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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

Table 1. Indirect energy consumption factors for a park-and-ride lot with 500-car capacity.

	Material		Energy Consumption (Btu 000 000s)			
Component	Type	Amount (tons)	Production	Hauling	Construction	Total
Loading zone	Portland cement	262	1983	20	343	2 346
	Aggregate	130	9	10	23	42
	Lime	16	96	1	8	105
Total			2088	31	374	2 493
Car parking area	Asphalt	1716	837	170	11 119	12 126
	Aggregate	4688	328	352	825	1 505
	Lime	703	4218	53	366	4 637
Total			5383	575	12 310	18 268
Total indirect			7471	606	12 684	20 761[a]

[a]Equivalent to 166 400 gal of gasoline (1 gal = 125 000 Btu).

provided to the CBD or other destination at freeway speeds. Most commuters were assumed to drive their cars to the lot and park them all day at no charge. Kiss-and-riders, those transit users driven to the lot by someone else, were also considered. The scenario here further assumed that the lot would be served by buses because this is the principal form of public transportation in the Dallas-Fort Worth area at this time. These indirect and direct energy assumptions are described in more detail below.

Indirect Energy Considerations

The amount of energy consumed in the construction of a prototype 500-space lot included energy estimates for the production and hauling of materials (aggregate, asphalt, cement, and lime) and the construction of a lot consisting of a reinforced-concrete loading zone and an asphalt parking area. Table 1 (1,4) gives the indirect energy consumption factors used for this lot. All energy consumption was converted into equivalent gallons of gasoline for easy comparison. This table indicates that an estimated 166 400 equivalent gallons of gasoline of indirect energy are consumed by this lot. In addition, the energy cost of a simple passenger shelter was estimated to be 600 equivalent gallons of gasoline (2).

Because the lot considered here was assumed to be of a single, basic design, energy demands for lot improvements, such as fencing, gutters, channelizations, signing, and landscaping, were not included in this analysis. Information on energy costs of such items is available if these are to be included in the lot design (1,2). The indirect energy estimates used should therefore be considered the minimum for a paved lot. It was further assumed that the buses used to provide the park-and-ride service are taken from the existing fleet. If new buses must be purchased, the construction energy cost of these vehicles can be included in the indirect cost estimates. The energy cost of a new bus has been estimated to be 8160 equivalent gallons of gasoline (2), equivalent to about 5 percent of the energy costs of the 500-space lot.

The energy used, even for this simple lot, appears to be considerable, however. The construction of the lot with 500-vehicle capacity and shelter, for example, would expend the equivalent of approximately 167 000 gal of gasoline. In addition, maintenance costs for the lot, including resurfacing estimated at 630 Btu/ft^2/year (2), were considered.

Direct Energy Considerations

The amount of direct energy consumed by the automobiles and buses affected by the park-and-ride lot was determined. The variables used in this estimation process and input into the computer program are described below.

Number of Riders

It was assumed that the size of a park-and-ride lot would be determined directly by use; i.e., a lot will be built at the most efficient size to accommodate users. The size of the lot should be designed so that 80-90 percent of the parking spaces are occupied (5, p. III-9). For example, about 450 automobiles will be parked in a 500-space lot on an average day. By assuming an average automobile occupancy for travel to the lot (1.1 persons/car is used here) and accounting for kiss-and-riders (assumed to be 15 percent of total riders) (6, p. III-5), the total number of one-way riders can be calculated. Because of this approach, no modal-split estimates were necessary.

Lot Distance from Home

Based on surveys of local park-and-ride users (excluding kiss-and-riders) in the Dallas-Fort Worth area, the average distance by automobile from home to a lot was found to be approximately 3.5 miles (6). This distance was input to the model to estimate fuel use between home and the lot.

Lot Distance from Destination

The distance of remote-lot bus service to the destination ranges from 6 to 20 miles in the Dallas-Fort Worth area (7, p. II-4). The model examined distances of 5, 10, 15, and 20 miles from the primary destination point.

