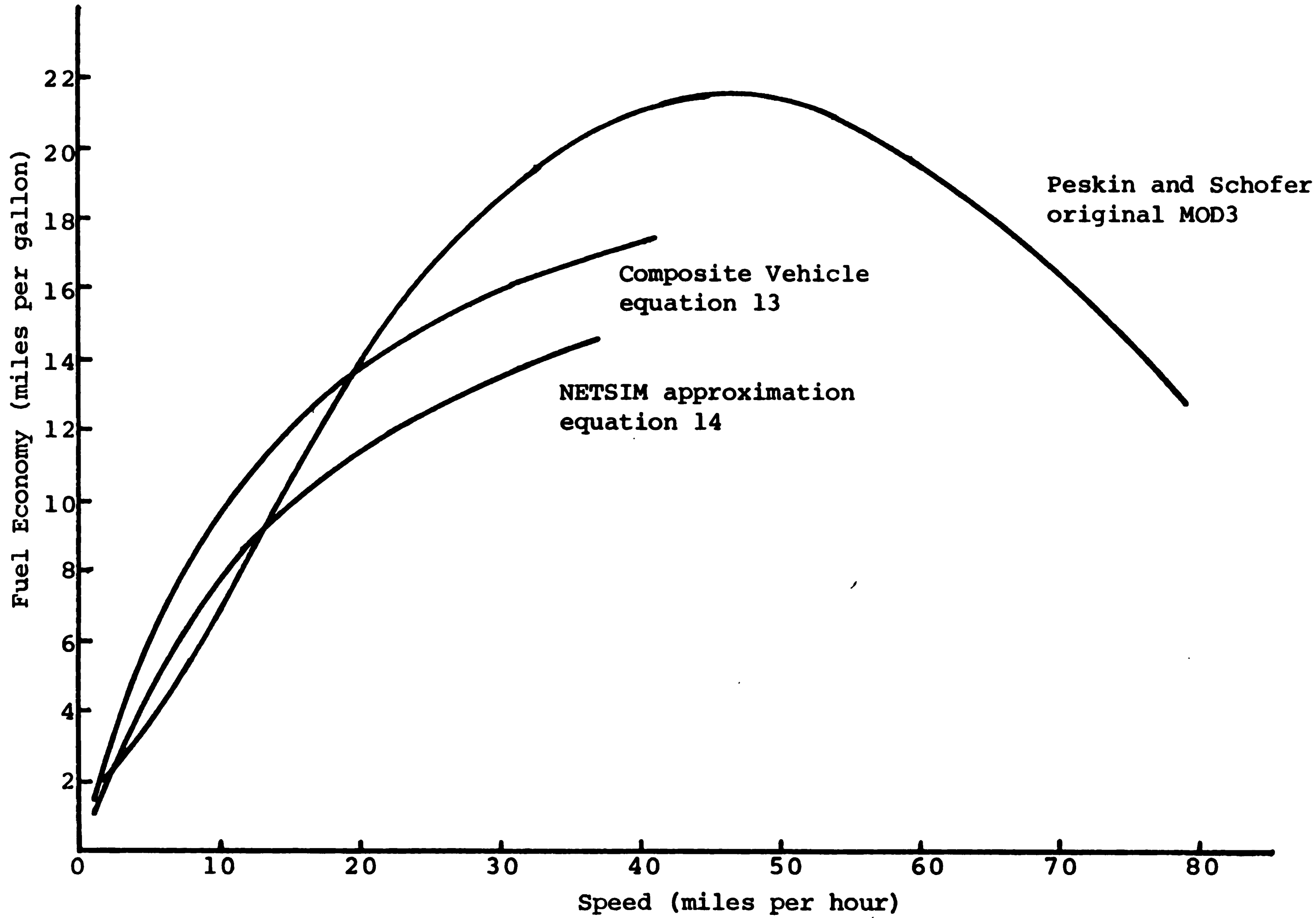


Figure 18. Automobile Fuel Economy as Related to Vehicle Speed in Urban Traffic.

consumption/speed-acceleration relationship used in NETSIM is shown in Figure 19.

In two separate reports (Evans and Herman (1978), and Evans (1979)) it has been shown that the simulated fuel consumption rates generated by NETSIM can be approximated accurately by a relationship of the form of equation 8. Evans and Herman (1978) calibrated equation 8 to data generated in a simulation study by the Honeywell Traffic Management Center (1976) for a network of 34 intersections. The results were:

$$\phi = 0.047 + 0.0133\ \bar{t}\ \text{gal/mi} \quad (\bar{v} < \approx 35\ \text{mi/hr.}) \tag{14}$$

where

$\bar{t}$ is in min/mi.

The values of k_1 and k_2 used in equation 14 yielded an r^2 (square of the correlation coefficient) value of 0.998 and a root mean square error in prediction of 2.21 when compared to the Honeywell data.

Evans (1979) also showed that equation 14 closely approximated the NETSIM fuel consumption statistics reported by Christopherson and Olafson (1978). The values of k_1 and k_2 in equation 14 also compare favorably to the values in equation 13 generated for the 1976 composite vehicle. The relationship in equation 14 is also plotted in Figure 18.

It can be seen in Figure 18 that the relationship originally used by Peskin and Schofer (1977) in MOD3 uses slightly higher fuel consumption rates than either equation 13 or equation 14 for speeds less than 12 mph and 20 mph respectively. Equation 13 uses a lower fuel consumption rate than equation 14 for the entire range of speeds. However, it should be noted that equation 13 represents the fuel consumption relationship for a fully warmed-up vehicle. Atherton and Suhrbier (1979) report that cold-start condition, typical of most urban work trips, reduces fuel economy

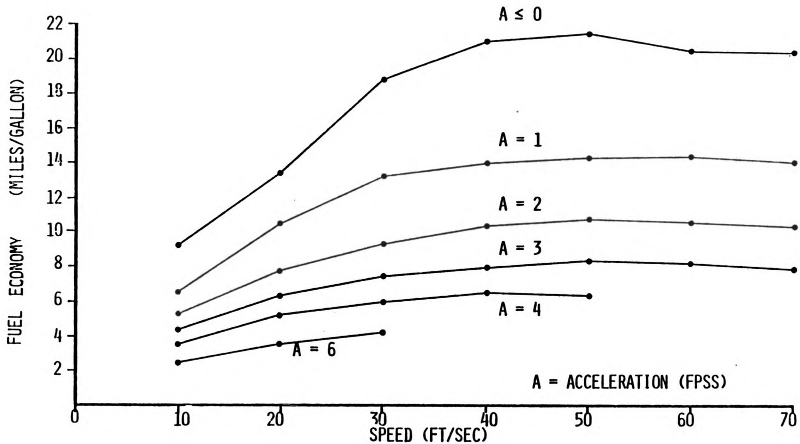


Figure 19. Auto Fuel Economy versus Speed Relationships used in NETSIM for Several Acceleration Rates.

Source: Lieberman and Rosenfield (1977), p. 4.

by almost 45 percent for short trips. The percentage reduction in fuel economy for cold starts compared to the fully-warmed-up condition decreases with trip length and ambient temperature. Figure 20 represents an example of this relationship for an ambient temperature of 10 degrees Centigrade.

With the assumption that the majority of urban work trips are made under cold start conditions, the linear approximation of the fuel efficiency relationship in equation 14 was used in place of the relationship used by Peskin and Schofer. This relationship satisfied the criterion for selection in that it appeared to more accurately represent the current vehicle fleet mix fuel efficiency over the range of speeds tested, and it considers the effect of congestion on fuel consumption.

Within the MOD3 program, the automobile fuel consumption computations are expressed in British Thermal Units (BTU's). The conversion factor used in this research was 125,000 BTU's per gallon of gasoline consumed (Macy and Paullin (1974), p. 4).

3.2.7 Transit Fuel Consumption

Transit fuel consumption was based on data generated from simulation tests by the General Motors Corporation (1974) for vehicle speeds ranging from 5 to 30 miles per hour in increments of five miles per hour. This relationship is shown in Figure 21. MOD3 requires that the transit bus fuel economy be expressed in increments of 5 miles per hour of speed from 2.5 to 27.5 miles per hour. The GM data were interpolated to meet these requirements. The data point for the speed of 2.5 miles per hour came from Peskin and Schofer (1977).

This relationship neglects the influence of bus age, number of stops per mile, season, and the number of bus passengers. It is also for a highway of zero grade. The effect of congestion is ignored, and buses are

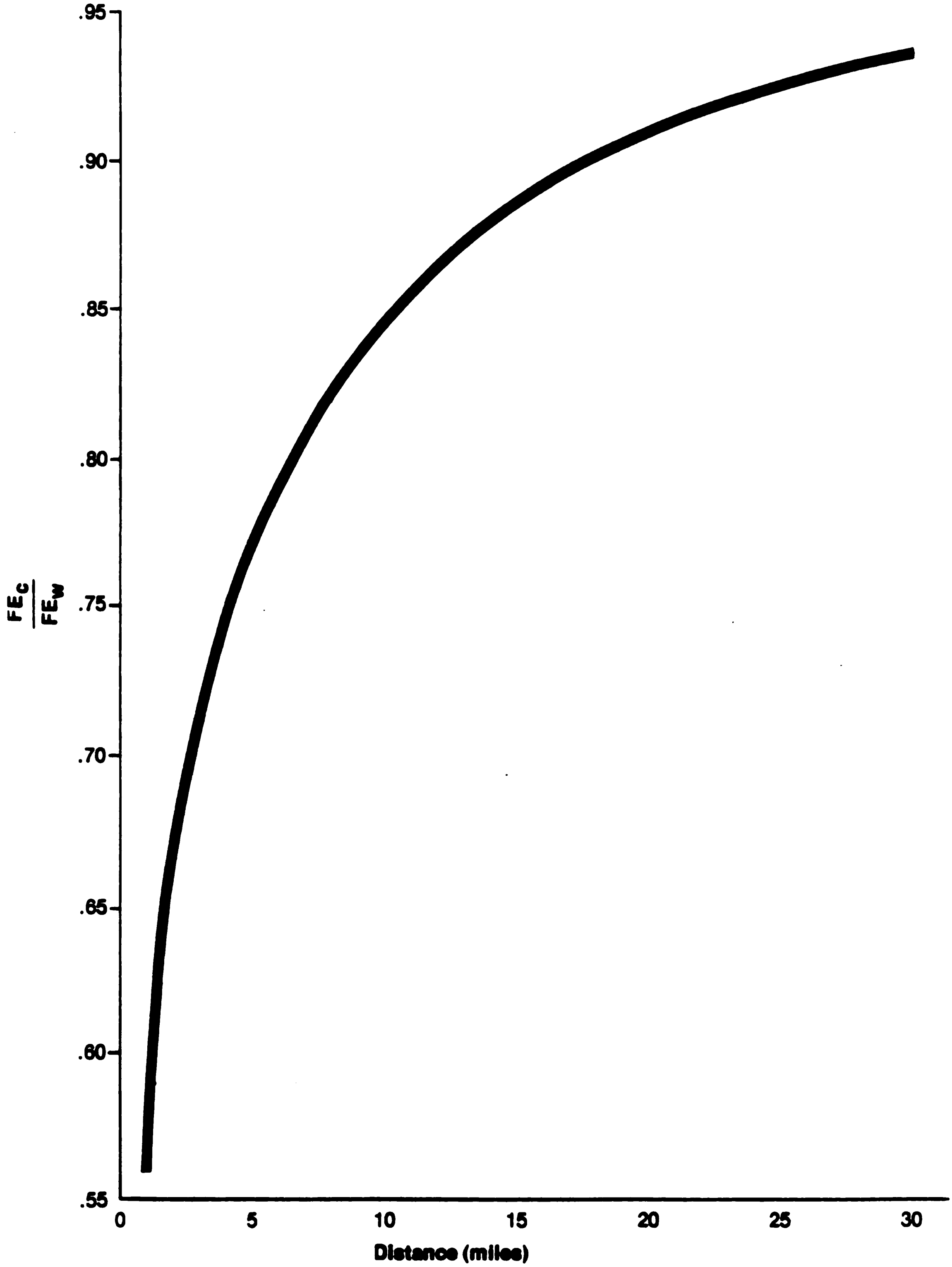


Figure 20. Rate of Cold Start to Fully-Warmed-Up Fuel Economy as a Function of Trip Length (Ambient Temperature = $10^{\circ}C$).

Source: Atherton and Suhrbier (1978), p. A-15.

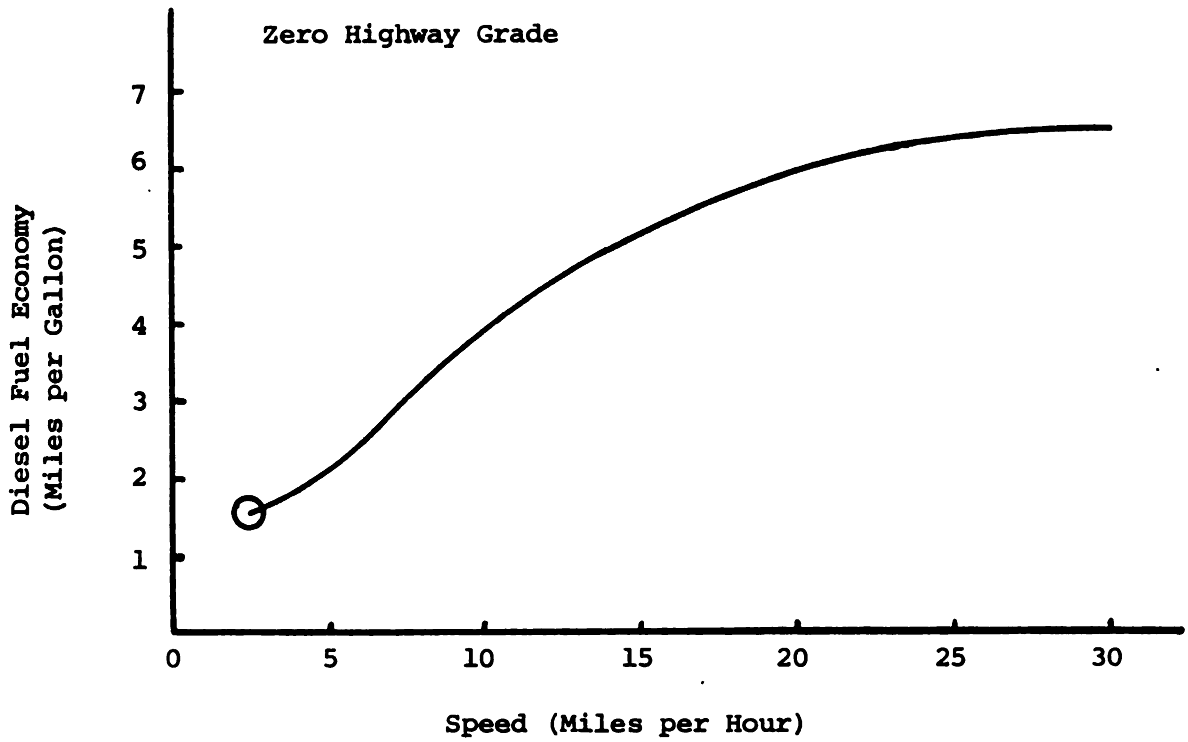


Figure 21. Diesel Fuel Economy for Transit Buses.
Source: Sanders et. al. (1979) p. III-8. Cited from General Motors Corporation (1979).
Data are based on Standard GMC 51-Seat Passenger Bus Equipped with Standard Diesel Engine (6Y71N/C51).

⊙ Data point from relationship used by Peskin and Schofer (1977).

assumed to travel over each link at an exogenously specified speed.

The conversion of gallons of diesel fuel consumed to BTU's was based on a factor of 138,800 BTU's per gallon (Macy and Paullin (1974), p. 4).

3.3 Limitations of MOD3 for this Research

MOD3 is an aggregation of several modeling techniques commonly used in urban transportation planning. The overall structure of MOD3 has only once been subjected to a validation attempt to replicate a real city (Bowman et. al. (1976) study of Amarillo, Texas). The model estimated only 30 percent of the total vehicle miles traveled and only 37 percent of the total gasoline consumption for all trip types. Recognizing that some trips are not generated by MOD3, and that gasoline sales data were imprecise, Bowman et. al. concluded that the model was doing a reasonable job of simulating energy consumption since some of the aggregate measures of travel, such as link flows and travel time distributions, were close to those observed in the real city. The estimated work trip component of fuel consumption generated by MOD3 has never been separately validated with respect to real world data, however it is assumed to be more accurate than the total fuel consumption estimate since work trips can be more accurately modeled than other trip types.

The individual components of MOD3 have an accepted theoretical foundation, and have had application in many transportation studies. However, many simplifying assumptions have been built into the model theory and structure. Some of these assumptions could have an important adverse impact on the experimental results, while others may not affect the results to a significant extent. In many cases, the degree to which these assumptions affect the results cannot be quantified.

The adaptation of the MOD3 program to evaluate short-term as opposed to long-term transportation impacts eliminates the important model limitations that are an outgrowth of the future projections. Whether or not the model produced realistic future land use or transportation patterns was not an issue in this research. It was only important that the model generate a reasonable land use pattern, reflecting the influence of the exogenously specified data, to be used as a basis for analysis. However, several types of trips usually encountered in daily urban traffic are not simulated by MOD3. These include trips from outside the urban area as well as commercial, recreational, dual mode and taxi trips. This did not represent a significant problem for this research in that the impact of these trips on traffic congestion was accounted for through adjustments in the highway link capacity available for work trips. Voorhees and Morris (1959) have indicated that urban work trips often account for 60 to 70 percent of all trips during peak hours. Only work trips are assigned to the network by MOD3; other trips were accounted for through adjustments in the free-flow link capacity. Neglecting work trips that enter from outside the boundaries of the urban area would certainly force the model to underestimate fuel consumption. The magnitude of this impact is directly proportional to the number of trips which might be expected to enter the urban area for a city of the size simulated.

The network congestion levels generated by MOD3 are a direct result of the specified capacity for each link, the number of links available, and the network assignment technique used. The link capacity values, although subjective, were based on the information contained in the Highway Capacity Manual (1965) for arterial highways. Clearly, the specification or adjustment of link capacity would have a profound impact on fuel consumption. The congestion levels generated by MOD3 may be unrealistic due to the user specified capacity levels, in which case the fuel consumption levels would certainly be biased in the direction opposite to the error of the specified link capacity values.

The number of available highway links would also restrict available highway capacity. The program limitations on the number of links that can be specified, and the network configuration, may have restricted available highway capacity in such a manner as to generate unrealistically high congestion levels. Unrealistically high congestion levels used as a basis for analysis could result in an overestimate of policy effectiveness on energy consumption as congestion levels are relaxed.

Two important factors must be mentioned regarding the traffic assignment technique used by MOD3. First, the capacity-restrained equilibrium assignment attempts to minimize total travel costs on the network. This represents a system-optimization as opposed to a user-optimization algorithm. User-optimization is generally regarded as the more realistic route selection criteria, since it is unlikely that individual drivers recognize the effect of their decisions on total system travel costs, or value system efficiency above their own time savings (Hatfield (1979)). Unfortunately, it is difficult to model the route selection process of individual drivers subject to congestion delays. The general result of a system-optimization algorithm would be a lower total congestion level than would be expected with a user-optimization approach. This, in turn, would result in a lower fuel consumption level.

The second factor pertaining to the assignment technique concerns the iterative nature of the optimization algorithm. The algorithm oscillates higher and lower than the optimum, while approaching closer to the optimum after each iteration. It is possible that after the specified number of iterations have been performed, that the optimum set of flows has not been reached. This may result in the values of total fuel consumption in some experiments being less than optimum, while others are greater, thus affecting the accuracy of the comparisons. Experiments during this research indicated that the number of iterations required to dampen the magnitude of the oscillations increased with an increased level of overall congestion, but the total effect of this is unknown.

The limited number of zones and highway links in the city structure may also have biased the results. The small size of the city may have resulted in work trips that are unrealistically short. This would cause an underestimate of the magnitude of the total fuel consumption, but should not severely alter the relative results measured between experiments. The limited number of zones and highway links in the CBD of the simulated city may have resulted in a degree of congestion in the central business district that is unrealistically low. This would also cause an underestimate of the fuel consumption, and could also have caused an underestimate of the effectiveness of the policies tested.

MOD3 does not consider the congestion impact of transit vehicles in the traffic stream. To facilitate the estimation of the impact of transit on congestion or vice versa would necessitate the simulation of transit vehicle stops and passenger boarding and alighting. This could become an important factor if the frequency of transit trips on a selected route is increased to encourage transit travel or if the estimated number of transit trips increased beyond the transit system capacity. More transsit vehicles and longer stops would decrease the capacity of the highway link. For this research, the small city size and the limited number of transit vehicles simulated on each route were such that this was not considered to have a significant impact on link congestion.

MOD3 does not assign transit trips to the transit network. Where multiple transit routes exist between zones it would be difficult to trace variations in transit ridership to changes in transit service characteristics. However, MOD3 does generate a mode split origin-destination matrix which can be utilized to chart variations in transit ridership. In this research the hypothetical city was served by only one transit path between zone pairs. Multiple routes existed only in the central business district (CBD) of the test city, but work travel between CBD zones was virtually nonexistant in the simulation.

The constant and coefficient values in the logit mode split values are assumed to remain constant over time. The degree to which this assumption remains valid as the policy parameters in this research change is subject to question. The extent of this effect on the experimental results is unknown.

Another exogenously specified constant is the automobile occupancy rate. A more realistic approach would be to specify automobile occupancy as a function of the level of service of automobile and transit travel, and as a function of energy availability. These considerations were not made in MOD3 because of the complex nature of the relationship. It is thus possible that an unrealistic description of travel resulted from the fixed value of automobile occupany.

3.4 Modifications of MOD3 for this Reasearch

There are two facets of MOD3 which restricted its application in this research. These limitations were such that modification of the MOD3 procedure was required. The first modification concerned the adaptation of MOD3 to the evaluation of short-term, rather than long-term, policy impacts. As originally written, the model automatically applied an incremental layer of growth to the urban area for a projected twenty year time horizon. Changing the values of data supplied for various transportation parameters would cause a change in the living, working, and travel patterns of the incremental growth layer such that short-term changes in travel due to policy alternatives could not be tested. It was necessary to add the option of maintaining a fixed pattern of urban development by surpressing the incremental growth layer. This resulted in a fixed origin-destination matrix for work travel, and allowed the simulation of short-term policy alternatives.

The second severe limitation in MOD3 encountered in this research is the static network assignment technique used by this simulation package. The temporal distribution of the work trips entering the network is uniform for the time period implied by the specified free-flow link capacity. This is unrealistic, and hampers the effective simulation of a variable work hour program. The model was modified to allow only a specified portion of the total work trip matrix to be loaded in the network for a specified time period. Further flexibility was gained by assigning only a portion of the work trips to be loaded from different zones. This permits the simulation of traffic entering the network in specific time increments and yields a more realistic representation of the temporal distribution of traffic flow during the peak period. Even so, the assignment technique is static in that vehicles from different time increments do not interact on the network. The impact of this interaction on energy consumption is unknown. However, given the relatively short average work trip lengths (approximately 3 miles) it is doubtful that trips originating in different time elements would interact significantly provided the time elements simulated are longer than about 10 minutes. Therefore, the effect of this interaction on energy consumption was assumed negligable. The details of these changes to the computer program are contained in Appendix A.

Overall, the degree to which the limitations and assumptions within

MOD3 affect the realism of the results is unknown. Clearly, the interpretation of the results should be made with an understanding that the assumptions could be unrealistic. This discussion has attempted to identify some of the potential problems in interpreting the research results.

CHAPTER IV

The Simulation Process

4.1 Introduction

The simulation process and the evaluation of the work trip transportation energy requirements were performed using an adapted version of the MOD3 modeling package (Peskin and Schofer (1977)). The analysis involved the simulation of the activity distribution and travel patterns for a hypothetical city of 100,000 people. The analysis was composed of a base case representing the existing conditions of the city and several test cases consisting of alternative variable work hour configurations and transit bus scheduling policies. Both the variable work hour and the transit scheduling programs were tested alone and in combination to judge the impact of the individual action and the combined effect of both types of policies.

As originally written, the MOD3 program was designed as a tool to evaluate the longer-term impacts of transportation and land use policies on future urban development and travel patterns. For this research, the program was modified to maintain a fixed work trip pattern irrespective of the policy alternatives tested. This allowed for the evaluation of TSM policies without alteration of the work trip travel demand patterns. The results can be interpreted as reflecting the short-term impacts that might be experienced in a situation where changes in living patterns were not immediately possible. The impacts on work trip travel were confined to mode and route selection.

The overall evaluation procedure used is shown schematically in Figure 22. The procedure consisted of the generation and evaluation of a base case and the valuation of several variable work hour programs and

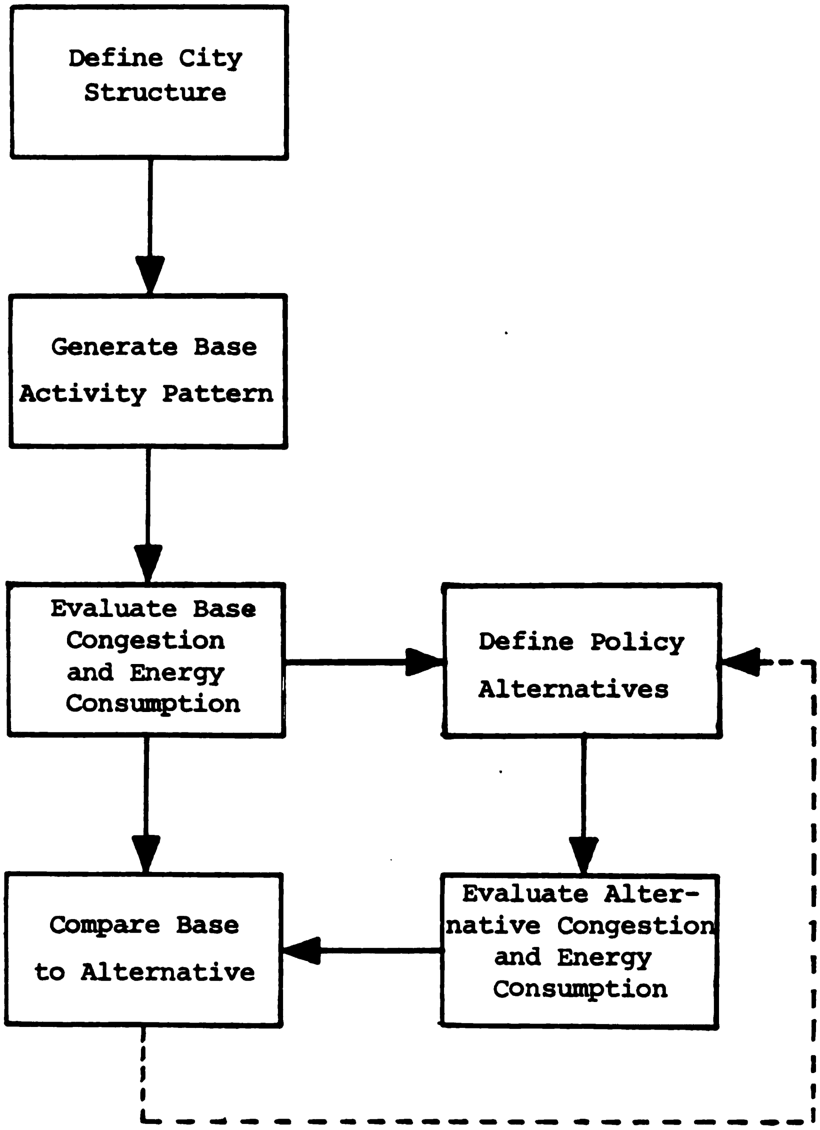


Figure 22. Overall Simulation Procedure.

alternative transit policies. The dashed line in Figure 22 represents the feedback from policy evaluation to alternative policy selection.

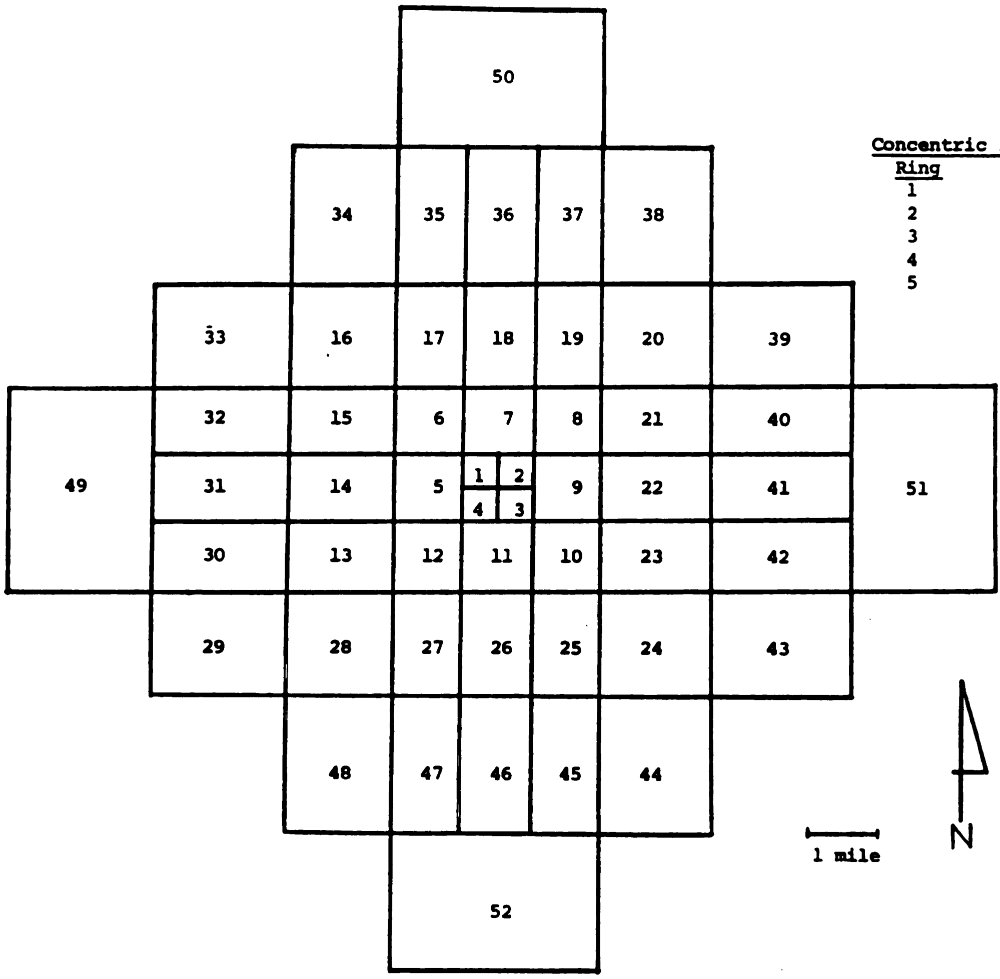
4.2 The City Structure

The city structure was selected and the travel patterns and energy consumption determined to supply the infrastructure of a generalized urban area through which the policy analysis could proceed. The city structure, shown in Figure 23, differs from that used by Peskin and Schofer in that it is slightly elongated along two of the major travel corridors rather than having an overall square configuration. It was felt that this was a better representation of urban development along major travel corridors.

The four central zones represent the central business district (CBD) having a total area of one square mile. The CBD was surrounded by four concentric rings of development with progressively increasing zone sizes toward the periphery. The total land area was approximately 100 square miles. The distribution of basic employment (shown in Figure 24) was concentrated most heavily in the CBD and the adjacent ring of zones. Lower levels of basic employment were specified for the zones in ring 3. This configuration is characteristic of urban areas of the size simulated.

The highway network used in the simulation is shown in Figure 25. The network was a grid pattern and consisted solely of arterial streets connecting zone centroids. Local streets were assumed to handle intrazonal trips, and therefore are not depicted. The vast majority of the highway network consisted of two-way links except those one-way links connecting the CBD zones. Freeway links were omitted from the city structure, since for cities of the size simulated, there are usually few, if any, freeway links used for intraurban travel.

The transit network, as shown in Figure 26, was also similar to that



Concentric Ring City

Ring	Zones
1	1- 4(CBD)
2	5-12
3	13-28
4	29-48
5	49-52

Figure 23. Zonal Structure of the Simulated Urban Area.

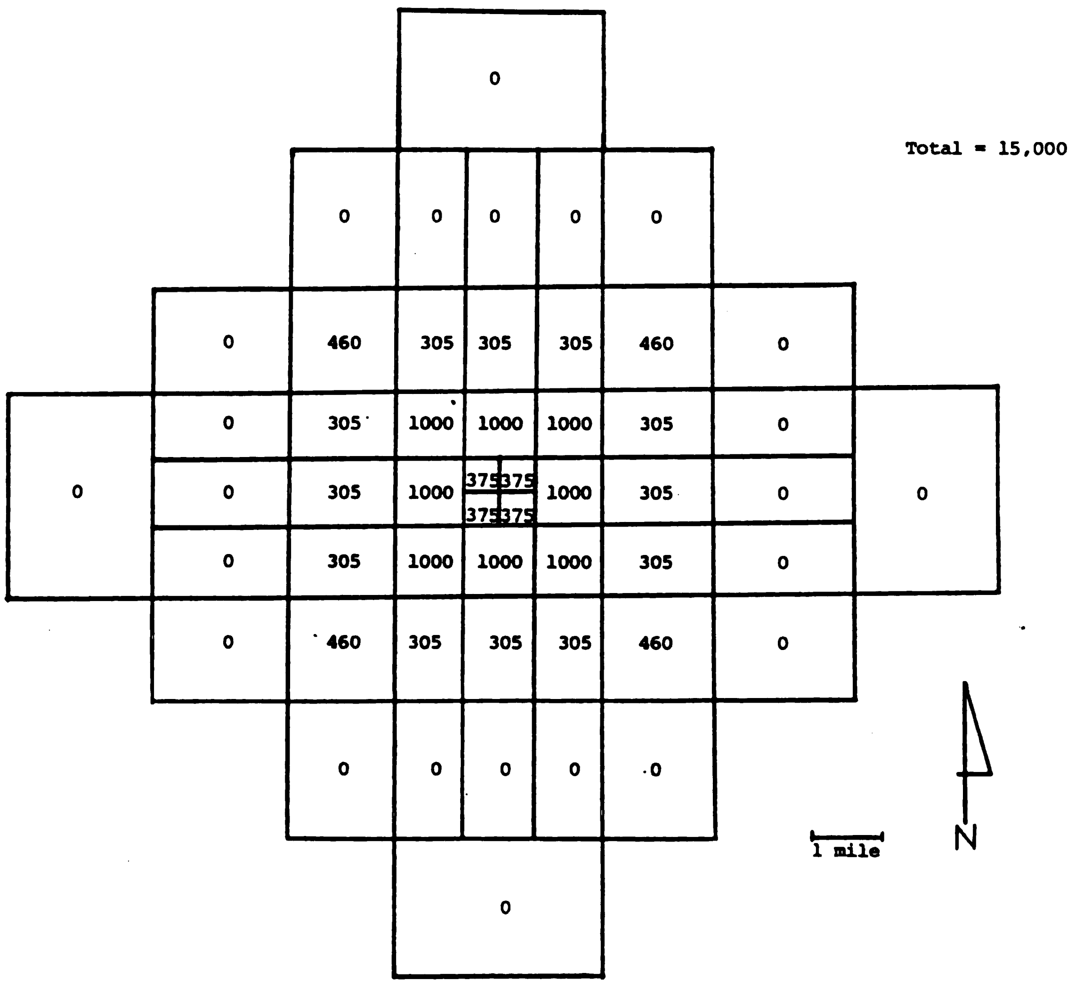


Figure 24. Basic Employment Distribution of the Simulated Urban Area.

