# The Effect of Land Use Planning and Transport Pricing Policies in Express Transit Planning

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The effect of variation in future land use and transport pricing on an express transit system is investigated. Through travel forecasting and mode choice estimating processes, changes in land use densities and residential-employment locational patterns were studied for their impact on travel patterns and the mode of travel during a peak period for a single fixed regional express transit and highway system. The land use elements were held constant, and differing transport charges were investigated for the effect on the mode of travel. Transit usage was significantly increased when the centralization of employment and the length of corridor land use development were increased, but not in a simple way: travel patterns were altered substantially, trip lengths were changed, and other aspects of travel were shifted. The study of transport pricing showed a significant increase in the use of transit to the central area for user costs more favorable to transit. Transit usage to areas of inherently low transit usage was not as significantly affected.

•FORECASTING AND PLANNING for growth thrust both the professional planner and the public decision-maker into an area where the problems of uncertainty and imperfect information are the rule. As is often the case, definite decisions must be made on capital programs to satisfy projected needs. When uncertainty exists, it is difficult to commit people and resources to a course of action. Because of this, the decision-maker desires a set of alternatives with information on their implications and the probability of occurrence of the premises on which they are based. Clearly, the decision-maker, to optimize his final course of action, strives to minimize the amount of uncertainty and imperfectness in the information available to him. With his knowledge of the probability of various policy actions and their effect on growth and planning concepts, he is able to evaluate alternative courses of action and make his decision on the most probable outcome.

The material presented in this paper is an outgrowth of an express transit planning study for Canberra, Australia, where land use and transport development is under the full direction and control of the national government. Planning decisions are to be made for regional growth to accommodate an estimated population of 500,000 at an interim development stage and for 1,000,000 persons in the long range; only 100,000 persons now live in the region. Because the amount and rate of anticipated growth are so significant and the pattern of this growth is not restricted by entrenched trends and policies, several forms of development can be considered within a basic regional pattern of corridor development. Decisions leading to the ultimate growth plan are to be based on the most probable mix of policy alternatives.

Policy alternatives affect levels of transport pricing, land use patterns, activity densities, and the type and form of transport systems. Combinations of these are all possible, and each has a certain probability of occurring. The study examined the effect

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of these resulting outcomes on the feasibility of express transit. The goal of the study was not to select a single development plan that would result in the most feasible express transit system but rather to determine the range over which combinations of planning and policy decisions will create an environment that enhances the feasibility of express transit without sacrificing other desirable development goals.

## GROWTH AND TRANSPORT POLICIES

Basic highway and transit system configurations in this study were established in a prior study concerned with the framework of long-range, regional and subarea town development (1). This particular study was concerned with variations in patronage and, hence, the feasibility of that transit system if variations occurred in development policy within the context of the long-range regional framework.

Because no single land development program has been established by the Canberra government, a series of land development alternatives was established. From these, 4 basic schemes were selected for transport analysis. Each of these represented fundamental differences in development concepts, and the collection of these provided a bracket or range that should contain the actual development that will take place. It was hoped that, by having these 4 basic patterns defined, we could make an inference of the results of any plan that fell between 2 of the defined growth strategies or patterns.

In developing the alternatives, we gave attention to factors that are of concern because of their implications on transit planning. Land use planning policies expressed or questions most commonly heard in discussions of the effect of land use on transportation are length of development corridors, strong centralization, weak centralization with multinucleated centers, high-density residential corridors, and dispersed patterns of residential density.