Fuel-Efficiency Rates

An average fuel-efficiency rate for automobiles and buses, based on local and national estimates, was assigned to each model run. Because fuel-efficiency rates for cold engines are significantly less than those for warmed-up vehicles, the rate for automobiles was modified by accounting for the cold-start factor (8, p. II-4). The average automobile fuel efficiencies examined ranged from 14.7 miles/gal (the approximate 1979 fleet) to 100 miles/gal (an arbitrary assumed maximum potential). The fuel efficiency of buses was also varied from the assumed average of 6.25 miles/gal. Diesel fuel use was converted into equivalent gallons of gasoline (1 gal of diesel fuel is the energy equivalent of approximately 1.12 gal of gasoline).

Bus Load Factor

Differences in the bus load factor were assumed by varying the number of buses that serve a lot while keeping the number of riders constant. A full bus load was assumed to be 50 persons/vehicle.

Additional Assumptions

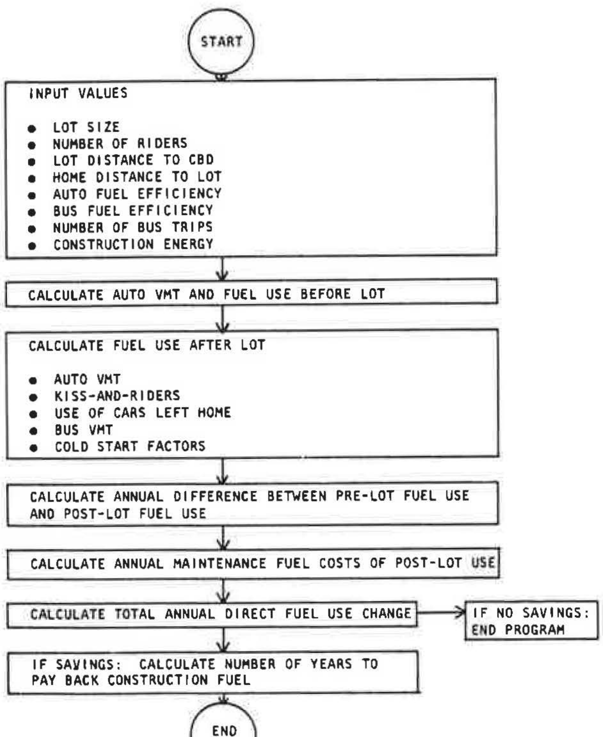
Consideration of use of the cars left home when commuters kiss-and-ride to the lot was also included in this analysis. It has been estimated that 40 percent of the potential savings in vehicle miles of travel (VMT) will be lost during the day by home-based non-work-trip use of automobiles not parked in the lot (9). The resultant VMT saving of kiss-and-ride patrons was adjusted by this factor; i.e., the kiss-and-ride VMT saving equals 60 percent of the normal work-trip VMT.

Energy Use Model

In order to speed the analysis of the numerous park-and-ride lot scenarios examined in this study, the calculations were automated. This simple computer program basically calculated the fuel used by automobiles and buses during the park-and-ride lot operations and then estimated the fuel that park-and-ride patron automobiles would have consumed if the lot did not exist. Other assumptions and factors, such as automobile cold-start factors and energy use for lot maintenance, were also considered. The difference between the vehicle fuel use without the lot and with the lot was then calculated.

If it was determined that the lot saved direct energy, this annual saving was then divided into the total indirect energy cost of the lot. This produced the payback time in years for direct energy savings to equal the indirect energy expenditures. This program is shown graphically in Figure 1.

Figure 1. Flow of park-and-ride energy program.



FINDINGS

Because the characteristics of each individual park-and-ride lot can vary greatly, several lot scenarios rather than a single hypothetical lot were examined. It was hypothesized that variations in lot size, lot distance to destination, number of riders, number of buses in service, and automobile and bus fuel efficiencies possibly had an impact on energy savings and payback time for a park-and-ride lot. To help determine whether these variables had a significant impact on the energy payback time, a sensitivity analysis of the variables was performed. This analysis was performed by altering one variable while the others were held constant. The results of this analysis, shown in Figure 2, indicated that distance to the CBD (or other destination), bus load factor, and automobile fuel-efficiency rates were the most significant variables whereas lot size and bus fuel efficiency were relatively unimportant. The importance of each of these variables is discussed in more detail below.

