THE IMPACT OF RAPID TRANSIT ON URBAN DEVELOPMENT: THE CASE OF THE PHILADELPHIA-LINDENWOLD HIGH SPEED LINE

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PREFACE

This paper was originally presented in 1973 at the Symposium on Urban Growth and Development sponsored by the Washington Operations Research Council and the Urban Institute. It will be published later this year by Praeger in the conference proceedings, Urban Problems and Public Policy Choices.

We wish to thank David E. Boyce of the University of Pennsylvania, who directed the research on which this Paper draws. We also acknowledge the aid of Leon N. Moses who first presented the simple market area model developed herein in the early 1960's. Naturally, the authors alone are responsible for the viewpoints and any errors in the Paper.

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I. INTRODUCTION

When a transportation investment is contemplated, the important question of how to measure the benefits of the investment (which are needed to compare the project to other projects) and how to demarcate the investment's areas of impact arises.

This Paper attempts to develop a theory which measures the benefit area and identifies the areas of equal benefit. The model naturally abstracts from reality. Its assumptions involve many inelasticities. However, the inelasticities make the model simple in nature, and hence simple to test. It is expected that others will be stimulated to widen the scope of the current research. The directions and foundations are hopefully provided herein.

The analysis is perfectly general in nature, but is discussed in the terms of the Lindenwold High Speed Line (Philadelphia, Pennsylvania to Lindenwold, New Jersey), a new radial commuter line to Philadelphia.

Mohring (1961) and Mohring and Harwitz (1962) have shown the impact area and zones of equal benefit for a transportation improvement entailing continuous access. Walters (1969) has shown a similar situation in the context of economic development of the hinterlands. Both cases calculate benefits based on the change in economic rent from before to after the transportation innovation. In the former case the "rent" is the saving in transport cost accruing to individuals as the result of the new investment. In the latter case, the rent is the saving in transport cost accruing to producers as increased profits.

The analysis is expanded in this Paper to encompass the market area of a transportation investment that has discrete access, to delineate the market areas of each access point, and to develop areas of equal impact concerning the effects of the line.

It is important to point out that impact will be defined in terms of transportation savings accruing to individuals. These savings will be dependent upon values of the parameters chosen, e.g., value of time, automobile operating costs per mile, etc. Mohring uses real estate transaction prices to estimate value of time. In this Paper, we will use a reverse process and use a priori estimates of such items as value of
time to delimit impact areas. Estimates of the savings accruing to a particular area will be one of several variables used to explain the transaction price of residential real estate in the area.

Both approaches must be pursued with care. The boundaries of the metropolitan area are not fixed as Mohring and Harwitz assume. Nor is the individual's demand for land constant and independent of price and location, as the same authors assume. To assume that the transportation savings will be capitalized into the sales price of the land ignores important supply and demand effects, such as an increase in supply of land which is x minutes or y dollars away from a large employment center, etc. It is not at all clear, in a micro context, how and in what magnitude land rents will change. What is ultimately needed to solve the problem is a model that is general equilibrium in nature. Thus, before data on real estate transactions can be utilized to determine parameter values, more thought about the supply and demand for land must be forthcoming.

Policy-makers will find interesting the number of control variables in the model. The model suggests how modal split and station choice will change as parking charges, road user charges, transit fares, traffic control, etc., change. Furthermore, the model suggests the effects of changes in station location, access to stations, parking lot capacity, etc., for investments in the planning stages, i.e., longer-run or non-reversible control variables. Since the areas of impact are delimited, the model also suggests areas which would be fruitful to zone for high-density living. Lastly, the model suggests the value of benefits received from the transport investment. This is of use for those wishing to assess the benefits and costs of the project. It also has potential for the tax assessor who wishes to capture the market value of each piece of property.
II. THEORY

The model presented below represents a unique application of the market-area theory of Fetter (1924) and Hyson & Hyson (1950) to the problems of transportation choice and access choice. Involved is a significant departure from traditional market-area theory, which treats several points with fixed F.O.B. prices and treats market boundaries of loci of equal delivered prices from the sources.