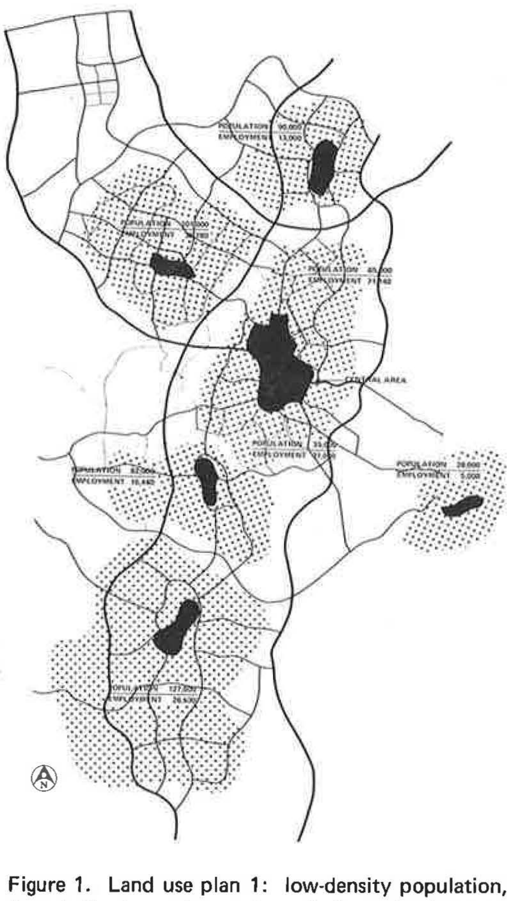

Figure 1. Land use plan 1: low-density population, decentralized employment, and short development corridors.

These 5 points were matched in several combinations resulting in land use patterns that could have a widely divergent effect on public transport planning. The 4 alternative land use plans that emerged were as follows:

1. Low-density population, decentralized employment, and short development corridors;
2. High-density population, centralized employment, and short development corridors;
3. Low-density population, centralized employment, and long development corridors; and
4. Low-density population, decentralized employment, and long development corridors.

These are shown in Figures 1 through 4.

Comparative trip cost by mode has been shown to have an effect on choice of mode and, hence, on the total demand for the mode. Variations in trip cost between public and private transport can be affected through pricing policies (2, 3). These variations, in turn, affect the level of mode demand and can influence the feasibility of express transit. In addtion to its effect on public transport, the cost of transport

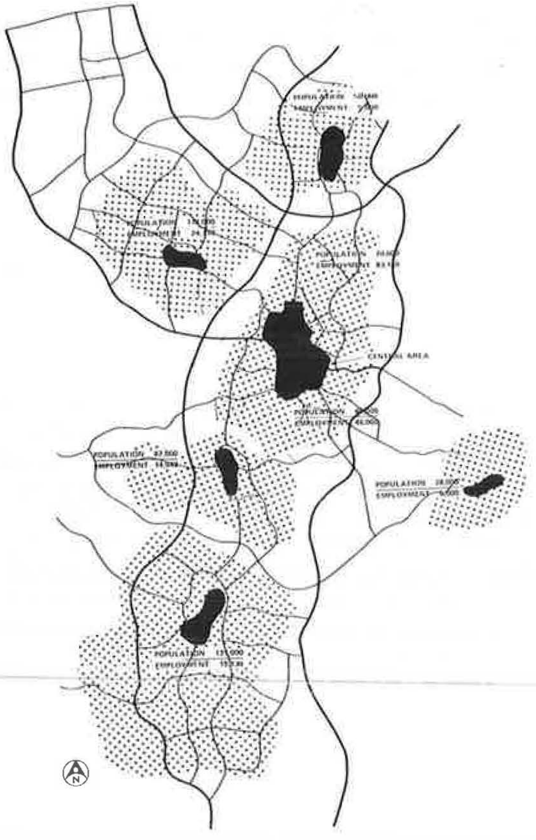

Figure 2. Land use plan 2: high-density population, centralized employment, and short development corridors.

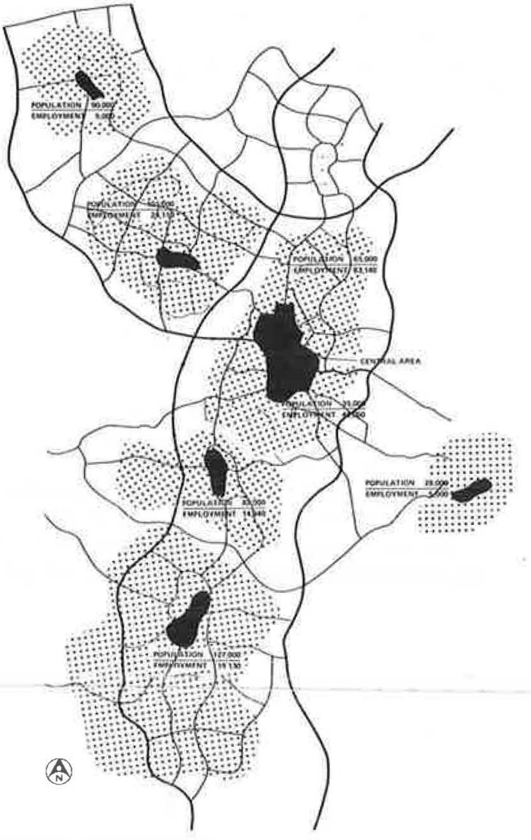

Figure 3. Land use plan 3: low-density population, centralized employment, and long development corridors.

