Telecommuting and Its Impacts on Vehicle-km Travelled

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EXTENDED ABSTRACT

A model is developed to examine and forecast impacts of telecommuting on vehicle-km travelled in urban areas. The impact of telecommuting including the change of commuting trips as well as non-commuting trips are estimated in term of network vehicle-km saved. The model to calculate the reduction of commuting trips is explained using a concept diagram and mathematical expressions. A formulation is developed to form the model specific to examine impacts on vehicle-km travelled. A classification of telecommuting into full-day and part-day telecommuting is proposed to allow the systematic evaluation of impacts of the full or part substitution of journeys to work with arrangements to work at alternative locations.

The proposed model accounts for a range of variables including employment, telecommuting proportion, telecommuting frequency, transport mode split and a number of transport network performance measures. Travel pattern adjustments of commuters when telecommuting arrangements introduced are also quantified in the model. The growth of telecommuting is simulated using the Logistic function of the technological substitution. The model has been calibrated from aggregate results of previous telecommuting studies. The model aims to enable the simulation of transport scenarios under different employment attendance arrangements to assist decisions related to allocation of funds and resources to promote telecommuting. Furthermore, the estimation of vehicle-km travelled allows evaluation of impacts on fuel consumption and related environmental analysis.

The main focus of this research work has been to develop a forecasting methodology using data available from published sources. Four scenarios for New South Wales have been analysed and presented in the paper to illustrate background concepts, relative magnitude of variables and the application of the model. It would be shown that savings of vehicle-km travelled is considerable and would increase rapidly when the telecommuting proportion and telecommuting frequency are encouraged to increase.

1. INTRODUCTION

As cities have become larger and more congested, commuting trips become longer and more stressful. An effective solution for the travel of commuters is sought in almost every large city. Some flexible work arrangements have been proposed, such as flexitime and compressed work weeks as potential solutions. Recently, using information technologies and telecommunications to substitute journeys to work has received attentions of transport researchers.

The substitution of journeys to work by working from alternative locations using information technologies and telecommunications is defined as telecommuting. There are two determinants to support telecommuting. (1) Telecommuting helps to increase the productivity while decreasing the overhead for the business. (2) Telecommuting increases the quality of life and alleviates travel expenses, delay, and stress associated with most commute trips. Although more research is needed, for last three decades many projects have attempted to analyse and evaluate impacts of telecommuting on different aspects of society. In transport sector, telecommuting has been expected to reduce travel and pollution (Nilles 1988, Mokhtarian *et al* 1997) particularly where the traffic congestion is high as in many large cities around the World.

In Australia, telecommuting is in a stage of rapid increase. According to Brewer and Hensher (1996), the proportion of telecommuters in workforce in Australia was 3.4% and only 1.8% companies had policies to allow workers to telecommute in 1994. The proportion of telecommuting has increased to 30% in 2005 (Vidal, 2004).

Reasonable incentives at this stage would further increase uptake of telecommuting in Australia. Analysis and forecast of travel impacts of telecommuting is particularly essential when Australian Government has been considering policies to encourage telecommuting (ATAC, 2006).

2. DEFINITION OF TELECOMMUTING

There are a variety of definitions and classifications of telecommuting. Differences depend on telecommuting time, location, type of communication and employment status (salaried or self-employed employees) (Figure 1).

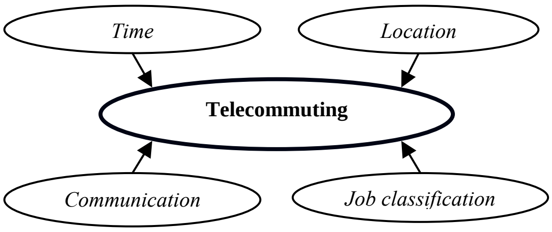

Figure 1. Main elements of existing definitions of telecommuting.

The location-based classification distinguishes telecommuting into three main categories. Home-based and centre-based telecommuting types are well known in the USA and Australia (Nilles, 1988; Shafizadeh et al, 2000; ATAC, 2006). The third type, mobile telecommuting (working in mobile offices, on trains, on cars, on flights or in hotels) is reported often in European case studies. Employment status is another attribute in telecommuting classification. In Europe, a self-employed person with home-office-small-office is not a telecommuter while self-employed person having a main office in a contractor premises can be considered a telecommuter (ECaTT, 2000). In terms of communication, most studies mentioned about substitution of commuting by information and communication technologies, from basic means such as telephone to advanced system like videoconferencing.

For the purpose of this paper, we prefer a transport-oriented definition. Telecommuting is the full or part substitution of journeys to work by working at alternative locations. Alternative locations can be home, mobile offices, telecentres, customer sites or a combination of them. The definition covers employed persons, including salaried and self-employed individuals. However, the definition excludes workers that their jobs require working in mobile offices such as truck drivers, bus drivers and delivery persons. The time-based classification in this definition categorises full-day and part-day telecommuting instead of full-time and part-time telecommuting as observed in other research works. This is because full-day and part-day telecommuting have different quantifiable impacts on transport. Commuting trips and commuting time of workers are totally eliminated during days of full-day telecommuting. While on days of part-day telecommuting, commuting trips have to be made and vehicle-km remains the same. The travel-time could be reduced (but not eliminated) in part-day telecommuting because the commuting trip can be made during off peak.

