# Telecommuting and Residential Location: Theory and Implications for Commute Travel in Monocentric Metropolis

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A simple partial equilibrium model was used to estimate the long-term effect of telecommuting on work trip vehicle distance traveled and residential location for households located in a monocentric metropolitan area and for workers employed in the metropolitan center. Although based on very simple assumptions, the model illustrates some aspects of the complexity of the effects of telecommuting on residential location and commute travel. Although telecommuting reduces the number of work trips, the long-term effects of telecommuting are likely to include change in residential location farther from the workplace, diminishing the reduction in commute distance traveled per year from telecommuting. This effect of residential relocation is most pronounced for metropolitan areas with flatter spatial variation in land prices—the trend in most metropolitan areas in recent decades.

Telecommuting is often suggested as a way to decrease traffic congestion, energy consumption, and air pollution by reducing commuting travel (*1–3*). Some critics have argued that these benefits are likely to be somewhat reduced because of higher nonwork travel, more local work-related trips, and shifts in mode of travel. It has also been argued that benefits to the transportation system from telecommuting might be diminished further by an increased flexibility in residential location.

This flexibility is expected to encourage residential location farther from the traditional workplace, thereby inducing additional travel on days when the employee travels to the traditional workplace. In the worst case, commute distance traveled after relocation could exceed commute distance traveled before (*4–7*).

On the basis of several studies, empirical evidence to date has found relatively positive transportation impacts of telecommuting. Nonwork travel has not increased and vehicle distance traveled, peak-period trips, fuel consumption, and emissions have all decreased as expected (*8–13*). However, evidence on the residential relocation effects of telecommuting is scanty because of the short-term duration of most evaluation efforts.

In his evaluation of the 2-year state of California pilot project, Nilles (*14*) found that 6 percent of the telecommuters indicated that they had moved or were considering moving, 72 km or more (45 mi or more) farther from work since they began to telecommute. However, no significant differences in number or length of work trips existed between actual moves of the telecommuters and those of a control group. In a study of San Diego telecommuters, Mokhtarian (*15*) found a small proportion of respondents reporting that the ability to telecommute was prompting consideration of moves two and three times farther away from the workplace than were their current residential locations. Such moves, if they occurred and if the frequency of telecommuting remained constant for those respondents, would certainly result in higher levels of commute travel than before.

This short paper presents a simple theoretical examination of residential relocation induced by telecommuting, for monocentric metropolis for commuters working in the metropolitan center. The theory provides quantitative and qualitative estimates of the importance of residential location effects in reducing the transportation system benefits of telecommuting. Although the residential location effects of telecommuting can be significant, they appear to detract only moderately from the effectiveness of telecommuting at reducing commuter-related urban travel.

## SIMPLE THEORY OF RESIDENTIAL LOCATION WITH TELECOMMUTING

An Alonso model of residential location would hold that households are located to minimize the summed cost of housing and travel (*16*). For a monocentric metropolis, this cost is expressed simply as

$$C(d) = h + AR(d) + c_T Td/r \quad (1)$$

where

- $C(d)$ = total location cost as function of distance from metropolitan area's center,
- $h$ = cost of dwelling,
- $A$ = land area desired (and assumed constant),
- $R(d)$ = cost of unit of land as function of location,
- $c_T$ = unit cost of commuting (cost per unit of distance traveled),
- $d$ = location's distance from workplace at metropolitan center,
- $r$ = real discount rate, and
- $T$ = number of one-way commuting trips taken per year.

Because households are assumed to minimize this cost in their locational decisions,

$$\frac{dC(d^*)}{dd} = 0 = A\frac{dR(d^*)}{dd} + \frac{c_T T}{r} \quad (2)$$

or

$$\frac{dR(d^*)}{dd} = -\frac{c_T T}{A} \quad (3)$$

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where the derivatives are evaluated at $d^*$, the least-cost residential location. Because land prices tend to decrease with distance from the metropolitan center, $dR(d^*)/dd < 0$.