Percent green time per hour = 50.0
Time period of simulation (hrs.) = 0.50
Percent capacity available for work trips = 90.0

TRAFIK = (0.50) (0.50) (0.90) = 0.225

Ring	Link Capacity (vphg)	Link Free Flow Speed (mph)
1	1,800	25 (one way)
2	2,000	30
3	2,000	35
4	1,500	35
5	1,500	35

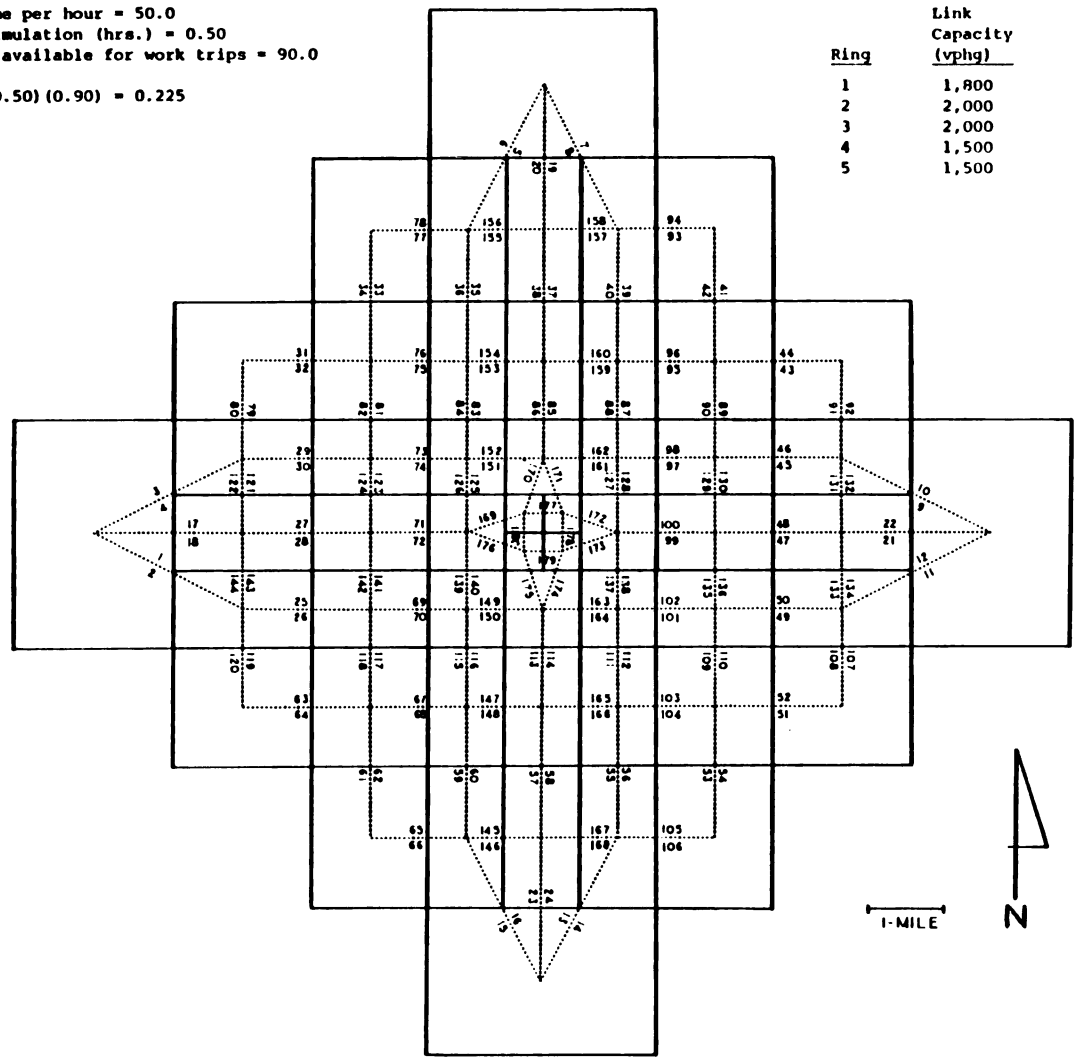


Figure 25. Highway Network Configuration for the Simulated Urban Area.

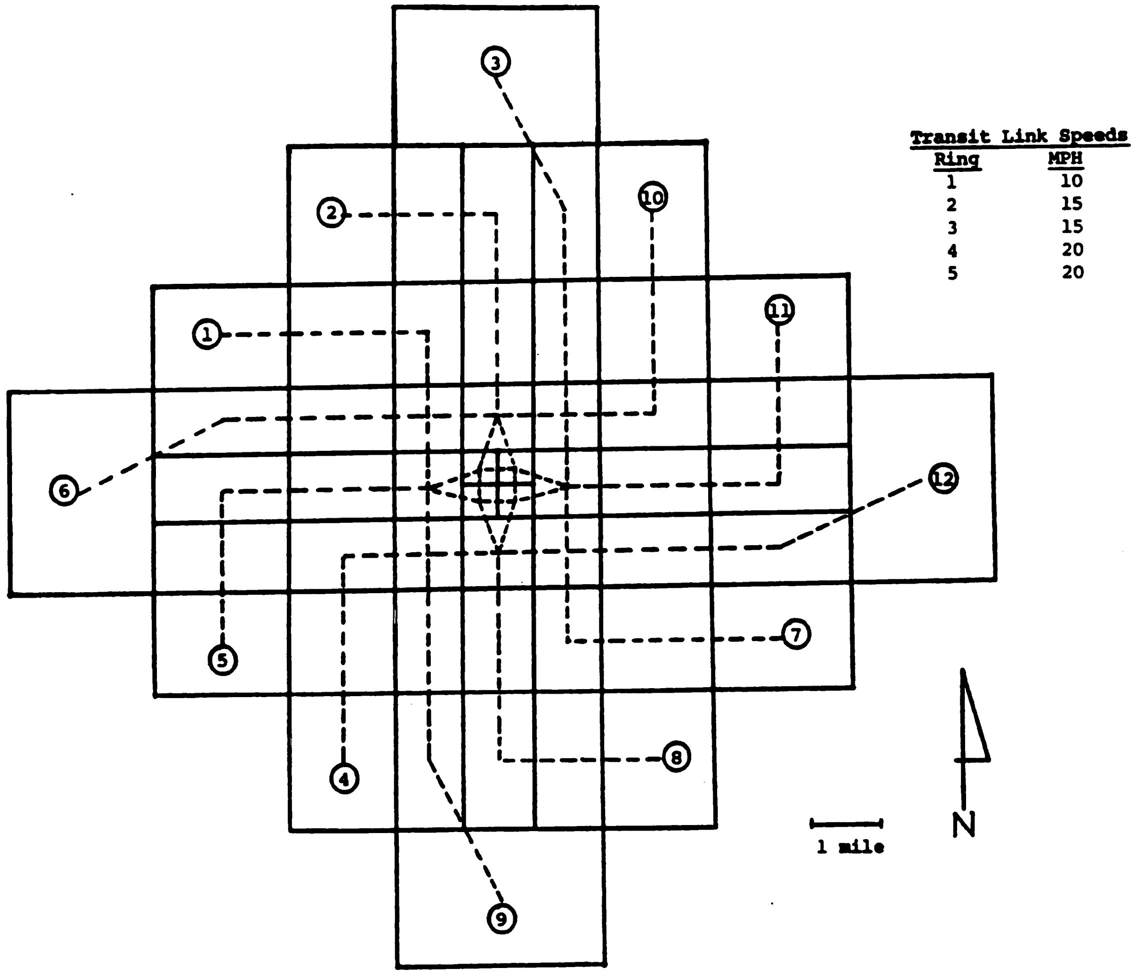


Figure 26. Transit Network for the Simulated Urban Area.

used by Peskin and Schofer (1977), and is representative of urban bus routes in United States cities in terms of route spacing and average link speeds. The focal point of the network was the CBD, and the network was designed such that each zone had access to transit. All routes began and ended at the city periphery. Where possible, the use of multiple routes serving any single zone was avoided to enhance the capability of monitoring changes in transit ridership that resulted from changes in route frequency.

4.3 The Base Case

The base case, used as the control to compare the effectiveness of alternative TSM policies, was generated using the MOD3 program first in the base run mode, and then with one run in the incremental run mode with the model constrained by a "no-growth" situation (see Chapter III for model description). The difference between the base run mode and incremental run mode is that, in the former, travel time was used to compute the interzonal friction factors and define the minimum paths in the highway network while in the latter, the generalized cost of travel was used. This resulted in a slightly different activity pattern when the base run output was used in the incremental run mode even though a no-growth situation was specified. All policy test runs were made in the incremental run mode (no-growth) to avoid the redistribution of urban activities from the policy alternative.

Table 7 and Figures 27 and 28 give the values of some of the input data required to describe the base activity pattern of the study area. A complete listing of the data set for the base case is shown in Appendix B. With this information as input, the resultant population and employment distributions are shown in Figures 29 and 30.

Table 7. Input Data for the Generation of the Base Case Activity Pattern

Percentage of persons working at home	=	2.3%
Value of travel time for work trips	=	$5.00
Price of gasoline per gallon	=	$1.00
Automobile Occupancy rate for work trips	=	1.3
Automobile Ownership per household	=	1.3
Parking cost - CBD: Work trips	=	$2.50
Per day Non Work trips	=	$1.00
Ring 1: Work trips	=	$1.25
Non Work trips	=	$ .50
Elsewhere:	=	Free
Number of transit routes	=	12
Peak period transit frequency of service (buses per hour)	=	3
Transit bus trips per day on each route	=	43
Transit fare	=	$ .35
Transit transfer fare	=	$0.00
Labor force participation rate (persons per employee)	=	2.5

Base travel time distributions - Supplied by Peskin and Schofer (1977), originally taken from a Texas Department of Highways (1964), study of Amarillo, Texas.

Acres of land available for development in each zone (see Figure 27).

Maximum Residential Density, in persons per acre per zone (see Figure 28).

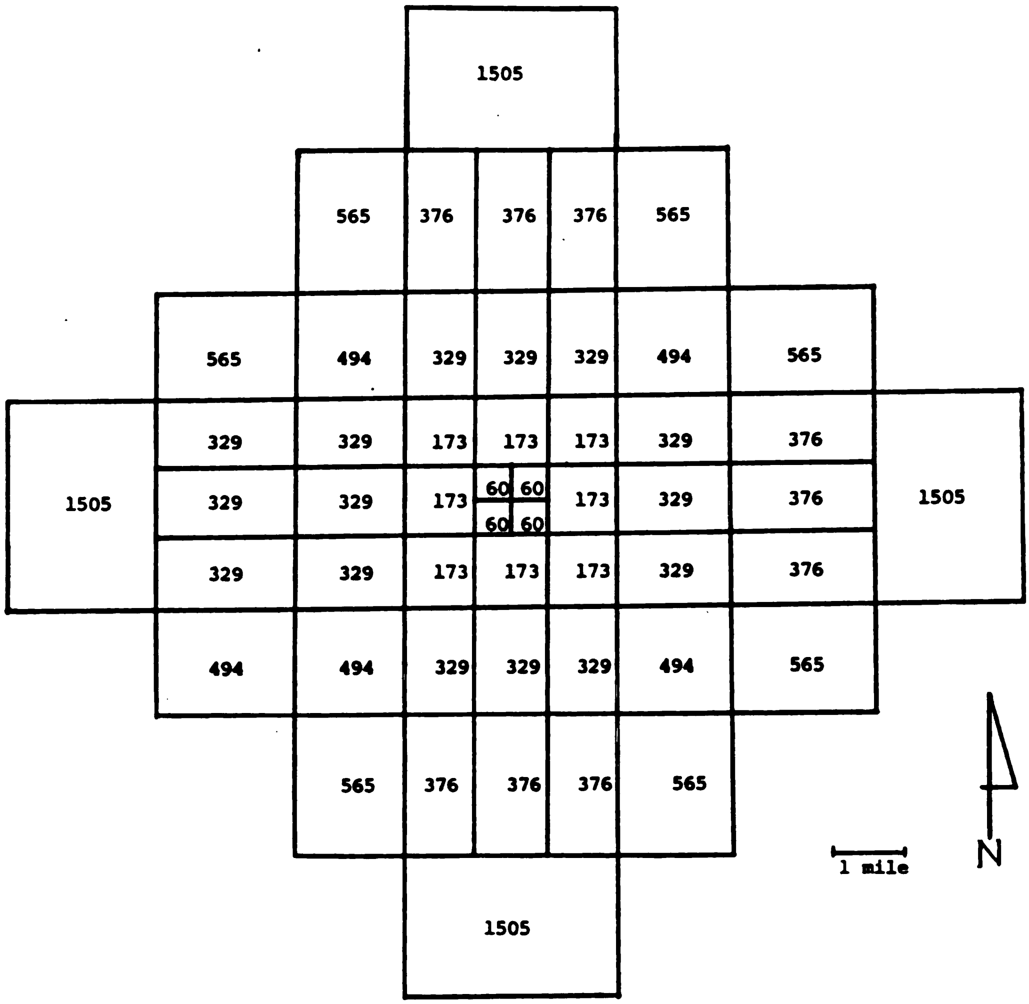


Figure 27. Base Run Land Area (acres) Available for Development.

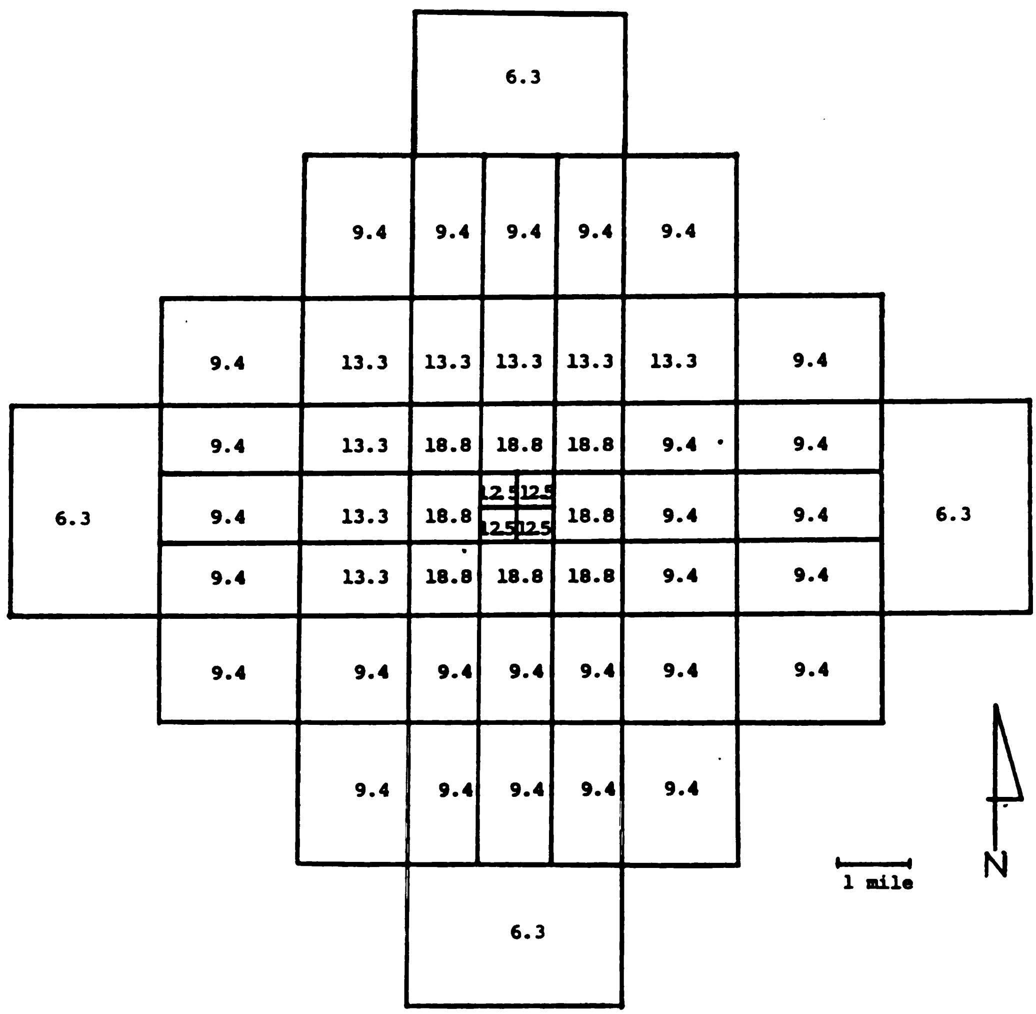


Figure 28. Base Run Maximum Residential Density (persons/acre).

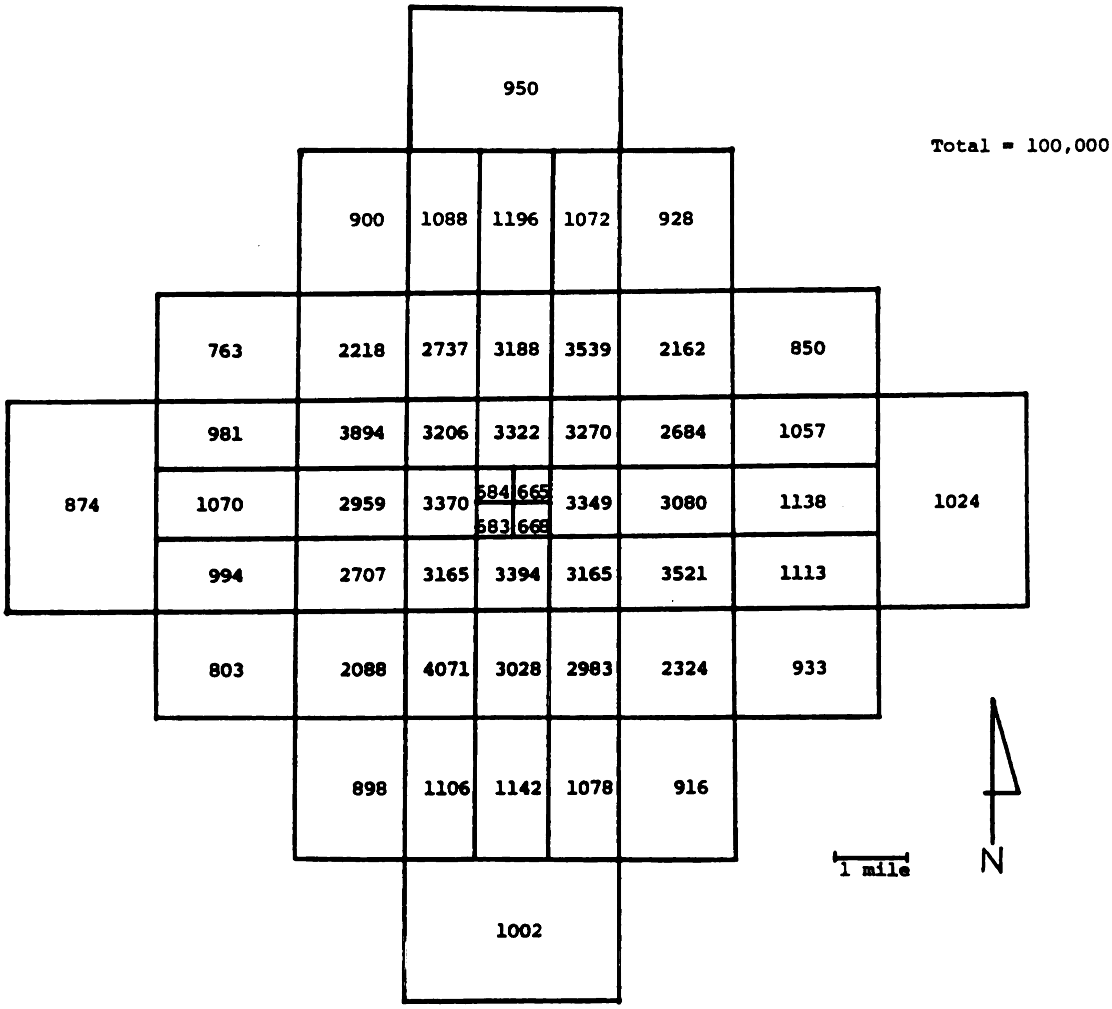


Figure 29. Population per Zone for the Simulated Urban Area.

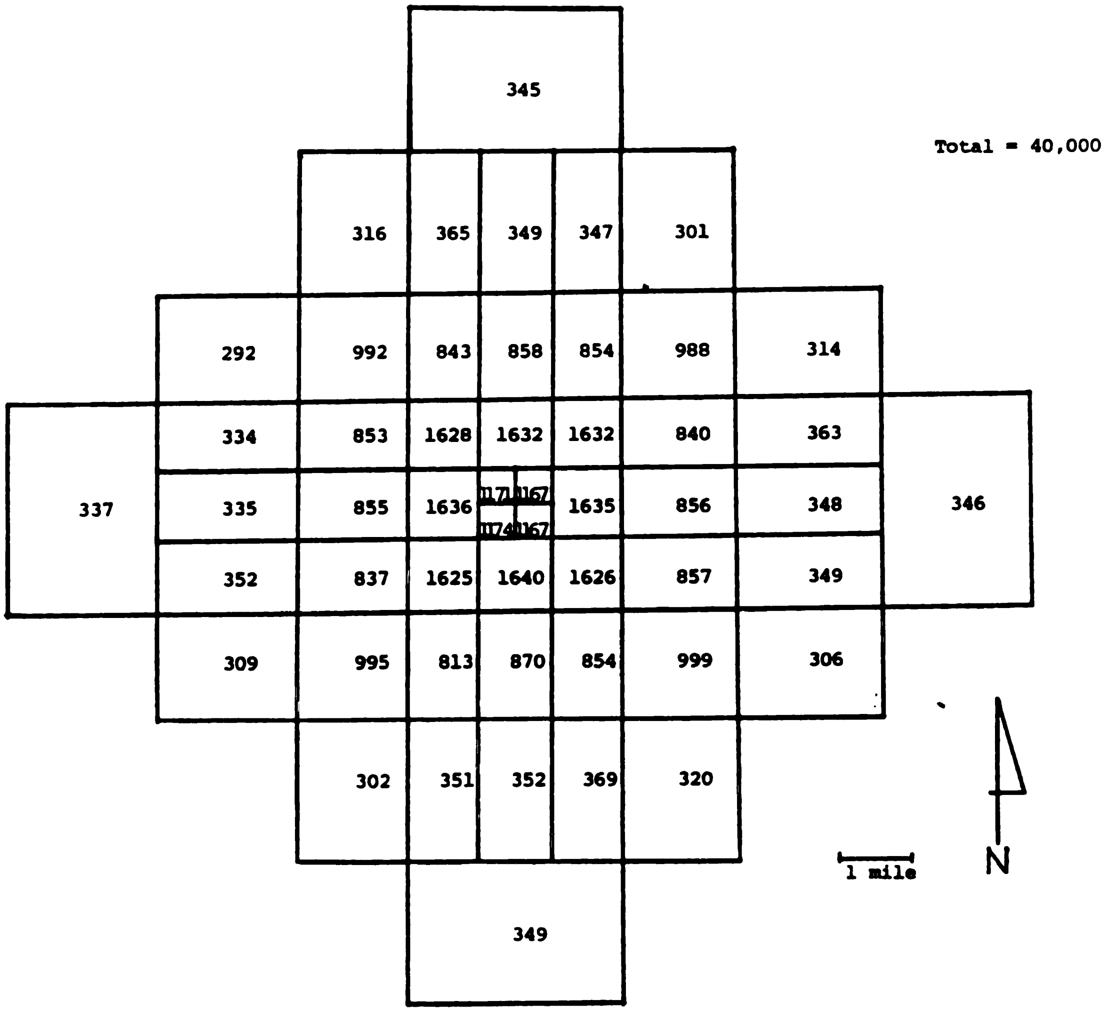


Figure 30. Total Employment per Zone for the Simulated Urban Area.

4.3.1 Base Case Work Trip Simulation

To facilitate the testing of staggered and flexible work hour programs, the total PM peak travel period was segmented into five discrete time elements. The work trip travel for each time element was then simulated using the adaptations made to MOD3 for this purpose. The sum of the energy consumed during these five time elements represented the total for the entire peak period.

The peak travel period was specified to have a length of 2.5 hours and was divided into the five half hour periods. Half hour time periods were selected for three basic reasons. First, it was felt that half hour periods were adequate to describe the peaking characteristics of urban work travel. Simulating more time periods of a smaller duration would have resulted in only a small increase in descriptive capability at a substantial increase in computer costs. Second, the work by O'Malley and Selinger (1973) stressed that a travel time period shift of at least 30 minutes was necessary with a variable work hour program to require a definite change in commuting habits. Third, the use of half hour time periods eliminated the potential problem of vehicles from different time periods interacting on the network. Which was a condition the simulation process was incapable of accounting for. The mean work trip travel time for a city of the size simulated is about 8 to 10 minutes (Peskin and Schofer (1977)).

The base case temporal distribution of evening work travel is shown in Figure 31. The general shape of the distribution is similar to the distributions found in studies of urban work trips (Port Authority of New York and New Jersey (1977), Santerre (1966)), although the peaking characteristic of the base case is slightly less exaggerated than than found in the literature. It was found that loading the simulated network with more than 50 percent of the total work trips during a half hour

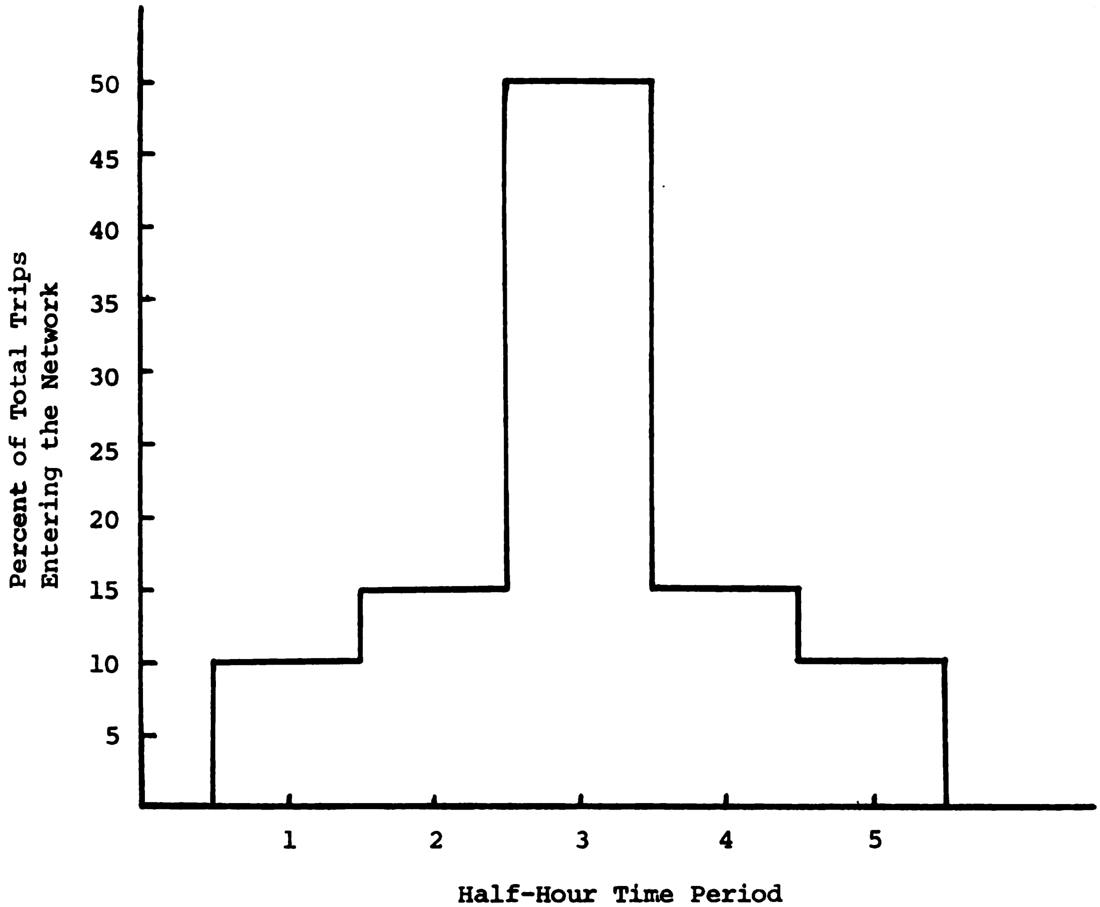


Figure 31. Temporal Distribution of Work Trips Entering the Network for the Base Case.

period resulted in unrealistically high levels of congestions. Each half hour time period was simulated to determine the levels of network congestions, transit ridership and energy consumption for the work trips.

The highway congestion index (HCI) reported by MOD3 was used as a measure of average congestion on the entire network. The HCI is the mean of all the congestion indices computed for each link of the network. The congestion index for each link is defined as the ratio of the link free flow travel speed to the link travel speed when adjusted by the link volume of traffic. As the level of congestion increases, so does the HCI.

4.3.2 Results of the Base Case Simulation

The results of the base case simulation for each time period, and for the entire peak period are shown in Table 8. The last column in Table 8 contains the weighted mean values of the travel and congestion indices for the peak period. The mean values for the entire peak period were computed by summing the weighted mean values for each time element. For example, the mean highway congestion index reported for each time element was combined into a mean for the entire peak period based on the number of automobile trips occuring in each time element. That is,

$$HCI_{mean} = \sum_{i=1}^{n} \frac{wt_i}{WT} * hc_i \tag{15}$$

where

HCI_{mean} = the mean highway congestion index for the entire peak period,

n = the number of time elements in the peak period,

wt_i = the number of automobile work trips occuring in time period i,

WT = the total number of automobile work trips = $\sum_{i=1}^{n} wt_i$, and

hc_i = the mean highway congestion index for the time period i.

Table 8. Base Case Travel Demand and Energy Consumption

Time Period	1	2	3	4	5	Weighted Mean	
Peak Period Demand Distribution (Proportion of Total Work Trips)	0.10	0.15	0.50	0.15	0.10		
Auto Work Trip Energy (BTU's x 10^6)	418.727	628.446	2,692.891	628.446	418.727	4,787.237	Total
Daily Bus Energy (BTU's x 10^6)						142.847	Total
Highway Congestion Index	1.008	1.038	2.897	1.038	1.008	1.943	
Auto Work Person Trips	5,772	8,656	27,682	8,656	5,772	56,538	Total
Transit Work Trips:							
Person Trips	1,122	1,686	6,791	1,686	1,122	12,407	
Percent of Work Trips	13.009	13.032	15.876	13.032	13.009	14.499	
Average Auto Work Trip:							
Length (miles)	2.672	2.661	2.593	2.661	2.672	2.630	
Time (minutes)	7.524	7.570	10.899	7.570	7.524	9.192	
Speed (mph)	21.306	21.099	14.275	21.094	21.306	17.796	
Average Transit Work Trip:							
Length (miles)	1.340	1.341	1.462	1.341	1.340	1.406	
Time (minutes)	36.783	36.804	38.961	36.804	36.783	37.943	
Speed (mph)	2.186	2.187	2.251	2.187	2.186	2.220	

This was done for all of the summary statistics, except for the automobile and transit energy consumption. The total automobile energy consumption is simply the summation over all time periods, and the transit energy consumption is a daily total.

4.4 Description of Alternative Policies

The policy alternatives tested by this research were divided into three basic categories:

1. Variable work hour policy only,
2. transit policies only, and
3. combined variable work hour and transit policies.

The work hour and transit policies were tested individually and in combination to determine whether or not the combined policy alternatives could further improve the savings in energy consumption of the individual policies.

Within each policy category, individual policy alternatives were grouped based on the underlying structure of the policies. These groups are summarized in Table 9. Each group was designed to test specific parameters relating to policy effectiveness. Detailed descriptions of each group are contained in the sections that follow.

4.4.1 Variable Work Hour Policies (Groups A, B and C)

The simulation of variable work hour programs was accomplished by changing the temporal distribution of work trips entering the network. Several variations were simulated to test the impact of both the number of participants in the program and the location of the participants. The variations tested represented the potential impact of both staggered and flexible work hour programs for a five-day work week. For all the policies tested, workers were assumed to remain on a five-day work schedule.

Table 9. Summary of Policy Alternatives

Variable Work Hour Alternatives	Transit Alternatives	Combined Variable Work Hour and Transit Alternatives
Group A Basic Policy Structure: Shift travelers away from the peak half hour. Vary magnitude of shift by 10, 30, 50 and 60 percent of peak half hour. Vary zones involved.	**Group D** Transit Bus Redistribution with base Temporal Distribution of work trips.	**Group F** Combine Group A with Group D policies
Group B Apply total temporal distribution of work travel resulting from Group A policies to all zones in the study area.	**Group E** Addition of 6 transit buses to network, with base temporal distribution of work trips.	**Group G** Combine Group C with Group D policies.
Group C Apply 10 percent shift to zones along east-west and north-south transit corridors for different time periods.		**Group H** Combine Group C with Group E policies.

The basic structure for testing the staggered work hour programs was to shift work travelers away from the peak half hour to each adjacent half hour period. This was continued (incrementally) until the adjacent half hour periods each contained approximately 20 percent of the work travel for the zones under study. Additional travelers were then shifted to time periods on both sides of the peak, until a uniform distribution was established (that is, 20 percent of travel during each time period).

The shifts were made in increments of 10, 30, 50 and 60 percent of the peak period travelers. The 60 percent participation rate for the peak period travelers equaled a uniform distribution for the zones involved in the travel time shift.

To test the impact of the location of the participants, as well as the overall number of travelers, the simulation began with only the CBD zones participating, and progressed outward from the CBD adding adjacent rings of zones in successive program runs. In all, seventeen variations of the basic staggered work hour programs were tested while maintaining the base transit frequency (runs A1-A17). Table 8 shows the zones involved in the staggered work hour program along with the temporal distribution of all travelers from all zones. These alternatives are described in tabular form in Table C1 in Appendix C.

For five cases (runs B1-B5) the overall temporal distribution of work travel that resulted from the staggered work hour simulations for selected zones (runs A4, A5, A8, A9 and A12) were applied to all zones. This was done to test the impact of concentrating the staggered work hour program in selected zones as opposed to generating the same overall temporal distribution of travelers over all zones. These runs are also described in Table C1.

