Transit Use and Energy Crises: Experience and Possibilities

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A representative sample of 66 urbanized areas is used to examine the relation between gasoline supply and transit ridership during the second and third quarters of 1979. An overview of the effect of the 1979 gasoline shortfall on transit ridership indicates that ridership increased by 5.1 percent in the time frame of the study over the corresponding period in 1978. The largest percentage increases in ridership were seen in western U.S. urbanized areas and small urbanized areas. Cross elasticities of transit ridership with respect to gasoline supply are calculated for various categories broken down by region and system size. The measure used for this calculation is arc elasticity. Cross elasticities vary from -0.45 for large systems in the Northeast to -4.99 for small systems in the West, and the cross elasticity for the entire sample is found to be -0.75. The role of transit in alleviating the impact of the 1979 energy crisis is found to be minor: Gasoline savings due to transit patronage increases amounted to less than 5 percent of the decrease in gasoline sales. Methods of calculating ridership increases and gasoline savings attributable to transit for a variety of energy futures are developed. The results indicate that transit cannot be expected to play a major role in a future energy emergency.

As energy efficiency became a newly discovered concern in the wake of the 1973-1974 energy crisis, transit ridership trends rose for the first time in a generation. The 1979 crisis did not catch America completely by surprise: Transit systems around the country were generally in sounder shape than in 1973, thanks in part to an infusion of federal money in the form of operating assistance as well as capital grants. The 1979 energy crisis resulted in a further growth in transit ridership.

This paper is intended to assess the relation between transit ridership and energy supply in the 1979 crisis. The relation is important in both directions. Of direct concern is the effect of a gasoline shortfall on transit ridership, but also investigated is the degree to which transit can soften the impact of a gasoline shortfall by providing an alternative means of transportation and thereby preventing some of the loss of mobility that would otherwise occur. Many studies (1-7) have examined the first part of this problem, but none has focused directly on the second part.

DATA AND PROCEDURES

This study uses a sample of 66 U.S. urbanized areas to examine the relation between gasoline supply and transit ridership during the second and third quarters of 1979. Selection of urbanized areas for the sample was guided primarily by the availability of data for ridership and gasoline supply. Data were also collected for other factors such as population size and density, service and fare levels, gasoline price, region of the country, and transit system size. These other factors were analyzed to determine whether any factor showed a relation with either gasoline supply or transit ridership and whether any factor affected the supply-ridership relation.

A word on the measurement of the key variables involved is in order. Data on ridership and gasoline supply were obtained by month and aggregated both by quarter and by the entire six-month period. Comparison with the corresponding time period in 1978 determined changes in ridership and supply. Ridership data were obtained from the American Public Transit Association (APTA) (8), and monthly gasoline sales by state were available from the Federal Highway Administration (FHWA) (9). These were apportioned to urbanized areas within each state by use of the ratio of daily vehicle miles of travel (DVMT) in a given urbanized area to statewide DVMT (10). This approach assumes that gasoline sales and shortfalls are distributed within each state in the same proportion as DVMT. Sources for other variables may be found in the literature (10-12 and various issues of the Oil and Gas Journal).

Two further notes on data sources should be made. Gasoline prices in neighboring urbanized areas were remarkably similar, and an average of neighboring prices was used where the information was not available for a given urbanized area. In addition, total transit VMT was not available for all urbanized areas, and so system size was measured by peak-hour vehicle requirement. This presents no problem since, where transit VMT was available, its correlation with peak-hour vehicle requirement was very high.

The time frame of the study consists of the second and third quarters of 1979 and comparisons with the corresponding time period of 1978 to determine changes. In larger urbanized areas, all operators are considered part of the same overall transit system.

IMPACT OF 1979 CRISIS ON TRANSIT USE

In the second quarter of 1979, transit ridership rose by 3.3 percent over 1978. In the third quarter, as the impact of the gasoline shortfall hit home, ridership increased by 6.7 percent. The increase in ridership for both the second and third quarters was 5.1 percent.

Data given in Table 1 (8) show that transit ridership grew at a much faster pace on transit systems in the West. As Table 2 (8, 11) indicates, small urbanized areas experienced greater percentage changes in ridership than did large urbanized areas. Table 3 (8, 11) indicates that, when size of transit system replaces population, virtually the same relation holds: Smaller systems show greater percentage increases in ridership. An interesting exception is that the smallest systems rank below moderately small systems in percentage change in ridership. This suggests that there may be a minimum base system size necessary for optimal growth in transit ridership during an energy crisis.