So long as this relationship holds and because telecommuting lessens the number of work trips per year ($T_1 < T_0$),

$$\left[\frac{dR(d^*)}{dd}\right]_{T0} < \left[\frac{dR(d^*)}{dd}\right]_{T_1} < 0 \tag{4}$$

Assuming that land prices follow a conventional exponential decay *(17,18)*,

$$R(d) = R_0 e^{-kd} \tag{5}$$

where $R_0$ is the land price at the metropolitan area center and $k$ is a decay constant. Therefore,

$$\frac{dR(d)}{dd} = -R_0 k e^{-kd} \tag{6}$$

Combining Equations 3 and 6 yields

$$R_0 k e^{-kd^*} = \frac{c_T T}{Ar} \tag{7}$$

where $d^*$ is the least-cost location. This simplifies to

$$e^{kd^*} = \frac{ArR_0 k}{c_T T} \tag{8}$$

or

$$d^* = \frac{\ln\left(\frac{ArR_0k}{c_T}\right)}{k} - \frac{\ln(T)}{k} \tag{9}$$

Note that this relationship consists of a constant that does not vary with commuting trips per year minus a term that increases logarithmically with the number of annual commuting trips.

## CHANGE IN EQUILIBRIUM LOCATION WITH TELECOMMUTING

How should residential location change with the onset of telecommuting? Here it is assumed that telecommuting is only partial. The employee remains at home or works nearby some fraction of the work days but must commute to work physically for the remaining work days.

To examine this case, define the change in least-cost location, $\Delta d^* = d^*(T_1) - d^*(T_0)$. Replacing Equation 9 into this definition yields

$$\Delta d^* = \frac{\ln(T_0) - \ln(T_1)}{k} = \frac{\ln(T_0/T_1)}{k} \tag{10}$$

Note that this change in equilibrium location is affected only by the change in commuting trips and the decay constant of land prices. Other factors entering into the initial locational decision do not affect the magnitude of change in the equilibrium least-cost location.

## EFFECTS OF TELECOMMUTING ON ANNUAL WORK-RELATED DISTANCE TRAVELED

Define annual vehicle-kilometers traveled as $VKT(T) = Td^*$. The change in vehicle-kilometers traveled with the onset of some level of annual posttelecommuting trips $T_1$ relative to some prior annual number of trips $T_0$ is then

$$\Delta\, VKT(T_1) = VKT(T_1) - VKT(T_0) = T_1 d_1^* - T_0 d_0^* \tag{11}$$

where $d_0^*$ and $d_1^*$ are the least-cost locations before and after the onset of telecommuting. Noting that $\Delta d^* = d_1^* - d_0^*$, this expression can be changed to the following form:

$$\Delta\, VKT(T_1) = T_1 \Delta d^* + d_0^*(T_1 - T_0) \tag{12}$$

Combining Equations 10 and 12 yields

$$\Delta\, VKT(T_1) = T_1 \frac{\ln(T_0/T_1)}{k} + d_0^*(T_1 - T_0) \tag{13}$$

as a final predictive equation for changes in annual vehicle-kilometers traveled to work in the metropolitan core.

## EXAMPLE

Some implications of this simple theory are illustrated by the following example. Consider a household initially located 10 km from the metropolitan center ($d_0^* = 10$) where 400 one-way commuting trips are made annually ($T_0 = 400$). Land prices decay exponentially at a constant rate ranging from 5 to 50 percent per kilometer ($k = 0.05$ to 0.5/km). For this case, Figure 1 shows the change in equilibrium residential location and Figure 2 shows the change in annual VKT with number of commuting trips for this range in decay constants for metropolitan land prices. Figure 3 shows the ratio of annual commute VKT after telecommuting to that before telecommuting.

Figures 2 and 3, indicate that for the steeper rates of decay ($k \geq 0.1$), VKT with telecommuting and after residential relocation is still lower than that without telecommuting, for all levels of telecommuting. For the flattest rate of decay, however ($k = 0.05$), VKT after beginning to telecommute and after residential relocation is higher than that before at all but the greatest frequencies of telecommuting. For example, the person presently living 10 km from the center who begins telecommuting half of the time ($T_1 = 200$) will find a new equilibrium residential location about 24 km from the center (nearly 2.5 times farther away than before), and annual commute VKT will increase 19 percent (from 4000 to nearly 4800 km).