Distance to Destination

The distance vehicles must travel to their destination, generally the CBD, appears to have a considerable impact on energy savings and energy payback time. Because of the fuel saved by automobiles not going to the CBD, lots farther from the destination would generally result in more energy savings and, therefore, less time for construction energy payback. For the cases examined, all variables (lot size, load factor, etc.) except lot distance were held constant. This analysis indicated, for example, that the energy payback time for a 500-space lot 5 miles from the CBD would be more than three years whereas that for a lot 20 miles away would be less than one year (see Figure 3).

Figure 2. Sensitivity curves for energy analysis variables.

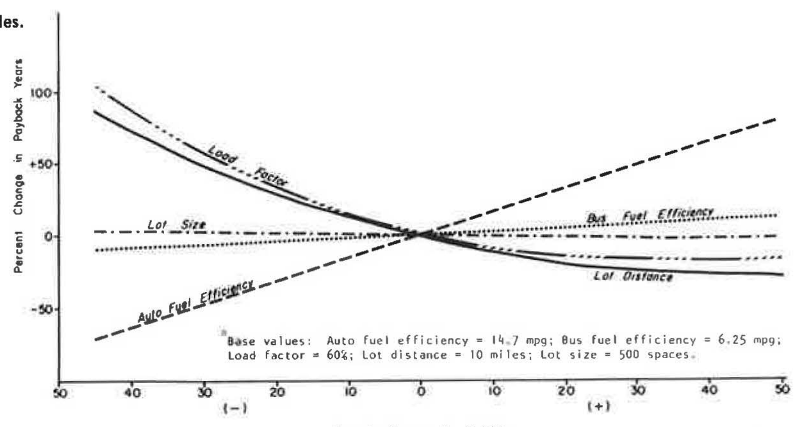


Figure 3. Impact of lot distance from destination.

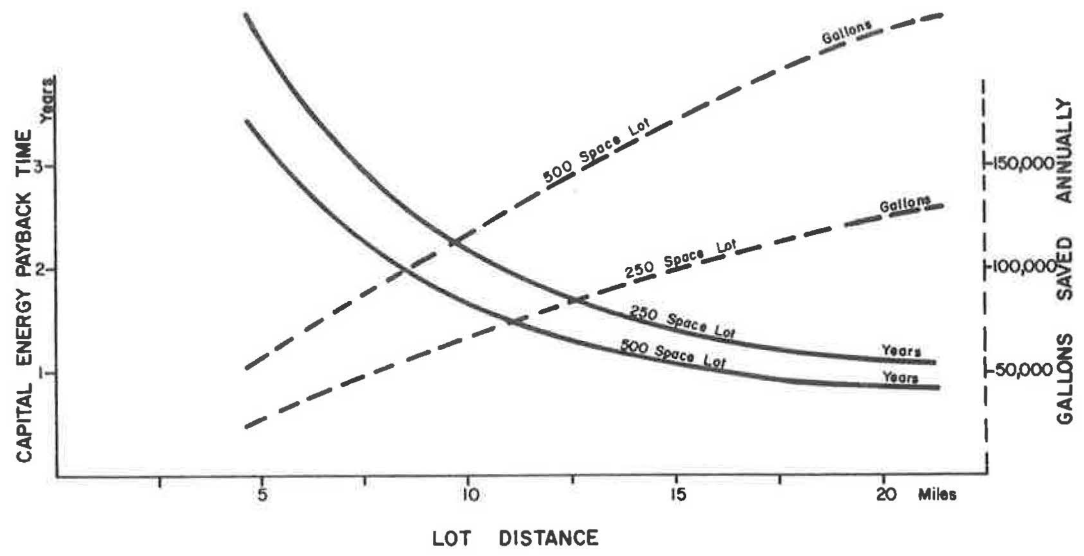


Figure 4. Impact of load factor.