Tables 1-3 indicate that small systems and systems in the West showed the greatest percentage increases in transit ridership during the 1979 energy crisis. Ridership levels are lowest on small systems and on systems in the West (Table 1), and so there is more room for growth. In addition, population growth in the West may have accelerated ridership increases.

Data given in Table 4 (8-10) show no clear relation between percentage changes in gasoline supply and ridership. The trends of percentage changes in ridership with increasing percentage shortfalls are opposite in the second and third quarters. Attempts to find a suppressor variable affecting the supply-ridership relation were unsuccessful, nor did a clear relation emerge when the time frame was expanded to include both quarters. Given the different responses of urbanized areas of different sizes and in different regions, it seemed appropriate to take size and region into account in analyzing the supply-ridership relation. This approach is used in the following section.

Other variables for which data were collected are

Table 1. Percentage change in ridership by region for 1978-1979.

Region	No. of Systems	Change in Ridership (%) Second Quarter	Change in Ridership (%) Third Quarter	Mean Monthly Ridership (000s)
Northeast	13	2.4	6.0	11 633
South	24	2.5	6.0	1 725
North Central	16	5.0	6.3	4 180
West	13	13.7	15.8	1 275
Total	66	3.7	6.7	4 183

Table 2. Percentage change in ridership by urbanized-area population.

Urbanized-Area Population	No. of Systems	Change in Ridership (%) Second Quarter	Change in Ridership (%) Third Quarter
>1 000 000	12	3.1	6.0
500 000 to 1 000 000	12	7.2	9.6
250 000 to 500 000	11	5.5	10.9
100 000 to 250 000	22	8.4	12.9
<100 000	9	24.1	18.0
Total	66	3.7	6.7

Table 3. Percentage change in ridership by size of system.

Peak Requirement (no. of buses)	No. of Systems	Change in Ridership (%) Second Quarter	Change in Ridership (%) Third Quarter
>200 + rail	5	3.2	5.8
>200, bus only	16	4.5	8.5
80 to 200	11	6.1	10.8
40 to 80	18	10.0	12.9
<40	16	6.9	11.7
Total	66	3.7	6.7

Table 4. Percentage change in ridership by percentage change in gasoline supply.

Supply Decrease (%)	Second Quarter No. of Systems	Second Quarter Change in Ridership (%)	Third Quarter No. of Systems	Third Quarter Change in Ridership (%)
>9	4	11.0	15	5.9
7 to 9	13	2.9	12	6.3
5 to 7	13	2.3	17	12.3
3 to 5	21	11.6	11	7.2
<3	15	8.2	11	8.2
Total	66	3.7	66	6.7

not of particular use in this analysis. The range of percentage changes in gasoline price was too narrow to yield significant results. Urbanized areas in the midrange of population density showed the greatest percentage increases in ridership. Ridership changes vary directly with service changes, but it is difficult to determine whether service changes preceded or followed ridership changes in 1979. Fare changes, as might be expected, tend to hold down ridership increases.

In general, size of system and region were salient variables in determining the impact of the 1979 energy crisis on transit use. These two variables are taken into account in the examination of the supply-ridership relation in the next section.

Table 5. Cross elasticities of transit ridership with respect to gasoline supply.

Region	System Size	No. of Systems	Cross Elasticity
Northeast	Large	8	-0.45
	Small	5	-3.40
	Total	13	-0.48
South	Large	10	-0.87
	Small	14	-0.98
	Total	24	-0.90
North Central	Large	5	-0.66
	Small	11	-1.57
	Total	16	-0.69
West	Large	6	-2.55
	Small	7	-4.99
	Total	13	-2.79
All regions	Large	29	-0.68
	Small	37	-2.11
	Total	66	-0.75

CROSS ELASTICITIES OF TRANSIT RIDERSHIP WITH RESPECT TO GASOLINE SUPPLY

Cross elasticity measures the sensitivity of the demand for a particular product to changes in the characteristics of some other product. In this case, what is being measured is the sensitivity of transit ridership to changes in gasoline supply. Transit systems are categorized by system size (large or small, with a peak-hour requirement of 100 vehicles as the dividing line) and by region. Within each category, an aggregate approach is used to measure the changes in ridership and gasoline supply over the six-month period (including both quarters) in 1979 compared with the same time period in 1978. Arc elasticity, which has emerged in the transportation literature as the preferred measure of elasticity (13-15), is used to measure the cross elasticities of transit ridership with respect to gasoline supply. The cross elasticity for the category of system size i and region j is

$$e_{ij} = (\log R_{79ij} - \log R_{78ij})/(\log G_{79ij} - \log G_{78ij}) \qquad (1)$$

where R_{xij} is the sum of riders on transit systems of size i in region j in year x and G_{xij} is the sum of gasoline sales in urbanized areas with transit systems of size i in region j in year x.