Let us suppose the following situation:

(a) All places of work are found in the central business district (CBD). (Multi-centers of activity can be handled but unnecessarily clutter the analysis.)

(b) A homogeneous transportation plain exists with respect to costs, except for the speed line. (A grid network or a non-homogeneous plain can be added. The non-homogeneous plain causes considerable difficulty.)

(c) The analysis is short-run in nature and all locations are fixed.

(d) One station exists in the CBD and one in the suburbs. (More stations are easily added.) The High Speed Line is assumed to be a straight-line system. (The model is easily generalized to allow for circuitous systems.)

(e) The "cost" of transportation on the speed line is different from on the rest of the plain.

(f) "Cost" is considered to be monetary cost. Other costs, such as time costs, convenience, etc., can be added to the analysis if proper conversion factors (to monetary units) can be defined or the market-area analysis can be done solely with one of the other variables.

(g) All trips are assumed to be work trips.

(h) Two modes of transportation exist: car and the speed line.

Since the origins and destinations are fixed and the trips involved are work trips, it is assumed that two trips are made per day. Thus, since the origin and destination and the number of trips are given, cost minimization is synonymous with utility maximization.

The following notation is employed:

A Location of CBD station
B Location of the suburban station
D_{AB} Distance from A to B
C Cost by car per unit distance
F\_B \quad \text{Fare by the speed line from station B}

M \quad \text{Bridge tolls}

P\_B \quad \text{Parking charges and any other charges independent of distance traveled at station B}

P\_A \quad \text{Parking charges and any other charges independent of distance traveled at the CBD}

D\_{BX} \quad \text{Distance from point of indifference X, between driving to the CBD or driving to the station and taking the speed line to the CBD, and the station B}

D\_{AX} \quad \text{Distance from an indifference point X (as described above) and the CBD at A. (Note that the CBD is assumed to be a point. Also, it is assumed that an individual does not need his car during the business day.)}

Given the above situation, an individual would be indifferent to either driving to work or taking the speed line to work if:

(1) \quad 2 \, CD\_{AX} + 2 \, M + P\_A = 2 \, CD\_{BX} + 2 \, F\_B + P\_B

Equation (1) can be rearranged to read:

(2) \quad D\_{AX} - D\_{BX} = \frac{F\_B}{C} - \frac{M + P}{2C} = \frac{F\_B - M - \frac{P}{2}}{C}

where \( P = P\_A - P\_B \)

All items on the right-hand side of (2) are known parameters. Hence, the right-hand side of (2) can be called \( K \), a constant. \( K \) will be \( \geq 0 \) as \( F\_B \geq M + \frac{P}{2C} \) (or as the speed-line fare \( \geq \) bridge tolls and one-half the parking fees). Note that equation (1) provides the theoretical justification for one-half the parking costs, which often appears in modal split models.

The left-hand side of (2) is the difference between two variables. The equation form of (2) is that of a hyperbola. The exact form of the hyperbola will depend on the sign and magnitude of \( K \). If \( K = 0 \), the hyperbola will be the perpendicular bisector of the line \( AB \). If \( K > D\_{AB} \), then the hyperbola is non-existent, and everyone will drive to \( A \). If \( K = D\_{AB} \), then the hyperbola is the line \( AB \) extended to the right of \( B \). For \( D\_{AB} > K > 0 \), the hyperbola bends around \( B \) with its vertex to the right of the midpoint of \( AB \) (at distance \( \frac{K}{2} \) from the midpoint). The larger \( K \) becomes in this range, the closer the vertex of the hyperbola comes to \( B \) and the less "spread" the hyperbola has. Analogous types of situations occur for \( -D\_{AB} < K < 0 \) (see Figure 1).
Fig. 1. Market areas for one station case
The hyperbola defines the market boundary between driving to the CBD as opposed to taking the train to the CBD. If \( K < 0 \), use of the speed line will be favored. If \( K > 0 \), driving will be favored. This situation is shown in Figure 1.