Increasing the decay constant of land prices (to levels above 0.1/km) increases the reduction in VKT, as shown in Figure 2. As $k$ decreases, the spatial variation in land prices decreases, and the effect of telecommuting on least-cost location becomes more pronounced. This, in turn, diminishes the reduction in work trip VKT from telecommuting. This effect may be fairly important, given the long-term trend toward relatively flat urban land markets.

However, the total cost function in the neighborhood of the least-cost location is very flat. There are many near-least-cost locations in the neighborhood of the least-cost location. The spatial breadth of the near-least-cost region increases with the flatness of the land

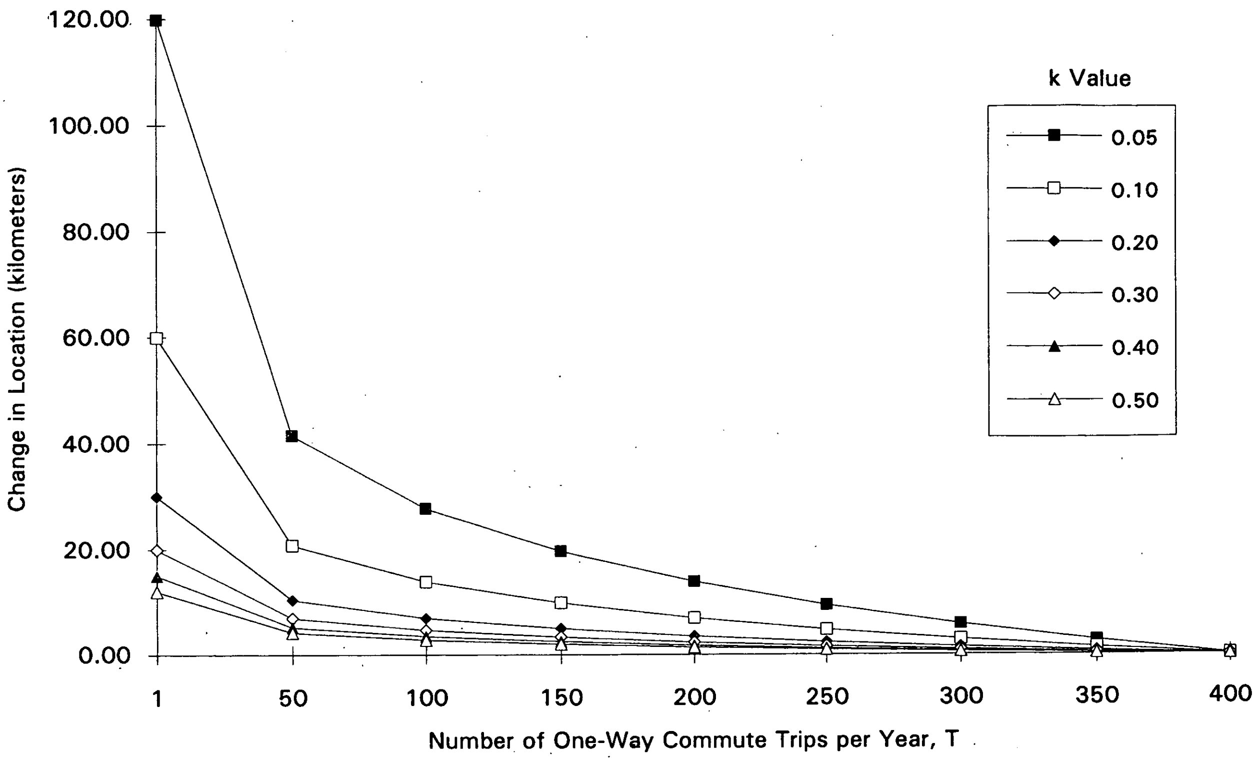


**FIGURE 1 Change in equilibrium residential location with telecommuting for example case.**

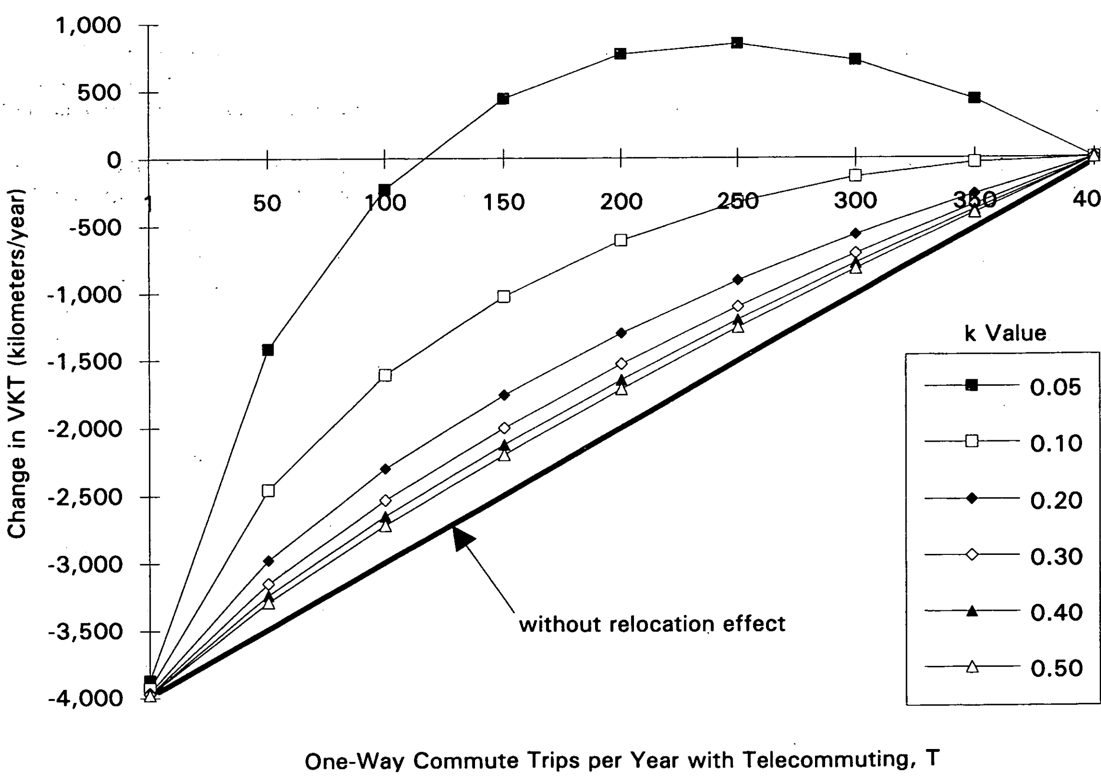


**FIGURE 2 Change in VKT after telecommuting for example case.**

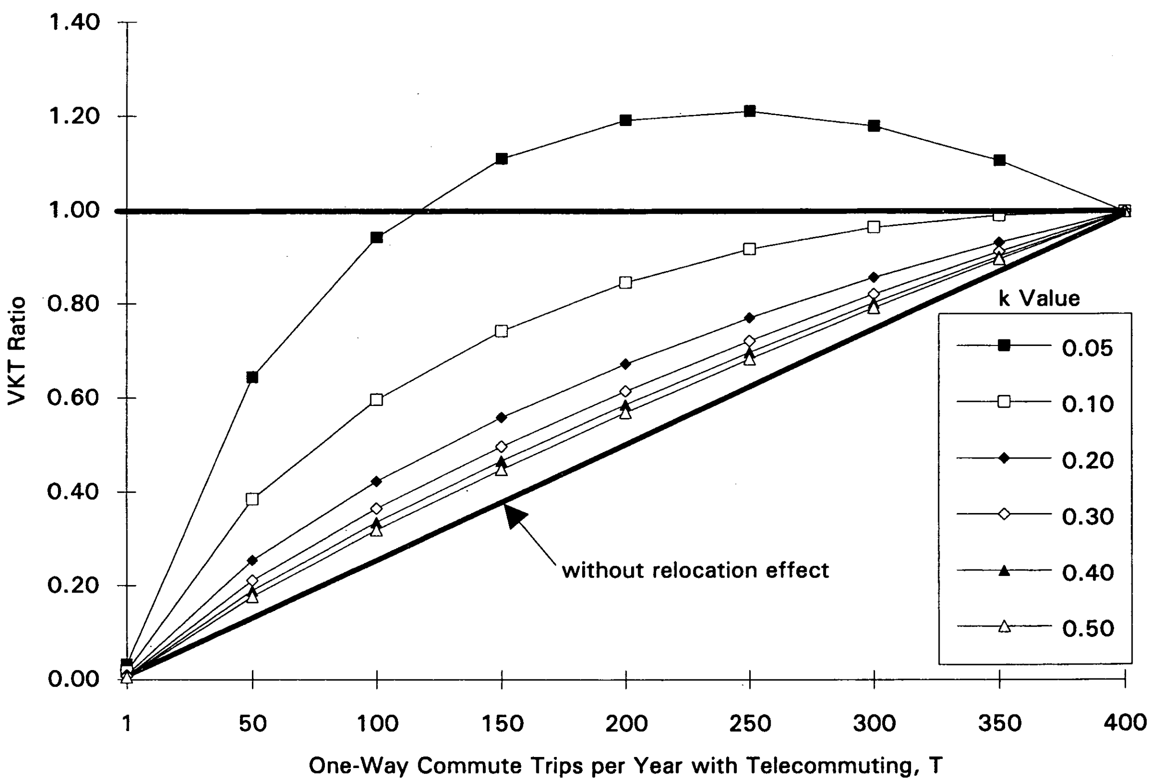


**FIGURE 3 Ratio of work trip VKT after telecommuting to before telecommuting for example case.**

price decay rate. This wide area of near-optimal locations is likely to increase the role of other locational factors (such as amenity and local neighborhood effects). Nevertheless, the net effect of telecommuting is to induce an outward location of residences from traditional centrally located workplaces.