Table 5 gives the cross elasticities derived from the above calculations. The response of ridership to gasoline supply is much more elastic in western urbanized areas than in other regions of the country. In every region, small systems show greater cross elasticities (in terms of absolute value) than large systems.

The difference in cross elasticity by system size is particularly pronounced in the Northeast. However, a majority of the small transit systems sampled in the Northeast are in Pennsylvania, where an unexplained discrepancy in gasoline data masks the severity of the gasoline shortfall and so exaggerates the calculated cross elasticity. The difference between small and large systems in the Northeast is therefore also exaggerated. In the South, on the other hand, the difference is very small. Many of the small systems in the South actually lost riders in the second and third quarters of 1979; of the 10 systems that lost ridership, 7 were small systems in the South. This was balanced somewhat by the relatively minor gasoline shortfalls in southern urbanized areas in the sample. Nonetheless, the South is the only region in which ridership was relatively inelastic with respect to gasoline supply for small systems.

In general, the relation between transit ridership and gasoline supply is inelastic except in the West: Cross elasticities range from -0.48 in the Northeast to -2.79 in the West. The same pattern holds for large systems: Cross elasticities range from -0.45 in the Northeast to -2.55 in the West. Among small systems, the relation is elastic except in the South: Cross elasticities range from -0.98 in the South to -4.99 in the West. The cross elasticity for the entire sample is -0.75.

It has been suggested that transit systems in the West have excess capacity and so have a greater ability to respond to a crisis situation (16). This might explain the greater cross elasticities in the West. It is possible that small systems have more flexibility than large systems and so are also more able to respond to a crisis. By this line of reasoning, system capacity and flexibility are the important factors affecting the cross elasticity of transit ridership with respect to gasoline supply.

Several other studies have attempted to gauge the effect of a gasoline supply decrease on transit ridership. Sacco and Hajj (4) suggest that a 10-15 percent decrease in supply would result in a short-term transit ridership increase of 5-7 percent, which implies a cross elasticity of approximately -0.5. Carlson (7) reports a 1979 ridership increase of 10 percent matching a peak gasoline shortage of 10 percent, implying a cross elasticity of approximately -1.0. Navin (5) estimates increases in downtown work trips by transit for Minneapolis and north suburban Chicago that correspond to 10 and 25 percent decreases in supply. The implied cross elasticities in Navin's study range from -1.69 to -4.45. An ongoing project at the New York State Department of Transportation (NYSDOT) (17) yields a preliminary cross elasticity of -0.21 for urbanized areas in New York State. Horowitz (6) models responses to various gasoline allocation plans for a 15 percent gasoline shortfall. Transit ridership rises by 20-40 percent, which implies a range of cross elasticities from -1.33 to -2.07. Interestingly, in Horowitz' model the smallest increase in transit ridership occurs in the scenario where gasoline price is highest, and the largest increase occurs in the non-price-based scenario. A National Cooperative Highway Research Program report (1) ties future gasoline supply to future gasoline price, thus making it difficult to extract a ridership-supply cross elasticity from the model. If price is ignored as a factor, in accordance with the assumption that gasoline price has little short-term impact on transit ridership, the implied cross elasticity of ridership with respect to gasoline supply is in the range of -2.26 to -3.05 for the work-trip model and -0.95 to -1.37 overall.

The cross elasticities of Table 5 are within the range found in this review of the literature. This range indicates the likelihood that there is no one firmly established figure and so supports the separate-category approach taken in Table 5.

EFFECT OF INCREASED TRANSIT USE ON 1979 CRISIS

The role of transit in the 1979 energy crisis can be determined by calculating the energy savings resulting from ridership increases and comparing these savings with the gasoline shortfall in each urbanized area. Results are aggregated by region and by size of urbanized area; complete results are given by Boyle (18).