All the area contained within a hyperbola is the market area of the station around which the hyperbola bends. Thus, in Figure 1, if \( K = \hat{K} \), then all people who work in the CBD and live in the shaded area will use the speed line and all other people will drive to the CBD.

One would certainly want to argue that not all monetary costs are perceived by the commuter. For instance, out-of-pocket driving costs are not well known (see Lansing and Hendricks, 1967). In addition, time may be the crucial variable for urban commutation. Furthermore, values of time (the conversion factor to put time into monetary terms) are likely to vary with income which, in turn, is likely to vary with distance from the CBD (up to some finite distance). Driving costs and speeds are not likely to be uniform across the plain, nor is access to the stations or to the CBD "as the crow flies." In fact, travel costs and travel time per mile are likely to rise as the CBD is approached, due to congestion.

All the above (and more, of course) are legitimate criticisms of the model, but all can be handled within the general framework of the model. The purpose of this first section is to establish the framework.

It is important to note both the control variables in the analysis and the influence on the market areas affected by exercising control.

As shown in equation (1), \( K = \frac{B}{C} - \frac{M}{C} - \frac{P}{2C} \). Variables \( F_B \), \( C \), \( M \), and \( P \) are in the short-run control of the authorities. Tolls may be raised or lowered, generally by direct action. Parking fees may be raised or lowered, generally by indirect action (since many parking lots are privately owned) such as tax policy changes, changes of fees in municipally-run garages, or by direct action such as enforcing on-street parking ordinances, etc. Speed-line fares are directly controllable, although subject to possible actions by regulatory agencies. Automobile costs are controlled through taxes of gasoline or even more directly through road-user pricing. The problem with auto costs is in the perception of costs related to the specific trip which are not directly "out-of-pocket."

Evidence (Lansing and Hendricks, 1967) has shown that the marginal costs (the appropriate cost if the car were retained for non-commuting uses, which would most frequently be the case) are poorly perceived by drivers.
In the long run, the location of stations is a control variable. Land-use planning will also affect the density of population within the impacted area. Other control-variables exist, of course, but not within the framework of the model as developed to this point.

By differentiating \( K \) with respect to \( M, P, F_B, \) and \( C \), the impacts of changes in the control variables can be seen:

\[
\frac{\partial K}{\partial M} = -\frac{1}{C} < 0
\]

\[
\frac{\partial K}{\partial P} = -\frac{1}{2C} < 0
\]

\[
\frac{\partial K}{\partial F_B} = \frac{1}{C} > 0
\]

\[
\frac{\partial K}{\partial C} = -\frac{F_B}{C^2} + \frac{M + P}{2C^2} = \frac{P}{2} + M - \frac{F_B}{C^2} = -\frac{K}{C} < 0 \text{ as } K > 0.
\]

As shown in Figure 1, as \( K \) becomes larger the market area for transit becomes smaller. Thus (3) and (4) show that increasing bridge tolls and the price for CBD parking will increase the speed line's market area.

As shown in (5), as the speed-line fares increase the line will lose part of its market area.

The effect of an increase in perceived driving cost, \( C \), depends upon the sign of \( K \). If \( K \) exceeds zero, the market area of the speed line will increase as auto costs increase. If \( K < 0 \), the reverse occurs. In both cases, however, an increase in \( C \) tends to make the hyperbola approach the perpendicular bisector of \( AB \).