can affect the intensity of private automobile usage (4, 5). To have a better understanding of the relationship of pricing and transport cost to transit patronage and automobile usage, we felt that an examination of the effect of varying pricing policies was necessary.

The method for relating mode costs was based on the difference in out-of-pocket trip cost between public and private modes. In this study, the transit fare was held constant and parking cost for private mode trips was varied to produce the change in trip cost difference. As in the establishment of the land use plan alternatives, the parking costs chosen were primarily in the range of those charges that could be realistically set. An evaluation of their effect on transit patronage and automobile usage within this range would enable inferences to be drawn for any intermediate cost differences resulting from policies affecting transit fares and parking charges. The 4 pricing alternatives developed for parking are given in Table 1.

TABLE 1

PRICING ALTERNATIVES FOR PARKING

| Parking Pricing Alternative | Transit Fare | Parking Cost for 9 Hours | |
|---|---|---|---|
| | | Town Centers | Central Area |
| 1 | Constant | $0.00 | $0.00 |
| 2 | Constant | 0.00 | 0.70 |
| 3 | Constant | 0.25 | 0.70 |
| 4 | Constant | 0.50 | 1.00 |

Evaluation of the public transport system feasibility for the land use plan and transport cost alternatives was confined to the morning peak period of travel. Public transport, particularly express transit, if it is to have any impact on travel and if it is to be feasible, must show this in a peak-period situation.

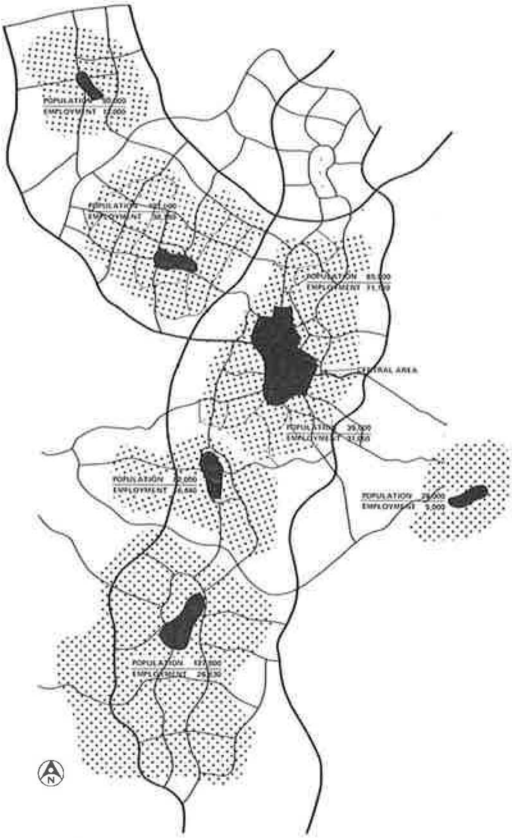

Figure 4. Land use plan 4: low-density population, decentralized employment, and long development corridors.

## SIMULATION TEST STRAGEGY

To isolate the effects of the alternatives required an orderly approach in the simulation process. The strategy for testing was to first ascertain how variations in land use planning policies affected public transport usage and then to investigate the results of transport pricing changes.

Each of the 4 land use plans was taken in combination with a single, common pricing alternative; pricing alternative 2 (Table 1) was selected. Therefore, for this phase of the study, the transport cost and transport systems were held constant and only the land use plan was allowed to vary so that public transport patronage would be affected only by these variations. Isolating the results of transport cost change was accomplished by holding both the land use plan and the transport systems constant while allowing the cost to vary. Land use plan 3 (Fig. 3) was selected as the constant base. We thought that relative transport usage change with cost variation could be taken as representative and could allow inferences to be drawn for other land use plans under similar transport cost changes.