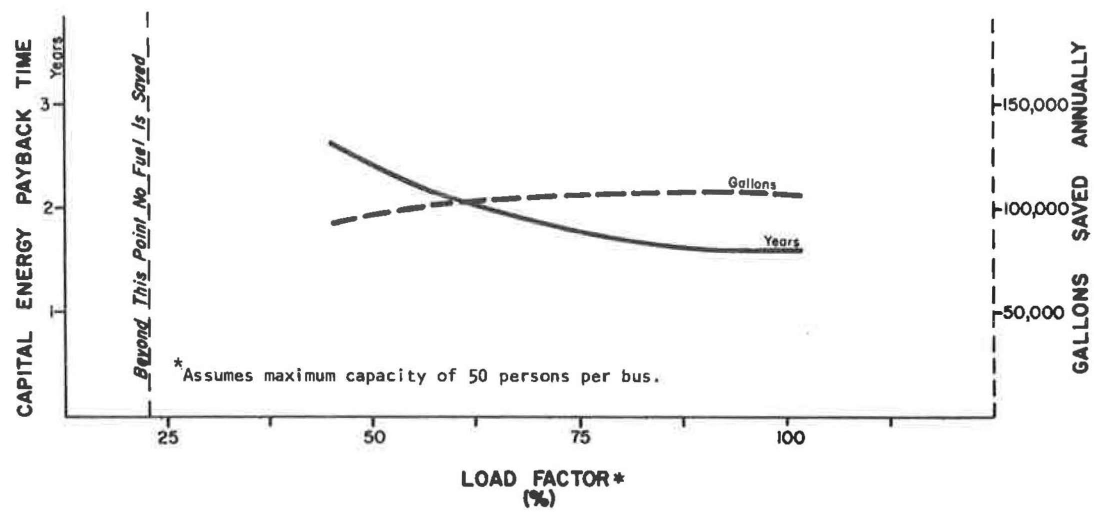


Figure 5. Impact of automobile fuel efficiency.

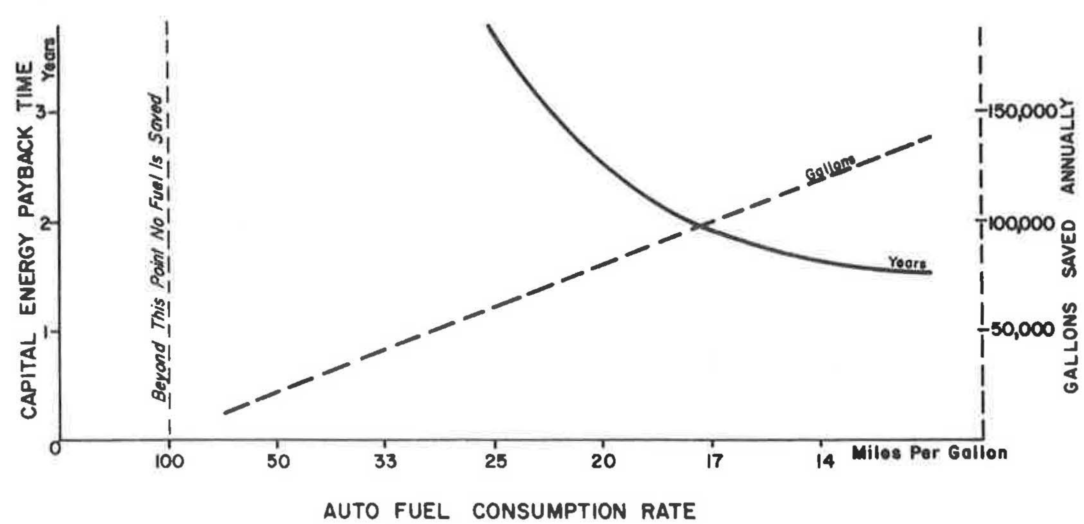


Figure 6. Impact of lot size.