Many observers of urban transportation would argue that time is a more important decision variable for suburban commuters than is cost. Time differences can be treated explicitly as follows: the average on area roads is assumed to be \( y \) miles per hour. Dividing \( y \) into one hour yields a result, \( g \), in hours per mile. The time it takes to drive directly from location \( X \) to the CBD is therefore \( t_D^{AX} \), and the similar time to station \( B \) is therefore \( t_D^{BX} \). The average speed on the high-speed line is \( z \) miles per hour \((z > y)\), which is easily converted to \( h \) hours per mile. The time from station \( B \) to the CBD is therefore \( t_D^{AB} \).
The above information is, in general, not sufficient to permit the drawing of market boundaries. If cost is also an important decision variable, in order to combine this analysis with the analysis presented above, a value of time (V) must be found so that \( gD_{AX} \) (with a dimension of hours) can be combined with \( CD_{AX} \) (with a dimension of dollars). Obviously the measurement units of \( V \) are in dollars/hour.

Once a value of \( V \) is determined, equation (1) becomes:

\[
(7) \quad 2C D_{AX} + 2Vg D_{AX} + 2M + P_A = 2CD_{BX} + 2VgD_{BX} + 2F_B + 2VhD_{AB} + P_B
\]

which can be transformed to:

\[
(8) \quad D_{AX} - D_{BX} = \frac{F_B + VhD_{AB}}{C + Vg} - \frac{M}{C + Vg} - \frac{P}{C + Vg} = K',
\]

where \( P = P_A - P_B \).

The right-hand side of (8) is a constant and hence (8) is the equation of a hyperbola.

Other variables, such as waiting time, could easily be added.

One might be tempted to argue that \( V \) could be estimated from a fit of the model to modal split. However, the model as stated above contains a variable, \( C \), which is the perceived automobile cost. One might also argue that \( C \) (or better yet, \( W \), a constant which measures perceived cost as a percentage of actual cost) could be estimated from a fit of the actual data. Unfortunately, an infinite number of combinations of \( V \) and \( C \) exist which yield the exact same \( K \). The value of one of the desired "variables" cannot be estimated without specifying the value of the other. Such specification may be allowable if some good \textit{a priori} information exists concerning the magnitude of one of the "variables."

Analysis of cases of zones with different values of time, curved speed lines, multiple stationed lines, multiple speed lines, multiple employment centers, grid network transport plains, actual highway configuration networks, etc., have been developed and are presented elsewhere (Boyce, Allen, Mudge, Slater, and Isserman, 1973) and (Boyce, Allen, Desfor, and Zuker, 1973).
III. MEASUREMENT OF IMPACT

The simple model of equation (1) provides the basis of an impact theory. Prior to the existence of the speed line, all inhabitants of the plain drove to the CBD (subject to the constraint that the wage net of commutation exceeds the return from working on the land). After introduction of the speed line, the market area analysis shows that some will use the line while others continue to drive. Obviously, those who use the line reveal that they benefit by doing so, since their old option of driving, while still available to them, is rejected.

Savings from the use of the speed line are defined as auto cost less speed-line cost. Obviously, then, equation (1), the market boundary equation, describes the locus of zero savings, i.e., \( S = 0 \). In general, the locus of equal savings is defined as:

\[
(9) \quad 2CD_{AX} + 2M + P - 2CD_{BX} - 2F_B = S, \quad \text{where} \quad P = P_A - P_B.
\]

Equation (9) can be rearranged to read,

\[
(10) \quad D_{AX} - D_{BX} = \frac{F_B}{C} - \frac{M}{C} - \frac{P}{2C} + \frac{S}{2C} = \frac{F_B - M - 2}{C} + \frac{S}{2C} = K + \frac{S}{2C} = K''.
\]

Equation (10) is identical to equation (2), except for the \( \frac{S}{2C} \). If \( S = 0 \), equation (10) reduces to equation (2), the market-boundary equation.

For \( S \), held at a given level of savings, \( \frac{S}{2C} \) is constant and hence the right-hand side of equation (10) is a constant \( K'' \). Therefore equation (10) is also that of a hyperbola. Since \( K'' > K \), the equal-savings loci will bend more around \( B \) (relatively) than will the market boundary.