For the purposes of this analysis, it is assumed that all "new" transit riders accounting for the ridership increases are former automobile users and that there is no use of the "car left home". Clearly, these are optimistic assumptions that tend to overestimate the energy-saving role of transit. Given these assumptions, the number of cars left at home due to modal shifts can be obtained by dividing the ridership increase for each urbanized area by an average automobile occupancy of 1.6 persons/automobile. The number of cars left home can then be multiplied by the average trip length to obtain the vehicle miles not traveled, or "saved", by transit. Several sources were consulted to determine average trip length (19-23); the figure finally chosen is 9.0 miles. This is a somewhat liberal estimate. It can be justified by the assumption that the impact of a gasoline crisis is felt most strongly by those who make the longest trips and so the average trip length of those diverted to transit is greater than the overall average trip length.

The formula for computing VMT saved by transit in urbanized areas is as follows:

$$\mathrm{VMT}_i = (\Delta R_i/1.6) \cdot 9.0 \tag{2}$$

This can be converted to gallons of gasoline saved by transit by dividing by the average fleet efficiency in miles per gallon. This figure is available by state through the year 1977 (24), and fleet efficiencies for New York State have been calculated by NYSDOT through 1979. An average 1979 fleet efficiency for a given urbanized area can be computed as follows:

$$\mathrm{MPG}_{i1979} = \mathrm{MPG}_{i1977} \cdot (\mathrm{MPG}_{\mathrm{NY}1979}/\mathrm{MPG}_{\mathrm{NY}1977}) \tag{3}$$

The formula for gasoline savings S in urbanized area i is then

$$S_i = \mathrm{VMT}_i/\mathrm{MPG}_{i1979} = [(\Delta R_i/1.6)/\mathrm{MPG}_{i1979}] \cdot 9.0 \tag{4}$$

Note that S_i is gasoline savings due to transit. These savings can be compared with the total reduction in gasoline use in the urbanized area and also to the urbanized-area gasoline consumption in the second and third quarters of 1978.

Tables 6 and 7 (8-11, 24) present mean savings due to transit as a percentage of reduction in gasoline use and of 1978 consumption, aggregated by region and size of urbanized area. Overall, gasoline savings due to transit total only 4.4 percent of the reduction in gasoline use and 0.3 percent of 1978 consumption. It can be seen from Table 6 that increased transit use contributed most to gasoline savings in the West and the Northeast (if the Pennsylvania cases in which there is an unexplained discrepancy in the data on gasoline sales are excluded, the mean percentage savings for the Northeast drops to 5.5 percent). Data given in Table 7 show that the proportion of energy savings due to transit is highest in the largest urbanized areas.

Tables 6 and 7 suggest that transit did not play a major role in the energy conservation effort. Other factors, such as increased fleet efficiency, actual reduction in travel, formation of carpools, or trip chaining, must account for the bulk of energy savings.

The conclusion that the role of transit in alleviating the 1979 energy crisis was minor is reached under the optimistic assumptions that all new transit riders came from automobiles and that cars left at home were not used. Barring unforeseen changes in the operation of transit systems, transit may be expected to play a minor role in any future energy emergency.

FUTURE SCENARIOS: TRANSIT RIDERSHIP AND ENERGY SAVINGS

The methods and results developed and obtained thus

Table 6. Gasoline savings accounted for by transit ridership increases by region.

Region	No. of Systems	Mean Gallons Saved by Transit (000s)	Reduction in Sales: Mean Gallons (000s)	Reduction in Sales: Due to Transit (%)	April-September 1978: Mean Gallons Used (000s)	April-September 1978: Reduction Due to Transit (%)
Northeast	13	1143	17 240	6.6	211 421	0.5
South	24	161	5 709	2.8	127 808	0.1
North Central	16	566	18 587	3.0	248 350	0.2
West	13	392	6 505	6.0	135 399	0.3
Total	66	498	11 320	4.4	174 319	0.3

Table 7. Gasoline savings accounted for by transit ridership increase by size of urbanized area.

Population	No. of Systems	Mean Gallons Saved by Transit (000s)	Reduction in Sales: Mean Gallons (000s)	Reduction in Sales: Due to Transit (%)	April-September 1978: Mean Gallons Used (000s)	April-September 1978: Reduction Due to Transit (%)
>1 000 000	12	2069	40 746	5.1	574 612	0.4
500 000 to 1 000 000	12	369	9 488	3.9	187 407	0.2
250 000 to 500 000	11	158	6 952	2.3	107 297	0.1
100 000 to 250 000	22	65	2 538	2.6	44 068	0.1
<100 000	9	47	1 331	3.5	23 455	0.2
Total	66	498	11 320	4.4	174 319	0.3

far may be used in several ways to address future scenarios. One use is to derive a factor for adjusting ridership forecasts in the event of a future energy shortfall. Another use is to predict ridership response and energy savings due to transit in various energy situations.