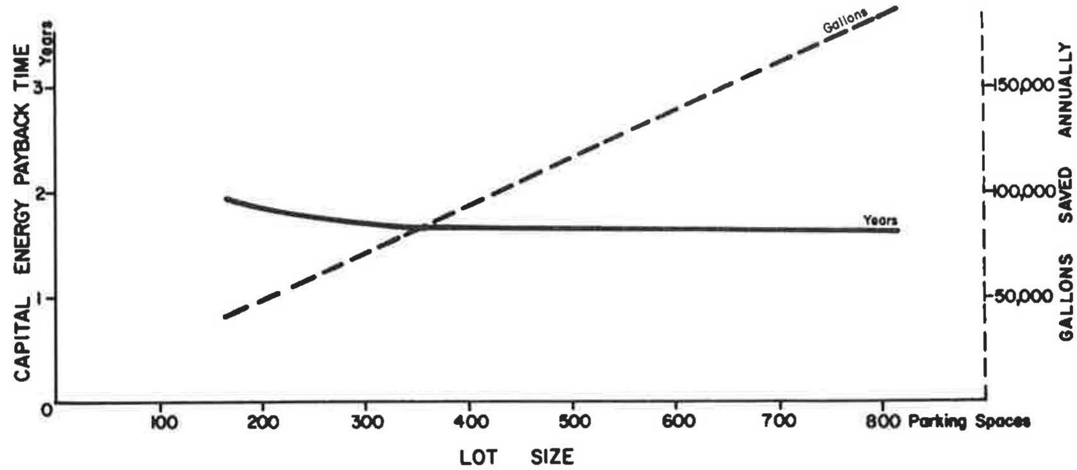


Table 2. Park-and-ride lots in Dallas-Fort Worth area: 1979.

Lot	No. of Spaces	Distance to CBD (miles)	No. of One-Way Person Trips	Direct Energy Saved per Year (gal)	Years to Pay Back Indirect Energy Use
Garland[a]	627	18	710	200 000	1.0
Las Colinas	170	12	75	-3 800	-[b]
North Central	356	11	550	38 000	3.2
Pleasant Grove	710	9	170	700	-[c]
Redbird	100	7	140	6 100	6.6
Ridglea	150	6	85	7 400	-[c]

[a]Combination of two lots.
[b]Payback not included.
[c]Joint-use lots; construction costs not applicable.

Load Factor

To estimate the impact of the bus load factor on total energy use, lot size and number of riders were held constant while the number of buses operating the service varied. Largely due to the relatively small impact of bus fuel use on total direct fuel consumption for the lot, as discussed previously, the impact of load factor on energy savings was not as great as might have been thought. For example, a 100 percent load factor would result in a payback time of 1.6 years, whereas doubling the number of bus trips to reduce the load factor to 50 percent would increase payback time to 2.5 years (see Figure 4). For this case, an average load factor of 22.5 percent was the point at which energy savings would no longer occur.

Fuel Efficiency

Due to federal automobile fuel consumption guidelines and public desire for more fuel-efficient automobiles, the fuel efficiency of the U.S. automobile fleet is expected to continue to improve in the future. The impact of these improved efficiencies on the energy payback time of a park-and-ride lot was therefore investigated.

As might be expected, the analysis indicated that park-and-ride fuel savings appear to be the greatest when automobile fuel efficiencies are lowest. At 14.7 miles/gal for each automobile, an average park-and-ride lot would take 1.6 years in payback time; at a 25-mile/gal rate, this would more than double to 3.7 years (see Figure 5).

This implies, then, that park-and-ride lots in the future will have less potential for saving energy than they do now. Figure 5 also shows that the automobile fuel-efficiency rate would have to increase to about 100 miles/gal before no energy savings would occur.

The sensitivity analysis indicated that the fuel efficiency of buses has a minor impact on indirect energy payback time, probably due to the relatively small proportion of direct energy use attributed to bus use in comparison with automobile use. Because of the relatively small variations in bus fuel efficiency that exist today and improvements expected in the near future, a separate impact analysis of bus fuel efficiency was not considered necessary.

Lot Size

The impact of varying lot sizes, assuming a similar lot use rate, was found to have little impact on energy payback time. Because it was assumed that the size and indirect energy consumption for the bus loading zone would be the same for all lot sizes, a slight efficiency of size was realized (see Figure 6).