In fact \( \frac{dk''}{ds} = \frac{1}{2C} > 0 \), demonstrating that as the savings level increases, \( K'' \) increases, thus causing the savings hyperbola to bend more and more about \( B \). There are limits, however, to the level of savings available. The savings hyperbola will not exist if \( K'' > D_{AB} \). This is easily translated into the cost formulation. Consider Figure 2.
Fig. 2. Sketch diagram of speed line with two stations

A resident at B will save:

\[ 2CD_{AB} + 2M + P - 2F_B = S'. \]

Likewise, a resident at R will save:

\[ 2CD_{AR} + 2M + P - 2F_B - 2CD_{BR} = S'; \]

or,

\[ 2CD_{AB} + 2M + P - 2F_B = 2CD_{AR} - 2CD_{BR} + 2M + P - 2F_B \]

since \( D_{AR} = D_{AB} + D_{BR}. \)

Thus, the residents cannot save any more than the bridge tolls, parking costs, and twice the fare differential from A to B between the two modes. This result is also shown from the mathematical structure of the model by setting the \( K' \) in equation (10) equal to \( D_{AB} \) (the maximum \( K' \) possible to still get a hyperbola) and equating that to the initial right-hand side of equation (10) and solving for \( S. \)

The equal-savings loci for the situation depicted in equation (1) is shown below in Figure 3, assuming that \( K > 0. \)

The equal-savings loci are easily drawn for the other cases described in the preceding section.

**Use of Impact Areas**

A method has now been outlined to yield areas of equal impact of the speed line. All individuals living along a given equal-savings locus benefit by the same amount. If it were desirable to tax individuals based on the benefit received, the model would be able to identify the location and degree of benefit to each location.

It might be suggested that such benefits might be capitalized into the sales price of houses in the impact area. While this result will be true to a degree, it is very difficult to get before and after transactions on the same piece of property. (The desire to use the same property is due to the need to hold constant the structural characteristics and amenities of the particular house, although such controls can also be
Fig. 3. Equal-savings loci for one station
handled statistically, as will be shown below.) In addition, the existence of the line will increase the supply of housing with certain time and cost characteristics of getting to the CBD and hence provide a possible dampening effect on the capitalization argument.

But most importantly, the model dispels the claims of equal bands of impact surrounding a facility (not necessarily a transport facility) with limited access. Clearly, the areas of impact are not of equal width about the line as has been alluded to in the literature (see the description by Mohring and Harwitz, p. 140). The impact area of the line spreads wider and wider as distance from the CBD increases.

Statistical Analysis of Transportation Impact on Residential Sales Prices

Residential property values are determined by many factors. Thus even if we are interested in only a single element, such as changes in access to the CBD, a general model must be formulated. One classification of the types of variables which might be included in such a model is as follows:

1. Site Elements, describing the individual property, e.g.,
   lot size, characteristics of the structure, topography, etc.

2. Neighborhood Variables, describing the areas immediately adjacent to the property. Possible variables might include measures of neighborhood homogeneity, the occupational status of the residents, the age distribution of the residents, the predominant type of families (e.g., retired, extended), the general physical condition of local housing, the degree of crowding, and the degree to which other land uses intrude on the area.

3. Regional Variables, measuring such items as location on the urban rent gradient; access to shopping, jobs, and schools; local tax rates; and the quality of local services.

4. Historical or Externally-Imposed Factors, such as zoning limitations, financial markets, special prestige areas, inflation (in a time-series model), etc.
(5) *Impact Variables*, measuring the expected impact (derived above) of the speed line.

The basic hypothesis of this section is that property values are a function of the five types of variables listed above. The specific variables chosen to represent the effect of each of these factors are limited in two general ways:

(1) their accuracy as measures of the phenomena they are intended to represent;

(2) their availability, cost of procurement, and detail.

The data base consisted of approximately 24,000 residential property transactions between July 1964 and June 1971 in Camden and Gloucester Counties in South Jersey (exclusive of Camden City).* These data were screened so as to include only those sales that represented valid market transactions, i.e., between a willing buyer and a willing seller. The analysis was restricted to residential (at time of sale), suburban properties to ensure a large, yet relatively homogeneous sample. Further data on each property and its surrounding area were also obtained from the local county tax assessor’s records and the U.S. Census.