Simulation of mode usage for the test strategy was accomplished by application of mathematical models. Three steps were necessary to simulate the results of each of the 8 land use-transport cost alternatives: develop travel patterns, determine public transport patronage, and determine automobile usage. Models to accomplish these steps were developed from a composite analysis of several urban areas.

Basic travel patterns for each land use plan were synthesized by the use of a gravity model technique that allowed changes in locational patterns and intensities of activity to produce different patterns or flows of trips. Allocation of total person travel to private and public modes was simulated by a transit-nontransit mode choice model. This model was formulated on the comparative differences between private and public transport systems and on trip-maker characteristics (6). Conceptually, the model allowed for evaluation of change in trip cost, travel time, and nonmoving trip time. Automobile usage was simulated by a driver-passenger mode choice model with average vehicle occupancy related to trip cost, trip length, and trip-maker characteristics (7).

## EFFECT OF LAND USE PATTERNS ON TRAVEL PATTERNS

Travel market patterns reflect land use linkages and intensities, and vary as the land use pattern changes. Knowledge of travel market characteristics is extremely important in planning an express transit system. Major characteristics are trip purpose, trip orientation, trip length, trip concentration toward a specific area, and trip concentration through a specific area.

Rapid transit is well suited for travel patterns where large numbers of trips are concentrated into well-defined heavy-usage corridors or where large numbers of trips are made to high-density activity concentrations. Conversely, transit and especially

TABLE 2

PEAK-HOUR WORK TRIP CHARACTERISTICS FOR FOUR LAND USE PLANS

| Land Use Plan | Total Work Trips | External Trips | | Total Intra-regional Trips | Intrazonal Trips | | Average Trip Length (min) | Total Desire Person-Miles of Travel on Spider Network |
|---|---|---|---|---|---|---|---|---|
| | | Number | Percent of Total | | Number | Percent of Intra-regional | | |
| 1 | 305,536 | 45,861 | 15.0 | 259,675 | 14,564 | 5.6 | 23.7 | 2,007,000 |
| 2 | 305,518 | 51,880 | 17.0 | 253,638 | 11,343 | 4.5 | 24.5 | 2,082,000 |
| 3 | 306,166 | 51,950 | 17.0 | 254,216 | 11,341 | 4.5 | 26.3 | 2,293,000 |
| 4 | 306,144 | 45,938 | 15.0 | 260,206 | 16,342 | 6.3 | 24.8 | 2,136,000 |

rapid transit is not competitive with the private automobile for serving low-density areas or diverse short travel patterns.

We ascertained the nature of the travel market patterns for each of the 4 alternative land use plans by a simulation of trip-making to obtain morning peak-hour travel patterns as previously described. The results are given in Table 2. Land use plans 1 and 4, the decentralized employment versions of the 2 basic corridor development schemes, show an average trip length in minutes shorter than that shown by land use plan 3, the comparable corridor scheme with centralized employment. Land use plans 1 and 4, the nucleated centers, tend to minimize long trips, most of the travel desires being satisfied closer to the location of trip production. In both of these decentralized plans, concentration of travel at comparable locations is lower than in the centralized plans. As a result of the reduction in trip concentration and the satisfaction of travel desires closer to the production area, development of high-density travel corridors is lessened.

Development of travel corridors can more easily be seen by the intertown travel flow. Figures 5 through 8 show the volumes of total person work travel throughout the region. Centralized employment (Figs. 6 and 7) produces heavier travel corridor volumes than decentralized employment (Figs. 5 and 8). As the degree of centralization increases, the magnitude of travel in the corridors increases, resulting in a larger travel market and a greater potential for rapid transit as a means of transport in the corridor. Further, as the length of the development corridor increases, corridor travel flow tends to increase.

Studying the variation in travel patterns resulting from the alternative land use plans reveals that, as the degree of centralization increases, average trip length increases, travel corridors are reinforced and travel magnitude increases, and development corridors are lengthened and magnitude of travel flow increases. All of these factors work toward increasing the potential for express transit as a corridor travel mode.