A variation of the staggered work hour policy was designed to coordinate the staggered work hour shift along selected transit corridors. In run C1, 10 percent of the travelers originating in the zones along the transit routes which traverse a general east-west direction were shifted from time period 3 (the peak period) to time period 2. The same percentage of travelers originating in zones along transit routes traversing a general north-south direction were shifted from time period 3 to time period 4. The purpose of this variation was to attempt to enhance the influence of the transit system on work travelers involved in the variable work hour program. This run is also described in Table C1. The policy structure described for run C1 was also used as a basis for testing combined staggered work hour and transit policies.

4.4.2 Alternative Transit Policies (Groups D and E)

The base case transit frequency of service was set at 4.5 vehicles per hour (13.33 minute headways) for the peak period. An analysis of the total travel time on each route revealed that this frequency could be maintained utilizing 3 buses per route, yielding a total fleet requirement of 36 buses. The total number of trips per day per route, which was used in the computation of the daily transit energy consumption, was set at 43 for the base case.

Two groups of transit policies were tested in this research. The first group assumed that the fleet size was fixed and that any increases in frequency requiring the addition of buses to a route would necessitate a decrease in frequency on one or more routes. Analysis of the automobile network assignment and subsequent congestion patterns suggested ways in which the transit fleet could be redistributed to reduce congestion and energy consumption during specific time periods. Several combinations of fleet redistribution were simulated using the base case temporal distribution of work trips. These alternatives are described in Table C2 (Appendix C), where, for example, in run D1 one bus was added to each of routes 2, 3, 8 and 9 during the peak half hour, increasing the bus frequency on these routes to 6 buses per hour for that half hour period. These buses were taken from routes 1, 4, 7 and 10, reducing the bus frequency to 3 buses per hour for the period. The purpose of this exercise was to determine if it was possible to reduce energy consumption through a redistribution of the transit fleet. Each redistribution of the fleet also resulted in a change in the total number of daily transit trips made on each route.

Evaluation of the impact of each alternative on energy consumption and congestion was used as feedback to suggest a means of gaining further improvement (see Chapter V). In all, five such policy alternatives were tested (runs D1-D5). The manual evaluation of the congestion patterns and interpretation of possible improvements was to illustrate the impact of these changes, and was not meant to produce an optimum distribution of the fleet.

In terms of a reduction in energy consumption, the transit redistribution policies provided only a slight improvement (see Chapter V). The redistribution policies severely penalized those routes where bus frequency was reduced with a loss in ridership, and therefore restricted the total benefit realized by the redistribution policies. As a result, a second type of transit policy was designed. This policy consisted of using 6 additional buses on the transit network. Only one bus addition policy was tested. This alternative is described in Table C2 as run E1.

4.4.3 Combining Variable Work Hours with Transit Policies (Groups F, G and H)

To evaluate the combined impact of the transit policies and the variable work hour programs, several alternatives were designed that included both a transit redistribution (or addition of vehicles), and a variable work hour alternative. In all, nine combined alternatives were simulated: six combined transit redistribution with the basic variable work hour policies (Group F), two combined transit redistribution policies with the transit corridor oriented variable work hour policy specifically designed to enhance transit ridership during the time periods adjacent to the peak half hour (Group G), and one combined the addition of transit vehicles with the transit corridor variable work hour policy (Group H).

The policy combinations in Group F were an attempt to determine the reduction in energy consumption of the basic variable work hour policies by combining them with the most successful transit redistribution policies. For example, run F1 combines the temporal distribution of work travel from run A2 with the transit bus distribution of run D5. However, feedback from the evaluation of these simulations indicated that changes in the bus redistribution strategies might further improve the energy conservation potential of an alternative. Therefore, slight deviations from the transit policies tested with the base travel distribution were made. These policies are described in detail in Table C3 in Appendix C.

The variable work hour policies used in combination in Group F were for both the 10 and 30 percent participation rates for the peak half hour. The location of the zones involved varied from strictly the CBD zones to all zones from the CBD to ring 3 of the urban area. The variation of the zone location for those zones involved in the variable work hour program resulted in a shift of traffic congestion on the network, and precipitated the re-evaluation of the transit distribution strategies tested in Group D (see Chapter V).

The policy combinations simulated in Groups G and H had, in effect, a common goal. These policies attempted to enhance the attractiveness of transit for work trips by shifting some of the work trips along the east-west and north-south travel corridors away from the peak half hour, and then improving transit frequency along the routes where the shifts were made. For example, Figure 32 shows the zones that experienced a 5 or 10 percent variable work hour shift to time period 2, and also shows the transit routes with an increased frequency of service during this time period. Figure 33 shows the same information for time period 4. The alternatives in Group G combine the corridor staggered work hour policies with transit redistribution policies. Group H combined the corridor staggered work hour policy with the transit addition policy. The results of all policies tested are described in detail in Chapter V.

4.5 Two Alternative Fuel Environments (Policy Groups I and J)

The 1973-1974 Arab oil embargo of the United States caused significant changes in work trip travel habits in many urban areas as a direct result of limited fuel availability and higher fuel prices. It has been estimated that these changes could include a potential 40 percent increase in daily transit ridership (Office of Technology Assessment (1975)), the majority of which would occur during peak hours due to work travelers changing mode. It is likely that the effect of TSM policies would be significantly different in an environment exhibiting rapidly increasing fuel prices and/or a limitation on fuel availability. Two alternative fuel environments and several policies were formulated to test this theory

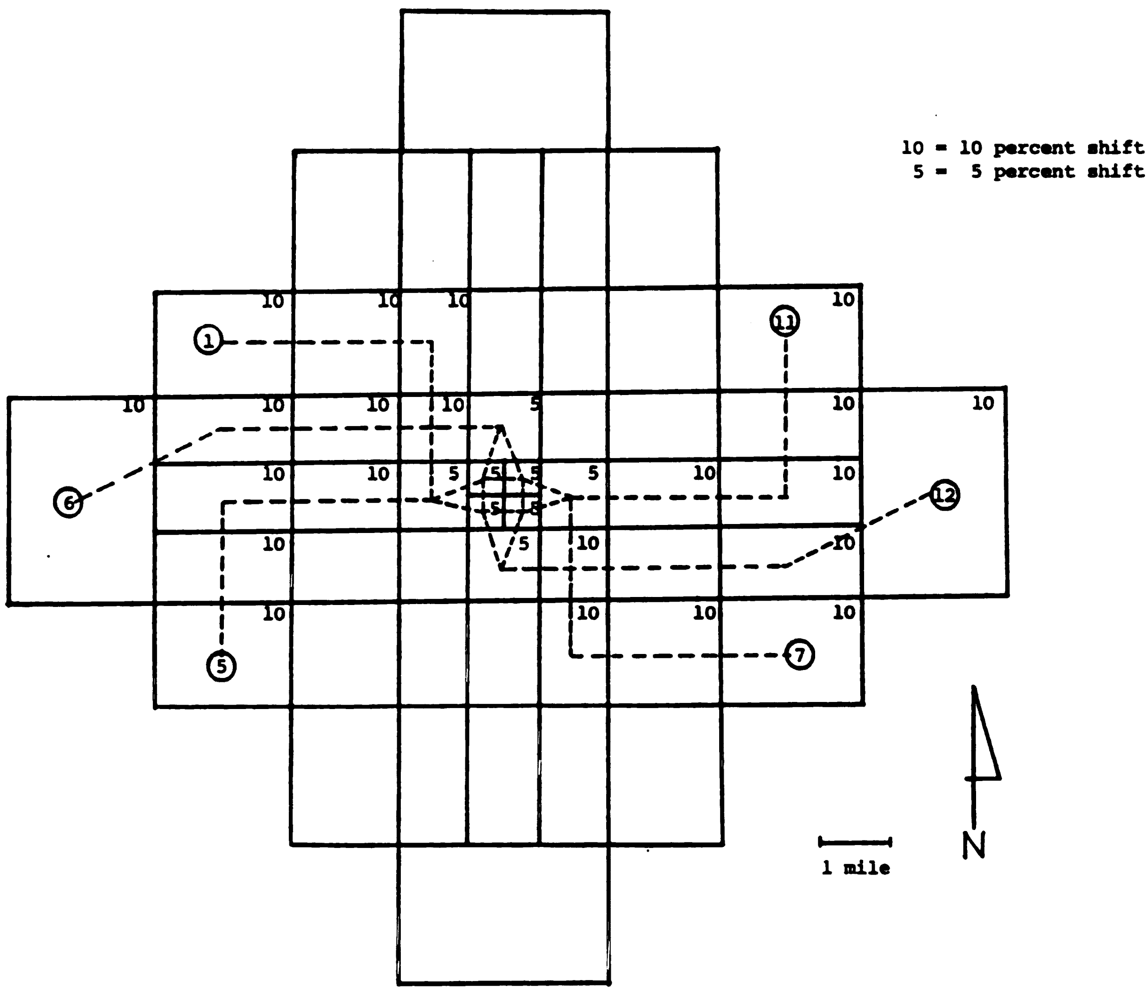


Figure 32. Zones with a 5 or 10 Percent Temporal Travel Shift to Time Period 2, and Associated Transit Routes.

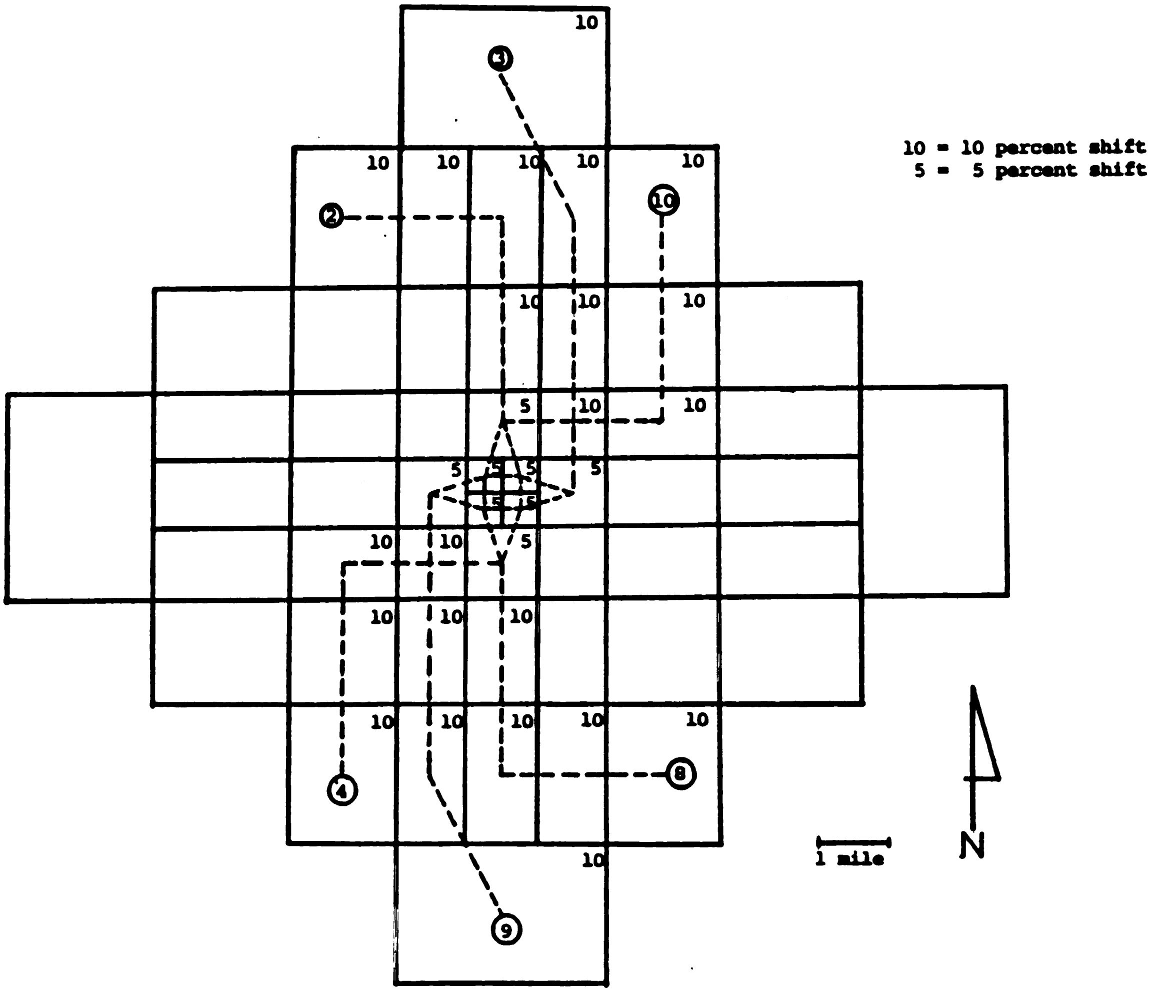


Figure 33. Zones with a 5 or 10 Percent Temporal Travel Shift to Time Period 4, and Associated Transit Routes.

using the MOD3 program.

The energy environment of the simulated urban area was altered drastically through two measures. The first was to raise the price of gasoline from $1.00 per gallon to $3.00 to represent a possible price reaction to another oil embargo (Group I policies). A second change was simulated by reducing by 50 percent the coefficient of the automobile/ bus travel time differential in the work trip mode split relationship in combination with the increased gasoline price (Group J policies). Hence, the relative importance of travel time in mode choice was reduced by half. This represent a possible user reaction to a severe limitation on fuel availability.

These changes were tested initially using the base case temporal distribution of work travelers. Combinations of policies were then tested beginning with the corridor staggered work hour policy (identical to that described for run C1) and including a bus addition policy similar to that described for run H1. The bus addition policy was nearly identical to that described for run H1 in that during time periods 2 and 4 one bus was added to each route that was coordinated with the corridor staggered work hour policy. A slightly different distribution of the additional buses was indicated for time period 3 by the analysis of the individual link congestion indices as described earlier. These policies and the prevailing fuel environments are summarized in Tables 10 and 11.

Table 10. Description of Alternative Fuel Environments and Policies Selected for Testing

Run Number	Fuel Environment	Temporal Distribution of Work Travelers	Bus Policy
I1	Gas $3.00/gal. Unlimited Availability	Base Case	Base Case
I2	Gas $3.00/gal. Unlimited Availability	Corridor Staggered work hours (See run C1)	Base Case
I3	Gas $3.00/gal. Unlimited Availability	Corridor Staggered work hours (See run C1)	Bus Addition (See Table 11)
J1	Gas $3.00/gal. Limited Availability*	Base Case	Base Case
J2	Gas $3.00/gal. Limited Availability*	Corridor Staggered work hours (See run C1)	Base Case
J3	Gas $3.00/gal. Limited Availability*	Corridor Staggered work hours (See run C1)	Bus Addition (See Table 11)

* The impact of limited fuel availability on work trip mode choice was simulated by reducing the coefficient of the automobile/bus differential travel time by 50 percent in the mode split relationship.

Table 11. Summary of Bus Policies Tested in the Alternative Fuel Environments

Run Numbers	Routes Receiving Buses	Number of Buses Added Per Route	Time Period
I3 and J3	1, 7	1	2
	5, 11		
	6, 12		
	1, 7	2	3
	3, 9		
	6, 12		
	2, 8	1	4
	3, 9		
	4, 10		

CHAPTER V

Policy Effects on Fuel Consumption

5.1 Introduction

Each of the policy alternatives described in Chapter IV was tested using the MOD3 program in the incremental mode with a no-growth situation specified. The primary measure of effectivenss was the relative change in work trip energy consumption with respect to the base case. Other evaluations were made with specific alternatives as the basis for comparison, for example, where a combination of policies was evaluated against each individual policy comprising the combination.

The total work trip energy calculation contains both the automobile and transit consumption data for an entire day's travel. Transit energy consumption is computed by MOD3 as a daily total and as such the contribution of transit energy consumption from each individual time element cannot be specified. However, this is not a major drawback in the analysis. Automobile energy consumption was reported for each individual time element and was a useful tool for the analysis of policy impacts.

For the base case, the total daily transit energy consumption was only 3 percent of the combined transit and automobile work trip energy consumption. For non-transit policies, the inclusion of the daily transit energy consumption resulted in a maximum difference of only 0.3 percent when evaluating the policy impacts on energy use. This occurred in conjunction with the staggered work hour policy that resulted in the largest percentage decrease in energy consumption. The difference was much smaller (approximately 0.1 percent) for non-transit policies, resulting in a lesser decrease in total energy consumption. Combining transit and automobile work trip energy consumption facilitated the direct comparison of transit and non-transit policies.

5.2 Staggered Work Hour Programs

The results of the staggered work hour alternatives simulated in this research can be interpreted to represent the potential of such alternatives to relieve congestion and reduce energy consumption for the city simulated. The variable work hour policies can be interpreted to represent either a staggered or a flexible work hour program, or a combination of both. The importance of the results resides in the magnitude of the shift obtained, not in the mechanism for obtaining the shift. For convenience, the policies are referred to as staggered work hours. The total energy consumption resulting from the staggered work hour policies was influenced by two primary parameters -- the total percent of the work force involved in the program and the location of the zones participating in the shift with respect to the CBD and the transit network.

5.2.1 Groups A and B: Impacts of the Number of Travelers, and Location of Zones Involved in Staggered Work Hour Programs

The results of the simulation of the staggered work hour programs on automobile work trip and daily transit energy consumption (hereafter referred to as total energy consumption) are shown in Figure 34. The results show that there is a strong relationship between the percentage of work travelers shifting away from the peak half hour period and the percentage decrease in total energy consumption. The smooth curve shown was manually fitted to the data, and represents the approximate relationship between work trip travel time shift and the potential energy savings. This relationship asymptotically approaches a 12.2 percent energy savings for work travel at the point where the temporal distribution of work travel is uniform over the length of the peak period.

The curve in Figure 34 indicates that the potential for energy savings from staggered work hour programs is much higher, for a city of the size simulated, than is indicated by the estimate made by Voorhees (1974), which was less than one percent. A 10 percent shift of work travelers away from the peak half hour resulted in a 4 percent savings in energy. A 10 percent shift can be considered a realistic goal for such a program based on the program results reported by O'Mally and Selinger (1973). In their study of the impacts of staggered work hours in downtown Manhattan it was reported that approximately 10 percent (46,000 employees) of the total CBD work force participated in a coordinated program from 113 different firms. Safavian and Mclean (1975) reported a 50 percent participation rate (35,000 employees) in a program in Ottawa, Ontario. However, all of these were federal government employees.

The data from this research also indicated that it is better from an energy standpoint to implement programs that have a dispersed area of influence rather than concentrating the effort in a small area. For example, simulation runs B1 and B5 resulted in a larger energy savings than runs A5 and A4 respectively. Runs B1 and B5 had the same total work trip shift from the peak periods as runs A5 and A4 but the shift was applied to the entire urban area rather than concentrating it in the CBD. This difference dissipates as the total base area of influence becomes larger as shown by the data points marked by the symbol "+" when compared to the other data points with the identical total percent traveler shift.

The influence of a dispersed program when compared to a more concentrated effort is more clearly shown in Figure 35. Here, the curves represent the trend of energy consumption versus percentage traveler shift for each successive ring of zones added to the program. As successive rings of zones were included in the work hour stagger, the general trend

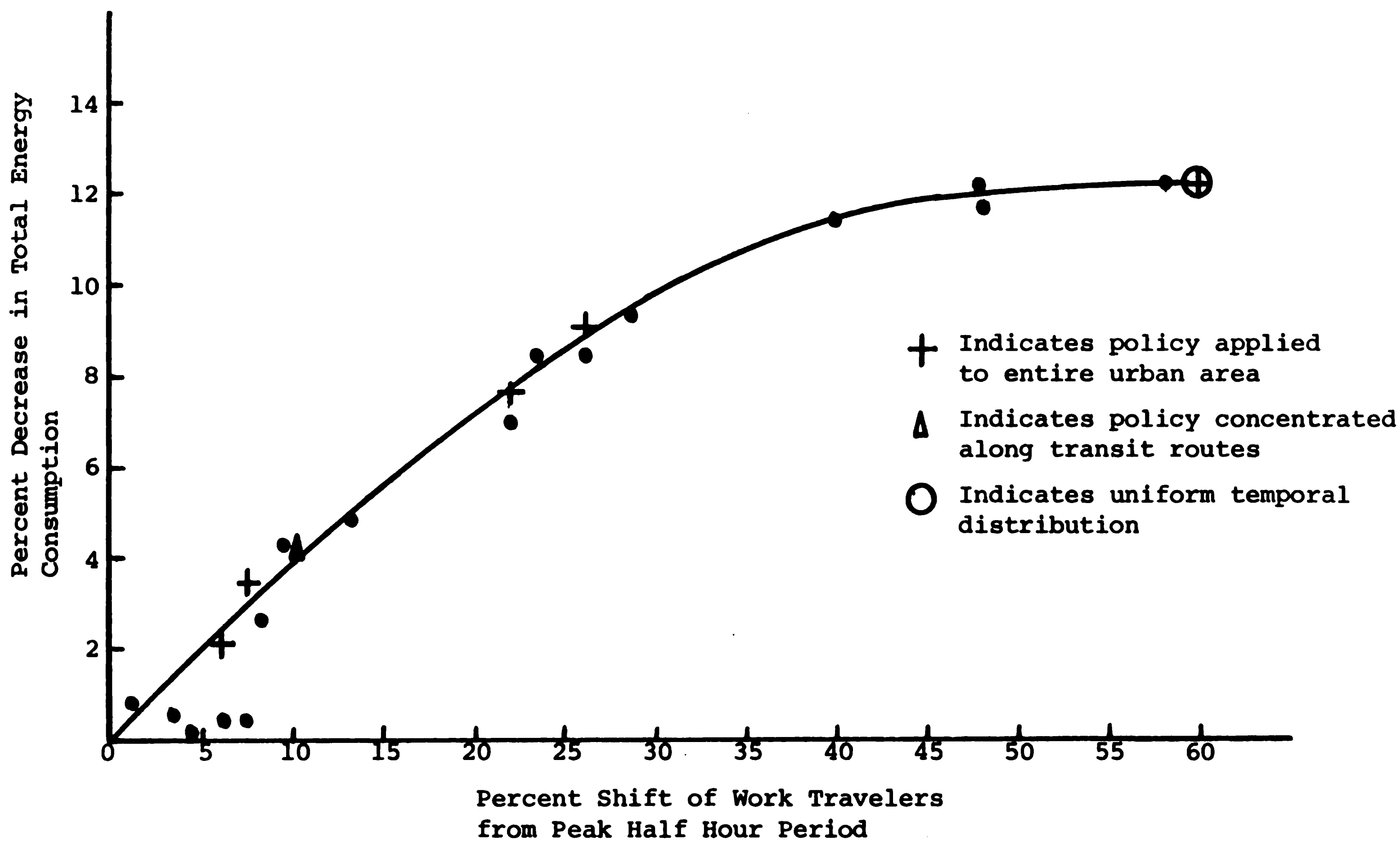


Figure 34. Impact of Variable Work Hour Policies on Total Energy Consumption.

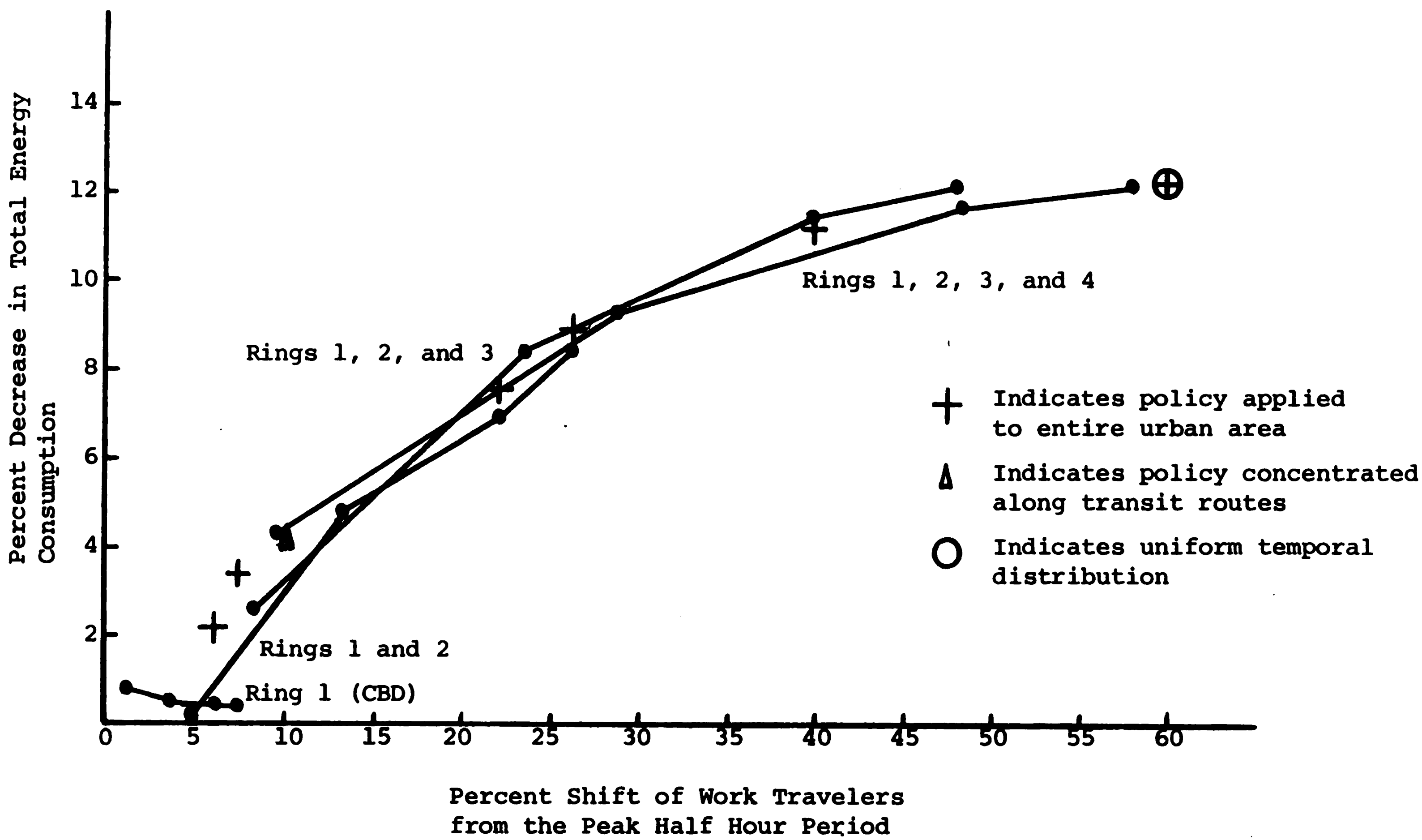


Figure 35. Impact of Variable Work Hour Policies on Total Energy Consumption by Location of the Participating Zones.

was for a greater reduction in energy use for a given percentage shift in travelers from the peak half hour. This difference became less pronounced as a larger percentage of travelers participate in the program. However, there was virtually no change in energy consumption with increased participation in the staggered work hours when the program was concentrated in the CBD (ring 1).

The anomaly of the relationship between staggered work hour participation and energy use for the CBD can best be explained by the fact that the majority of the simulated work trips to these zones were relatively short in length (generally only to the 2nd or 3rd ring) and were routed over only a few highway links. Also, the highway links within the CBD were generally uncongested. The combination of short trips and uncongested links resulted in no change in the energy consumption. However, this result is consistent with the literature which suggests that the effect of a concentrated program on congestion is lost within approximately two miles of the program location.

The variable work hour programs tested had a direct impact on highway congestion except when the policies were concentrated in the CBD zones, as shown in Figure 36. The percentage reduction in congestion resulting from the variable work hour policies increases as the program became more dispersed and included more zones. The maximum decrease in the mean network congestion, based on the HCI, was approximately 44 percent.

The relationship between highway congestion and energy consumption is shown in Figure 37. The relationship exhibits a strong linear tendency with an r^2 (the square of the correlation coefficient) value of 0.97 for the equation

$$\hat{y} = 0.20 + 0.27x \qquad (16)$$

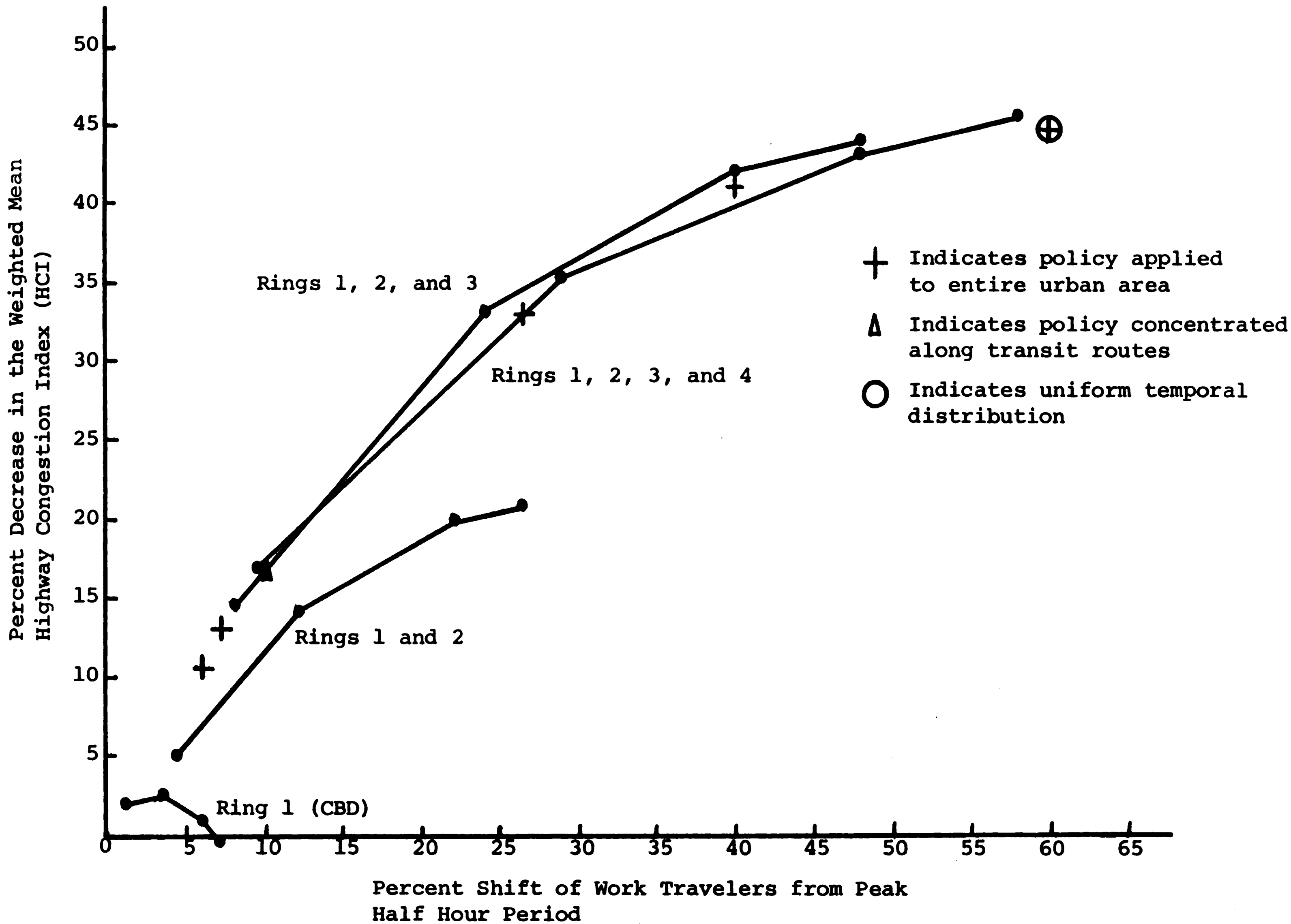


Figure 36. Impact of Variable Work Hour Policies on Highway Congestion.

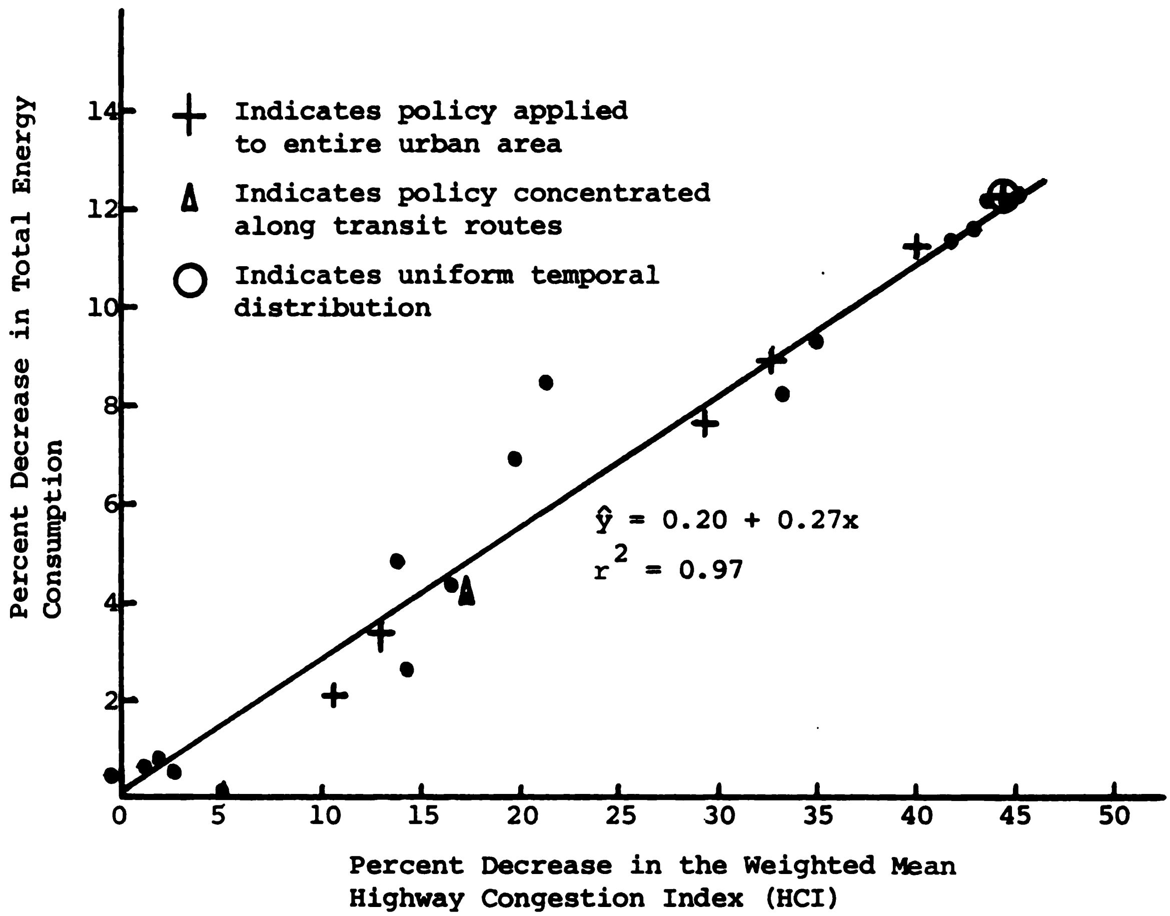


Figure 37. Relationship between the Highway Congestion Index and Total Energy Consumption for the Variable Work Hour Policies.

where

$\hat{y}$ = the estimate of the percent reduction total energy consumption, and

x = the percent decrease in the weighted mean highway congestion index (HCI).