It should be noted, however, that the larger the lot the greater is the chance for traffic congestion to occur in and around it. This impact on energy use was not considered here, however. Such considerations should be accounted for in the design of the lot prior to construction (5).

ANALYSIS OF DALLAS-FORT WORTH AREA LOTS

To obtain some idea of the energy efficiency of local park-and-ride lots, the energy consumption model described here was applied to several local lots. The existing operational characteristics of each lot (number of riders, bus trips, distance, etc.) were input to the model. Other variables, such as automobile and bus fuel efficiency, were the same as those used in the model. Construction energy estimates, described earlier in this paper, were made for each of the lots except in the cases of joint-use lots (i.e., the lot was constructed for some other purpose, such as church or shopping-center parking).

Of the six local lots examined, three (Garland, North Central, and Redbird) appear to save sufficient energy to justify their construction. Due largely to low use, the Las Colinas lot does not appear to save energy when total energy costs are considered. A slight increase in ridership of about 15 more users daily would cause the lot to be a fuel-saving venture. In view of the recent trend toward ridership increases, this may have already

occurred. Two other lots, Pleasant Grove and Ridglea, are joint-use lots, so construction costs could not be considered. Table 2 gives these findings.

CONCLUSIONS

This paper has discussed a theoretical examination of the energy use and potential savings of "typical" park-and-ride lot operations and the variables most important in determining these savings. The purpose of this analysis was to determine to what extent park-and-ride operations conserve energy when indirect energy expenditures of the lot are considered. If it can be shown that energy savings from the lot operations can make up in a relatively short time for the energy used to construct the lot, then park-and-ride can be shown to be a truly energy-saving concept.

The findings indicated that, in most cases, the lot operations would save enough fuel to account for the construction energy in a relatively short time--less than 10 years and, in many cases, less than 3 years. It should be noted, however, that under some operational scenarios a lot would not conserve energy, and thus the energy payback would never be realized. An application of the model to operating lots in the Dallas-Fort Worth area indicated that this energy deficit may occur in at least one case locally. In this case, a park-and-ride lot may be provided in order to achieve objectives other than energy conservation.

It should also be remembered that the lots described here are very basic sites. Many lots are improved with landscaping, lighting, sidewalks, and other amenities not considered here. These would naturally entail a somewhat greater indirect energy expenditure and, thus, a longer payback time. These improvements would probably increase the amount of construction energy by approximately 5-10 percent.

The study does not attempt to predict all energy-related implications of a park-and-ride lot. Considerations such as land use changes, traffic diversions, and changes in automobile ownership are beyond the scope of this study and would require far more sophisticated analysis methods than those used here.

Additional study and analysis of this concept appear to be warranted in several areas. For one, a comprehensive examination of the type of energy used or saved is needed. For example, it may be difficult to compare electrical and natural gas energy used to manufacture cement for concrete with gallons of gasoline saved by commuters. If it is determined that it is more important to save one energy type (e.g., petroleum) than others, such factors should be considered.

Energy considerations for the future are also an issue here. Due to uncertain future energy supplies, it may be important to expend energy now, while it is available, in order to develop projects that will save energy in the future. The questions of how much energy to invest and when to invest it are areas that need further investigation.

To summarize, this initial investigation of indirect energy implications of a park-and-ride lot demonstrates that these energy costs are significant enough to warrant consideration by planners and engineers. Of the variables examined, several are, to some extent, within the realm of control by decisionmakers. Lot distance, lot size, and bus load factor are elements that can be altered through the careful planning of park-and-ride lots.

The major study findings appear to be the following:

1. Lot distance, bus load factor, and automobile fuel efficiency are important factors in determining energy savings for park-and-ride lots.
2. Lot size and bus fuel efficiency are relatively unimportant factors in total energy use.
3. Indirect energy expenditures can be accounted for by direct energy savings in less than three years of lot operation in most cases examined.
4. In some cases, park-and-ride lots contribute to increased energy use rather than energy savings.
5. Automobile fuel-efficiency rates must be very high, about 100 miles/gal for the prototype example, before a park-and-ride lot becomes ineffective as an energy-saving measure.

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