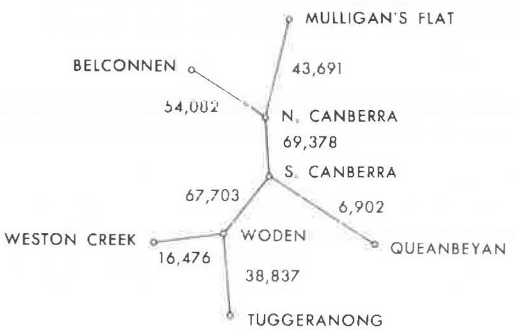


Figure 5. Intertown work travel for land use plan 1.

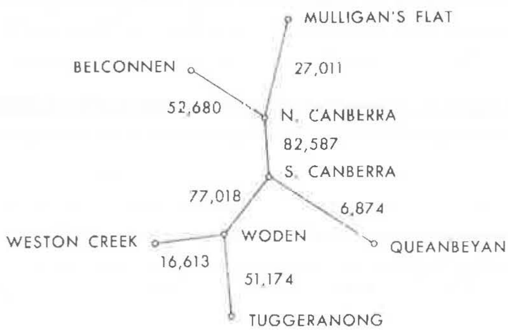


Figure 6. Intertown work travel for land use plan 2.

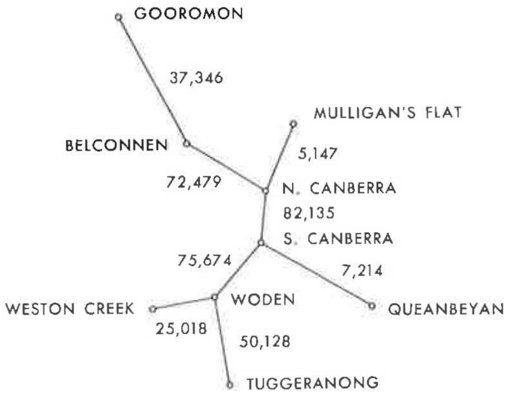


Figure 7. Intertown work travel for land use plan 3.

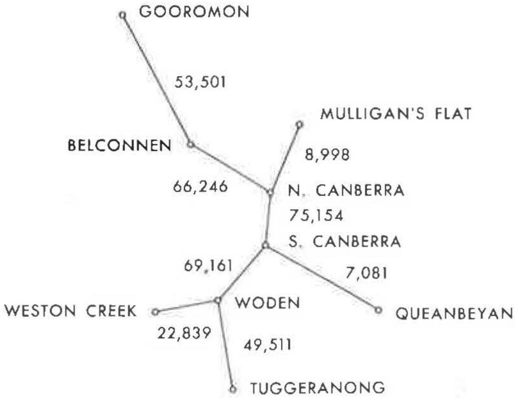


Figure 8. Intertown work travel for land use plan 4.

## EFFECT OF LAND USE ON TRANSIT USAGE

Results of the simulation of the effect of land use plan variation on transit usage for a constant pricing policy are given in Table 3. Analysis shows several basic relationships that cause transit usage to change. Centralized versions of a basic corridor pattern indicate levels of transit usage significantly higher than those indicated by decentralized versions. Comparisons of transit usage levels based on 2 centralized and 2 decentralized employment distributors—land use plan 2 compared to plan 1 and land use plan 3 compared to plan 4—show that longer development corridors produce longer travel patterns and result in higher transit usage. Inferences drawn from the simulation and evaluation reinforce those previously observed in the analysis of the effect of land use on travel patterns. Findings that emerge from this comparison are as follows: As the degree of centralization increases, transit usage increases; as the length of the travel corridor increases, trips are longer and transit usage tends to increase; and short trips are difficult to serve by transit and do not result in heavy transit usage.

A more detailed comparison of the characteristics of transit trip-making resulting from land use configuration difference is more readily seen from the results of transit system assignments given in Table 4. Comparison of the assigned morning peak-hour transit trip characteristics points up significant variations in ridership patterns. Each of the 2 basic land pattern configurations—long and short corridor development, decentralized and centralized employment—results in approximately the same length of transit and rapid transit trips measured in both time and distance. A comparison of the 2 different employment patterns—centralized and decentralized—shows that longer development corridors have both higher average transit time and longer distances; these differences are from 10 to 15 percent higher for longer corridor plans.