The maximum reduction in energy consumption was approximately 12 percent for a reduction of 44 percent in the HCI.

The reduction in the HCI would have resulted in an even greater decrease in energy consumption had a mode shift not occurred as a result of the decrease in network congestion. This phenomena is shown in Figure 38 were the percentage change in work trip transit ridership is expressed as a function of the percentage reduction in the HCI for the peak period. The work trip bus ridership was reduced an average of 4 percent by an average reduction in the HCI of 22 percent. At this point, the elasticity of bus ridership to the highway congestion index is 0.18.

The relationship between the percentage change in bus ridership and the percentage change in the HCI can be expressed by the equation:

$$\hat{y} = -0.65 + 0.21x \qquad (17)$$

where

$\hat{y}$ = the percent change in bus ridership, and

x = the percent change in the weighted mean highway congestion index.

This relationship was generated using simple linear regression with all the data points shown in Figure 38. The regression resulted in a r^2 value of 0.91 indicating good linear correlation. This result indicates that a decrease in congestion due to the implementation of a staggered work hour program would have a negative impact on work trip bus ridership unless steps were taken to deter the mode shift. The possibility

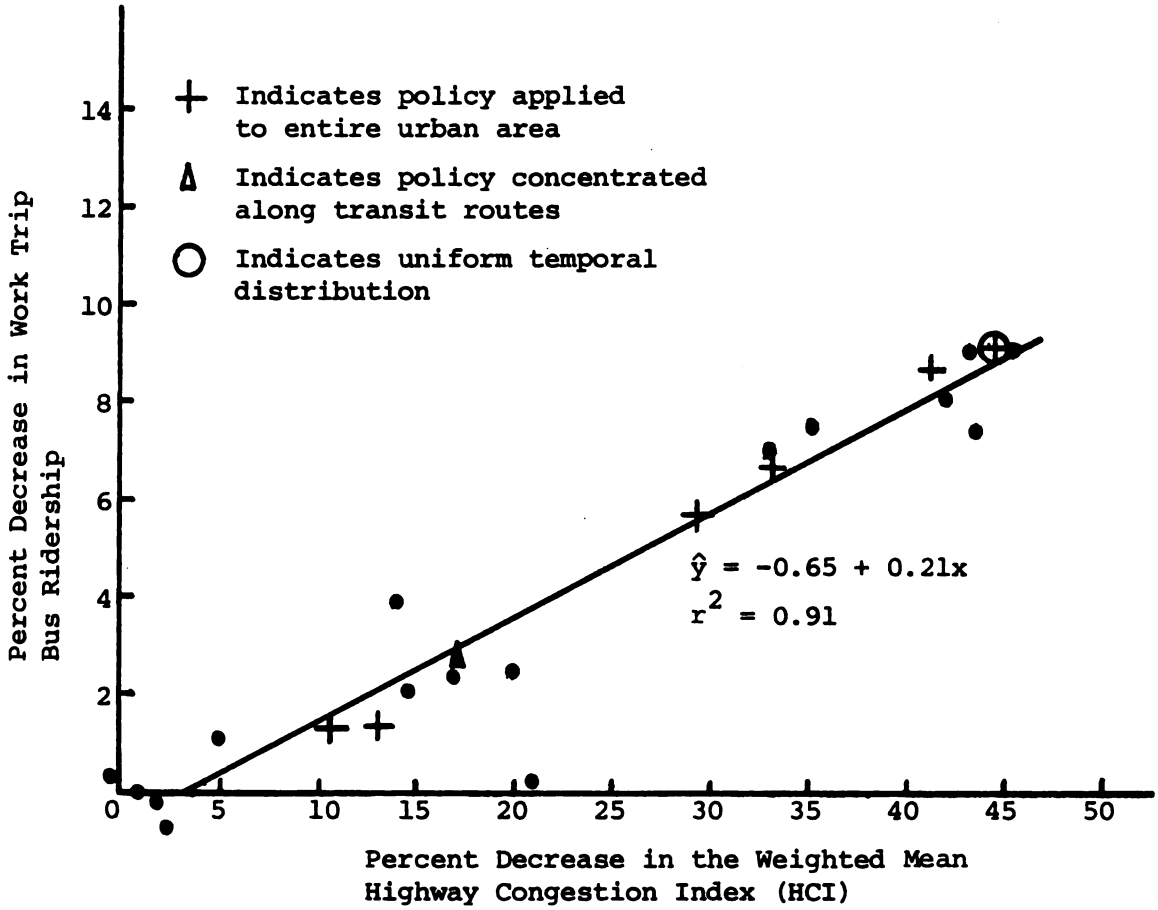


Figure 38. Relationship between the change in the Highway Congestion Index and Bus Ridership Resulting from the Variable Work Hour Policies.

still exists that during an energy shortage transit ridership would increase even with the implementation of a staggered work hour program. Under conditions of normal fuel availability this does not appear likely.

The impact of the staggered work hour programs on work trip length, time, and travel speed is described in part by Table 12 for both the automobile and transit modes. The variable work hour policies had no apparent affect on transit trips, except perhaps for trip length. The data shows that the average transit trip length was reduced by 2.2 percent, indicating that the reduction in congestion may have eliminated more of the longer transit trips.

Automobile work trips were affected by the reduction in congestion resulting from the staggered work hours. The parameters most affected by the staggered work hour policies were automobile work trip time and speed. Figure 39 shows the relationship between the percent of work traveler shift during the peak half hour period and the decrease in automobile work trip travel time. The family of curves again suggests that concentrating these programs in a small area (the CBD) is less effective than a more dispersed approach. There is a distinct advantage in reduced work trip travel time through the implementation of variable work hour programs. The amount of the travel time decrease is dependent on both the location of the program and the number of participants.

The decrease in highway congestion and the improvement in automobile work trip travel time are related as shown in Figure 40. As would be expected, the relationship shows nearly a perfect linear correlation with an r^2 value of 0.996 for the data shown. The relationship can be expressed as:

$$\hat{y} = 0.217 + 0.370x \qquad (18)$$

Table 12. Impact of Variable Work Hour Programs on Work Trip Characteristics

MODE:	AUTO		BUS	
Trip	Mean % Change	Standard Deviation	Mean % Change	Standard Deviation
Length	-0.23	1.68	-2.20	1.74
Time	-8.73	6.08	-1.48	1.10
Speed	7.87	6.13	-0.72	0.58

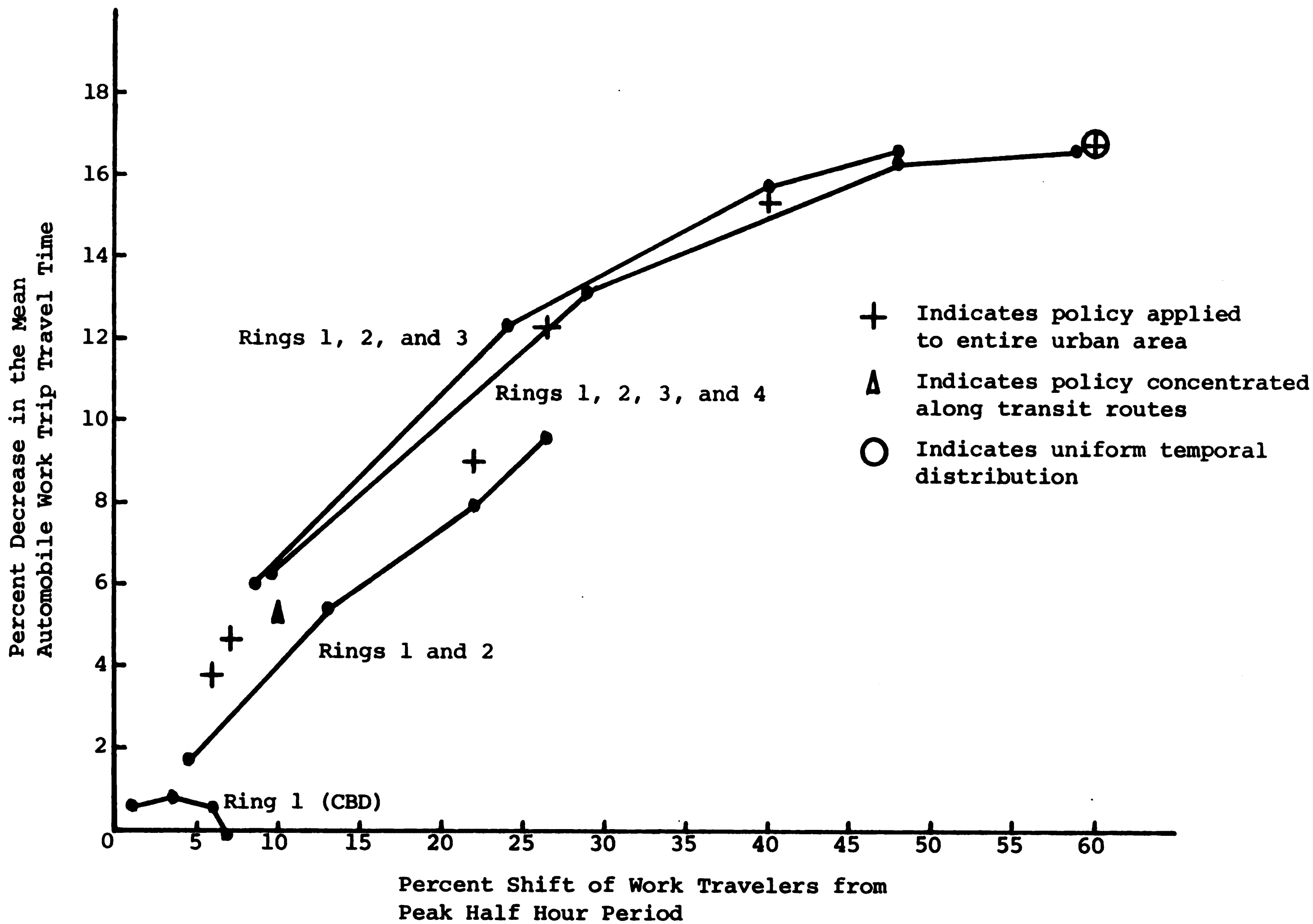


Figure 39. Impact of Variable Work Hour Policies on Automobile Work Trip Travel Time.

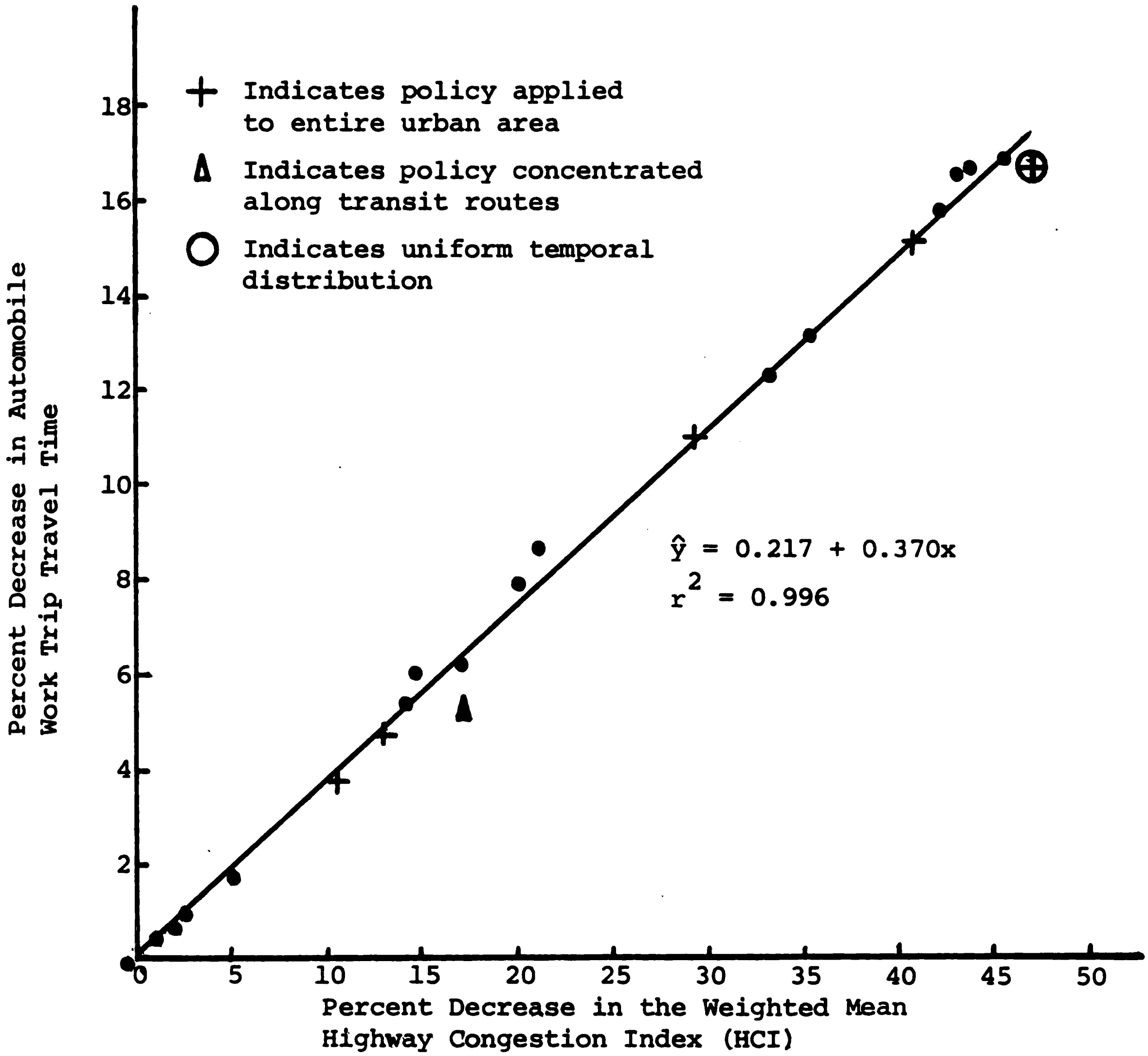


Figure 40. Relationship between Highway Congestion and Automobile Work Trip Travel Time.

where

$\hat{y}$ = percent decrease in automobile work trip travel time, and

x = percent decrease in the weighted mean highway congestion index.

The decrease in automobile work trip time results in an energy savings as shown in Figure 41.

Automobile work trip length showed only a slight decrease on the average. However, in some individual cases large changes were realized. This resulted from a redistribution of the traffic on the network (a change in the network assignment) resulting from the decreased congestion.

5.2.2 Group C: Staggering Work Hours Along Transit Corridors

Only one simulation run was performed with a staggered work hour program constructed to conform to the shape of the transit network while maintaining the base level of transit service. The results of the simulation are plotted in Figures 34 through 41 and are indicated by the symbol "Δ" for run number C1. This singular policy was not particularly different from the other staggered work hour policies in terms of its effect on energy consumption, highway congestion, or transit ridership and was designed as a basis for comparison to similar policies that combined staggered work hours with bus redistribution measures.

5.3 Groups D and E: The Transit Alternatives

Several attempts were made to reduce total energy consumption through a redistribution of the transit fleet during the peak period. The base distribution of vehicles was three per route (4.5 buses per hour). The basis for the redistribution was an evaluation of the highway network congestion patterns produced by MOD3. Initally an analysis was performed on the mean link congestion index (LCI). The LCI is defined as the ratio

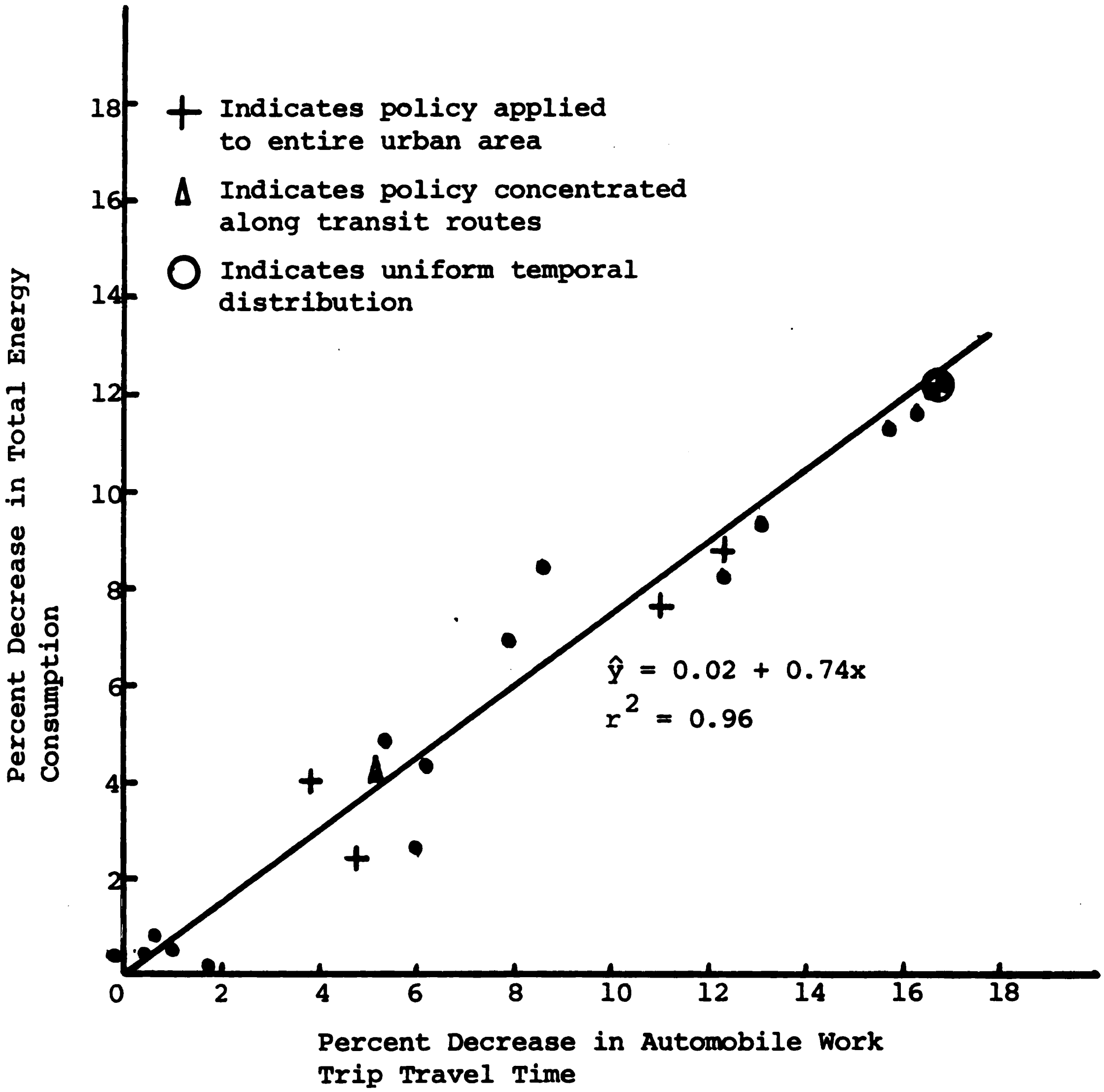


Figure 41. Relationship between Automobile Work Trip Travel Time and Total Energy Consumption.

of the actual link travel time to the free flow link travel time. The average LCI was computed for each transit route pair which taverse the same links in opposite directions. Since the mean values showed a relatively small difference (approximately 4.0 percent) between route pairs, an alternative selection procedure was used. This procedure redistributed buses to route pairs with the highest LCI on individual links. For example, for run D2 route pairs 2-8, 3-9 and 6-12 (with maximum LCI on each route ranging from 6.000 to 8.999) were assigned additional buses while route pairs 1-7, 4-10 and 4-11 (with the maximum LCI on each route ranging from 4.000 to 5.999) were assigned fewer buses during the peak period.

The overall policy structure for these runs is described in detail in Chapter IV for runs D1 through D5. In each case, the base temporal distribution of work travel was used.

The base distribution of congestion is shown as a histogram in Figure 42 for the peak half hour period with the links grouped according to their individual link congestion index. Only those links with an LCI greater than or equal to 1.5 are shown. Also shown in Figure 42 is the transit route that contains each link. This arrangement facilitates the tracing of changes in the congestion patterns as a result of the transit policies.

The results of the redistribution of transit vehicles is shown as a network summary in Table 13. The link congestion analyses similar to Figure 42 are contained in Appendix D for these runs. The histograms in Appendix D for runs D2, D3 and D5 are the same because the travel and transit distribution during the peak half hour period were identical.

The results indicate that although these policies were instrumental in reducing congestion on several of the most heavily congested links, the overall effect on network congestion was minimal, averaging only a 1.0 percent reduction in the mean highway network congestion index (HCI).

Total Links Shown: 76

Number of Interzonal Links	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999		4.000 4.499		4.500 4.999		5.000 5.499		5.500 5.999		6.000 6.499		6.500 6.999		7.000 7.499		7.500 7.999		8.000 8.499		8.500 8.999	
	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
19	167	8																												
18	160																													
17	159																													
16	149	10																												
15	148																													
14	145																													
13	144	11																												
12	137	1	147																											
11	133		139	3	164	6																								
10	130		135		152	12																								
9	125	7	128	9	118																									
8	124		123		96						129																			
7	106	8	120	11	95				165		83	7																		
6	93		104	1	75	1	103	7	141		69	10																		
5	92	5	82		63		81		110		55																			
4	90	10	67		59	3	68		76	7	53				153															
3	79		57	2	49	12	61	10	41	4	51	1			117															
2	78	8	31	7	47	5	39	9	33		45		97	4	111	1					101	6								
1	65		27	11	43		37	8	25		35		71	11	99	5	89	4	113	2	85	8	87	9			73	12	115	3

Link Congestion Index

Figure 42. Peak Half Hour Congestion Pattern for the Base Case.

LN = Link Number

R = Route Number

Table 13. Effectiveness of Transit Policies

					Percent Change from Base Case			
Run Number	Route Pairs Receiving Buses	Route Pairs Losing Buses	No. of Buses Shifted Per Route*	Time Period(s)	Auto Work Trips	Highway Congestion Index	Bus Work Trips	Total Energy
D1	2, 8 3, 9	1, 7 4, 10	1	3	0.0	0.6	0.0	-0.7
D2	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	3	-0.1	-2.2	1.5	-0.8
D3	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	1, 2, 3, 4, 5	-0.1	-2.1	1.5	-0.8
D4	2, 8 3, 9 6, 12	1, 7 } 4, 10 } 5, 11	2 (1, 7 and 4, 10) 1 (5, 11)	3	-0.2	0.9	-0.3	-0.4
D5	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	2, 3, 4	-0.1	-2.0	1.6	-1.0
E1	2, 8 3, 9 6, 12		1	2, 3, 4	-4.4	-2.9	3.3	-1.5

* The base case frequency of service was 4.5 buses per hour (3 buses per route at 13.33 minute headways).

These policies resulted in a very small reduction in automobile work trips and increased bus ridership by only 0.90 percent on the average. Total energy consumption was reduced by less than one percent.

Further evaluation of the link congestion patterns suggest at least one reason for the disappointing outcome of these policies. In most cases, the links that showed an increase in congestion were links on bus routes which lost buses to the redistribution. This indicates that transit ridership had decreased on those routes having a reduced frequency of service offsetting the increased ridership on the other routes. This hypothesis was tested by the addition of more buses to the routes that were most heavily congested without reducing the frequency on other routes.

The effect on individual link congestion of adding one vehicle to each of six of the transit routes is shown in Figure D6 (see Appendix D). The effect on fuel consumption is shown in Table 13 for run E1. The addition of these buses represents a 37.5 percent increase in bus frequency on the affected routes. This policy produced the best results of the transit-only policies. Bus work trips increased by 3.3 percent, while automobile work trips and network congestion were reduced by 4.4 percent and 2.9 percent respectively, and total energy consumption was reduced by 1.5 percent. This result indicated that the earlier redistribution policies failed to increase total transit ridership due to the lost ridership on those routes with fewer assigned bus trips. Overall, the transit policies realized considerably less improvement in energy consumption than the variable work hour programs.

The modeling structure used to determine the work travel mode choice for this research was calibrated for an environment of "normal" energy availability. Under these conditions, it would be difficult to reduce energy consumption through improvements in transit frequency alone. However, this does not rule out the possibility that a greater savings in fuel could be accomplished through transit improvements in an environment with restricted fuel availability.

5.4 Groups F, G and H: Combined Staggered Work Hour and Transit Policies

Several policy alternatives were tested in an effort to determine the combined impact of variable work hour programs and transit scheduling policies. These alternatives were in three distinct groups and included policies which combined staggered work hours with transit redistribution, policies which combined corridor transit redistribution with the corridor application of staggered work hours, and a policy which combined the corridor application for staggered work hours with the coordinated addition of buses.

5.4.1 Group F: Staggered Work Hours with Transit Redistribution

Six alternatives were tested to determine the combined impact of the staggered work hour programs and the transit redistribution policies. In each case a staggered work hour policy from Group A was selected such that 10 and 30 percent of the peak half hour travelers were staggered for each of rings 1, 2 and 3 of the urban area (runs A2-A3, A6-A7 and A10-A11). The congestion patterns for runs A2, A3 and A6 (see Appendix D) were similar to that of the base case and therefore the transit redistribution policy used in run D5 was also used with these staggered work hour policies. This formed the basis for runs F1, F2 and F3. These policies are summarized in Table 14. The congestion patterns for runs A7, A10 and A11 (see Appendix D) indicated that slightly different transit redistributions would be more suitable for cases F4, F5 and F6. These distributions were based on the maximum LCI described earlier, and the policies are summarized in Table 14.

Table 14. Summary of Staggered Work Hour and Transit Redistribution Policies (Group F)

Run Number	Routes Receiving Buses	Routes Losing Buses	Number of Buses Shifted Per Route	Time Periods	Percent Change in Travelers During Peak Half Hour Period
(D5)*	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	2, 3, 4	0.0
F1	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	2, 3, 4	-1.2
F2	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	2, 3, 4	-3.6
F3	2, 8 3, 9 6, 12	1, 7 4, 10 5, 11	1	2, 3, 4	-4.4
F4	3, 9 4, 10 12	1, 2 5, 11 6	1	2, 3, 4	-13.2
F5	3, 9 6, 12	1, 7 5, 11	1	2, 3, 4	-8.0
F6	3, 9 6, 12	1, 7 4, 10	1	2, 3, 4	-24.0

* Run D5 is a transit redistribution policy related to runs F1, F2 and F3.

The results of the runs for Group F are shown in Table 15 along with the related staggered work hour and transit policy runs. In general, the results indicate that the combined policies of transit redistribution and staggered work hours were no more effective at reducing total energy than the individual policies. Runs F1 and F2 produced combined results that were less effective than both of the related individual policy simulations. This could be due in part to the fact that both runs F1 and F2 concentrated the staggered work hour program in the CBD. The work trips originating in the CBD were of a relatively short length and therefore contributed only a small portion of the total energy use. The transit policy appeared to have a negative impact because the decrease in ridership on the routes that lost buses was not counterbalanced by an increased in ridership on the routes that experienced an increase in frequency.

Run F3 showed a greater impact on energy than its related staggered work hour policy run A6. However, it also showed a slightly lower overall impact on energy than its related transit policy run D5. The results are similar for runs F4 and F6 where in each case there was a slightly lower energy impact than for the related staggered work hour policy. In only one other case (run F5) was the combined impact on energy consumption greater than the individual impact of the staggered work hour program.

Table 16 shows the effect of these combined policies on the work trip characteristics of length, travel time, and speed along with the same information for the related variable work-hour-only or transit-only policy. A comparison of the combined policy runs to their related individual policy runs showed no improvement in these trip characteristics as a result of the combined policy.

Table 15. Effectiveness of Staggered Work Hours Combined with Transit Redistribution (Group F)

	Percent Change from Base Case				
Run Number	Travelers During Peak Half Hour Period	Auto Work Trips	Highway Congestion Index	Bus Work Trips	Total Energy
F1	- 1.2	0.0	0.2	0.6	-0.3
(A2)*	- 1.2	0.0	0.6	0.0	-0.7
(D5)**	0.0	-0.1	- 2.0	1.6	-1.0
F2	- 3.6	-0.1	- 3.6	0.5	-0.4
(A6)	- 3.6	-0.2	- 2.4	0.7	-0.5
F3	- 4.4	0.2	- 6.2	-0.8	-0.9
(A6)	- 4.4	0.2	- 5.0	-1.1	-0.1
F4	-13.2	0.9	-11.0	-3.6	-3.4
(A7)	-13.2	0.9	-14.1	-3.9	-4.8
F5	- 8.0	0.6	-14.0	-2.5	-3.3
(A10)	- 8.0	0.5	-14.5	-2.0	-2.6
F6	-24.0	1.5	-32.8	-6.9	-7.9
(A11)	-24.0	1.5	-33.1	-7.0	-8.2

* Number in parenthesis indicates related staggered work hour policy.

** Run D5 is a transit redistribution policy related to runs F1, F2 and F3.

Table 16. Impact of Variable Work Hour and Transit Redistributions on Work Trip Characteristics (Group F)

Run Number	Percent Change from Base Case					
	Mean Auto Work Trip			Mean Transit Work Trip		
	Length	Time	Speed	Length	Time	Speed
F1	0.5	0.3	-0.2	-0.8	0.0	-0.8
(A2)*	0.0	- 0.6	0.4	0.2	0.1	0.1
(D5)**	0.3	- 0.7	3.4	-0.4	0.2	-0.1
F2	-0.1	- 0.9	0.6	-0.5	0.2	-0.5
(A3)	0.0	- 0.9	0.6	0.6	0.3	0.2
F3	0.1	- 2.0	1.5	-0.5	-0.2	-0.6
(A6)	0.6	- 1.7	1.9	0.1	-0.2	0.1
F4	-0.1	- 4.3	3.2	-1.2	-1.5	0.4
(A7)	-5.8	- 5.4	3.4	-1.4	-1.1	-0.5
F5	0.4	- 5.0	4.2	-2.1	-1.1	-0.8
(A10)	0.5	- 6.0	4.6	-1.1	-1.0	-0.4
F6	1.6	-12.2	11.6	-3.4	-2.1	-1.4
(A11)	0.8	-12.3	11.5	-3.3	-2.2	-1.2

* Number in parenthesis indicates related staggered work hour policy.

** Run D5 is a transit redistribution policy related to runs F1, F2 and F3.

5.4.2 Group G: Corridor Staggered Work Hours and Bus Redistribution Policies

Group G policies considered the combined effect of a staggered work hour policy oriented along the north-south and east-west transit corridors and a coordinated transit redistribution policy. In this group, travelers originating from zones along the east-west transit corridor were staggered from time period 3 to time period 2 (see Figure 32) and peak half hour travelers from zones along the north-south transit corridor were staggered to time period 4 (see Figure 33). The transit vehicles were redistributed to service the altered temporal travel distribution. These policies are summarized in Table 17.

The results for these policy alternatives are shown in Table 18 along with the results for the related staggered work-hour-only alternative (run C1). Here again, the combined policies showed no measurable improvement in bus ridership even when travel was shifted to match the increase in bus frequency. The decrease in ridership in the corridor with a lower frequency of service appeared to have offset any ridership increases in the increased service corridor.

Table 19 reveals that the combined policy alternatives caused a negligible improvement in the transit work trip travel time, while resulting in a slight improvement over the individual policy alternative for automobile work trip travel time.

5.4.3 Group H: Corridor Staggered Work Hours and Bus Addition Policies

To more fully examine the relationship between transit supply, staggered work hours, and energy consumption a combined policy of corridor staggered work hours and the addition of transit vehicles was tested. This policy employed the work trip stagger of run C1 and added 6 buses

Table 17. Summary of Corridor Staggered Work Hour and Transit Redistribution Policies (Group G)

Run Number	Routes Receiving Buses	Routes Losing Buses	Number of Bus Shifted Per Route	Time Period	Percent Change in Travelers During Peak Half Hour Period
(C1)*					-10.0
G1	1, 7 5, 11 6, 12	2, 8 3, 9 4, 10	2	2	-10.0
	2, 8 3, 9 4, 10	1, 7 5, 11 6, 12	2	4	
G2	1, 7 5, 11 6, 12	2, 8 3, 9 4, 10	1	2	-10.0
	2, 8 3, 9 4, 10	1, 7 5, 11 6, 12	1	4	

* Run C1 is a corridor staggered work hour policy related to runs G1 and G2.

Table 18. Effectiveness of Corridor Staggered Work Hour and Transit Redistribution Policies (Group G)

	Percent Change from Base Case				
Run Number	Travelers During Peak Half Hour Period	Auto Work Trips	Highway Congestion Index	Bus Work Trips	Total Energy
(C1)*	-10.0	0.6	-17.3	-2.6	-4.2
G1	-10.0	0.7	-17.1	-2.9	-4.1
G2	-10.0	0.6	-17.3	-2.3	-4.1

* Run C1 is a corridor staggered work hour policy related to runs G1 and G2.

Table 19. Impact of Corridor Variable Work Hour and Transit Redistributions on Work Trip Characteristics (Group G)

	Percent Change from Base Case					
	Mean Auto Work Trip			Mean Transit Work Trip		
Run Number	Length	Travel Time	Speed	Length	Travel Time	Speed
(C1)*	0.1	-5.2	3.6	-1.7	-1.1	-0.7
G1	0.2	-6.1	5.0	-0.9	-0.2	-0.4
G2	0.2	-6.3	4,8	-1.6	-0.9	-0.5

* Run C1 is the corridor staggered work hour policy related to runs G1 and G2.

during time periods 2 and 4 to the corridor containing the staggered work trips. The additional buses were shifted during the peak half hour (time period 3) to match the distribution used in run E1. In essence, six buses were added to the fleet during time periods 2, 3 and 4 and distributed such that they would appear to contribute the most benefit to energy reduction. This policy is summarized in Table 20.

The results for run H1 are shown in Table 21 along with the results of related staggered work hour policy run C1 and transit bus addition policy run E1. In this case, the transit supply policy did not change the total energy requirements from the related run C1 even though there was a slight improvement in transit ridership. When compared to run C1, the transit ridership in run H1 had fallen off sharply as a result of the stagger of travelers away from the peak half hour period. Under the conditions simulated, the decrease in transit ridership resulting from the staggered work hour program could not be offset by the simulated change in transit supply.