In an attempt to parallel the approach of the more traditional experimental sciences, a control corridor was chosen as a base for comparison with the High Speed Line impact corridor. The control corridor selected was centered on an abandoned commuter rail line passing through Woodbury, New Jersey (see Figure 4).

The travel-savings model described above predicts that the size of the impact a property should receive is proportional to the travel savings afforded by the transportation improvement. Thus, using the control-corridor methodology, we want to compare properties in the impact corridor with properties in the control corridor that are similar in as many ways as possible, including the level of saving. For example, we want to compare a house in the impact corridor with an estimated daily travel saving of two dollars, with a similar house in the control corridor that would provide a daily travel saving of two dollars if there were a rapid-transit line there also. Because the control corridor is also in South Jersey, it is still within the region of positive travel savings due to the High Speed Line. Thus, the saving for the hypothetical rapid-transit line in the control corridor must be calculated as net of the actual saving due to the High Speed Line.

*These data were kindly provided by Robert Johnston, Chief, Sales Ratio Section of the Local Property Tax Bureau of the New Jersey Division of Taxation.
Fig. 4. The Lindenwold and Woodbury Corridors and the High Speed Line
Estimates of travel savings were made for each of the approximately 350 Census block groups in the study area. Block groups are small enough so that any variation in savings within the block group is substantially less than the total level of savings at its centroid. The daily savings available to residents of block group \( i \) who travel to Center City Philadelphia are thus:

\[
S_i = 2C D_i + M - 2(C D_{ij} + F_j);
\]

where \( C \) is a cost-per-mile factor that includes vehicle-maintenance costs as well as travel-time costs; \( D_i \) is the distance from the centroid of block group \( i \) to the bridge to Center City Philadelphia; \( M \) is the round-trip bridge tolls, parking costs and other access costs in Philadelphia; \( D_{ij} \) is the distance to the minimum-cost station on the High Speed Line, and \( F_j \) is the fare from this station to Center City.

Results

One of the regression models from the impact analysis is presented in the table. The dependent variable is sales price in thousands of dollars and there are 24,082 observations. Most of the variables are entered as \((0,1)\) dummy variables since they represent either/or conditions (a house is brick or it is not). Of course, to ensure non-singularity of the covariance matrix, one variable from each set of dummy variables has been omitted. The land-use categories refer to those properties which changed from residential land use sometime after their sale. The eleven different neighborhood types were defined, using AID analysis, with 1970 Census data. Details of this process, as well as complete definitions of the other variables, may be found in Mudge (1972) and Boyce, Allen, Mudge, Slater, and Isserman (1973).

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*A value of travel time of $2.60 an hour was used because this value appeared to give the best fit between the observed station market areas and those predicted by the savings theory. A uniform automobile velocity was assumed.

**AID (Automatic Interaction Detection) is a multivariate technique based on a sequential application of analysis of variance to divide a set of observations into mutually exclusive groups to form a hierarchical tree.
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<th>Independent Variable</th>
<th>Regression Coefficient</th>
<th>t-statistic</th>
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<td>Number of Stories (two-stories omitted)</td>
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<td></td>
</tr>
<tr>
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<tr>
<td>1-1/2 stories</td>
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<td>2-1/2 stories</td>
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</tr>
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<td>3 stories</td>
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<td>1.59**</td>
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<td>over 3 stories</td>
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<td>0.32**</td>
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| Location and Impact         |                        |             |
| distance to City Hall       | -0.280                 | 19.60i      |
| impact corridor savings     | 0.149                  | 1.96i       |
| control corridor savings    | -0.246                 | 1.72**      |

Constant: 6.737

standard error = 5.894
R square = 0.526
F-ratio for regression = 722.15

*Not significant at .01 level
**Not significant at .05 level
The savings variables entered in the regression are the net daily savings for each corridor. However, both savings variables are set equal to zero for sales before July 1968, since the High-Speed Line was not in operation then. Since the time between July 1968 and the actual opening of the line in February 1969 is a time of possible anticipation of the line by the real-estate market, a positive savings level is valid for this time. After July 1968, the savings value depends on which corridor the sale is in and its location within that corridor. The effect of the savings variables is entered additively to conform with the basic hypothesis that the values of residential properties near new transportation facilities increase because of the capitalization of the stream of travel savings available to them.