A basic problem in forecasting is the emergence of variables considered unimportant or unpredictable at the time of the forecast as significant factors affecting the dependent variable at a later time. Hartgen (25) has shown that the original forecast can be updated in such a situation by use of an adjustment factor that takes the newly important variable into account. This approach can be applied to transit ridership forecasts. A factor for ridership increase in response to a gasoline shortfall can be computed by use of the cross elasticities in Table 5:

$$F_{ij} = 1 + [e_{ij} \cdot (g/100)] \tag{5}$$

where

F_{ij} = a factor to apply to ridership forecasts for an urbanized area in region j and with system size i,
e_{ij} = cross elasticity of ridership with respect to gasoline supply for an urbanized area with system size i and in region j, and
g = percentage change in gasoline supply for the urbanized area.

The original forecast of ridership can be multiplied by this factor to account for the effect of the gasoline shortfall on ridership. Original forecasts for years subsequent to a gasoline shortfall can also be adjusted by use of the factor.

Predicting ridership response and energy savings due to transit in various energy futures is also possible, but it is necessary to know something about the short-term price-ridership relation. Other studies have indicated little short-term relation between gasoline price and transit ridership (2-4, 26, 27). Navin (5) has noted that a 5 percent gasoline shortfall has the same impact on transit ridership as a doubling of gasoline price. Erlbaum and Koeppel (17) estimate the cross elasticity of ridership with respect to gasoline supply as -0.21 and with respect to gasoline price as 0.01 for urbanized areas in New York State. Both studies imply that the cross elasticity with respect to supply is of a magnitude 20 times greater than the cross elasticity with respect to price. A rough estimate of price cross elasticity can be obtained by multiplying the supply cross elasticity by -0.05. This price cross elasticity can then be used to calculate ridership changes for various price increases in a no-shortfall situation.

The supply cross elasticities were calculated in a period when there was a 30 percent price increase. These supply cross elasticities at the 30 percent price-increase level cannot be broken down into supply-only and price-only cross elasticities because the method of estimating price cross elasticity is noniterative. However, the no-shortfall price cross elasticities can be used to obtain the proportion of percentage change in ridership attributable to price at the 30 percent price-increase level. This proportion can then be adjusted to reflect different price increase levels. In mathematical terms,

$$r_{p,s} = r_{30,s} - \{[1 - (p/30)] \cdot (r_{30,0}/r_{30,s})\} \tag{6}$$

where $r_{p,s}$ is the percentage change in ridership corresponding to percentage changes in gasoline price (p) and supply (s).

This formula can be used to estimate the percentage change in ridership for various energy futures. An example is provided in Table 8, which gives percentage ridership increases and gasoline savings due to transit for the scenario involving a 15 percent shortfall and a 30 percent price increase. It is assumed in this example that base transit ridership in 1985 is 6 percent higher than in 1979 (a conservative assumption given post-1973 trends) and the base gasoline consumption in 1985 is 6.5 percent lower than in 1979, in line with predictions for New York State (25).

Table 8 indicates that the role of transit in alleviating a future crisis is likely to be minor, as it was in 1979. A more detailed analysis, including other scenarios, is given elsewhere (18). The detailed analysis reveals that, although price has

Table 8. Effect of 15 percent shortfall and 30 percent price increase in 1985.

Region	System Size	Increase in Transit Ridership (%)	Energy Savings Due to Transit (%)
Northeast	Large	6.8	5.7
	Small	51.0	10.9
South	Large	13.1	3.4
	Small	14.7	0.8
North central	Large	9.9	2.7
	Small	23.6	1.5
West	Large	38.3	5.8
	Small	74.9	8.1

some effect on transit ridership in a no-shortfall situation, the price effect is negligible in a shortfall situation.

SUMMARY AND CONCLUSIONS

Transit ridership for the sample of 66 urbanized areas rose by 5.1 percent in the second and third quarters of 1979 compared with the same time period in 1978. For the second quarter alone, ridership rose by 3.7 percent; the ridership increase for the third quarter was 6.7 percent. Small urbanized areas and urbanized areas in the West showed the largest percentage increases in ridership.

The cross elasticity of transit ridership with respect to gasoline supply ranges from -0.45 for large systems in the Northeast to -4.99 for small systems in the West. The overall cross elasticity for the entire sample is -0.75. The calculated cross elasticities are within the range of those found in or extracted from other studies. Small systems and systems in the West show the most elastic response. In general, however, transit ridership is relatively inelastic with respect to gasoline supply.