The information in Table 22 suggests that the combined policy alternative (run H1) showed only a slight improvement over the related transit alternative (run E1) in transit work trip travel time, and was less effective in reducing automobile trip travel time. Overall, the combined policy showed more potential to reduce total energy consumption, based on the reduction in congestion and travel time, than the related staggered work hour alternative (run C1). However, the results were nearly identical.

5.5 Policy Effectiveness in the Alternative Fuel Environments

The alternative fuel environments, as described in section 4.5, were used to determine if the fuel environment could affect the impact of the policies tested. This was accomplished by increasing the price of gasoline

Table 20. Summary of Corridor Staggered Work Hour and Transit Addition Policy (Group H)

Run Number	Routes Receiving Buses	Number of Buses Added Per Route	Time Period(s)	Percent Change in Travelers During Peak Half Hour Period
(C1)*				-10.0
(E1)**	2, 8 3, 9 6, 12	1	2, 3, 4	0.0
H1	1, 7 5, 11 6, 12	1	2	
	2, 8 3, 9 6, 12	1	3	-10.0
	2, 8 3, 9 4, 10	1	4	

* Run C1 is the corridor staggered work hour policy related to run H1.

** Run E1 is the corridor transit addition policy related to run H1.

Table 21. Effectiveness of Corridor Staggered Work Hour and Transit Addition Policy (Group H)

	Percent Change from Base Case				
Run Number	Travelers During Peak Half Hour Period	Auto Work Trips	Highway Congestion Index	Bus Work Trips	Total Energy
(C1)*	-10.0	0.6	-17.3	-2.6	-4.2
(E1)**	0.0	-4.4	- 2.9	3.3	-1.5
H1	-10.0	0.3	-18.3	-0.8	-4.1

* Run C1 is the corridor staggered work hour policy related to run H1.

** Run E1 is the corridor transit addition policy related to run H1.

Table 22. Impact of Corridor Variable Work Hour and Transit Addition on Work Trip Characteristics (Group H)

	Percent Change from Base Case					
	Mean Auto Work Trip			Mean Transit Work Trip		
Run Number	Length	Travel Time	Speed	Length	Travel Time	Speed
(C1)*	0.1	- 5.2	3.6	-1.7	-1.1	-0.7
(E1)**	0.2	-14.8	11.7	1.2	-1.6	3.1
H1	0.2	- 6.7	5.5	-0.9	-2.7	4.3

* Run C1 is the corridor staggered work hour policy related to run H1.

** Run E1 is the transit addition policy related to run H1.

to $3.00 per gallon (Group I), and then, in addition, decreasing the automobile/transit differential travel time coefficient by 50 percent in the mode choice relationship. Complete policy descriptions are found in Tables 10 and 11. Corridor staggered work hours, and a combined corridor staggered work hour and bus addition policy were tested using MOD3. The results are shown in Tables 23 and 24.

The results indicated that the effectiveness of a staggered work hour policy, or the combined staggered work hour and bus addition policy, may be dependent on the existing transportation/fuel environment. The total fuel savings resulting from these policies was clearly greater in the environment of higher fuel prices than in the base case. However, the fuel savings resulting from the policies tested was less in the higher cost/limited availability environment than in the fuel environment of the base case. The additional energy savings resulting from the work trip stagger was only 2.9 percent and 1.0 percent for Group I and Group J respectively, while the energy savings amounted to 4.2 percent in the base fuel environment (see run C1 Table 23). The addition of buses with the staggered work hour policy resulted in an energy savings of 3.0 percent and 0.8 percent for Group I and Group J respectively, while bus addition reduced energy consumption by 4.1 percent in the base energy environment (see run H1 Table 23). This indicated that the majority of the fuel savings was a result of the fuel environment and not the TSM policies tested. If large numbers of travelers were diverted to transit because of higher fuel costs or limited fuel availability, the TSM policies tested would appear to be of little additional benefit in reducing energy consumption.

However, an important point remains to be considered when interpreting these results. That is, the analysis assumes that all of the additional transit passengers could be carried by the transit system. The

Table 23. Summary of Policy Impacts in the Alternative Fuel Environments

Run Number	Percent Change from Base Case: Travelers During Peak Half Hour Period	Auto Work Trips	Highway Congestion Index	Bus Work Trips	Total Energy	TSM Policy % Increase in Energy Savings
(C1)*	-10.0	0.6	-17.3	-2.6	- 4.2	4.2
I1	0.0	-12.9	-21.5	60.0	- 5.2	
I2	-10.0	-12.1	-31.8	59.6	- 8.1	2.9
I3	-10.0	-12.6	-32.2	62.6	- 8.2	3.0
(H1)*	-10.0	0.3	-18.3	-0.8	- 4.1	4.1
J1	0.0	-15.8	-25.7	78.0	-10.1	
J2	-10.0	-14.7	-32.0	72.7	-11.1	1.0
J3	-10.0	-15.1	-32.3	74.7	-10.9	0.8

* Run C1 and H1 are the related corridor staggered work hour and combined transit addition runs with the base case fuel environment.

Table 24. Summary of Policy Impacts on Trip Characteristics in the Alternative Fuel Environments

Run Number	Percent Change from Base Case: Mean Auto Work Trip Length	Time	Speed	Mean Bus Work Trip Length	Time	Speed
I1	-1.9	9.9	-13.1	41.4	18.8	19.1
I2	-1.5	6.8	-10.6	39.8	18.0	18.6
I3	-1.7	6.0	-10.2	39.5	15.6	20.9
J1	-1.9	7.0	-10.9	47.7	22.6	20.6
J2	-1.9	5.2	- 9.8	46.6	21.9	20.5
J3	-1.6	5.1	- 9.2	45.7	19.1	22.6

existing modeling system was not capable of evaluating transit passenger demand and route capacity. Under the extreme conditions simulated, it is unlikely that the large increase in transit passenger demand could be accommodated by the existing transit system. Actual demand would be detered by limited capacity. Under these conditions, spreading peak period travel demand would improve the effectiveness of transit supply. Variable work hours may be a necessity under such conditions along with an increase in transit system capacity. The overall effect would be to divert fewer riders back to the automobile than was indicated by the results and hence the TSM policies would have a larger incremental effect than shown.

CHAPTER VI

Summary and Conclusions

6.1 The Policy Alternatives

For the activity pattern simulated by this research it has been shown that variable work hour programs (staggered and flexible) could reduce network congestion and hence reduce automobile work trip energy consumption. The reduction in total energy consumption (automobile work trip plus daily transit) could be a maximum of approximately 12 percent with a uniform temporal distribution of work trips. A more realistic goal of a 4 percent reduction in total energy could be achieved with only a 10 percent shift in work travelers away from the peak period.

However, the effectiveness of a variable work hour program was also dependent on the location of the program. It has been shown that concentrating the program in a small area, such as the CBD, was less effective (approximately 85 percent) in reducing energy consumption than a program involving the same number of travelers who work at locations that were evenly dispersed over the urban area. This result is consistent with other research efforts (Tannir (1977), Safavian and Mclean (1975)) which indicated that the effectiveness of a staggered work hour program was lost within approximately two miles of the work place.

Under the conditions simulated, variable work hour programs have been shown to have a negative impact on work trip transit ridership. The decrease in congestion during the peak half hour period resulted in a proportional decrease in automobile travel time, which in turn resulted in a mode shift to the automobile. A 10 percent shift in travelers from the peak half hour has been shown to result in a 12 to 17 percent change in the highway congestion index, depending on the location of the variable work hour program. This resulted in a 2 to 3 percent decrease in work trip bus ridership. The maximum decrease in transit ridership was approximately 9 percent resulting from the uniform temporal distribution of work travel. Staggered work policies acted against transit incentives under conditions of "normal" fuel availability.

Transit redistribution policies did not significantly reduce energy consumption. Increased transit ridership on routes given supply priority failed to offset ridership losses on routes sacrificing buses for transit redistribution.

The addition of six buses to the transit fleet (one bus allocated to each of six routes yielding a transit frequency increase in service from 4.5 to 6.0 buses per hour) resulted in a modest 3.3 percent increase in transit ridership and a 1.5 percent reduction in total energy consumption. However, when this policy was coordinated with a staggered work hour program, bus ridership decreased slightly compared to the base case, and energy consumption was not improved beyond that of the staggered work-hour-only alternative.

The combined effects of variable work hours and transit scheduling did not generally improve the energy consumption beyond the level of the variable work-hour-only policy. The policies tested did not appear to coordinate well under the conditions simulated. The total energy consumption was influenced only by changes in the demand patterns. Increased transit ridership on routes given supply priority failed to offset losses on routes sacrificing buses for transit redistribution.

One reason for the absence of response to changes in the supply parameters may be the design of the base case. The urban area, the travel patterns, and the structure of the transit and highway systems were all nearly symmetric. Although some transit routes did exhibit higher levels of link congestion than others, there were no clearly dominant congestion patterns or transit demand patterns that could be influenced by a redistribution of the transit fleet.

The conditions simulated resulted in a mean transit work trip travel time approximately three times longer than that for automobile work trips. This large differential between transit and automobile travel time would certainly result in only minor changes in mode choice unless major reductions in transit travel time resulted from the supply changes. This did not occur for the transit policies tested.

The possibility exists that extraneous environmental changes could result in a mode shift to transit regardless of the travel time differential. This appears to have been the case during the oil embargo of 1973-1974 when limited fuel availability caused a substantial, but temporary, mode shift in many urban areas. Under a simulated condition of higher fuel price and limited availability, transit ridership was shown to increase dramatically. With this prevailing fuel environment, the transit supply and staggered work hour policies were found to be less effective in reducing total fuel consumption than they were in the base case fuel environment. A large fuel savings was evident as a result of the increased cost (direct and indirect) of obtaining gasoline. However, the large increase in transit ridership could only be accomodated through increased transit supply and a coordinated system of demand management such as a staggered work hour system. This would result in a greater reduction in fuel consumption from the policies tested than was indicated by this research. Limitations in the modeling technique prevented the proper evaluation of the policy impacts in the alternative fuel environments.

6.2 Research Limitations

This research study had several limitations which may restrict the application of the results. The limitations stem primarily from the simulation technique and its scope of application.

Transit trips were not assigned to routes, nor was route capacity a consideration in determining transit ridership. This becomes a factor when simulating a condition where unusually large numbers of transit trips are generated. The transit fuel consumption algorithm did not explicitly consider the number of transit stops per mile, nor the effect of highway congestion on transit speed. These considerations could alter the work trip mode choice, although the direction of this impact is unknown.

Overall limitations of this research resulted from the scope of its application. A hypothetical urban structure was utilized for the simulation. The modeling system has not as yet been sufficiently tested on an actual urban area, and it remains to be determined whether or not the modeling system generates a reasonable picture of a real city. The shape and size of the area simulated may also have had an impact on the policy effectiveness. This possibility was not investigated by this research. Whether or not the policies tested would be more or less effective for a larger urban area, or in an area with a different spatial distribution of population and employment, is unknown.

The relationship between the policy effectiveness and alternative transportation infrastructures also remains to be investigated. Changes in the highway network structure or the addition of expressways may alter policy effectiveness. This may also be true for alterations in the transit network structure, such as changes in route configuration or the addition of a rapid transit system.

Planning for energy contingencies is a complex process. The evaluation of many policy alternatives is necessary for each individual urban area. The results of this research indicated that staggered or flexible work hour programs could be a valuable tool in reducing work trip energy demand, and should be given strong consideration as an operationally inexpensive method of reducing gasoline consumption.

The high potential for energy savings through implementation of variable work hours indicated by this study suggests that further research be done to expand on these results. This should be done with the objective of answering the questions raised by the limitations of the research, to further expand the modeling system, and to test other TSM policy alternatives individually and in combination.

APPENDIX A

APPENDIX A

Documentation of MOD3 Program Changes for this Research

A.1 Program Changes and Documentation

A complete program listing and user's manual for MOD3 are contained in the work by Peskin (1977). The documentation given here indicates the changes to MOD3 required to duplicate this research effort. All of the line numbers indicated with Fortran statements refer to the program listing given by Peskin (1977). Every effort has been made to insure that the documentation of the program revisions is consistent with the user's manual supplied by Peskin.

Table A1 shows the revised input data sequence required to execute the modified version of MOD3. Only those variables added to the input sequence through modifications for this research will be detailed here. The description of the additional input variables is given in Table A2.

The following additions to the Fortran coding for MOD3 should be made where indicated by the line numbers specified. These statements allow the program to operate while surpressing the incremental layer of growth. This allows for "short-term" policy analysis.

Fortran Statement	Line No.
Read 10, IRUN, BASERN, NOGROW	250
BE(J) = BASIC(J)*ESUB	9350
IF(NOGROW.EQ.YES) BE(J) = 0.0	9350.1
1250 CONTINUE	9350.2
IF(NOGROW.EQ.YES) Y(I) = 0.0	10440.1
IF(XPOP2.EQ.0.0) GO TO 1675	12700.1
GO TO 1679	12710.1
1675 CONTINUE	12710.2
PERC = 1.0	12710.3
1679 CONTINUE	12710.4

In addition to these changes the variable NOGROW must be added to COMMON block in the program MAIN and all subroutines.

Table A1. Revised Data Input Sequence

Run Type: Base	Run Type: Incremental	Run Type: Auto Only	Run Type: Auto & Transit	DESCRIPTION	Number of Cards
X	X	X	X	IRUN, BASERN, NOGROW	1
X	X	X	X	KOMMNT	1
X	X	X	X	CODE, N, NARC, NIT2, IFIB, FLAG, NDUM, FLAG4	1
X	X		X	VAR1, VAR2, VAR3, VAR4, VAR5	1
X	X		X	VAR6, VAR7, VAR8, VAR9, VAR10	1
X	X		X	VAR11, VAR12, VAR13, VAR14, VAR15	1
X	X	X	X	WKINZN(30,5)	20
X	X	X	X	HMWRK	1
X	X	X	X	VALUE(5)	1
X	X	X	X	AUTO(40)	5
X	X	X	X	BTUPER	1
X	X	X	X	PRICE, OCC(5), OWNRSH	1
X	X	X	X	TRAFIK	1
X	X	X	X	I, J, AA(i), BB(i), CC(i), Z (Highway Network)	NARC
X	X	X	X	FIXD, FIXSP	1
X	X	X	X	PARK(N)	N/8
X	X	X	X	PRKTM	1
X	X	X	X	WLKTM	1
X	X	X	X	PKRATE	1
X	X	X	X	NR	1

Table A1. (continued)

Run Type

Base	Incremental	Auto Only	Auto & Transit	DESCRIPTION	Number of Cards
X	X		X	FR(NR)	NR/8
X	X		X	FRDAY(NR)	NR/8
X	X		X	TRANST(6)	1
X	X		X	WALK(N)	N/8
X	X		X	WAITWT, WALKWT, WPLS	1
X	X		X	RANDOM(N)	N/8
X	X		X	FARE, TFARE	1
X	X		X	I, J, TIME, DIST, IRTE, Z (Transit Network)	varies
X		X	X	F(200,5)	125
X	X	X	X	ICOST, BASE	1
X	X	X	X	ALPH	1
X	X	X	X	BASIC(N)	N/8
X	X	X	X	INCR(6)	1
X	X	X	X	CAPX	1
X	X	X	X	BETA(2)	1
X	X	X	X	GAM(N,4)	4 x N/8
X		X	X	LA(N)	N/8
X	X	X	X	DEN(N)	N/8
X	X	X	X	S(N,2)	2 x N/8
X	X	X	X	FS(N,2)	2 x N/8
X	X	X	X	FSPOP(N)	N/8

Table A1. (continued)

Run Type: Base	Incremental	Auto Only	Auto & Transit	DESCRIPTION	Number of Cards
X	X	X	X	FG(N)	N/8
X	X	X	X	G(N,3)	3 x N/8
X	X	X	X	XCOORD(N), YCOORD(N)	N
*	X	X	X	F(200,5)	125
*	X	X	X	LA(N)	N/8
*	X	X	X	BASESV(N,20)	2 x N/8
*	X	X	X	BASEPO(N)	N/8
*	X	X	X	BASEBE(N)	N/8
*	X	X	X	BASERT(N)	N/8
*	X	X	X	B(N,N) (Base work trip matrix)	N x N/8
	X	X	X	NOFACTS	1

* Note: These seven data variables are transferred to the incremental run from the base run as a PUNCH file.

Table A2. Description of Additional Input Variables for the Adapted Version of MOD3.

FACT(NOFACTS) (10F6.4) A vector of factors between 0 and 1 applied to the origin zone of the work trip matrix. Up to five different factors are possible, i.e., NOFACTS can be any value between 2 and 5. These factors are used to proportion the total work trips entering the highway network from a specified zone during a specified time element (used only for short-term policy testing of variable work hour programs).

FACT1 (F6.4) This variable is used when only a single factor is to be applied to all zones to proportion the number of work trips entering the highway network. This variable can be set at any value between 0 and 1. This variable is usually used to test variable work hour programs.

IZONES(20, NOFACTS) (40I2) An array containing the zone numbers that each individual factor FACT(NOFACTS) will be applied to when proportioning the work trip for testing variable work hour programs (up to 20 zones per factor FACT). Specified only when NOFACTS is greater than one.

NOFACTS (I1) The number of factors to be applied to proportion the work trip matrix when testing variable work hour alternatives. Up to five factors can be specified, however, 0 must be specified if this option is not to be used. NOFACTS should only be specified other than zero when NOGROW . EQ . YES (0).

NOGROW (I10) A Flag. When NOGROW . EQ . YES (0), a no-growth condition is indicated and all future growth is supressed in the incremental run. This allows for the short-term testing of policy alternatives. When NOGROW · EQ · NO (1). The program will generate growth in the incremental run as originally written.

NOZONES(NOFACTS) A vector containing the number of zones each factor FACT(NOFACTS) will be applied to when proportioning the work trip matrix for the testing of variable work hour programs. Used only when NOFACTS is greater than one.

The program block in Table A3 should be inserted between lines 5870 and 5880. Subroutine ZONEWT (Table A4) should also be added to MOD3. These changes allow for the simulation of variable work hour programs.

Program block from card 5870.01 to 5870.25: Factor Work Trip Matrix for simulation of Variable Work Hour Programs. Developed as an adaptation to the original MOD3 program.

EXTERNALS USED: ZONEWT

INPUT:

B(N,N)	work trip matrix from base run
NOFACTS	number of factors to be applied to work trip matrix
FACT(NOFACTS)	a vector of the factors to be applied to the work trip matrix (NOFACTS > 1)
FACT1	a single factor to be applied to the work trip matrix (NOFACTS = 1)
IZONES(20,NOFACTS)	vector of zone numbers that each factor will be applied to

OUTPUT:

IBIG	largest number of zones any one factor will be applied to
B(N,N)	factored work trip matrix

ALGORITHM:

This program block factors the work trip matrix for the simulation of variable work hour programs. Up to five different factors can be applied to the work trip matrix to proportion the number of trips to be assigned to the transportion network. Each factor may be applied to as many as 20 zones, or a single factor can be applied to the entire work trip matrix (see Section A.2 Testing Variable Work Hour Programs). A schematic diagram of the altorithm is shown in Figure A1.

Table A3. Program MAIN Changes for Simulating Staggered Work Hours

```
C    READ IN NUMBER OF FACTORS TO BE APPLIED TO WORK MATRIX
      READ 1010,NOFACTS
1010  FORMAT(I1)
      IF(FLAG.EQ.1) PRINT 1015,NOFACTS
1015  FORMAT(*0 NUMBER OF FACTORS TO BE APPLIED TO WORK MATRIX: *
     +,I1)
      IF(NOFACTS.EQ.0) GO TO 1080
      IF(NOFACTS.EQ.1) GO TO 1040
C    READ IN NUMBER OF ZONES EACH FACTOR WILL BE APPLIED TO
      READ 1020,(NOZONES(I),I=1,NOFACTS)
1020  FORMAT(10I2)
      IF(FLAG.EQ.1) PRINT 1025, (NOZONES(I),I=1,NOFACTS)
1025  FORMAT(*0 NUMBER OF ZONES PER FACTOR: *,10(I2,2X))
C    FIND LARGEST NUMBER OF ZONES ANY ONE FACTOR WILL BE APPLIED TO
      IBIG=0
      DO 1030 I=1,NOFACTS
      IF(NOZONES(I).GT.IBIG) IBIG=NOZONES(I)
1030  CONTINUE
      CALL ZONEWT(IZONES,FACT,IBIG,NOFACTS)
      GO TO 1080
1040  CONTINUE
C    READ IN FACTOR TO BE APPLIED TO ENTIRE MATRIX
      READ 1050,FACT1
1050  FORMAT(F4.2)
      IF(FLAG.EQ.1) PRINT 1055,FACT1
```

Table A4. Subroutine ZONEWT

```
C*************************************************************
C
C      THIS SUBROUTINE READS IN AT LEAST TWO DIFFERENT
C      FACTORS TO MULTIPLY SPECIFIC ZONES OF THE WORK
C      TRIP MATRIX BY. THIS SUBROUTINE READS IN THE
C      ZONE NUMBERS TO APPLY THE FACTORS TO AND
C      PERFORMS THE MULTIPLICATION
C
C*****************************************************************
       SUBROUTINE ZONEWT(IZONES,FACT,IBIG,NOFACTS)
       DIMENSION IZONES(IBIG,NOFACTS),FACT(NOFACTS)
       COMMON /WMW/ ALPH,BASE,BASERN,BTUPER,CODE,DISTNC,ESUB,FARE,FLAG,
      1FLAG4,FSUB,ICOST,IFIB,IFIBB,NOGROW,        IRUN,K,N,NARC,NDUM,NIT2,
      *NO,PKRATE,
      2PRKTM,PRICE,OWNRSH,SUM1,SUM2,SUM3,TFARE,TIME,TXS,TXS1,TXS2,
      3VAR1,VAR2,VAR3,VAR4,VAR5,VAR6,VAR7,VAR8,VAR9,VAR10,VAR11,VAR12,
      4VAR13,VAR14,VAR15,WALKWT,WLKTM,XS,XS1,XS2,XX,XX1,XX2,YES,
      5AUTO(40),AA(300),BAL(55),BASEBE(55),BASEPO(55),BASERT(55),
      6BASESV(55,2),BF(55),BETA(2),BASIC(55),BB(300),CAP(55),CC(300),
      7DEN(55),EMP(55,2),F(200,5),FG(55),FS(55,2),FSPOP(55),FR(50),
      8FRDAY(50),GAM(55,4),INCR(6),LA(55),NODARC(300,2),OCC(5),PARK(55),
      9RANDOM(55),RETAIL(55),S(55,4),TOTEMP(55),TRANST(6),TSEMP(55),
      *VALUE(5),WALK(55),WKINZN(30,5),YX(55),XCOORD(55),YCOORD(55),
      1G(55,3),TEM(55),U(55,3),DD(300),EE(300),PP(300),QQ(300),Y(55)
       COMMON /BLK1/ A(55,55),B(55,55),C(55,55),D(55,55),E(55,55)
       INTEGER BASERN,CODE,FLAG,FL,FLAG4,FG,YES
       REAL LA,LR,LH,INCR
       COMMON /NOZONES/ NOZONES(5)
C    READ IN FACTORS
       READ 10,(FACT(I),I=1,NOFACTS)
10     FORMAT(10F4.2)
       DO 50 I=1,NOFACTS
       NOZONE=NOZONES(I)
C    READ IN ZONES TO APPLY FACTOR TO
       READ 20,(IZONES(IJ,I),IJ=1,NOZONE)
20     FORMAT(40I2)
       DO 40 J=1,NOZONE
       INDEX=IZONES(J,I)
C    PERFORM MULTIPLICATION
       DO 30 ICTR=1,N
       B(INDEX,ICTR)=B(INDEX,ICTR)*FACT(I)
30     CONTINUE
40     CONTINUE
50     CONTINUE
       RETURN
       END
```

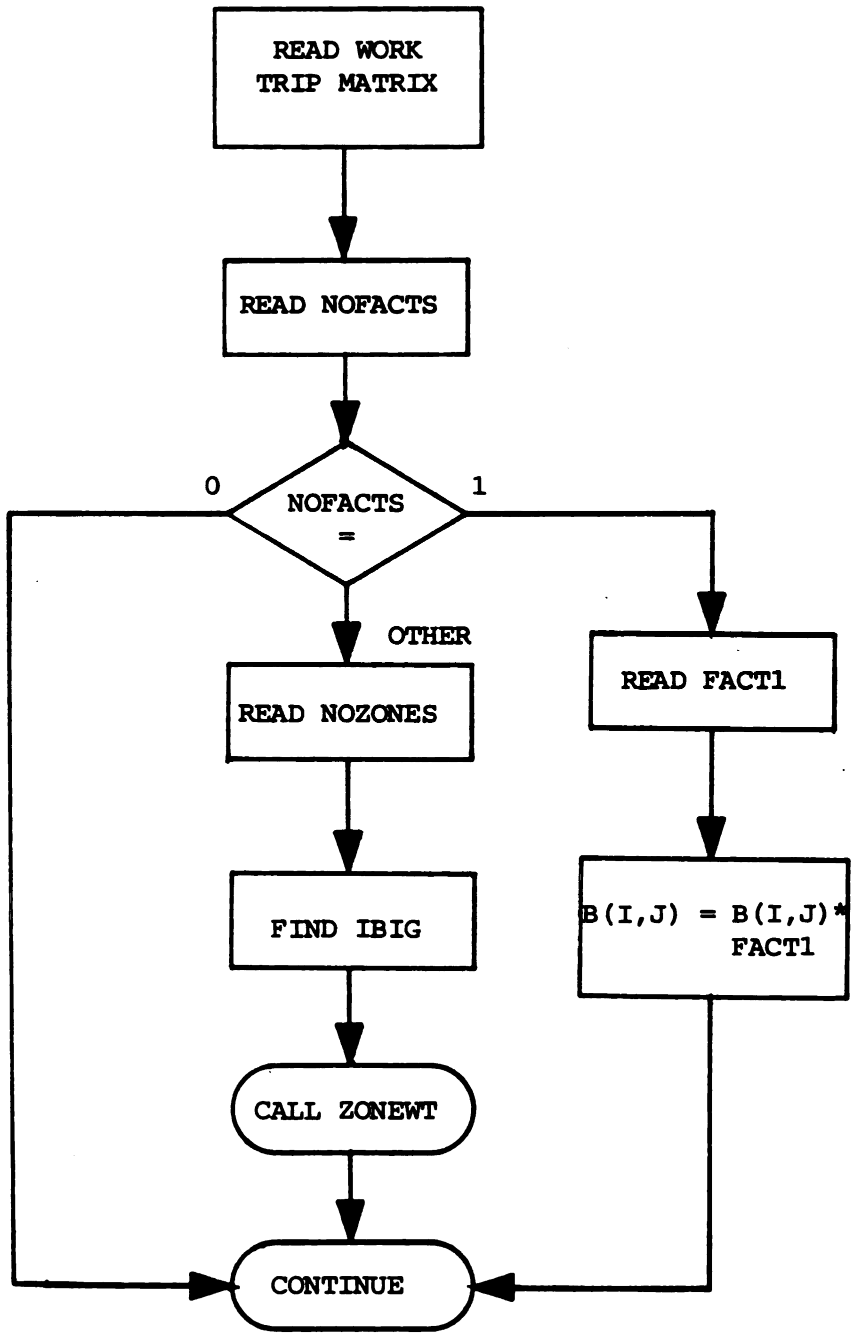


Figure A1. Algorithm to Factor the Work Trip Matrix for Simulating Variable Work Hour Programs.

SUBROUTINE ZONEWT (card to) Reads in at least two different factors and uses these to proportion the work trips originating in specific zones.

CALLED FROM: MAIN (card)

EXTERNALS USED: none

INPUT:

IZONES(20,NOFACTS)	vector of zones numbers that each factor will be applied to
FACT(NOFACTS)	vector of factors to be used
IBIG	largest number of zones any factors will be applied to
NOFACTS	number of factors to be used
B(N,N)	work trip matrix from base run

OUTPUT:

B(N,N)	proportioned work trip matrix

ALGORITHM:

The work trip matrix is proportioned by multiplying each cell B(I,J) by the appropriate factors (FACT) for zone I. The algorithm is shown schematically in Figure A2.

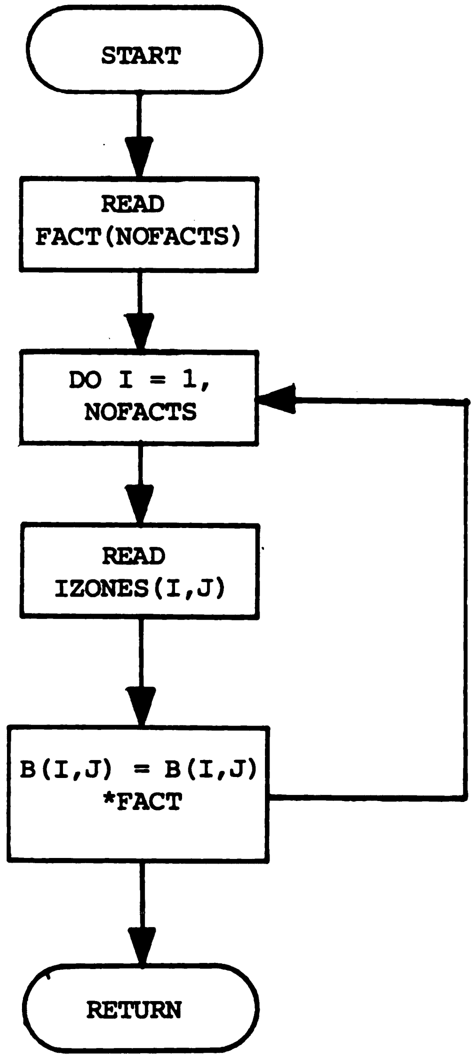


Figure A2. Subroutine ZONEWT.

A.2 Testing Variable Work Hour Programs

The MOD3 program, as adapted, can be used to test the impact of variable work hour programs on traffic congestion, mode choice and energy consumption for the urban work trip. The variable work program adaptations include staggered and flexible work hour capabilities.

As with other policy testing runs, testing variable work programs is done in the incremental run mode of MOD3. However, a no-growth condition must be specified, that is, variable NOGROW must equal zero. The variable work hour option will only affect the total number of work trips simulated by MOD3. All other trip information computed will represent that for an entire day's travel.

In order to test variable work hour programs the length of the total time period to be simulated must be established. Usually, this will represent the total PM peak period for the urban work trip. The peak period can be divided into any number of discrete time elements of any arbitrary length (15 - 30 minute time periods are recommended). At present, one simulation run must be made for each discrete time element in order to simulate the entire peak period.

The proportion of the peak period work trips made during each individual time element must also be estimated. The estimate can represent the proportion of trips entering the traffic stream from all zones, in which case, a single factor (FACT1) is applied to all zones, or up to five different factors may be applied each to as many as twenty zones. This latter option will allow for a more accurate representation of the variation in work quitting times between zones. For example, Figure A3 compares three temporal distributions of work trips for a hypothetical 52 zone city during a 2.5 hour PM peak period.

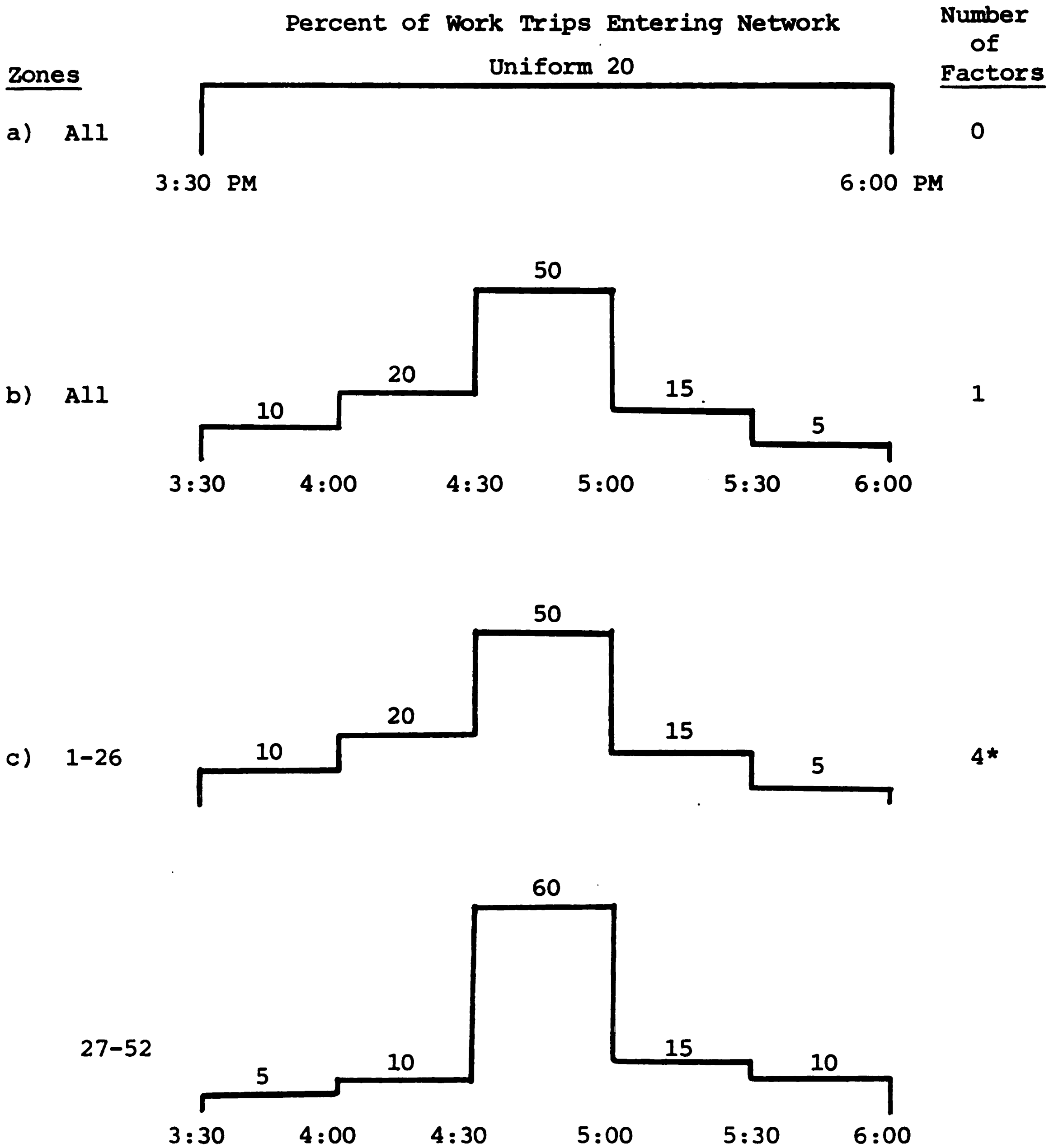


Figure A3. Three Alternative Temporal Distributions of Work Trip Travel for the PM Peak Period.