The regression coefficient for the impact-corridor savings can be interpreted as an addition to the sales price of $149 for each dollar of savings. This is the increased value of the property due to the High Speed Line. The savings values range from about fifty cents to over three dollars. Of course, the savings function is a relative amount and not an attempt to measure precisely the actual travel savings.

Although the coefficient for the control-corridor savings is not significant, the negative sign is in accord with theories of transportation impact which believe the impact is really a transfer from one part of the region to another. Such a transfer seems to be indicated here, although it is hard to say whether there is a complete balance. Because the savings function used for the control corridor is net of High Speed Corridor savings, the mean level of savings in the control corridor is significantly less than the corresponding mean for the High Speed Corridor. It should be noted that the basic conclusions drawn from this regression were confirmed by more detailed analysis of specific neighborhoods and housing types.

The travel-savings model is a flexible tool. It was easily applied to a more detailed analysis of the timing of the impact as well as to different sub-markets of the real-estate market. An alternative model based on shifts over time in rent gradients with respect to the High Speed Line (a linear model in contrast to the hyperbolic form of the savings model) was also tested. The results showed that, for at least this data set, the travel-savings model performed with greater consistency.
IV. SUMMARY

A very simple model has been developed which delineates the areas which receive given levels of transport cost savings as a result of a transportation improvement. It is hypothesized that a portion of these savings will be capitalized into the value of residential property. Statistical tests which control for other determinants of housing value, e.g., neighborhood characteristics, physical characteristics of the property, etc., have indeed shown a positive impact on property values, attributable to the presence of transport cost savings made available by the High Speed Line.

Refining and testing of the models developed herein continues. The travel-savings model and the empirical application presented above have important policy implications. The theory clearly indicates the control variables available to policy-makers and the relative strength of these variables in shifting modal choice boundaries, station or interchange market areas, and the level of travel savings. The iso-savings line analysis should allow for improved land use planning in urban transportation corridors.

There is increasing interest when evaluating the impact of proposed projects, not just in arriving at grand totals for the benefits and costs, but in identifying which social and geographic groups receive or incur these benefits and costs. The iso-savings lines provide a simple and theoretically sound basis for examining the relative impacts of a transportation improvement. As we have shown with our analysis of the Lindenhof High Speed Line, it is not difficult to connect a file of predicted savings with a file of Census characteristics.

While we have not done any analysis of the impacts of the High Speed Line on different social and economic groups, certain general conclusions seem clear. The spatial pattern of savings suggested by the model is quite different from the conventional wisdom that benefits are strictly a function of distance from the transportation improvement. One implication of this is that for radial improvements the greatest travel-savings benefits will accrue to residents of the outer suburbs as opposed to residents of the generally older and poorer inner suburbs. If local taxes are to be used to finance the improvement, the savings model should be of great help in adjusting the incidence of taxes to those who receive the benefits of the change.
As the empirical analysis presented above shows, the model can be useful in assessing the impact of transportation on property values. Work on the Lindenwold High-Speed-Line indicates that while residential property values surrounding the line increased in conjunction with the line, property values in a nearby corridor increased less than would be expected if the Lindenwold Line had not been built. Preliminary work indicates that the increase in the Lindenwold corridor is closely balanced by the relative decreases in residential values outside the corridor. If this is true, there are important ramifications for economic theory as well as for policy-makers who wish to tax the unearned increment in residential property values to help pay for rapid transit improvements.
BIBLIOGRAPHY