Transit played a relatively minor role in alleviating the impact of the 1979 energy crisis. Even with the assumptions that all new riders switched from automobile to transit and left their cars at home unused, the gasoline savings due to increased transit patronage amounted to less than 5 percent of the decrease in gasoline sales. Transit contributes most to energy savings in the Northeast and the West and in very large urbanized areas.

Methods of calculating energy savings and ridership increases for future energy scenarios have been developed. The results indicate that the role of transit in alleviating a future crisis is likely to be minor.

Although it is not the purpose of this paper to examine in detail the reasons for the role of transit in alleviating the 1979 energy crisis, it appears that transit systems do not have the capacity to absorb large numbers of riders in a short-term situation. Even if ridership increases (and, therefore, energy savings due to transit) were doubled, the role of transit would still have been relatively minor, accounting for less than 10 percent of the drop in gasoline sales. Actions to encourage transit use should be part of energy contingency plans, but it must be recognized that other actions will shoulder most of the burden in alleviating a future energy shortfall.

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Indirect Energy Considerations of Park-and-Ride Lots

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The expenditure of energy to construct and operate a park-and-ride lot is seldom weighed against the motor fuel savings generated by the park-and-ride service. An initial attempt to establish this relation is presented. A procedure is developed to estimate the indirect energy requirements of a prototype park-and-ride lot based on lot size and the fuel savings incurred by various lot usage scenarios. From this, the number of years required for lot fuel savings to account for indirect energy expenditures is determined. The impact on fuel savings of lot operational variables, such as distance to the CBD, bus load factor, and fuel-efficiency rates, is examined. This analysis of energy expenditures and savings is then applied to existing park-and-ride lots in the Dallas-Fort Worth area. It is concluded that indirect energy expenditures are significant enough to warrant consideration in the transportation planning process. It is noted that the indirect energy costs can be accounted for in less than 10 years for most park-and-ride projects. This payback period is significant because it represents the point in time at which energy conservation truly occurs.

The establishment of park-and-ride lots served by express transit operations is generally considered by urban transportation planners and policymakers to be an effective way of conserving energy as well as reducing air pollution and traffic congestion. By leaving their automobiles at specially designated lots and riding transit to the central business district (CBD) or other destinations, commuters, theoretically at least, will use less fuel for transportation.

Spurred by recent petroleum shortfalls, planners and local officials have accelerated the planning and construction of park-and-ride lots as a transportation system management technique. Often not considered in the evaluation of park-and-ride services as energy savers, however, is the fact that the development and construction of these lots and services also entail the expenditure of energy. For instance, fuel is consumed by the vehicles used in lot construction and materials hauling. The materials themselves require energy from mining or manufacturing processes, and the construction of the lot consumes energy. The energy used in these types of activities is termed "indirect" energy (1, p. 5), or energy "implementation costs" (2, p. 5). It has been estimated that indirect transportation energy consumption accounts for more than 40 percent of all transportation-related energy use in the United States. The question that then arises is how long it will take for direct fuel savings from the park-and-ride operations to repay the energy expenditure of costs involved in their establishment. This is important because the point where operational energy savings exceed the energy expended in lot construction is the point at which energy conservation begins.

Because the practice of making estimates of indirect energy use is not well established, such energy costs are seldom considered in the planning of park-and-ride services (as well as other transportation projects). The following discussion is an initial investigation of this energy accounting question that, it is hoped, will lead to more consideration of total energy impacts of transportation projects.

This paper first describes a "typical" park-and-ride lot and its operation as used in this analysis. The indirect and direct energy savings and costs related to this prototype park-and-ride lot are identified and examined. Next, the impact of variations in park-and-ride lot operations and characteristics on energy savings and the payback time of indirect energy expenditures is analyzed through the use of a simple computer program. Finally, this energy savings/cost analysis approach is applied to an examination of existing lots in the Dallas-Fort Worth area.

PARK-AND-RIDE SCENARIO

The assumed characteristics of the prototype park-and-ride lot operations examined here are based largely on data from actual lot operations in the Dallas-Fort Worth area. A recent study (3) of these lots identified and quantified such variables as local bus ridership, lot size, service area, and distance to the CBD for typical park-and-ride operations in the area.

The basic lot itself was considered to consist of an asphalt-covered parking area, a reinforced-concrete bus loading zone, and a simple passenger shelter. Express bus service was assumed to be