* Note: The number of factors specified in (c) is 4 instead of 2 because a single factor can be applied to only 20 zones maximum, and 26 zones are specified for each factor. Therefore, the input requirements would be that the same factor would be applied twice, once to zones 1-20, and once to zones 21-26. The factor would be applied in the same manner to zones 27-52.

The uniform distribution in Figure A3a represents the temporal distribution of the network loading in MOD3 as the program was originally written. That is, the entire work trip origin-destination (O-D) matrix is assigned to the network for the time period specified by the free-flow link capacity. In this case, the link capacity would represent that capacity available for a 2½ hour program. This is done through one execution of the program.

Figure A3b represents an example of how the temporal distribution of the network assignment can be changed to more accurately represent the peaking characteristics of urban work travel. In this case, five executions of the program are required (one for each half hour time element) to describe the entire 2½ hour peak period. For each half hour period the factor indicated in Figure A3b would be applied to the work trip O-D matrix to determine the proportion of work trips to be loaded onto the network.

In Figure A3c, two factors are used during each time period and applied to separate sets of zones. This example represents a case where the work quitting times may differ between zones. As many as five different factors can be used in this manner, each being applied to as many as twenty zones. Here again, five program executions are required to describe the entire 2½ hour peak period.

When the work trip matrix is proportioned in this manner, the MOD3 program output for work trips (including energy consumption) is reported as twice the calculated value for the time element being simulated. This represents both the AM and PM contribution of travel for the specified time element. All other statistics reported for the remaining trip types are for an entire day's travel.

The work trip summary statistics for the entire peak period can be computed by manually summing the weighted values from each time element. For example, the mean highway congestion index reported for each time element can be combined into a mean value for the entire peak period based on the number of highway trips occuring in each time element. That is

$$HCI_{mean} = \sum_{i=i}^{n} \frac{wt_i}{WT_a} * hc_i \tag{A1}$$

where

HCI_{mean} = the weighted mean highway congestion index for the entire peak period,

n = the number of time elements the peak period is divided into,

wt_i = the number of automobile work trips occuring in time period i,

WT_a = the total number of automobile work trips = $\sum_{i=i}^{n} wt_i$, and

hc_i = the mean highway congestion index for time period i.

This should be done for all summary statistics such as auto work trip length, time, speed, etc., where these values are substituted for the highway congestion index in the above relationship. The same procedure can be applied to the transit trip summaries where transit person work trips replace auto person trips.

The specification of the length of the time period being investigated if provided through the highway link capacity (vehicles per element of time, usually per hour) input for each link, or the adjustment of the link capacity through the variation in the parameter TRAFIK, which is also supplied as input. For example, the link capacity may be input as vehicles per hour of green signal time on the network. The parameter TRAFIK is used to adjust the capacity of each link to represent the available capacity on the network which provides 0.5 hours of green time per clock hour for a time period of 0.5 hours in length, when 90 percent of the total capacity is available for work trips. Therefore TRAFIK = 0.5 * 0.5 * 0.9 = 0.225.

The input capacity of each link is automatically adjusted by the factor TRAFIK. This eliminates the need to repeatedly change the input link capacity values when time periods of various lengths are to be simulated.

The actual testing of variable work hour programs begins with the simulation of the existing conditions to form the basis for comparison. Various alternative temporal distributions of work travel can be hypothesized and simulated through changes in the factors applied to the zonal O-D matrix as described on the previous page. These alternatives can be compared to the existing condition to determine the potential for improving traffic flow.

Variable work hour programs can also be tested in combination with alternative transit strategies by varying transit route structure, cost, or bus frequency. It should be noted that work trip transit ridership is related to the input value of the parameter FR(NR), which is the frequency of bus service. The energy consumption of transit travel is computed using FRDAY(NR), which is the daily total number of bus trips per bus route.

When segmenting the total peak period into discrete time elements the automobile work trip energy consumption reported as output will be twice the value calculated for the time element. This represents both the AM and PM contributions to the energy consumption. The transit energy consumption represents that for the entire day.

In order to perform policy tests with variable work hour programs, the data in Table A5 must be included in the data input after the input variable NOFACTS shown in Table A1.

Table A5. Additional Data Requirements for Testing Variable Work Hours

1. When NOFACTS · EQ · 1 add

Run Type

Base	Incremental	Auto Only	Auto & Transit	DESCRIPTION	Number of Cards
X	X	X		FACT1	1

2. When NOFACTS · GT · 1 (2 through 5) add

Base	Incremental	Auto Only	Auto & Transit	DESCRIPTION	Number of Cards
X	X	X		NOZONES (NOFACTS)	1
X	X	X		FACT (NOFACTS)	1
X	X	X		IZONES (20, NOFACTS)	NOFACTS

APPENDIX B

APPENDIX B

Data Set for the Generation of the Peak Half Hour Travel for the Base Case

```
10=         013              1           0
20=BASE CASE, INCREMENTAL MODE, TIME PERIOD 3
30=           2             52         232           7           5           0           0           0
40=        -4.8           0.11       -0.04        -2.2         3.8
50=        -6.8           0.37      -0.065        -4.1         2.2
60=        -6.0            0.6       -0.09        -6.0         2.2
70=        .460           .400        .350        .280        .210        .160        .120        .100
80=        .090           .080        .070        .060        .050        .042        .038        .025
90=        .022           .021        .020        .018        .015        .012        .008        .005
100=        .002          .001        .000        .000        .000        .000
110=        .460          .400        .350        .280        .210        .160        .120        .100
120=        .090          .080        .070        .060        .050        .042        .038        .025
130=        .022          .021        .020        .018        .015        .012        .008        .005
140=        .002          .001        .000        .000        .000        .000
150=        .460          .400        .350        .280        .210        .160        .120        .100
160=        .090          .080        .070        .060        .050        .042        .038        .025
170=        .022          .021        .020        .018        .015        .012        .008        .005
180=        .002          .001        .000        .000        .000        .000
190=        .460          .400        .350        .280        .210        .160        .120        .100
200=        .090          .080        .070        .060        .050        .042        .038        .025
210=        .022          .021        .020        .018        .015        .012        .008        .005
220=        .002          .001        .000        .000        .000        .000
230=        .460          .400        .350        .280        .210        .160        .120        .100
240=        .090          .080        .070        .060        .050        .042        .038        .025
250=        .022          .021        .020        .018        .015        .012        .008        .005
260=        .002          .001        .000        .000        .000        .000
270=       0.023
280=         5.0           2.5         2.5         2.5         2.5
290=   105875.0        39208.3     25875.0     20160.7     16986.1     14965.9     13567.3     12541.7
300=    11757.4        11138.2     10636.9     10222.8      9875.0      9578.7      9323.3      9100.8
310=     8905.3         8732.1      8577.7      8439.1      8314.0      8200.6      8097.2      8002.6
320=     7915.8         7835.8      7761.8      7693.2      7857.5      7913.1      8145.8      8548.0
330=     8601.1         8876.8      9231.9      9717.7     10107.9     10812.5     11350.6     12147.2
340=    125000.
350=        1.00           1.3         1.6         1.6         1.5         2.0         1.3
360=        .225
370=    30     49        1.411       1500.         35.
380=    49     30        1.411       1500.         35.
390=    32     49        1.411       1500.         35.
400=    49     32        1.411       1500.         35.
410=    35     50        1.411       1500.         35.
420=    50     35        1.411       1500.         35.
430=    37     50        1.411       1500.         35.
440=    50     37        1.411       1500.         35.
450=    40     51        1.411       1500.         35.
460=    51     40        1.411       1500.         35.
470=    42     51        1.411       1500.         35.
480=    51     42        1.411       1500.         35.
490=    45     52        1.411       1500.         35.
500=    52     45        1.411       1500.         35.
510=    47     52        1.411       1500.         35.
520=    52     47        1.411       1500.         35.
530=    31     49        1.225       1500.         35.
540=    49     31        1.225       1500.         35.
550=    36     50        1.225       1500.         35.
560=    50     36        1.225       1500.         35.
570=    41     51        1.225       1500.         35.
580=    51     41        1.225       1500.         35.
590=    46     52        1.225       1500.         35.
600=    52     46        1.225       1500.         35.
610=    13     30         1.05       1500.         35.
620=    30     13         1.05       1500.         35.
630=    14     31         1.05       2000.         35.
640=    31     14         1.05       2000.         35.
650=    15     32         1.05       1500.         35.
```

660=	32	15	1.05	1500.	35.
670=	16	33	1.05	1500.	35.
680=	33	16	1.05	1500.	35.
690=	16	34	1.05	1500.	35.
700=	34	16	1.05	1500.	35.
710=	17	35	1.05	1500.	35.
720=	35	17	1.05	1500.	35.
730=	18	36	1.05	2000.	35.
740=	36	18	1.05	2000.	35.
750=	19	37	1.05	1500.	35.
760=	37	19	1.05	1500.	35.
770=	20	38	1.05	1500.	35.
780=	38	20	1.05	1500.	35.
790=	20	39	1.05	1500.	35.
800=	39	20	1.05	1500.	35.
810=	21	40	1.05	1500.	35.
820=	40	21	1.05	1500.	35.
830=	22	41	1.05	2000.	35.
840=	41	22	1.05	2000.	35.
850=	23	42	1.05	1500.	35.
860=	42	23	1.05	1500.	35.
870=	24	43	1.05	1500.	35.
880=	43	24	1.05	1500.	35.
890=	24	44	1.05	1500.	35.
900=	44	24	1.05	1500.	35.
910=	25	45	1.05	1500.	35.
920=	45	25	1.05	1500.	35.
930=	26	46	1.05	2000.	35.
940=	46	26	1.05	2000.	35.
950=	27	47	1.05	1500.	35.
960=	47	27	1.05	1500.	35.
970=	28	48	1.05	1500.	35.
980=	48	28	1.05	1500.	35.
990=	28	29	1.05	1500.	35.
1000=	29	28	1.05	1500.	35.
1010=	47	48	.875	1500.	35.
1020=	46	47	.875	1500.	35.
1030=	27	28	.875	1500.	35.
1040=	28	27	.875	1500.	35.
1050=	12	13	.875	2000.	35.
1060=	13	12	.875	2000.	35.
1070=	5	14	.875	2000.	30.
1080=	14	5	.875	2000.	30.
1090=	6	15	.875	2000.	35.
1100=	15	6	.875	2000.	35.
1110=	16	17	.875	1500.	35.
1120=	17	16	.875	1500.	35.
1130=	34	35	.875	1500.	35.
1140=	35	34	.875	1500.	35.
1150=	32	33	.875	1500.	35.
1160=	33	32	.875	1500.	35.
1170=	15	16	.875	1500.	35.
1180=	16	15	.875	1500.	35.
1190=	6	17	.875	2000.	35.
1200=	17	6	.875	2000.	35.
1210=	7	18	.875	2000.	30.
1220=	18	7	.875	2000.	30.
1230=	8	19	.875	2000.	35.
1240=	19	8	.875	2000.	35.
1250=	21	20	.875	1500.	35.
1260=	20	21	.875	1500.	35.
1270=	39	40	.875	1500.	35.
1280=	40	39	.875	1500.	35.
1290=	37	38	.875	1500.	35.
1300=	38	37	.875	1500.	35.
1310=	19	20	.875	1500.	35.
1320=	20	19	.875	1500.	35.
1330=	8	21	.875	2000.	35.
1340=	21	8	.875	2000.	35.
1350=	9	22	.875	2000.	30.
1360=	22	9	.875	2000.	30.
1370=	10	23	.875	2000.	35.
1380=	23	10	.875	2000.	35.
1390=	24	25	.875	1500.	35.
1400=	25	24	.875	1500.	35.
1410=	44	45	.875	1500.	35.
1420=	45	44	.875	1500.	35.
1430=	42	43	.875	1500.	35.
1440=	43	42	.875	1500.	35.
1450=	23	24	.875	1500.	35.
1460=	24	23	.875	1500.	35.
1470=	10	25	.875	2000.	35.
1480=	25	10	.875	2000.	35.
1490=	11	26	.875	2000.	30.
1500=	26	11	.875	2000.	30.
1510=	12	27	.875	2000.	35.
1520=	27	12	.875	2000.	35.
1530=	13	28	.875	1500.	35.

1540=	28	13	.875	1500.	35.
1550=	29	30	.875	1500.	35.
1560=	30	29	.875	1500.	35.
1570=	31	32	.70	1500.	35.
1580=	32	31	.70	1500.	35.
1590=	14	15	.70	2000.	35.
1500=	15	14	.70	2000.	35.
1610=	5	6	.70	2000.	30.
1620=	6	5	.70	2000.	30.
1630=	8	9	.70	2000.	30.
1640=	9	8	.70	2000.	30.
1650=	21	22	.70	2000.	35.
1560=	22	21	.70	2000.	35.
1670=	40	41	.70	1500.	35.
1680=	41	40	.70	1500.	35.
1690=	41	42	.70	1500.	35.
1700=	42	41	.70	1500.	35.
1710=	22	23	.70	2000.	35.
1720=	23	22	.70	2000.	35.
1730=	9	10	.70	2000.	30.
1740=	10	9	.70	2000.	30.
1750=	5	12	.70	2000.	30.
1760=	12	5	.70	2000.	30.
1770=	13	14	.70	2000.	35.
1780=	14	13	.70	2000.	35.
1790=	30	31	.70	1500.	35.
1900=	31	30	.70	1500.	35.
1810=	46	47	.70	1500.	35.
1820=	47	46	.70	1500.	35.
1830=	26	27	.70	2000.	35.
1840=	27	26	.70	2000.	35.
1850=	11	12	.70	2000.	30.
1860=	12	11	.70	2000.	30.
1870=	6	7	.70	2000.	30.
1880=	7	6	.70	2000.	30.
1890=	17	18	.70	2000.	35.
1900=	18	17	.70	2000.	35.
1910=	35	36	.70	1500.	35.
1920=	36	35	.70	1500.	35.
1930=	36	37	.70	1500.	35.
1940=	37	36	.70	1500.	35.
1950=	18	19	.70	2000.	35.
1960=	19	18	.70	2000.	35.
1970=	7	8	.70	2000.	30.
1980=	8	7	.70	2000.	30.
1990=	10	11	.70	2000.	30.
2000=	11	10	.70	2000.	30.
2010=	25	26	.70	2000.	35.
2020=	26	25	.70	2000.	35.
2030=	45	46	.70	1500.	35.
2040=	46	45	.70	1500.	35.
2050=	1	5	.553	1800.	25.
2060=	7	1	.553	1800.	25.
2070=	2	7	.553	1800.	25.
2080=	9	2	.553	1800.	25.
2090=	3	9	.553	1800.	25.
2100=	11	3	.553	1800.	25.
2110=	4	11	.553	1800.	25.
2120=	5	4	.553	1800.	25.
2130=	2	1	.35	1800.	25.
2140=	3	2	.35	1800.	25.
2150=	4	3	.35	1800.	25.
2160=	1	4	.35	1800.	25.
2170=	1	1	.175	10000.	15.
2180=	2	2	.175	10000.	15.
2190=	3	3	.175	10000.	15.
2200=	4	4	.175	10000.	15.
2210=	5	5	.35	10000.	15.
2220=	6	6	.35	10000.	15.
2230=	7	7	.35	10000.	15.
2240=	8	8	.35	10000.	15.
2250=	9	9	.35	10000.	15.
2260=	10	10	.35	10000.	15.
2270=	11	11	.35	10000.	15.
2280=	12	12	.35	10000.	15.
2290=	13	13	.438	10000.	15.
2300=	14	14	.438	10000.	15.
2310=	15	15	.438	10000.	15.
2320=	16	16	.525	10000.	15.
2330=	17	17	.438	10000.	15.
2340=	18	18	.438	10000.	15.
2350=	19	19	.438	10000.	15.
2360=	20	20	.525	10000.	15.
2370=	21	21	.438	10000.	15.
2380=	22	22	.438	10000.	15.
2390=	23	23	.438	10000.	15.
2400=	24	24	.525	10000.	15.
2410=	25	25	[illegible]	[illegible]	[illegible]

2420=	26	26	.438	10000.	15.				
2430=	27	27	.438	10000.	15.				
2440=	28	28	.525	10000.	15.				
2450=	29	29	.525	10000.	15.				
2460=	30	30	.438	10000.	15.				
2470=	31	31	.438	10000.	15.				
2480=	32	32	.438	10000.	15.				
2490=	33	33	.525	10000.	15.				
2500=	34	34	.525	10000.	15.				
2510=	35	35	.438	10000.	15.				
2520=	36	36	.438	10000.	15.				
2530=	37	37	.438	10000.	15.				
2540=	38	38	.525	10000.	15.				
2550=	39	39	.525	10000.	15.				
2560=	40	40	.438	10000.	15.				
2570=	41	41	.438	10000.	15.				
2580=	42	42	.438	10000.	15.				
2590=	43	43	.525	10000.	15.				
2600=	44	44	.525	10000.	15.				
2610=	45	45	.438	10000.	15.				
2620=	46	46	.438	10000.	15.				
2630=	47	47	.438	10000.	15.				
2640=	48	48	.525	10000.	15.				
2650=	49	49	.875	10000.	15.				
2660=	50	50	.875	10000.	15.				
2670=	51	51	.875	10000.	15.				
2680=	52	52	.875	10000.	15.	1.			
2690=		0.18	10.5						
2700=		1.00	1.00	1.00	1.00	0.50	0.50	0.50	0.50
2710=		0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00
2720=		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2730=		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2740=		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2750=		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2760=		0.00	0.00	0.00	0.00				
2770=		2.0							
2780=		1.0							
2790=		2.50							
2800=		12							
2810=		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
2820=		4.5	4.5	4.5	4.5				
2830=		43.	43.	43.	43.	43.	43.	43.	43.
2840=		43.	43.	43.	43.				
2850=		88407.6	45359.5	30305.7	24830.1	22387.1	21519.4		
2860=		3.25	3.85	3.85	3.85	7.7	7.7	7.7	7.7
2870=		7.7	7.7	7.7	7.7	9.625	9.625	9.625	11.55
2880=		9.625	9.625	9.625	11.55	9.625	9.625	9.625	11.55
2890=		9.625	9.625	9.625	11.55	11.55	9.625	9.625	9.625
2900=		11.55	11.55	9.625	9.625	9.625	11.55	11.55	9.625
2910=		9.625	9.625	11.55	11.55	9.625	9.625	9.625	11.55
2920=		19.25	19.25	19.25	19.25				
2930=		1.5	1.5	5.0					
2940=		1.	1.	1.	1.	0.	0.	0.	0.
2950=		0.	0.	0.	0.	0.	0.	0.	0.
2960=		0.	0.	0.	0.	0.	0.	0.	0.
2970=		0.	0.	0.	0.	0.	0.	0.	0.
2980=		0.	0.	0.	0.	0.	0.	0.	0.
2990=		0.	0.	0.	0.	0.	0.	0.	0.
3000=		0.	0.	0.	0.				
3010=		0.35	0.00						
3020=	33	16	3.15	1.05	1				
3030=	16	17	3.5	.875	1				
3040=	17	6	3.5	.875	1				
3050=	6	5	2.8	.7	1				
3060=	5	4	3.318	.553	1				
3070=	4	3	2.1	.35	1				
3080=	3	9	3.318	.553	1				
3090=	9	10	2.8	.7	1				
3100=	10	25	3.5	.875	1				
3110=	25	24	3.5	.875	1				
3120=	24	43	3.15	1.05	1	1.			
3130=	34	35	2.625	.875	2				
3140=	35	36	2.8	.7	2				
3150=	36	18	4.2	1.05	2				
3160=	18	7	3.5	.875	2				
3170=	7	1	3.318	.553	2				
3180=	1	4	2.1	.35	2				
3190=	4	11	3.318	.553	2				
3200=	11	26	3.5	.875	2				
3210=	26	46	4.2	1.05	2				
3220=	46	45	2.8	.7	2				
3230=	45	44	2.625	.875	2	1.			
3240=	50	37	4.234	1.411	3				
3250=	37	19	4.2	1.05	3				
3260=	19	8	3.5	.875	3				
3270=	8	9	2.8	.7	3				
3280=	9	2	3.318	.553	3				
3290=	2	1	2.1	.35	3				

3300=	1	5	3.318	.553	3	
3310=	5	12	2.8	.7	3	
3320=	12	27	3.5	.875	3	
3330=	27	47	4.2	1.05	3	
3340=	47	52	4.234	1.411	3	1.
3350=	48	28	3.15	1.05	4	
3360=	28	13	3.5	.875	4	
3370=	13	12	3.5	.875	4	
3380=	12	11	2.8	.7	4	
3390=	11	3	3.318	.553	4	
3400=	3	2	2.1	.35	4	
3410=	2	7	3.318	.553	4	
3420=	7	8	2.8	.7	4	
3430=	8	21	3.5	.875	4	
3440=	21	20	3.5	.875	4	
3450=	20	38	3.15	1.05	4	1.
3460=	29	30	2.625	.875	5	
3470=	30	31	2.8	.7	5	
3480=	31	14	4.2	1.05	5	
3490=	14	5	3.5	.875	5	
3500=	5	4	3.318	.553	5	
3510=	4	3	2.1	.35	5	
3520=	3	9	3.318	.553	5	
3530=	9	22	3.5	.875	5	
3540=	22	41	4.2	1.05	5	
3550=	41	40	2.8	.7	5	
3560=	40	39	2.625	.875	5	1.
3570=	49	32	4.234	1.411	6	
3580=	32	15	4.2	1.05	6	
3590=	15	6	3.5	.875	6	
3600=	6	7	2.8	.7	6	
3610=	7	1	3.318	.553	6	
3620=	1	4	2.1	.35	6	
3630=	4	11	3.318	.553	6	
3640=	11	10	2.8	.7	6	
3650=	10	23	3.5	.875	6	
3660=	23	42	4.2	1.05	6	
3670=	42	51	4.234	1.411	6	1.
3680=	43	24	3.15	1.05	7	
3690=	24	25	3.5	.875	7	
3700=	25	10	3.5	.875	7	
3710=	10	9	2.8	.7	7	
3720=	9	2	3.318	.553	7	
3730=	2	1	2.1	.35	7	
3740=	1	5	3.318	.553	7	
3750=	5	6	2.8	.7	7	
3760=	6	17	3.5	.875	7	
3770=	17	16	3.5	.875	7	
3780=	16	33	3.15	1.05	7	1.
3790=	44	45	2.625	.875	8	
3800=	45	46	2.8	.7	8	
3810=	46	26	4.2	1.05	8	
3820=	26	11	3.5	.875	8	
3830=	11	3	3.318	.553	8	
3840=	3	2	2.1	.35	8	
3850=	2	7	3.318	.553	8	
3860=	7	19	3.5	.875	8	
3870=	18	36	4.2	1.05	8	
3880=	36	35	2.8	.7	8	
3890=	35	34	2.625	.875	8	1.
3900=	52	47	4.234	1.411	9	
3910=	47	27	4.2	1.05	9	
3920=	27	12	3.5	.875	9	
3930=	12	5	2.8	.7	9	
3940=	5	4	3.318	.553	9	
3950=	4	3	2.1	.35	9	
3960=	3	9	3.318	.553	9	
3970=	9	8	2.8	.7	9	
3980=	8	19	3.5	.875	9	
3990=	19	37	4.2	1.05	9	
4000=	37	50	4.234	1.411	9	1.
4010=	38	20	3.15	1.05	10	
4020=	20	21	3.5	.875	10	
4030=	21	8	3.5	.875	10	
4040=	8	7	2.8	.7	10	
4050=	7	1	3.318	.553	10	
4060=	1	4	2.1	.35	10	
4070=	4	11	3.318	.553	10	
4080=	11	12	2.8	.7	10	
4090=	12	13	3.5	.875	10	
4100=	13	28	3.5	.875	10	
4110=	28	46	3.15	1.05	10	1.
4120=	39	40	2.625	.875	11	
4130=	40	41	2.8	.7	11	
4140=	41	22	4.2	1.05	11	
4150=	22	9	3.5	.875	11	
4160=	9	2	3.318	.553	11	
4170=	2	1	2.1	.35	11	

4180=	1	5	3.318	.553	11				
4190=	5	14	3.5	.875	11				
4200=	14	31	4.2	1.05	11				
4210=	31	30	2.8	.7	11				
4220=	30	29	2.625	.875	11	1.			
4230=	51	42	4.234	1.411	12				
4240=	42	23	4.2	1.05	12				
4250=	23	10	3.5	.875	12				
4260=	10	11	2.8	.7	12				
4270=	11	3	3.318	.553	12				
4280=	3	2	2.1	.35	12				
4290=	2	7	3.318	.553	12				
4300=	7	6	2.8	.7	12				
4310=	6	15	3.5	.875	12				
4320=	15	32	4.2	1.05	12				
4330=	32	49	4.234	1.411	12	1.			
4340=		5	100.						
4350=		2.5							
4360=		500.	500.	500.	500.	218.	219.	219.	219.
4370=		218.	219.	219.	219.	0.	0.	0.	0.
4380=		0.	0.	0.	0.	0.	0.	0.	0.
4390=		0.	0.	0.	0.	0.	0.	0.	0.
4400=		0.	0.	0.	0.	0.	0.	0.	0.
4410=		0.	0.	0.	0.	0.	0.	0.	0.
4420=		0.	0.	0.	0.				
4430=		0.30	0.25	0.20	0.15	0.10	0.00		
4440=		1.10							
4450=		0.125	0.125						
4460=		.2	.2	.2	.2	.2	.2	.2	.2
4470=		.2	.2	.2	.2	.2	.2	.2	.2
4480=		.2	.2	.2	.2	.2	.2	.2	.2
4490=		.2	.2	.2	.2	.2	.2	.2	.2
4500=		.2	.2	.2	.2	.2	.2	.2	.2
4510=		.2	.2	.2	.2	.2	.2	.2	.2
4520=		.2	.2	.2	.2				
4530=		.3	.3	.3	.3	.3	.3	.3	.3
4540=		.3	.3	.3	.3	.3	.3	.3	.3
4550=		.3	.3	.3	.3	.3	.3	.3	.3
4560=		.3	.3	.3	.3	.3	.3	.3	.3
4570=		.3	.3	.3	.3	.3	.3	.3	.3
4580=		.3	.3	.3	.3	.3	.3	.3	.3
4590=		.3	.3	.3	.3				
4600=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4610=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4620=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4630=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4640=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4650=		1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
4660=		1.5	1.5	1.5	1.5				
4670=		.2	.2	.2	.2	.2	.2	.2	.2
4680=		.2	.2	.2	.2	.2	.2	.2	.2
4690=		.2	.2	.2	.2	.2	.2	.2	.2
4700=		.2	.2	.2	.2	.2	.2	.2	.2
4710=		.2	.2	.2	.2	.2	.2	.2	.2
4720=		.2	.2	.2	.2	.2	.2	.2	.2
4730=		.2	.2	.2	.2				
4740=		12.5	12.5	12.5	12.5	18.8	18.8	18.8	18.8
4750=		18.8	18.8	18.8	18.8	16.5	16.5	16.5	16.5
4760=		16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5
4770=		16.5	16.5	16.5	16.5	9.4	9.4	9.4	9.4
4780=		9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
4790=		9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
4800=		6.3	6.3	6.3	6.3				
4810=		1.	1.	1.	1.	1.	1.	1.	1.
4820=		1.	1.	1.	1.	1.	1.	1.	1.
4830=		1.	1.	1.	1.	1.	1.	1.	1.
4840=		1.	1.	1.	1.	1.	1.	1.	1.
4850=		1.	1.	1.	1.	1.	1.	1.	1.
4860=		1.	1.	1.	1.	1.	1.	1.	1.
4870=		1.	1.	1.	1.				
4880=		1.	1.	1.	1.	1.	1.	1.	1.
4890=		1.	1.	1.	1.	1.	1.	1.	1.
4900=		1.	1.	1.	1.	1.	1.	1.	1.
4910=		1.	1.	1.	1.	1.	1.	1.	1.
4920=		1.	1.	1.	1.	1.	1.	1.	1.
4930=		1.	1.	1.	1.	1.	1.	1.	1.
4940=		1.	1.	1.	1.				
4950=		330.	330.	330.	330.	330.	330.	330.	330.
4960=		330.	330.	330.	330.	1100.	1100.	1100.	1100.
4970=		1100.	1100.	1100.	1100.	1100.	1100.	1100.	1100.
4980=		1100.	1100.	1100.	1100.	1100.	1100.	1100.	1100.
4990=		1100.	1100.	1100.	1100.	1100.	1100.	1100.	1100.
5000=		1100.	1100.	1100.	1100.	1100.	1100.	1100.	1100.
5010=		1100.	1100.	1100.	1100.				
5020=		630.	630.	630.	630.	630.	630.	630.	630.
5030=		630.	630.	630.	630.	2110.	2110.	2110.	2110.
5040=		2110.	2110.	2110.	2110.	2110.	2110.	2110.	2110.
5050=		2110.	2110.	2110.	2110.	2110.	2110.	2110.	2110.

5060=	2110.	2110.	2110.	2110.	2110.	2110.	2110.	2110.
5070=	2110.	2110.	2110.	2110.	2110.	2110.	2110.	2110.
5080=	2110.	2110.	2110.	2110.				
5090=	250.	250.	250.	250.	500.	500.	500.	500.
5100=	500.	500.	500.	500.	1250.	1250.	1250.	1250.
5110=	1250.	1250.	1250.	1250.	1250.	1250.	1250.	1250.
5120=	1250.	1250.	1250.	1250.	2500.	2500.	2500.	2500.
5130=	2500.	2500.	2500.	2500.	2500.	2500.	2500.	2500.
5140=	2500.	2500.	2500.	2500.	2500.	2500.	2500.	2500.
5150=	2500.	2500.	2500.	2500.				
5160=	0	0	0	0	0	0	0	0
5170=	0	0	0	0	0	0	0	0
5180=	0	0	0	0	0	0	0	0
5190=	0	0	0	0	0	0	0	0
5200=	0	0	0	0	0	0	0	0
5210=	0	0	0	0	0	0	0	0
5220=	0	0	0	0				
5230=	0.1	0.1	0.1	0.1	3.0	3.0	3.0	3.0
5240=	3.0	3.0	3.0	3.0	30.0	30.0	30.0	30.0
5250=	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
5260=	30.0	30.0	30.0	30.0	20.0	20.0	20.0	20.0
5270=	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
5280=	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
5290=	20.0	20.0	20.0	20.0				
5300=	15.	15.	15.	15.	2.	2.	2.	2.
5310=	2.	2.	2.	2.	2.	2.	2.	2.
5320=	2.	2.	2.	2.	2.	2.	2.	2.
5330=	2.	2.	2.	2.	2.	2.	2.	2.
5340=	2.	2.	2.	2.	2.	2.	2.	2.
5350=	2.	2.	2.	2.	2.	2.	2.	2.
5360=	2.	2.	2.	2.				
5370=	6.	6.	6.	6.	1.	1.	1.	1.
5380=	1.	1.	1.	1.	1.	1.	1.	1.
5390=	1.	1.	1.	1.	1.	1.	1.	1.
5400=	1.	1.	1.	1.	1.	1.	1.	1.
5410=	1.	1.	1.	1.	1.	1.	1.	1.
5420=	1.	1.	1.	1.	1.	1.	1.	1.
5430=	1.	1.	1.	1.				
5440=	4.375	4.725						
5450=	4.725	4.725						
5460=	4.725	4.375						
5470=	4.375	4.375						
5480=	3.65	4.55						
5490=	3.85	5.25						
5500=	4.55	5.25						
5510=	5.25	5.25						
5520=	5.25	4.55						
5530=	5.25	3.85						
5540=	4.55	3.85						
5550=	3.85	3.85						
5560=	2.975	3.85						
5570=	2.975	4.55						
5580=	2.975	5.25						
5590=	2.975	6.125						
5600=	3.85	6.125						
5610=	4.55	6.125						
5620=	5.25	6.125						
5630=	6.125	6.125						
5640=	6.125	5.25						
5650=	6.125	4.55						
5660=	6.125	3.85						
5670=	6.125	2.975						
5680=	5.25	2.975						
5690=	4.55	2.975						
5700=	3.85	2.975						
5710=	2.975	2.975						
5720=	1.925	2.975						
5730=	1.925	3.85						
5740=	1.925	4.55						
5750=	1.925	5.25						
5760=	1.925	6.125						
5770=	2.975	7.175						
5780=	3.85	7.175						
5790=	4.55	7.175						
5800=	5.25	7.175						
5810=	6.125	7.175						
5820=	7.175	6.125						
5830=	7.175	5.25						
5840=	7.175	4.55						
5850=	7.175	3.85						
5860=	7.175	2.975						
5870=	6.125	1.925						
5880=	5.25	1.925						
5890=	4.55	1.925						
5900=	3.85	1.925						
5910=	2.975	1.925						
5920=	.7	4.55						
5930=	4.55	[illegible].4						