TABLE 3

TRANSIT TRIP DEMAND BASED ON WORK AND ADULT SCHOOL TRIPS WITH PARKING PRICING ALTERNATIVE 2 FOR FOUR LAND USE PLANS

| Land Use Plan | Transit Trip Demand | | | | | Percent By Transit | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Intratown | | Intertown | | Total Internal Demands | Intratown Demands | Intertown Demands |
| | | Number | Percent | Number | Percent | | | |
| 1 | 43,887 | 10,587 | 24.1 | 33,300 | 75.9 | 15.5 | 10.4 | 18.4 |
| 2 | 51,654 | 10,632 | 20.6 | 41,022 | 79.4 | 18.6 | 12.0 | 21.7 |
| 3 | 54,025 | 9,541 | 17.7 | 44,484 | 82.3 | 19.4 | 11.8 | 22.6 |
| 4 | 45,248 | 10,149 | 22.4 | 35,099 | 77.6 | 15.9 | 10.2 | 19.0 |

TABLE 4

PEAK-HOUR TRANSIT TRIP CHARACTERISTICS WITH PARKING PRICING ALTERNATIVE 2 FOR FOUR LAND USE PLANS

| Land Use Plan | Transit Trips | Riders | | Person-Hours | | | Person-Miles | | | Trip Time (min) | | Trip Length (miles) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Transit | Rapid Transit | Transit | Rapid Transit | | Transit | Rapid Transit | | Transit | Rapid Transit | Transit | Rapid Transit |
| | | | | | Number | Percent | | Number | Percent | | | | |
| 1 | 10,331 | 20,517 | 9,376 | 3,578 | 2,036 | 56.9 | 87,163 | 64,194 | 73.6 | 20.8 | 13.0 | 8.4 | 6.8 |
| 2 | 12,176 | 23,301 | 10,928 | 4,045 | 2,405 | 59.5 | 99,836 | 75,586 | 75.7 | 19.9 | 13.2 | 8.2 | 6.9 |
| 3 | 12,750 | 25,392 | 11,647 | 4,725 | 2,873 | 60.8 | 119,703 | 92,319 | 77.1 | 22.2 | 14.8 | 9.4 | 7.9 |
| 4 | 10,660 | 21,345 | 9,613 | 3,905 | 2,277 | 58.3 | 97,323 | 73,133 | 75.1 | 22.0 | 14.2 | 9.1 | 7.6 |

A characteristic that appears for both long and short corridor development is the increase in the proportion of total transit trips by rapid transit as centralization increases. Major findings indicate the following:

1. The length of the development corridor has a greater effect on transit trip length than the density of employment and residential development.
2. As the degree of centralization increases within each basic corridor development plan, the percentage of transit trips made on rapid transit increases.

## THE EFFECT OF TRANSPORT PRICING ON TRANSIT USAGE

Impact of relative change in the difference between private and public transport trip cost was simulated using the test strategy of a single land use alternative, plan 3, and the 4 pricing alternatives for parking. The goal of this study aspect was to provide an insight into variations in transit and automobile usage rates and the resultant demands that might be placed on the transport systems if transport cost was considered as a separate planning concept for a given land use and transport system configuration. We thought that the relationship and distribution of mode usage with respect to relative transport cost changes could be used to infer mode usage changes for each of the other land use alternatives, other factors such as trip length taken into account, and, hence, for a wide range of land use plans.

Table 5 gives the results of the simulation for the central area and nucleated town centers. The effect of a parking cost increase and the resultant increase in public transport usage are more significant in the central area than in the town centers. An increase in parking from no charge to 70 cents all day increased transit usage by almost 100 percent in the central area, and an increase from no charge to $1.00 all day produced an increase in transit usage by almost 250 percent. On the other hand, an increase in parking cost in town centers produced very little increase in transit usage. Sensitivity of transit usage to change in transport cost appears to be greater for the