## CONCLUSIONS

The effect of residential relocation in diminishing the transportation benefits of telecommuting has been explored with the aid of a simple economic model. The magnitude of this effect is greatest for intermediate levels of telecommuting in metropolitan areas characterized by relatively flat declines in land prices from the metropolitan center.

Most telecommuting today occurs at relatively low frequencies: 1 or 2 days a week on average (*19*). At those levels, work trip VKT will usually still be lower than it was previously after telecommuting begins and residential relocation takes place. It is plausible that the average frequency of telecommuting will increase over time, however, as individual telecommuters adapt to the concept, as managers grow more comfortable with the idea, as technology improves to permit more types of work to be done cost-effectively remotely, and as telecommuting centers close to home become more commonplace. Thus, for metropolitan areas with flatter land price contours, increasing telecommuting might increase total vehicle commute travel until high levels of telecommuting are achieved.

Residential relocation is likely to be partially self-regulating: many people may choose not to move very far away unless they can telecommute often enough to reduce their vehicle commute travel. For some people, however, other reasons to move (e.g., scenic or recreational opportunities at the new location) may more than outweigh commute considerations.

The effects discussed here are entirely divorced from any effects of telecommuting on local, near-home trips and trip-chaining behavior. Many other factors are also neglected, such as short-term resistance to moving and imperfect behavioral assumptions in the pure Alonso model. The model also does not directly assess the change in work trip travel for households both located and employed in suburban locations. However, the same economic effect should exist for households located farther from the metropolitan center than the traditional workplace.

Nevertheless, this simple model illustrates one mechanism that can somewhat detract from the beneficial transportation impacts of telecommuting. This same mechanism also has implications for land use policies because the encouragement given by telecommuting for movement to the metropolitan periphery could increase pressure for land development on the periphery.

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