5940=	8.4	8.4						
5950=	4.55	.7						
5960=	0.0000000	15.2164272	6.1561497	5.0134913	15.3362560	5.4766156	5.2842265	5.1100362
5970=	4.2181159	4.4378787	3.3646783	3.1524660	7.9326992	3.4524104	3.2426003	1.2504958
5980=	.8742891	.3433707	.1932742	.1271482	.0990114	.0732497	.0469828	.0896123
5990=	.2135710	1.9934539	.0062351	1.1857431	.0133135	.0061147	.0024768	.9230645
6000=	.0002076	0.0000000	0.0000000	.0011373	.0160662	.0015733	.2949417	.0101405
6010=	.0010269	1.1836664	.0426074	.0156941	.5293054	.0595363	.2353703	.0783274
6020=	.2393631	.0101338	.0501372	.3418206	.0412545	.0380525	.0129492	.2100082
6030=	.0191575	.2500195	.0048143	.1300955	.0579652	.0038287	.0115616	.0278928
6040=	.0667612	.0147139	.0073919	.0261863	.0297315	.0355372	.0479069	.0154429
6050=	.0152289	.0056041	.0167757	.0081355	.0195089	.0093870	.0499978	.0090199
6060=	.0047306	.0057091	.0210131	.0054858	.0030394	.0016968	.0012301	.0035688
6070=	.0008802	.0035968	.0010777	.0015061	.0024597	.0002069	.0001125	.0007461
6080=	.0000000	.0001301	.0002634	.0008352	.0005374	.0000472	.0002613	.0003652
6090=	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000	0.0000000
6100=	0.0000000	.0000201	0.0000000	0.0000000	0.0000000	.0000172	0.0000000	0.0000000
6110=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6120=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6130=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6140=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6150=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6160=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6170=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6180=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
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6200=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6210=	0.0000000	5.2048270	5.6768585	8.2801825	9.5989008	10.2868039	7.8664925	9.2786185
6220=	9.9178573	5.6622466	5.1658489	2.1061208	5.9114996	1.0695155	1.8503737	2.3268455
6230=	1.3277008	.9521908	1.1523359	.4933310	.1728097	.2000022	.0142363	0.0000000
6240=	.8562804	.0652535	.0017137	.0927114	.1544274	.1070965	.1550014	.1353809
6250=	.1993486	.0144650	0.0000000	.0416182	.0110308	.0896234	.1085783	.1145353
6260=	.0092655	.3100713	.3561239	.0376250	.2419504	.0343909	.1759225	.0491643
6270=	.1282909	.0010567	.0717577	.2570266	.0069162	.2951892	.1479239	.2703642
6280=	.0186861	.0822315	.2047976	.0859788	.1810380	.0246802	.0803746	.0572198
6290=	.0494393	.0323118	.0172431	.0392199	.0076883	.0135997	.0091560	.0024934
6300=	.0064967	.0044087	.0025445	.0012273	.0078606	.0010196	.0008947	.0019988
6310=	.0069426	.0006476	.0004334	.0004032	.0001179	.0006178	.0001520	.0000562
6320=	.0000642	.0000589	.0000292	.0000340	.0000174	.0000045	.0000045	.0000184
6330=	.0000009	.0000042	.0000036	.0000080	.0000025	.0000098	.0000028	.0000013
6340=	.0000007	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000	0.0000000
6350=	0.0000000	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000
6360=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6370=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6380=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6390=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6400=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6410=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6420=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6430=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6440=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6450=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6460=	0.0000000	7.8324047	7.0168806	8.2073003	12.1656988	11.8829174	7.5697272	8.4235578
6470=	7.8933100	4.3350480	4.0812310	1.5786014	7.2340852	.8259036	1.5648378	1.9332509
6480=	1.0469215	.7546558	.9111043	.3832204	.1344927	.1544733	.0117257	0.0000000
6490=	.8871465	.0362639	.0009393	.0588296	.1001779	.0706088	.1000410	.0847795
6500=	.1402449	.0089911	0.0000000	.0221158	.0078338	.0596024	.0824122	.0757671
6510=	.0049261	.2374191	.2333461	.0231896	.1686734	.0252388	.1164693	.0319832
6520=	.0901480	.0010425	.0496368	.1879674	.0049474	.1954874	.0983264	.1847563
6530=	.0133158	.0709425	.1319345	.0593951	.1246405	.0190289	.0527857	.0407157
6540=	.0359030	.0239963	.0135115	.0272497	.0065555	.0109597	.0080593	.0020551
6550=	.0051028	.0035063	.0020376	.0010565	.0060869	.0008415	.0007666	.0016412
6560=	.0050093	.0005443	.0003573	.0003295	.0001987	.0004927	.0001222	.0000516
6570=	.0000530	.0000539	.0000241	.0000300	.0000176	.0000038	.0000036	.0000156
6580=	.0000007	.0000038	.0000031	.0000070	.0000025	.0000008	.0000025	.0000014
6590=	.0000006	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000	0.0000000
6600=	0.0000000	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000
6610=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6620=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6630=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6640=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6650=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6660=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6670=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6680=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6690=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6700=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6710=	0.0000000	4.0553178	5.5744044	9.0366813	8.3421840	13.5008445	7.1273481	11.6151447
6720=	6.7150357	6.3192472	5.8743106	1.8121647	3.4030876	3.9403296	2.4575555	4.5953867
6730=	2.4382642	1.3725894	1.0371559	.4442965	.1521118	.1403523	.0228674	0.0000000
6740=	.6264126	.0424616	.0010122	.0329149	.0176467	.0067051	.0378633	.0580320
6750=	.0601581	.0019965	0.0000000	.0160726	.0039992	.0288053	.0185179	.0022389
6760=	.0074989	.0145219	.0044241	.0007748	.0041155	.0002866	.0048801	.0046161
6770=	.0030851	.0000015	.0015689	.0030259	.0000710	.0030512	.0020699	.0011271
6780=	.0003538	.0009640	.0011034	.0005947	.0030350	.0002711	.0005787	.0006204
6790=	.0006906	.0001209	.0001657	.0003407	.0000343	.0000561	.0000428	.0000056
6800=	.0000269	.0000249	.0000045	.0000018	.0000265	.0000014	.0000015	.0000018
6810=	.0000153	[illegible]	.0000004	.0000004	.0000001	.0000004	.0000001	.0000000

6820=	.0000001	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
6830=	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
6840=	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000	0.0000000
6850=	0.0000000	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000
6860=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6870=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6880=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6890=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6900=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6910=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6920=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6930=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6940=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6950=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
6960=	0.0000000	6.4203522	6.3791153	7.0215179	2.1420465	14.9030292	6.8754361	10.3325665
6970=	7.1934048	4.9954352	5.2093590	1.9894514	3.9135206	3.6733259	2.9992466	3.6122258
6980=	2.3051647	1.3729669	.2848870	.6088504	.1642020	.1596721	.0269542	0.3000000
6990=	.0481374	.0259345	.0082948	.0914170	.1262544	.0722274	.0945578	.0565594
7000=	.0343671	.0070119	0.0000000	.0177054	.0030949	.0313745	.0170615	.0068390
7010=	.0012266	.0383845	.0191881	.0020619	.0155684	.0021184	.0075976	.0156446
7020=	.0055019	.0000012	.0026944	.0112681	.0000341	.0135121	.0049605	.0123528
7030=	.0005495	.0010969	.0092112	.0032753	.0036246	.0002351	.0030941	.0012196
7040=	.0007653	.0001687	.0001416	.0006844	.0000380	.0000577	.0000332	.0000084
7050=	.0000333	.0000299	.0000062	.0000025	.0000127	.0000020	.0000022	.0000022
7060=	.0000068	.0000012	.0000005	.0000005	.0000001	.0000004	.0000002	.0000000
7070=	.0000001	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
7080=	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000	.0000000
7090=	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000	0.0000000
7100=	0.0000000	.0000000	0.0000000	0.0000000	0.0000000	.0000000	0.0000000	0.0000000
7110=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7120=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7130=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7140=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7150=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7160=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7170=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7180=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7190=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7200=	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000	0.0000000
7210=	26.995	27.146	27.122	26.919	77.762	85.322	81.001	82.856
7220=	79.426	86.531	76.379	86.552	135.027	119.347	65.743	327.454
7230=	132.679	105.999	86.126	331.010	136.022	112.500	86.909	320.839
7240=	117.963	114.416	55.100	334.586	379.197	169.266	181.975	192.110
7250=	455.672	439.237	224.518	213.500	227.788	436.039	444.034	228.327
7260=	220.131	222.764	435.845	436.068	225.473	219.417	223.447	439.388
7270=	1380.776	1371.595	1363.103	1365.338				
7280=	468.610	466.773	467.015	470.308	288.910	289.739	287.487	291.186
7290=	286.649	289.354	290.386	288.926	259.082	269.048	263.742	261.803
7300=	261.430	270.097	264.635	260.349	260.465	269.761	266.406	265.368
7310=	265.665	275.433	267.853	263.426	158.261	175.650	165.358	164.543
7320=	149.126	161.165	181.501	171.206	169.973	153.068	160.333	180.266
7330=	171.032	170.957	155.470	163.202	183.092	173.070	172.027	153.858
7340=	180.530	184.077	184.451	185.879				
7350=	327.578	325.506	325.792	328.637	347.269	338.053	344.757	340.461
7360=	346.309	336.534	349.303	336.325	273.113	291.252	294.681	270.416
7370=	276.568	282.626	283.957	267.173	274.715	291.332	285.911	274.109
7380=	282.946	289.983	290.143	272.069	150.569	176.285	169.606	169.309
7390=	142.558	154.646	184.498	177.592	176.924	147.669	153.199	162.525
7400=	176.947	175.066	150.469	156.692	186.040	179.124	179.230	148.452
7410=	156.849	160.785	161.165	162.679				
7420=	684.377	665.175	667.742	683.209	3369.666	3205.916	3322.405	3270.243
7430=	3349.409	3164.509	3394.305	3165.699	2706.693	2959.325	3894.262	2217.634
7440=	2737.299	3188.192	3539.247	2161.664	2684.372	3079.618	3520.755	2324.116
7450=	2963.121	3027.599	4071.296	2967.527	803.413	994.463	1069.669	980.634
7460=	762.744	900.187	1088.039	1195.737	1071.531	927.984	850.317	1057.324
7470=	1138.224	1113.473	933.022	915.590	1077.681	1142.345	1106.187	897.540
7480=	873.869	949.556	1023.599	1001.592				
7490=	375.000	375.000	375.000	375.000	1000.000	1000.000	1000.000	1000.000
7500=	1000.000	1000.000	1000.000	1000.000	305.000	305.000	305.000	460.000
7510=	305.000	305.000	305.000	460.000	305.000	305.000	305.000	460.000
7520=	305.000	305.000	305.000	460.000	0.000	0.000	0.000	0.000
7530=	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7540=	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7550=	0.000	0.000	0.000	0.000				
7560=	8.288	8.244	8.250	8.316	7.211	7.064	7.164	7.130
7570=	7.195	7.059	7.252	7.053	19.772	20.416	20.450	19.710
7580=	20.018	20.520	20.437	19.516	19.894	20.440	20.577	19.979
7590=	20.414	21.002	20.819	19.531	11.290	12.975	12.391	12.356
7600=	10.671	11.561	13.520	12.925	12.862	11.019	11.470	13.393
7610=	12.890	12.942	11.215	11.711	13.635	13.047	13.026	11.076
7620=	12.156	12.437	12.465	12.574				
7630=	149.575	.078	.091	7.723	339.679	.210	.074	.186
7640=	.079	.204	217.644	176.463	1.761	1.551	1.506	1.625
7650=	1.651	1.491	1.662	1.264	1.405	1.751	1.779	1.494
7660=	1.697	1.834	1.651	1.557	.996	1.108	1.186	.904
7670=	.996	.815	.888	.904	.996	.788	.904	.996
7680=	1.060	1.060	.921	.957	1.060	1.134	1.108	.957
7690=	.802	.802	.802	.843				

7700=	7.692	145.239	.038	.997	217.886	174.541	344.740	.201
7710=	.072	.192	.077	.202	1.641	1.814	1.831	1.540
7720=	1.742	1.930	1.490	1.608	1.831	1.475	1.644	1.250
7730=	1.393	1.742	1.760	1.449	.929	1.049	1.121	1.096
7740=	.947	.985	1.096	1.173	.695	.985	.793	.879
7750=	.895	.985	.780	.895	.945	1.049	1.049	.911
7760=	.834	.806	.780	.793				
7770=	1.013	7.620	145.820	.039	.078	.204	225.601	170.739
7780=	340.188	.210	.071	.193	1.406	1.758	1.776	1.491
7790=	1.694	1.679	1.849	1.554	1.756	1.946	1.504	1.622
7800=	1.848	1.488	1.659	1.262	.903	.994	1.058	1.058
7810=	.920	.955	1.058	1.131	1.106	.955	.994	1.106
7820=	1.184	.920	.994	.813	.887	.903	.994	.787
7830=	.800	.856	.800	.800				
7840=	.039	1.001	7.635	149.291	.073	.195	.081	.199
7850=	222.162	177.361	337.312	.211	1.860	1.498	1.671	1.270
7860=	1.416	1.770	1.798	1.472	1.667	1.892	1.860	1.565
7870=	1.770	1.961	1.514	1.634	.896	.893	.909	1.001
7880=	.793	.909	1.001	1.089	1.066	.926	.944	1.066
7890=	1.139	1.114	.962	1.001	1.114	1.192	.926	1.001
7900=	.793	.819	.647	.806				
7910=	.010	.019	.095	.156	419.311	58.263	7.558	8.403
7920=	5.531	8.624	10.085	58.263	85.803	181.496	144.908	26.266
7930=	85.803	26.108	.031	.027	.030	.000	.000	.028
7940=	.031	25.845	144.908	3.181	.019	.000	34.662	.000
7950=	.020	.020	.000	.020	.018	.016	.015	.017
7960=	.018	.018	.016	.016	.018	.020	2.125	.020
7970=	35.297	.021	.018	.000				
7980=	.019	.003	.010	.026	12.013	581.736	12.326	9.907
7990=	1.793	1.406	1.757	10.219	13.964	57.900	278.207	53.831
8000=	97.072	53.611	13.964	.016	1.691	.016	.015	.013
8010=	.015	.017	28.091	.017	.009	.011	1.136	18.539
8020=	.000	1.136	18.539	1.136	.011	.009	.009	.010
8030=	.009	.009	.008	.008	.009	.009	.011	.009
8040=	9.384	18.879	.010	.011				
8050=	.145	.009	.017	.089	9.336	53.269	393.513	51.658
8060=	6.760	7.928	4.981	7.888	.029	58.080	132.536	24.024
8070=	91.679	234.454	99.014	2.909	78.478	2.892	.029	.025
8080=	.029	.029	.000	.026	.015	.016	.019	.000
8090=	.018	.019	1.943	52.694	.000	.019	.017	.019
8100=	.018	.016	.014	.014	.016	.017	.017	.015
8110=	.019	62.687	.019	.016				
8120=	.029	.020	.003	.011	1.923	11.050	13.328	609.768
8130=	13.034	11.050	1.909	1.521	.016	.018	30.374	.018
8140=	1.828	57.968	210.463	49.824	104.961	57.968	37.098	.018
8150=	15.099	.018	.017	.014	.008	.009	.010	.011
8160=	.010	.010	.011	.000	20.045	.000	.000	24.483
8170=	.000	.011	.010	.010	.011	.010	.009	.008
8180=	.011	1.229	20.413	.011				
8190=	.095	.152	.009	.019	5.355	8.379	10.176	54.874
8200=	408.772	56.606	7.071	8.422	.029	.000	.000	.026
8210=	.030	25.110	105.177	3.090	83.362	249.046	105.177	25.519
8220=	97.386	25.366	.000	.025	.015	.016	.018	.017
8230=	.015	.016	.017	.019	.000	.019	.019	.000
8240=	33.676	2.064	.020	.020	.000	.019	.017	.015
8250=	.017	.020	57.000	.000				
8260=	.010	.025	.018	.002	1.738	1.367	1.774	9.632
8270=	11.720	565.591	11.540	9.936	1.644	.016	.015	.013
8280=	.014	.016	33.357	.016	13.576	52.123	189.243	56.524
8290=	133.297	56.293	33.357	.015	.009	.010	.009	.008
8300=	.007	.008	.008	.009	.010	.009	.009	.011
8310=	1.105	29.959	1.105	9.124	29.959	1.105	.010	.009
8320=	.009	.010	22.418	30.508				
8330=	.020	.099	.161	.010	7.624	8.972	5.854	8.654
8340=	10.602	60.307	428.815	60.307	88.813	3.273	.000	.028
8350=	.031	.000	.000	.029	.032	26.752	112.054	27.188
8360=	103.754	187.863	149.992	3.292	.019	.022	.020	.018
8370=	.016	.016	.018	.019	.018	.016	.017	.019
8380=	.021	2.199	.021	.021	.000	35.678	2.199	.020
8390=	.022	.012	.000	36.536				
8400=	.002	.010	.025	.018	11.659	9.918	1.780	1.323
8410=	1.732	9.718	11.519	564.562	94.206	52.029	33.297	.016
8420=	1.641	.016	.015	.013	.015	.016	27.262	.016
8430=	13.552	56.191	269.993	44.719	.000	21.974	.000	.010
8440=	.009	.009	.010	.009	.009	.008	.007	.008
8450=	.009	.011	.009	.009	.011	1.103	29.904	1.103
8460=	22.377	.010	.011	22.377				
8470=	.001	.002	.003	.003	2.608	2.740	.381	.523
8480=	.372	2.740	2.020	9.745	134.854	94.242	66.469	15.562
8490=	6.251	1.883	1.048	.248	.831	1.883	6.251	1.283
8500=	6.251	11.615	53.263	97.455	35.618	55.054	35.509	18.389
8510=	6.413	4.167	1.255	.647	.166	.000	.000	.166
8520=	.554	.935	.554	.699	1.773	4.167	6.413	18.085
8530=	27.789	.647	.554	3.598				
8540=	.002	.002	.003	.008	3.956	7.126	1.142	.982
8550=	.390	1.013	1.098	5.588	99.276	142.357	109.665	42.899
8560=	10.113	5.585	2.802	.675	1.479	1.964	2.802	1.023
8570=	1.964	5.165	16.491	71.262	11.016	29.716	57.994	37.405

8580=	11.016	6.755	3.790	1.322	.682	.429	.000	.429
8590=	.584	.594	.175	.351	.736	1.868	3.790	8.173
8600=	37.902	1.322	.429	1.322				
8610=	.004	.001	.002	.004	3.294	12.309	2.650	3.355
8620=	.470	.692	.463	3.461	65.832	119.034	170.330	102.062
8630=	34.160	12.126	7.896	1.772	4.769	2.378	1.324	.771
8640=	1.324	2.378	7.896	19.054	6.555	9.780	34.432	42.605
8650=	12.971	22.843	6.555	4.544	1.586	.817	.421	.817
8660=	.421	.025	.000	.000	.514	.017	1.586	5.264
8670=	9.780	3.179	.514	.817				
8680=	.002	.001	.001	.001	.690	6.089	.708	1.066
8690=	.239	.160	.235	.890	17.790	46.558	111.417	163.931
8700=	111.417	77.340	31.330	8.900	3.041	1.110	.698	.000
8710=	.284	.950	3.041	8.900	4.113	7.332	11.955	40.720
8720=	62.941	75.910	40.720	21.055	7.332	4.113	1.435	.633
8730=	.189	.000	.000	.000	.000	.189	.633	1.435
8740=	8.870	8.270	.465	.189				
8750=	.003	.001	.002	.003	2.058	9.607	2.693	2.673
8760=	.374	.543	.369	2.758	6.291	9.661	41.151	81.319
8770=	135.711	104.976	85.608	15.659	6.291	2.677	1.055	.250
8780=	.977	1.895	6.291	1.895	.651	1.263	3.621	6.454
8790=	10.334	35.844	66.820	35.735	18.497	6.454	4.194	1.263
8800=	.651	.167	.000	.000	.167	.557	.941	.557
8810=	2.533	27.966	.651	.557				
8820=	.008	.001	.002	.003	1.102	5.591	4.063	6.911
8830=	1.117	1.014	.384	.820	1.985	5.688	12.241	42.919
8840=	99.324	142.125	109.937	55.906	10.118	5.688	2.803	1.023
8850=	1.985	1.479	2.803	1.023	.429	.682	.986	2.653
8860=	6.759	11.021	37.423	58.022	47.726	19.410	6.759	3.792
8870=	1.323	.682	.429	.021	.351	.351	.584	.021
8880=	.986	37.920	.986	.429				
8890=	.003	.003	.001	.002	.450	3.324	3.246	11.459
8900=	2.489	3.324	.444	.458	1.177	2.284	7.582	14.003
8910=	63.217	114.305	163.563	98.307	32.803	11.644	7.582	2.284
8920=	6.546	2.254	1.271	.741	.000	.201	.672	.848
8930=	3.053	6.295	12.658	33.064	52.175	33.165	21.935	6.295
8940=	3.053	1.523	.785	.672	1.135	.672	.201	.000
8950=	.672	12.658	3.053	.404				
8960=	.002	.002	.001	.001	.240	1.109	.714	5.953
8970=	1.229	1.109	.166	.162	.286	1.119	3.066	7.207
8980=	17.939	61.153	124.357	165.305	93.155	61.153	31.593	8.975
8990=	3.066	1.119	.576	.000	.000	.000	.191	.384
9000=	1.078	4.148	7.393	21.232	41.062	75.547	63.469	41.062
9010=	12.056	7.393	4.148	1.447	.639	.191	.000	.000
9020=	.191	8.945	8.945	.191				
9030=	.003	.003	.001	.002	.374	2.761	2.114	9.518
9040=	2.636	2.761	.369	.544	.976	1.897	6.298	1.414
9050=	5.437	9.672	41.197	81.410	135.864	105.094	85.704	15.677
9060=	6.298	2.680	1.056	.250	.000	.167	.558	.704
9070=	.336	.704	1.786	4.199	6.461	18.221	35.894	55.466
9080=	35.775	18.518	6.461	4.199	1.265	.652	.410	.000
9090=	.336	3.625	27.998	.652				
9100=	.003	.008	.001	.002	.387	1.009	1.126	5.396
9110=	3.956	7.098	1.095	1.009	1.472	1.976	2.791	.872
9120=	1.976	5.663	12.187	55.659	98.886	141.499	109.453	55.659
9130=	12.187	4.559	2.791	.872	.000	.427	.350	.427
9140=	.000	.427	.679	1.317	3.775	8.141	10.973	37.258
9150=	57.766	37.258	10.973	8.141	3.775	1.317	.679	.427
9160=	.174	1.317	37.753	1.317				
9170=	.002	.003	.003	.001	.431	.627	.442	3.087
9180=	3.041	11.325	2.348	3.184	4.386	1.631	1.218	.289
9190=	31.428	13.497	7.264	1.218	.473	.752	.387	.000
9200=	1.126	2.198	6.271	13.416	60.567	109.514	156.707	93.899
9210=	.000	.000	.193	.644	1.087	4.181	7.452	12.128
9220=	41.263	63.975	31.775	21.016	7.452	4.181	2.060	.752
9230=	.473	.644	21.359	4.181				
9240=	.001	.002	.002	.001	.231	.156	.237	1.037
9250=	.673	5.922	1.167	1.069	1.560	.924	.556	.000
9260=	.276	1.079	2.094	6.959	17.299	58.974	108.346	159.414
9270=	108.346	75.209	30.467	6.950	1.040	.371	.022	.000
9280=	.000	.000	.000	.184	.616	1.396	4.633	7.130
9290=	20.475	39.598	73.818	73.818	39.598	20.475	7.130	4.000
9300=	.022	.184	11.626	8.626				
9310=	.002	.003	.003	.001	.362	.527	.372	2.594
9320=	2.004	9.516	2.516	2.676	5.279	1.839	1.370	.243
9330=	.611	1.839	6.104	1.839	6.104	11.341	52.009	95.160
9340=	131.678	101.656	83.063	11.273	2.459	.682	.325	.020
9350=	.000	.000	.162	.541	.682	.541	.913	2.459
9360=	5.068	7.576	29.700	34.779	53.757	34.673	17.947	6.262
9370=	.325	.325	4.069	27.135				
9380=	.002	.003	.008	.002	1.143	1.041	.410	1.009
9390=	1.135	5.779	4.016	7.313	8.405	4.085	4.085	1.050
9400=	1.518	2.037	2.037	1.350	2.037	6.763	16.936	57.389
9410=	101.959	145.897	112.855	29.140	5.615	1.918	.756	.361
9420=	.022	.000	.440	.599	.440	.022	.361	.756
9430=	1.918	4.509	11.314	11.314	38.417	59.562	48.992	19.925
9440=	.756	.361	1.916	38.927				
9450=	.002	.002	.004	.004	2.796	3.747	.520	.715

9460=	.509	3.747	3.523	13.324	20.996	10.622	10.644	1.919
9470=	5.163	2.575	1.327	.340	1.327	2.575	8.547	15.785
9480=	71.261	106.837	184.377	67.691	10.417	5.658	2.424	1.279
9490=	.456	.456	.956	.757	.027	.000	.000	.557
9500=	.865	1.716	5.698	7.096	14.269	37.271	58.815	37.386
9510=	2.424	.455	.865	25.130				
9520=	.001	.001	.001	.002	.709	1.129	.175	.160
9530=	.245	.914	.700	6.254	114.429	79.425	32.175	9.140
9540=	2.211	1.140	.717	.000	.292	.975	3.123	7.339
9550=	18.269	62.280	114.420	168.350	64.638	41.818	12.278	7.529
9560=	4.224	1.474	.650	.194	.003	.000	.000	.000
9570=	.194	.650	1.474	4.224	6.093	12.278	32.104	64.638
9580=	9.110	.194	.478	9.110				
9590=	.000	.000	.000	.000	.134	.241	.033	.036
9600=	.024	.169	.133	.701	30.449	12.345	5.201	2.794
9610=	.627	.371	.111	.000	.000	.111	.434	1.189
9620=	2.794	5.201	23.476	49.265	42.720	29.035	20.154	12.344
9630=	4.673	.561	.248	.009	.000	.000	.000	.000
9640=	.000	.009	.289	.418	1.125	2.319	3.467	12.257
9650=	16.079	.074	.000	1.862				
9660=	.000	.000	.001	.001	.268	.427	.095	.081
9670=	.065	.345	.265	2.370	44.189	23.632	18.494	5.164
9680=	1.675	.623	.369	.013	.110	.369	.835	.431
9690=	.835	2.773	6.959	30.230	28.826	39.868	30.854	25.161
9700=	12.255	1.596	.415	.148	.009	.000	.000	.000
9710=	.009	.149	.073	.148	.310	.797	1.849	3.442
9720=	30.473	.246	.073	.787				
9730=	.000	.000	.001	.001	.643	.638	.155	.149
9740=	.085	.154	.121	.638	27.642	40.530	27.642	11.242
9750=	3.168	1.537	.571	.203	.203	.338	.395	.248
9760=	.395	1.082	3.168	11.242	18.352	28.299	36.585	28.299
9770=	23.487	2.112	.722	.284	.136	.008	.000	.000
9780=	.008	.008	.000	.008	.165	.284	.722	2.112
9790=	27.601	.284	.000	.284				
9800=	.000	.000	.000	.003	.258	1.748	.264	.322
9810=	.062	.060	.061	.410	17.761	28.942	42.436	22.764
9820=	4.959	3.317	1.609	.414	.447	.354	.260	.000
9830=	.260	.447	1.609	4.959	11.769	24.164	29.631	38.306
9840=	30.641	3.306	1.776	.755	.298	.142	.009	.173
9850=	.000	.000	.000	.000	.000	.142	.298	1.073
9860=	24.265	.755	.000	.142				
9870=	.000	.000	.000	.000	.121	.635	.125	.148
9880=	.022	.034	.029	.218	4.711	11.182	27.580	40.316
9890=	16.603	11.182	3.294	1.528	.393	.101	.000	.000
9900=	.000	.202	.762	2.530	4.233	11.181	23.363	29.109
9910=	38.695	14.462	4.233	2.101	1.456	.508	.262	.008
9920=	.000	.000	.000	.000	.000	.008	.135	.379
9930=	14.564	1.687	.000	.067				
9940=	.000	.000	.000	.000	.136	.709	.139	.236
9950=	.033	.038	.024	.171	2.825	5.260	24.147	49.826
9960=	30.795	12.486	5.260	2.825	.634	.375	.112	.000
9970=	.000	.014	.474	1.292	.423	1.138	2.346	3.507
9980=	16.147	43.205	29.765	20.384	12.485	4.726	.423	.151
9990=	.009	.000	.000	.000	.000	.000	.009	.250
10000=	1.684	16.262	.009	.005				
10010=	.001	.000	.009	.001	.286	2.530	.294	.442
10020=	.099	.289	.068	.369	.892	2.556	5.512	32.269
10030=	47.171	25.226	13.058	5.512	1.788	.665	.237	.000
10040=	.289	.394	1.260	.460	.158	.331	.840	1.974
10050=	3.675	30.771	42.579	32.936	26.859	13.082	1.192	.331
10060=	.158	.000	.000	.000	.000	.010	.158	.010
10070=	.840	32.529	.152	.078				
10080=	.001	.000	.000	.001	.128	.670	.693	.650
10090=	.159	.161	.088	.161	.415	.805	2.671	11.802
10100=	29.020	42.551	29.020	11.802	2.671	1.176	.448	.261
10110=	.415	.214	.448	.261	.009	.142	.299	.758
10120=	2.217	19.268	29.711	38.409	29.711	24.659	1.780	.536
10130=	.299	.174	.000	.000	.000	.000	.009	.000
10140=	.299	28.977	.299	.000				
10150=	.001	.001	.000	.000	.065	.427	.276	1.767
10160=	.270	.346	.064	.062	.271	.431	1.678	5.171
10170=	12.522	30.183	44.255	23.740	5.171	2.779	1.678	.431
10180=	.624	.431	.271	.000	.000	.000	.148	.311
10190=	1.115	12.274	25.199	30.901	39.948	31.954	3.448	1.599
10200=	.558	.311	.181	.009	.148	.009	.000	.000
10210=	.148	25.305	.558	.009				
10220=	.000	.000	.000	.000	.032	.235	.134	.661
10230=	.131	.235	.023	.036	.000	.265	.610	2.716
10240=	5.057	12.004	29.606	43.277	17.822	6.815	3.383	1.156
10250=	.422	.108	.000	.000	.000	.000	.000	.145
10260=	.406	4.544	12.003	25.080	31.249	41.537	11.918	3.371
10270=	2.255	1.094	.406	.291	.009	.000	.000	.000
10280=	.009	15.634	1.811	.000				
10290=	.000	.000	.000	.000	.024	.166	.136	.669
10300=	.133	.238	.032	.037	.000	.109	.461	1.171
10310=	3.426	6.903	29.986	46.517	29.926	6.903	5.122	2.751
10320=	.618	.366	.109	.000	.000	.000	.000	.000
10330=	.244	.553	1.5[illegible]	2.234	4.602	15.723	42.071	26.594

10340=	19.848	12.157	4.602	.553	.147	.009	.000	.000
10350=	.000	1.834	15.235	.073				
10360=	.001	.001	.000	.000	.067	.361	.288	2.401
10370=	.281	.446	.095	.087	.283	.385	1.233	.365
10380=	1.233	2.696	7.271	31.584	46.169	24.691	12.780	5.395
10390=	1.750	.650	.385	.000	.000	.000	.000	.189
10400=	.000	.154	.324	.822	1.932	4.848	30.117	41.675
10410=	32.237	26.289	12.605	1.668	.324	.154	.009	.000
10420=	.000	.822	31.638	.257				
10430=	.001	.001	.000	.000	.086	.160	.130	.643
10440=	.671	.664	.155	.160	.211	.352	.444	.105
10450=	.444	1.125	3.293	11.687	28.737	42.136	28.737	11.687
10460=	3.293	1.597	.594	.105	.000	.000	.000	.000
10470=	.000	.008	.141	.296	.750	2.196	19.080	29.421
10480=	38.035	29.421	24.418	2.196	.750	.295	.141	.008
10490=	.000	.296	28.695	.295				
10500=	.000	.001	.001	.000	.065	.062	.066	.415
10510=	.272	1.826	.266	.347	.467	.223	.272	.000
10520=	.223	.467	2.403	5.191	18.557	30.239	44.338	23.784
10530=	5.181	2.783	1.681	.223	.000	.181	.000	.000
10540=	.000	.000	.009	.148	.311	1.602	12.297	25.247
10550=	30.959	40.023	32.014	3.454	1.655	.789	.311	.146
10560=	.000	.247	25.352	.789				
10570=	.000	.000	.000	.000	.023	.036	.032	.227
10580=	.130	.680	.128	.234	.350	.013	.013	.000
10590=	.000	.217	.816	2.708	5.042	11.967	29.516	43.145
10600=	17.768	6.795	4.167	.816	.144	.000	.000	.000
10610=	.000	.000	.000	.009	.144	.544	4.530	11.966
10620=	25.003	31.153	41.411	15.477	4.530	2.248	1.559	.544
10630=	.000	.072	15.587	1.805				
10640=	.000	.000	.000	.000	.033	.044	.025	.165
10650=	.136	.707	.134	.243	.632	.374	.112	.000
10660=	.000	.112	.437	1.198	3.507	7.066	24.068	49.663
10670=	30.694	12.445	5.243	2.816	.421	.150	.009	.000
10680=	.000	.000	.000	.000	.009	.292	.566	1.621
10690=	2.338	4.711	16.095	43.064	29.269	20.317	12.444	4.711
10700=	.975	.000	2.338	16.209				
10710=	.000	.001	.001	.000	.096	.087	.069	.350
10720=	.281	2.477	.277	.446	1.750	.650	.385	.000
10730=	.115	.385	.873	.450	1.233	2.898	7.271	31.585
10740=	46.169	24.691	19.323	5.395	1.167	.324	.154	.009
10750=	.000	.000	.000	.000	.189	.077	.257	.434
10760=	1.167	1.932	4.848	30.118	41.676	32.237	26.289	12.805
10770=	.154	.009	.822	31.639				
10780=	.000	.001	.001	.000	.159	.161	.091	.156
10790=	.129	.671	.668	.671	3.328	1.614	.600	.261
10800=	.355	.355	.415	.261	.448	1.137	3.328	11.810
10810=	29.040	42.580	29.040	11.810	2.219	.758	.299	.142
10820=	.009	.000	.000	.009	.000	.000	.009	.142
10830=	.299	.758	2.219	19.281	29.731	38.436	29.731	24.676
10840=	.299	.000	.400	28.997				
10850=	.000	.000	.001	.001	.271	.349	.067	.061
10860=	.065	.431	.268	1.838	5.215	2.801	1.692	.435
10870=	.470	.372	.274	.000	.224	.470	2.418	5.215
10880=	18.677	30.435	44.626	23.936	3.476	1.612	.562	.313
10890=	.182	.074	.182	.009	.000	.000	.000	.009
10900=	.248	.419	1.612	12.377	25.410	31.159	40.282	32.222
10910=	.562	.000	.248	25.516				
10920=	.000	.000	.000	.000	.131	.235	.024	.035
10930=	.032	.235	.129	.682	17.838	6.822	4.183	1.157
10940=	.422	.108	.000	.000	.000	.217	.819	2.719
10950=	5.062	12.014	29.632	43.315	11.928	3.374	2.257	1.095
10960=	.407	.281	.009	.000	.000	.000	.000	.000
10970=	.009	.241	.546	4.548	12.013	25.102	31.275	41.573
10980=	1.612	.000	.072	15.648				
10990=	.000	.000	.001	.001	.342	.659	.174	.207
11000=	.058	.214	.168	.886	30.738	30.553	23.598	8.880
11010=	3.539	2.138	.794	.283	.283	.283	.549	.346
11020=	.593	1.506	4.407	8.880	20.369	38.882	38.397	32.239
11030=	20.369	2.359	1.004	.396	.314	.094	.000	.000
11040=	.000	.094	.000	.094	.199	.396	1.004	2.359
11050=	39.774	.366	.000	.366				
11060=	.001	.000	.000	.001	.175	.914	.362	.658
11070=	.176	.220	.059	.220	.611	1.097	3.643	9.142
11080=	31.644	31.454	24.294	9.142	3.643	1.550	.918	.356
11090=	.566	.356	.611	.291	.097	.323	.407	1.033
11100=	2.429	20.969	40.028	39.529	33.190	20.969	2.097	.732
11110=	.407	.194	.012	.000	.012	.000	.012	.000
11120=	.377	40.947	.377	.000				
11130=	.001	.001	.000	.000	.060	.219	.179	.864
11140=	.353	.676	.172	.219	.290	.355	.609	.355
11150=	.609	1.545	4.523	9.114	31.548	31.359	24.220	9.114
11160=	3.632	1.545	.815	.144	.000	.000	.000	.000
11170=	.000	.095	.322	.406	1.030	2.421	20.906	39.907
11180=	39.409	33.089	20.906	2.421	1.030	.406	.322	.096
11190=	.000	.406	40.823	.376				
11200=	.000	.001	.001	.000	.176	.221	.062	.214
11210=	.176	.918	.350	.681	3.660	1.557	.922	.357

```
11220=     .486     .293     .568     .293     .614    1.557    4.558    9.184
11230=   31.790   31.599   24.405    9.184    2.107     .735     .409     .195
11240=     .012     .009     .012     .000     .000     .000     .238     .324
11250=     .548    1.038    3.039   21.064   40.213   39.711   33.342   21.066
11260=     .379     .000     .409   41.135
11270=1
11280= .5
```