TABLE 5

TRANSIT USAGE AND AUTOMOBILE OCCUPANCY WITH FOUR PARKING PRICING ALTERNATIVES FOR LAND USE PLAN 3

| Parking Pricing Alternative | Central Area | | | | Woden | | Belconnen | | Tuggeranong | | Gooromon | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | North Canberra | | South Canberra | | T | A | T | A | T | A | T | A |
| | T | A | T | A | | | | | | | | |
| 1 | 16.4 | 1.24 | 17.4 | 1.23 | 12.0 | 1.27 | 12.8 | 1.27 | 12.9 | 1.26 | 12.6 | 1.30 |
| 2 | 30.5 | 1.36 | 32.3 | 1.34 | 12.0 | 1.27 | 12.9 | 1.27 | 12.8 | 1.26 | 12.6 | 1.30 |
| 3 | 30.5 | 1.36 | 32.3 | 1.34 | 13.6 | 1.30 | 14.7 | 1.29 | 14.9 | 1.29 | 14.2 | 1.32 |
| 4 | 40.4 | 1.48 | 42.2 | 1.44 | 16.0 | 1.37 | 17.3 | 1.35 | 17.8 | 1.36 | 16.1 | 1.40 |

Note: T is transit usage and A is automobile occupancy.

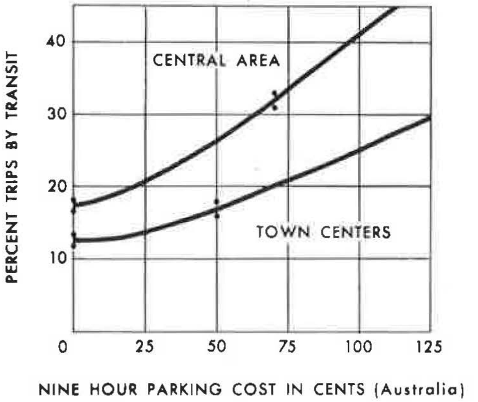


Figure 9. Variation in transit usage with parking cost for land use plan 3.

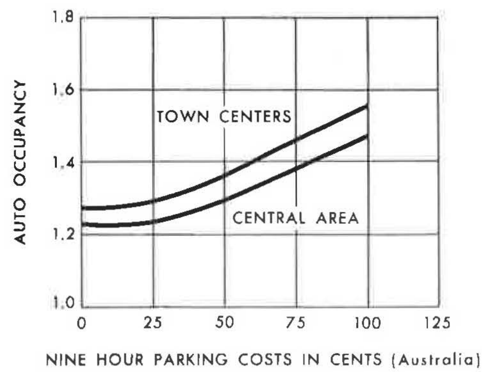


Figure 10. Parking costs and automobile occupancy for home-based work trips.

central area than for the nucleated town centers, and impact reflects a basic difficulty in serving short trips with transit. Because both cost and time are additive variables for the equivalent time computation in the mode choice model, the relative time difference between the public and private transport systems may place the usage relationship for short trips far into the insensitive area of the model and this may not be overcome, even by very high cost differences favoring transit. The corollary to this is that if the relative time differences between transport systems place application in a sensitive area of the usage relationship, a relative increase in nontransit trip cost will have a significant effect on transit usage.

Figure 9 shows the transit usage and parking cost relationship developed from the simulation for both the central area and the nucleated town centers. Although parking cost is the causal variable in this relationship, the base point for this analysis is dependent on other aspects of the trip such as relative trip time, service frequency, and trip distance. Therefore, longer trips, where basic usage is in the sensitive area of the model, appear to be more responsive to change in relative transport cost than short trips, which typically fall into the insensitive range of the model.

Automobile occupancy increases rather significantly as parking costs increase in both the central area and town centers at essentially the same rate (Table 5). Figure 10 shows the relationship of automobile occupancy to parking costs developed from the simulation for town centers and the central area. Trips to town centers have higher automobile occupancy than those to the central area. This is consistent with previous findings that show occupancy tends to be higher for shorter trips to work (4, 5).

In this study, we found that trips to dispersed town centers are shorter in length than those to the central area, a finding consistent with currently observed travel patterns. This characteristic occurs regardless of the length of corridor development. Associating this with the findings regarding automobile occupancy results in an interesting implication for increasing the intensities of automobile usage.