APPENDIX C

APPENDIX C

Detailed Description of Policy Alternatives

Table C1. Variable Work Hour Simulation Run Descriptions

Run No.	Zones Involved	Percent Participation	Temporal Distribution for Zones Involved: Time Period 1	2	3	4	5	Temporal Distribution for All Zones: Time Period 1	2	3	4	5
1	ALL	Base Case	--	--	--	--	--	.10	.15	.50	.15	.10
A1	ALL	60	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
A2	1-4	10	.10	.175	.45	.175	.10	.10	.153	.494	.153	.10
A3	1-4	30	.125	.20	.35	.20	.125	.103	.156	.482	.156	.103
A4	1-4	50	.175	.20	.25	.20	.175	.109	.156	.470	.156	.109
A5	1-4	60	.20	.20	.20	.20	.20	.112	.156	.464	.156	.112
A6	1-12	10	.10	.175	.45	.175	.10	.10	.161	.478	.161	.10
A7	1-12	30	.125	.20	.35	.20	.125	.111	.172	.434	.172	.111
A8	1-12	50	.175	.20	.25	.20	.175	.133	.172	.390	.172	.133
A9	1-12	60	.20	.20	.20	.20	.20	.144	.172	.368	.172	.144
A10	1-28	10	.10	.175	.45	.175	.10	.10	.170	.460	.170	.10
A11	1-28	30	.125	.20	.35	.20	.125	.120	.190	.380	.190	.120
A12	1-28	50	.175	.20	.25	.20	.175	.160	.190	.300	.190	.160
A13	1-28	60	.20	.20	.20	.20	.20	.180	.190	.260	.190	.180
A14	1-48	10	.10	.175	.45	.175	.10	.10	.174	.452	.174	.10
A15	1-48	30	.125	.20	.35	.20	.125	.124	.198	.356	.198	.124
A16	1-48	50	.175	.20	.25	.20	.175	.172	.198	.260	.198	.172
A17	1-48	60	.20	.20	.20	.20	.20	.197	.198	.210	.198	.197

Table C1. (continued)

Run No.	Zones Involved	Percent Participation	Temporal Distribution for Zones Involved: Time Period 1	2	3	4	5	Temporal Distribution for All Zones: Time Period 1	2	3	4	5
B1	ALL	NA						.112	.156	.464	.156	.112
B2	ALL	NA						.133	.172	.390	.172	.133
B3	ALL	NA						.144	.172	.368	.172	.142
B4	ALL	NA						.160	.190	.300	.190	.160
B5	ALL	NA						.109	.156	.470	.156	.109
C1	6,10,14, 15,16,17, 22,23,24, 25,30,31, 32,33,39, 40,41,42, 43,49,51	10	.10	.20	.45	.15	.10					
	8,12,13 18,19,20, 21,26,27, 28,34,35, 36,37,38, 44,45,46, 47,48,50, 52	10	.10	.15	.45	.20	.10					
	1,2,3, 4,5,7, 9,11	10	.10	.175	.45	.175	.45	.10	.175	.45	.175	.10

NA = Not Applicable

Table C2. Description of Transit-Only Policies

Run No.	Description	Time Period	Buses per Hour for Each Route — Route Number 1	2	3	4	5	6	7	8	9	10	11	12
1	Base Case	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		3	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	43	43	43	43	43	43	43	43	43	43	43	43
D1	Shift one bus to routes 2, 3, 8 and 9 from routes 1, 4, 7 and 10 for the peak half hour only.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		3	3	6	6	3	4.5	4.5	3	6	6	3	4.5	4.5
		4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	42	44	44	42	43	43	42	44	44	42	43	43
D2	Shift one bus to each of routes 2, 3, 6, 8, 9 and 12 from routes 1, 4, 5, 7, 10 and 11 for the peak half hour only.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	42	44	44	42	42	44	42	44	44	42	42	44
D3	Shift one bus to each of routes 2, 3, 6, 8, 9 and 12 from routes 1, 4, 5, 7, 10 and 11 for all five time periods.	1	3	6	6	3	3	6	3	6	6	3	3	6
		2	3	6	6	3	3	6	3	6	6	3	3	6
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	3	6	6	3	3	6	3	6	6	3	3	6
		5	3	6	6	3	3	6	3	6	6	3	3	6
		Daily Total	38	48	48	38	38	48	38	48	48	38	38	48

Table C2. (continued)

Run No.	Description	Time Period	Buses Per Hour for Each Route — Route Number 1	2	3	4	5	6	7	8	9	10	11	12
D4	Shift two buses to routes 2, 3, 8 and 9 from routes 1, 4, and 10. Shift one bus to routes 6 and 12 from routes 5 and 11 for peak half hour only.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		3	1.5	7.5	7.5	1.5	3	4.5	1.5	7.5	7.5	1.5	3	4.5
		4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	41	45	45	41	42	44	41	45	45	41	42	44
D5	Shift one bus to routes 2, 3, 6, 8, 9 and 12 from routes 1, 4, 5, 7, 10 and 11 for time periods 2, 3 and 4 only.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	6	6	3	3	6	3	6	6	3	3	6
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	3	6	6	3	3	6	3	6	6	3	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	46	46	40	40	46	40	46	46	40	40	46
E1	Add one bus to routes 2, 3, 6, 8, 9 and 12 for time periods 2, 3 and 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	4.5	6	6	4.5	4.5	6	4.5	6	6	4.5	4.5	6.0
		3	4.5	6	6	4.5	4.5	6	4.5	6	6	4.5	4.5	6.0
		4	4.5	6	6	4.5	4.5	6	4.5	6	6	4.5	4.5	6.0
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	43	46	46	43	43	46	43	46	46	43	43	46

Table C3. Description of Combined Variable Work Hour and Transit Policy Alternatives

Run No.	Description	Time Period	Buses per Hour for Each Route, Route Number 1	2	3	4	5	6	7	8	9	10	11	12
F1	Temporal Traffic Distribution from run A2. Transit bus Distribution from run D5.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	6	6	3	3	6	3	6	6	3	3	6
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	3	6	6	3	3	6	3	6	6	3	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	46	46	40	40	46	40	46	46	40	40	46
F2	Temporal Traffic Distribution from run A3. Transit bus Distribution from run D5.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	6	6	3	3	6	3	6	6	3	3	6
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	3	6	6	3	3	6	3	6	6	3	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	46	46	40	40	46	40	46	46	40	40	46
F3	Temporal Traffic Distribution from run A6. Transit bus Distribution from Run D5.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	6	6	3	3	6	3	6	6	3	3	6
		3	3	6	6	3	3	6	3	6	6	3	3	6
		4	3	6	6	3	3	6	3	6	6	3	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	46	46	40	40	46	40	46	46	40	40	46
F4	Temporal Traffic Distribution from run A7. Shift one bus to routes 3, 4, 9, 10 and 12, from routes 1, 2, 5, 6 and 11 for time periods 2, 3 and 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	3	6	6	3	3	4.5	4.5	6	6	3	6
		3	3	3	6	6	3	3	4.5	4.5	6	6	3	6
		4	3	3	6	6	3	3	4.5	4.5	6	6	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	40	46	46	40	40	43	43	46	46	40	46

Table C3. (continued)

Run No.	Description	Time Period	Buses per Hour for Each Route — Route Number 1	2	3	4	5	6	7	8	9	10	11	12
F5	Temporal Traffic Distribution from Run A7. Shift one bus to routes 3, 6, 9 and 12 from routes 1, 5, 7 and 11, for time periods 2, 3 and 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	4.5	6	4.5	3	6	3	4.5	6	4.5	3	6
		3	3	4.5	6	4.5	3	6	3	4.5	6	4.5	3	6
		4	3	4.5	6	4.5	3	6	3	4.5	6	4.5	3	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	43	46	43	40	46	40	43	46	43	40	46
F6	Temporal Distribution from run A11. Shift one bus to routes 3, 6, 9 and 12 from routes 1, 4, 7 and 10, for time periods 2, 3 and 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	3	4.5	6	3	4.5	6	3	4.5	6	3	4.5	6
		3	3	4.5	6	3	4.5	6	3	4.5	6	3	4.5	6
		4	3	4.5	6	3	4.5	6	3	4.5	6	3	4.5	6
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	40	43	46	40	43	46	40	43	46	40	43	46
G1	Temporal Distribution of run C1. Shift 2 buses to routes 1, 5, 6, 7, 11 and 12 from 2, 3, 4, 8, 9 and 10 during time period 2. Reverse shift for time period 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	1.5	7.5	7.5	7.5	1.5	1.5	1.5	7.5	7.5	7.5	1.5	1.5
		3	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		4	7.5	1.5	1.5	1.5	7.5	7.5	7.5	1.5	1.5	1.5	7.5	7.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	43	43	43	43	43	43	43	43	43	43	43	43

Table C3. (continued)

Run No.	Description	Time Period	Buses per Hour for Each Route — Route Number 1	2	3	4	5	6	7	8	9	10	11	12
G2	Temporal Distribution of run C1. Shift 1 bus to routes 1, 5, 6, 7, 11 and 12 from 2, 3, 4, 8, 9 and 10 during time period 2. Reverse shift for time period 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	6	3	3	3	6	6	6	3	3	3	6	6
		3	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		4	3	6	6	6	3	3	3	6	6	6	3	3
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	43	43	43	43	43	43	43	43	43	43	43	43
H1	Temporal Distribution of run C1. Add 1 bus to routes 1, 5, 6, 7, 11 and 12 during time period 2. Add 1 bus to routes 2, 3, 4, 8, 9 and 10 during time period 4.	1	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		2	6	4.5	4.5	4.5	6	6	6	4.5	4.5	4.5	6	6
		3	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		4	4.5	6	6	6	4.5	4.5	4.5	6	6	6	4.5	4.5
		5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
		Daily Total	43	43	43	43	43	43	43	43	43	43	43	43

APPENDIX D

APPENDIX D

Congestion Indices for Selected Policy Runs

Total Links Shown: 78

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
19	168	2																								
18	167	8																								
17	159																									
16	148																									
15	145																									
14	139	3																								
13	133																									
12	125	7																								
11	124		166		135																					
10	121		164	6	118				141																	
9	120	11	161	4	82				129																	
8	106	8	160		81				110																	
7	93		152	12	68		165		104	1																
6	92		147		61	10	149	10	103	7																
5	79		137	1	59	3	123		95		83	7	153													
4	78	8	90	10	49	12	96		69	10	53		117													
3	67		75	1	47	5	55		63		45		111	1			113	2			115	3				
2	65		57	2	37	8	43		51	1	33		97	4			89	4	99	5	101	6				
1	29	12	31	7	27	11	39	9	41	4	25		35		76	7	71	11	85	8	87	9			73	12
Link Congestion Index	1.500		2.000		2.500		3.000		3.500		4.000		4.500		5.000		5.500		6.000		6.500		7.000		7.500	
	1.999		2.499		2.999		3.499		3.999		4.499		4.999		5.499		5.999		6.499		6.999		7.499		7.999	

Figure D1. Peak Half Hour Congestion Indices for Run D1.

LN = Link Number
R = Transit Route Number

Total Links Shown: 80

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
21	166																							
20	159																							
19	157																							
18	154				164	6																		
17	145				152	12																		
16	137	1			148																			
15	133				147																			
14	132	5			125	7																		
13	131	11			124																			
12	130				104	1																		
11	128	9			103	7																		
10	122				96																			
9	121				81																			
8	120	11	160		68				165															
7	106	8	139	3	63		141		129															
6	93		118		59	3	135		123															
5	92	5	82		57	2	95		110				153											
4	90	10	75	1	49	12	61	10	83	7	117		111	1										
3	79		67		47	5	41	4	69	10	97	4	76	7	89	4								
2	78	8	43		37	8	39	9	59	3	53		71	11	73	12	113	2			87	9		
1	65		31	7	27	11	33		25		51	1	45		35		99	5	101	6	85	8	115	3
	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999		4.000 4.499		4.500 4.999		5.000 6.499		5.500 6.999		6.000 6.499		6.500 6.999		7.000 7.499	

Link Congestion Index

Figure D2. Peak Half Hour Congestion Indices for Runs D2, D3 and D5.

LN = Link Number
R = Route Number

Total Links Shown: 75

Number of Interzonal Links	1.500–1.999 LN	R	2.000–2.499 LN	R	2.500–2.999 LN	R	3.000–3.499 LN	R	3.500–3.999 LN	R	4.000–4.499 LN	R	4.500–4.999 LN	R	5.000–5.499 LN	R	5.500–5.999 LN	R	6.000–6.499 LN	R	6.500–6.999 LN	R	7.000–7.499 LN	R	7.500–7.999 LN	R	8.000–8.499 LN	R
20	167	8																										
19	166																											
18	159																											
17	157																											
16	156	8																										
15	149	10			164	6																						
14	148				147																							
13	145				139	3																						
12	142				135																							
11	133				123																							
10	130				118																							
9	124		160	12	104	1			165																			
8	121		152	12	82				153																			
7	106	8	137	1	57	2			129																			
6	93		128	9	49	12			103	7																		
5	92	5	125	7	47	5	110		95						117													
4	79		81		43		63		68						113	2												
3	78	8	75	1	37	8	61	10	51	1					97	4	111	1	115	3								
2	65		67		31	7	33		41	4	69	10	141		45		99	5	87	9								
1	29	12	59	3	27	11	25		39	9	63		76	7	35		89	4	71	11			106	6			73	12

Link Congestion Index

Figure D3. Peak Half Hour Congestion Indices for Run D4.

LN = Link Number
R = Route Number

Total Links Shown: 79

Number of Interzonal Links	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999		4.000 4.499		4.500 4.999		5.000 5.499		5.500 5.999		6.000 6.499		6.500 6.999		7.000 7.499	
	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
21	159																							
20	157																							
19	149	10																						
18	148																							
17	145																							
16	144	11	166																					
15	137	1	164	6																				
14	133		160																					
13	130		152	12																				
12	125	7	139	3																				
11	121		135		147																			
10	120	11	128	9	141																			
9	106	8	124		123																			
8	93		118		104	1																		
7	92	5	81		103	7					153													
6	90	10	75	1	96				165		129													
5	82		67		68		110		95		97	4												
4	79		63		59	3	61	10	69	10	83	7	117											
3	78	8	47	5	49	12	57	2	51	1	71	11	111	1	101	6								
2	65		31	7	43		37	8	41	4	55		89	4	99	5	113	2	85	8				
1	29	12	27	11	39	9	25		33		53		45		76	7	36		73	12	87	9	115	3

Link Congestion Index

Figure D4. Peak Half Hour Congestion Indices for Run E1.

LN = Link Number
R = Route Number

Total Links Shown: 80

Number of Interzonal Links	1.500–1.999 LN	R	2.000–2.499 LN	R	2.500–2.999 LN	R	3.000–3.499 LN	R	3.500–3.999 LN	R	4.000–4.499 LN	R	4.500–4.999 LN	R	5.000–5.499 LN	R	5.500–5.999 LN	R	6.000–6.499 LN	R	6.500–6.999 LN	R	7.000–7.499 LN	R	7.500–7.999 LN	R	8.000–8.499 LN	R
20	167	8																										
19	160																											
18	158																											
17	157																											
16	149	10																										
15	148																											
14	142		166																									
13	133		159																									
12	130		145																									
11	124		137	1	164	6																						
10	121		135		152	12																						
9	120	11	128	9	147																							
8	106	8	125	7	123																							
7	93		118		104		139	3			141				117													
6	92	5	81		82		96		165		89	4			113	2												
5	90	10	75	1	61	10	63		153		83	7			85	8												
4	79		68		59	3	47	5	110		69	10			76	7												
3	78	8	49	12	57	2	41	4	103	7	55				71	11												
2	67		37	8	43		39	9	97	4	53		129		35		111	1										
1	29	12	27	11	31	7	33		45		51	1	95		25		99	5	101	6	73	12	87	9			115	3

Link Congestion Index

Figure D5. Peak Half Hour Congestion Indices for Run F1.

LN = Link Number
R = Route Number

Total Links Shown: 71

Number of Interzonal Links	LN (1.500–1.999)	R	LN (2.000–2.499)	R	LN (2.500–2.999)	R	LN (3.000–3.499)	R	LN (3.500–3.999)	R	LN (4.000–4.499)	R	LN (4.500–4.999)	R	LN (5.000–5.499)	R	LN (5.500–5.999)	R	LN (6.000–6.499)	R
22	160																			
21	149	10																		
20	148																			
19	145		164	6																
18	137	1	152	12																
17	133		147																	
16	128	9	139	3																
15	125	7	135																	
14	124		118																	
13	121		104	1																
12	120	11	96																	
11	95		82																	
10	93		81				153													
9	92	5	75	1			141													
8	90	10	68				129													
7	79		63				123													
6	78	8	49	12	165		110													
5	67		47	5	103		97	4			113									
4	59	3	43		61	10	69	10	83	7	111	1								
3	57	2	39	9	55		53		76	7	99	5								
2	37	8	27	11	51	1	45		71	11	89	4			115	3				
1	31	7	25		41	4	33		35		85	8	117		73	12	101	6	87	9

Link Congestion Index

Figure D6. Peak Half Hour Congestion Indices for Runs C1, G1 and G2.

LN = Link Number
R = Route Number

Total Links Shown: 81

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
22	168	2																				
21	167	8																				
20	166																					
19	161	4																				
18	159																					
17	156	8																				
16	149																					
15	148	10	164	6																		
14	137	1	160																			
13	133		152	12																		
12	130		145																			
11	124		139	3																		
10	121		135		118																	
9	106	8	128		104	1	165															
8	93		125		96		147				153											
7	92	5	123		82		103	7			141											
6	90	10	120	11	68		95				129											
5	79		75	1	63		81		110		97	4										
4	78	8	61	10	57	2	41	4	69	10	83	7										
3	67		59	3	49	12	39	9	55		51	1			89	4	113	2				
2	65		43		47	5	37	8	53		45		117		76	7	99	5	101	6	115	3
1	29	12	31	7	27		33		25		35		111	1	71	11	85	8	87	9	73	12
	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999		4.000 4.499		4.500 4.999		5.000 5.499		5.500 5.999		6.000 6.499		6.500 6.999	

Link Congestion Index

Figure D7. Peak Half Hour Congestion Indices for Run F2.

LN = Link Number
R = Route Number

Total Links Shown: 79

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
24	166																							
23	157																							
22	154																							
21	149	10																						
20	148																							
19	145																							
18	139	3																						
17	137	1																						
16	133																							
15	130																							
14	128	9																						
13	125	7																						
12	121																							
11	120	11					129																	
10	106	8	164	6			110																	
9	93		160		147		104	1			117													
8	92	5	159		141		97	4			113	2												
7	90	10	152	12	135		81		165		95													
6	82		124		103	7	69	10	153		83	7												
5	79		118		68		61	10	123		76	7												
4	78	8	96		63		41	4	111	1	71	11												
3	75	1	67		59	3	39	9	57	2	53				101	6								
2	65		37	8	49	12	33		47	5	51	1	89	4	85	8	99	5						
1	29	12	31	7	43		27	11	25		45		55		73		35		87	9			115	3
	1.500		2.000		2.500		3.000		3.500		4.000		4.500		5.000		5.500		6.000		6.500		7.000	
	1.999		2.499		2.999		3.499		3.999		4.499		4.999		5.499		5.999		6.499		6.999		7.499	

Link Congestion Index

Figure D8. Peak Half Hour Congestion Indices for Run F3.

LN = Link Number
R = Route Number

Total Links Shown: 68

Number of Interzonal Links	1.500–1.999 LN	R	2.000–2.499 LN	R	2.500–2.999 LN	R	3.000–3.499 LN	R	3.500–3.999 LN	R	4.000–4.499 LN	R	4.500–4.999 LN	R	5.000–5.499 LN	R	5.500–5.999 LN	R	6.000–6.499 LN	R
20	164	6																		
19	160																			
18	155	2																		
17	152	12																		
16	148																			
15	147																			
14	139	3																		
13	137	1																		
12	133																			
11	130																			
10	128	9					153													
9	120	11					111	1			141									
8	118		135				104				101	6								
7	106	8	123				99	5	165		89	4								
6	93		103	7			71	11	129		85	8								
5	92	5	97	4	110		61	10	113		76	7	117							
4	82		81		96		57	2	49	12	59	3	95							
3	78	8	69	10	83	7	43		37	8	53		87	9						
2	75	1	68		67		41	4	33		47	5	51	1	115	3				
1	29	12	31	7	63		27	11	25		39	9	45		73	12	55		35	

Link Congestion Index

Figure D9. Peak Half Hour Congestion Indices for Run F4.

LN = Link Number
R = Route Number

Total Links Shown: 74

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R	LN	R
25	164	6																				
24	159																					
23	157																					
22	154																					
21	149	10																				
20	148																					
19	145																					
18	137	1																				
17	135		160																			
16	133		152	12																		
15	128	9	139	3																		
14	121		125	7																		
13	120	11	118																			
12	106	8	82				153															
11	104	1	81				141															
10	96		68				129															
9	93		63				123															
8	92	5	61	10			110															
7	90	10	59	3	165		97	4														
6	79		57	2	147		83	7														
5	78	8	43		103	7	69	10														
4	75	1	39	9	95		51	1					113		101	6						
3	67		37	8	55		45						111	1	99	5						
2	49	12	33		47	5	35		89	4	117		85	8	87	9						
1	31	7	27	11	41	4	25		53		76	7	71	11	73	12					115	3
	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999		4.000 4.499		4.500 4.999		5.000 5.499		5.500 5.999		6.000 6.499		6.500 6.999	

Link Congestion Index

Figure D10. Peak Half Hour Congestion Indices for Run F5.

LN = Link Number
R = Route Number

Total Links Shown: 54

Number of Interzonal Links	LN	R	LN	R	LN	R	LN	R	LN	R
30	164	6								
29	160									
28	159									
27	152	12								
26	147									
25	145									
24	139	3								
23	135									
22	129									
21	123									
20	104									
19	93									
18	82									
17	81									
16	79									
15	78	8								
14	68									
13	67		165							
12	61	10	153							
11	57	2	141							
10	55		110							
9	51	1	103	7						
8	47		97	4						
7	45		95							
6	43		89	4	117					
5	41	4	83		113	2				
4	39	9	69	10	111	1	115	3		
3	37	8	53		76	7	101	6		
2	33		49	12	73	12	99	5		
1	25		35		71	11	85	8	87	9
	1.500 1.999		2.000 2.499		2.500 2.999		3.000 3.499		3.500 3.999	

Link Congestion Index

Figure D11. Peak Half Hour Congestion Indices for Run F6.

LN = Link Number
R = Route Number

Total Links Shown: 71

Number of Interzonal Links	LN (1.500–1.999)	R	LN (2.000–2.499)	R	LN (2.500–2.999)	R	LN (3.000–3.499)	R	LN (3.500–3.999)	R	LN (4.000–4.499)	R	LN (4.500–4.999)	R	LN (5.000–5.499)	R	LN (5.500–5.999)	R
29	166																	
28	159																	
27	157																	
26	152	12																
25	149	10																
24	148																	
23	145																	
22	139	3																
21	137	1																
20	130																	
19	128	9																
18	124																	
17	120	11																
16	118																	
15	96																	
14	93		164	6														
13	92	5	160															
12	82		147															
11	79		135															
10	78	8	123															
9	75	1	104	1			165											
8	67		95				153											
7	61	10	81		111	1	141											
6	59	3	68		103	7	129											
5	57	2	63		69	10	97	4										
4	47	5	41	4	55		83	7			87	9						
3	43		39	9	51	1	53		117		85	8	113	2				
2	37	8	33		49	12	45		111	1	76	7	101	6				
1	31	7	27	11	35		24		89	4	71	11	99	5	115	3	73	12

Link Congestion Index

Figure D12. Peak Half Hour Congestion Indices for Run H1.

LN = Link Number
R = Route Number

LIST OF REFERENCES

LIST OF REFERENCES

Atherton, T. J., and Suhrbier, J. H., *Urban Transportation Energy Conservation: Analytic Procedures for Establishing Changes in Travel*, Final Report - Volume II, U.S. DOE, Office of Conservation and Advanced Systems Policy, Washington, D.C., DOE/PE/8628-1, 1979.

Batty, Michael, "Recent Developments in Land-Use Modeling: A Review of British Research," *Urban Studies*, Vol. 9, No. 2, June 1972, pp. 151-177.

Betz, J. M., and Supersad, J. N., "Traffic and Staggered Working Hours," *Traffic Quarterly*, Vol. 19, No. 2, April 1965.

Bowman, L. A., Goetsch, D. H., and Polzin, S. E., *A Model for Evaluating the Energy Conserving Potential of Transportation and Land Use Policies: Development and Preliminary Application*, unpublished M.S. research report, Department of Civil Engineering, Northwestern University, May 1975.

Charles River Associates, *A Disaggregate Behavioral Model of Urban Travel Demand*, final report prepared for Federal Highway Administration, contract DOT-FH-11-7566, March 1972.

Chang, M., Evans, L., Herman, R., and Wasiekewski, P., "Gasoline Consumption in Urban Traffic," *Transportation Research Record 599*, 1976.

Christopherson, P. D., and Olafson, G. G., "Effects of Urban Traffic Control Strategies on Fuel Consumption," *ITE Journal*, November 1978.

Claffey, P. J. and Associates, *Running Costs of Motor Vehicles as Affected by Road Design and Traffic*, NCHRP Report 111, 1971.

COMSIS Corporation, *Traffic Assignment: Methods, Application, Products*, U.S. Department of Transportation, Federal Highway Administration, Washington, D. C., August 1973.

Dupree, J. H., and Pratt, R. H., *Low Cost Urban Transportation Alternatives: A Study of Ways to Increase the Effectiveness of Existing Transportation Facilities, Volume I, Results of a Survey and Analysis of Twenty-one Low-Cost Techniques*, U.S. Department of Transportation, Office of the Secretary, January 1973.

Edwards, J. L., *Relationships Between Transportation Energy Consumption and Urban Spatial Structure*, unpublished Ph.D. dissertation, Department of Civil Engineering, Northwestern University, June 1975.

Evans, L., Herman, K., and Lam, T., "Multivariate Analysis of Traffic Factors Related to Fuel Consumption in Urban Driving," Transportation Science, Volume 10, No. 2, May 1976.

Evans, L., and Herman, R., "Automobile Fuel Economy: An Alternative Interpretation of Recent Computer Simulation Calculations," Transportation Research, Vol. 12, No. 2, 1978.

Evans, L., "How Does Traffic Speed Affect Urban Fuel Consumption," Letter to the Editor, ITE Journal, June 1979.

General Motors Corporation, Truck and Coach Division, "Vehicle Dynamics Simulation Model," Pontiac, Michigan, 1974.

Goldner, W., "The Lowry Model Heritage," Journal of the American Institute of Planners, Volume 37, No. 2, March 1971.

Greenberg, A. M., and Wright, D. M., Staggered Hours Final Evaluation -- Queen's Park Demonstration, Ontario Ministry of Transportation and Communication, May 1975.

Gross, J., Kocis, M., and Cohen, G., Preliminary Techniques for Estimating the Net Energy Savings of TSM Actions, Planning Research Unit, New York State Department of Transportation, Albany, New York, October 1978.

Hartgen, D. T., "Energy Analysis for Urban Transportation Systems: A Preliminary Assessment," Transportation Research Record 599, 1976.

Hatfield, F. J., "User Optimized Traffic Assignment," Transportation Engineering Journal, May 1974.

Highway Capacity Manual, Highway Research Board Special Report 87, National Academy of Sciences, National Research Council, Publication 1328, Washington, D. C., 1965.

Holland, D. D., A Review of Reports Relating to the Effects of Fare and Service Changes in Metropolitan Public Transportation Systems, Center for Urban Programs, St. Louis University. Prepared for the Office of Highway Planning, Federal Highway Administration, U.S. Department of Transportation, Grant No. 32-22-66, June 1974.

Honeywell Traffic Management Center, Fuel Consumption Study - Urban Traffic Control System (UTCS) Software Support Project, Federal Highway Administration, Report No. FHWA-RD-76-81, February 1976.

Jones, D. W. Jr., Nakamoto, T., and Cilliers, M. P., Flexible Work Hours: Implications for Travel Behavior and Transport Investment Policy, UCB-ITS-RR-78-r, Institute of Transportation Studies, University of California, Berkeley, December 1977.

LeBlanc, L. J., Mathematical Programming Algorithms for Large Scale Network Equilibrium and Network Design Problems, unpublished Ph.D. Dissertation, Transportation Center at Northwestern University, Evanston, Illinois, 1973.

le Clerq, F., "A Public Transport Assignment Method," Traffic Engineering and Control, Vol. 14, No. 2, June 1972.

Lieberman, E., and Rosenfield, N., Network Flow Simulation for Urban Traffic Control System -- Phase II, Volume 5, Extention of NETSIM Simulation Model to Incorporate Vehicle Fuel Consumption and Emissions, Final Report, Prepared for the Federal Highway Administration, Offices of Research and Development, Report No. FHWA-RD-77-45, Washington, D. C., April 1977.

Lowry, I. S., A Model of Metropolis, memorandum RM-4035-RC, the RAND Corporation, Santa Monica, California, August 1964.

Lutin, J. M., "Energy Savings for Work Trips: Analysis of Alternative Commuting Patterns for New Jersey," Transportation Research Record 561, 1976.

Masey, A. C., and Paullin, R. L., Transportation Vehicle Energy Intensities, Ames Research Center, Moffett Field, California, NASA TMX-62,404, U.S. Department of Transportation, DOT-TST-13-74-1, June 1974.

Mass Transportation Commission of the Commonwealth of Massachusetts, McKinsey & Co., Systems Analysis and Research Corp., and Joseph Napolitan & Assoc. Mass Transportation in Massachusetts. Sponsored by U.S. Housing and Home Finance Agency; Project No. MASS-MTD-1, July 1964.

O'Malley, B. W., and Selinger, C. S., "Staggered Work Hours in Manhattan," Traffic Engineering and Control, Printerhall Limited, London. Volume 14, No. 9, January 1973.

O'Malley, B. W., Work Schedule Changes, Staggered Work Hours in New York, Port Authority of New York and New Jersey, August 1974.

Owens, R. D., and Van Wormer, G. H., "The Effect of Staggered Working Hours on Traffic at a Large Industrial Complex," Traffic Engineering, August 1973.

Pratt, R. H., and Bevis, H. W., An Initial Chicago North Suburban Transit Improvement Program 1971-1975 - Volume II: Technical Supplement, Sponsored by the Urban Mass Transportation Administration, U.S. Department of Transportation; Project No. ILL-T9-2, July 1971.

Pratt, R. H., Pedersen, N. J., and Mather, J. J., Traveler Response to Transportation System Changes: A Handbook for Transportation Planners, Contract No. DOT-FH-11-8479, U.S. Department of Transportation, Federal Highway Administration, Urban Mass Transportation Administration, February 1977.

Peskin, R. L., and Schofer, J. L., The Impacts of Urban Transportation and Land Use Policies on Transportation Energy Consumption, U.S. Department of Transportation, Office of University Research, DOT-TST-77-85, April 1977.

Peskin, R. L., The Impacts of Urban Transportation and Land Use Policies on Transportation Energy Consumption, unpublished Ph.D. Dissertation, Department of Civil Engineering, Northwestern University, Evanston Illinois, 1977.

Port Authority of New York and New Jersey, Staggered Work Hours Study -- Phase I Final Report, August, 1977.

Quarmby, D. A., "Choice of Travel Mode for the Journey to Work - Some Findings," Journal of Transport Economics and Policy, London School of Economics and Political Science, London, W.C.2, Volume 1, No. 3, September 1967.

Remak, R., and Rosenbloom, S., Peak-Period Traffic Congestion: Options for Current Programs, NCHRP Report 169, 1976.

Safavian, R., and Mclean, K. G., "Variable Work Hours: Who Benefits?" Traffic Engineering, Institute of Transportation Engineers, Arlington, Virginia. Volume 45, No. 3, March 1975.

Sanders, D. B, Reynen, T. A., and Bhatt, B., Characteristics of Urban Transportation Systems: A Handbook for Transportation Planners, U. S. Department of Transportation, UMTA, UMTA-IT-06-0049-79-1, Whasington, D. C., June 1929.

Santerre, G. L., An Investigation of the Feasibility of Improving Freeway Operation by Staggering Work Hours, an unpublished thesis for the degree of M.S., Texas A & M University, Department of Civil Engineering, Houston, Texas, May 1966.

Shunk, Gordon A., and Bouchard, Richard J., "An Application of Marginal Utility to Travel Mode Choice," Highway Research Record 322, 1971.

Stopher, P. R., and Lavender, O. J., "Disaggregate, Behavioral Travel Demand Models: Empirical Tests of Three Hypotheses," Proceedings, Transportation Research Forum, Oxford, Indiana, pp. 321-336, 1972.

Talvitie, A., "Comparison of Probabilistic Modal-Choice Models: Estimation Methods and System Inputs," Highway Research Board Record 392, 1972.

Tannir, A. A., The Impacts of Feasible Work Hours and Compressed Workweek Policies on Highway Networks, Transportation Economics, Organizations and Employees, New York State Department of Transportation, Preliminary Research Report 129, August 1977.

Texas Department of Highways, Amarillo Urban Transportation Plan, Austin, Texas, 1964.

United States Congress, Office of Technology Assessment, Energy, The Economy and Mass Transit, December 1975.

Voorhees, A. M., and Morris, R., "Estimating and Forecasting Travel for Baltimore by Use of a Mathematical Model," Highway Research Board Bulletin 224, Washington, D.C., 1959.

Voorhees, A. M. and Associates, Inc., Factors and Trends in Trip Lengths, NCHRP Report 48, 1968.

Voorhees, A. M. and Associates, Inc., Guidelines to Reduce Energy Consumption through Transportation Actions, U.S. Department of Transportation, UMTA-IT-06-0092-74-2, May 1974.

Wardrop, J. G., "Some Theoretical Aspects of Road Traffic Research," Proc. Institute of Civil Engineers, Vol. 1, No. 2, Part II, June 1952.

West, D. T., "A Technical Report of the 1974 Union 76 Fuel Economy Tests," Automotive Fuel Economy, Progress in Technology Series, Vol. 15, Society of Automotive Engineers, 1976.

Witkowski, J. M., and Taylor, W. C., "Urban Transportation Planning Under Energy Constraints," Transportation Research Board Record 707, 1979.