## INTERACTION OF TRANSIT USAGE AND AUTOMOBILE OCCUPANCY

Variations in transit usage and automobile occupancy for the central area of a region and the dispersed centers of the region with changing transport cost have been shown in separate analyses. The combination of these 2 findings results in a relationship that takes on great significance in both the planning of transportation and the levels of activity in central areas and town centers. Combining these relationships such that the number of private vehicles required per hundred person trips is a function of parking cost (trip cost difference is implied for transit usage) clearly demonstrates the

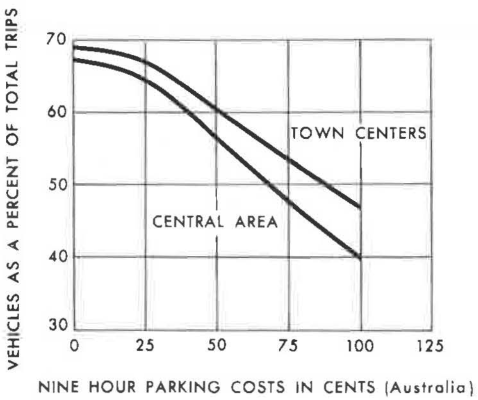


Figure 11. Parking costs, transit usage, and automobile occupancy.

impact of transport cost on the level of automobile activity in the respective areas.

Figure 11 shows that the composite effect has a greater impact on automobile travel to the central area than to town centers. This occurs as a result of the greater transit impact in the central area than in the town centers, which more than compensates for the lower central area automobile occupancy relationship.

Application of these relationships is significant in the planning of activity levels for specific areas within a region. If the cost of transport, parking costs, tolls, and transit fares are considered as a matter of policy and allowances are made for the possibility of varying the level of this cost, changes can be caused in the demand for various transport facilities while holding total travel demand and activity in the area constant. A second approach and perhaps more significant is the ability to plan for higher activity concentrations in an area by the use of policy controls as a means for shifting transport demand from one mode to another and for increasing the intensity of mode usage. In this way, vehicular traffic levels can be maintained on the highway system in and adjacent to the areas in question while at the same time total activity is increased. Transportation cost policy will cause a shift in travel from private to public transport facilities and also increase the automobile efficiency by raising automobile occupancy. (For the cost study, we assumed that activity levels and travel patterns were constant. We think that increasing travel cost to a particular location will have an effect on total travel to that area and possibly alter regional travel patterns. If so, then an important area of study is the investigation of transport cost implications of activity levels and basic travel patterns.)

## SUMMARY

Aspects of land use planning and transport pricing policy have been studied for their effect on transit planning. Four land use plans were used as points of reference to measure development variation, and 4 parking pricing policies were used to describe the possible range in transport pricing. Variation in transit for a fixed set of transport systems has been depicted. The goal of this study was not that of selecting the "best" land use pattern or the "best" parking cost policy for the region to adopt, but rather that of supplying the decision-makers with information on what might result if certain courses of action were taken or policies evolved. It is for the planner and the decision-maker to draw on simulated results occurring from the reference conditions and to formulate and reformulate their ultimate plans and decisions toward rapid transit if different planning goals or policies were to occur or be put into effect.

This study has been concerned with the effects of planning decisions on travel patterns and on mode usage characteristics. Findings show that a development plan with long corridors of development will tend to produce longer trip lengths and heavy corridor flow. Changes in the concentration of activity in one particular area of the region show that centralization tends to produce longer trips. This, in turn, reflects a higher demand for travel and transport facilities.

Transit usage was found to be higher for land use patterns based on long corridor development. Within any particular form of development, transit usage tends to increase as the degree of activity centralization increases.

Transport costs can significantly influence mode usage and intensity of mode usage. When noncost trip factors are favorable to transit, cost change has a significant effect on transit usage. However, for those areas where relative transit service quality is

difficult to develop, the effect of costs conducive to transit use does not produce the same relative increase in usage. Altering the cost of an automobile trip, besides causing a shift to public transport, can increase the intensity of vehicle usage.

These observations provide the planner and the decision-maker with an insight into the implications and results of certain actions. The decision-makers must evaluate the conditions and situations confronting them and, by using information from relationships similar to those discussed, formulate policies and make decisions for their particular regions. The objective is to combine results of different actions and to develop and visualize the effect of combined actions.

Relationships developed and shown in this paper help to move decision-making from the unknown to the known. Although none of these relationships is precise and will occur in the same manner, more knowledge is known of situations and the implications on mode choice for certain courses of action.

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