3. ANALYSIS METHODOLOGY

A computation model has been developed to evaluate and forecast impacts of telecommuting on transport performance indicators including network travel-time, traffic congestion, vehicle-km travelled and pollution of environment. This paper focuses on the computation of savings of vehicle-km travelled by telecommuting. Vehicle-km saved can be obtained from the magnitude of trip reduction and the unit impact. We will start with the explanation to calculate the reduction of number of trips.

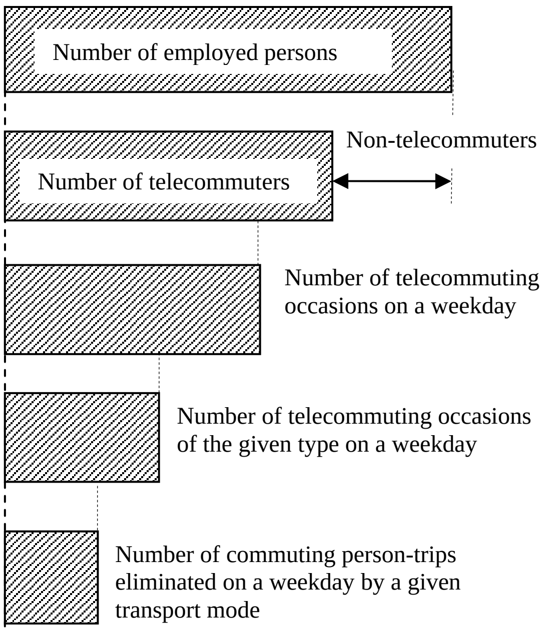

Figure 2. Schematic explanation of computing reduction of number of trip.

3.1. Computation of trip reduction

Steps to compute the number of trips eliminated by telecommuting is illustrated in Figure 2. Firstly, the number of telecommuters at a given time is computed from the number of employed persons (*E*) at that time and the proportion of telecommuting (*TC*). Then the frequency (*Fi*) of telecommuting type *i* is applied to compute the number of telecommuting occasions per weekday.

Next, the transport mode share (MSj) is introduced to calculate the average reduction of person trips of transport mode j. Therefore, the reduction of person commuting trips by telecommuting on a weekday (ΔTR) is given by:

$$\Delta TR = E \times TC \times \sum_i (\alpha_i F_i) \times \sum_j (\beta_j MS_j) \quad (1)$$

where α_i is the impact factor of telecommuting types and β_j is the impact factor of transport modes.

3.2. Vehicle-km travelled

The reduction of vehicle-km travelled is computed for a weekday. As mentioned before, vehicle-km travelled is not reduced by part-day telecommuters on telecommuting days as commuting trips are still made. Therefore, number of commuting person-trip reduction by telecommuting on a weekday is contributed only by full-day telecommuting only. Thus, α_1 (impact factor of full-day telecommuting) = 1 and α_2 (impact factor of part-day telecommuting) = 0.

Only drive alone mode share affects savings of vehicle-km travelled. The reason why we account only drive alone mode is (1) other private modes like car pool or drive share do not lead to vehicle-trip reduction and (2) with a small telecommuting proportion, person-trip reduction of public transport mode would not eliminate a bus or a train trip. Therefore, β_1 (impact factor of drive alone mode) = 1 and $\beta_{2,3,...}$ (impact factor of other modes such as car share, bus, train) = 0. Equation (1) can now be rewritten:

$$\Delta TR = E \times TC \times F_{FDTC} \times MS_{DA} \quad (2)$$

where F_{FDTC} is the frequency of full-day telecommuting and MS_{DA} is the drive alone mode share.

The reduction of person commuting trips on a weekday in Equation (2) is composed of the number of telecommuting occasions per weekday. Each full-day telecommuting occasion eliminates a round trip to work. Thus:

$$\Delta VKT = E \times TC \times F_{FDTC} \times MS_{DA} \times D \quad (3)$$

where ΔVKT is the reduction of vehicle-km travelled caused by telecommuting. D is average round trip distance between the work place and home of telecommuters. Commuters with long commuting distance tend to adopt telecommuting early, therefore the average commuting distance of telecommuters maybe different to the overall average commuting distance of general commuters.

Percentage of savings of vehicle-km travelled by telecommuting can be estimated using:

$$S = 100\, \Delta VKT \,/\, VKT \quad (4)$$

Where S is the percentage of savings of vehicle-km travelled by telecommuting and VKT is the vehicle-km of work trips by car of all commuters.

$$VKT = E \times PR \times D^* / O_c \quad (5)$$

where PR is the private mode share of work trips of general commuters, Oc is the car occupancy of work trips of general commuters anf D^* is the average distance of round trips for work of general commuter population.

3.3. Forecasting proportion of telecommuting

Proportion of telecommuting is an important input to estimate impacts of telecommuting (see Equation (1)). To forecast proportion of telecommuting, we adopt the model proposed by Blackman (1974) to forecast the uptake of a new technology. The model has been later applied to telecommuting by Handy and Mokhtarian (1996) and Shafizadeh *et al* (2000). According to Handy and Mokhtarian (1996), the telecommuting growth can be approximated by considering telecommuting as a new technology and its adoption follows an S-shape curve, characterized by low growth rates at the initial and final stages, and high growth rates around the midway point. The general model of Blackman (1974) is given by Equation (6)

$$\ln\left(\frac{f}{F-f}\right) = c_1(t - t_0) + c_2 \quad (6)$$

where f is the market share captured at time t, F is the carrying capacity of the market and t_0 is the year when the innovation first captures a portion of the market. c_1 and c_2 are constants.

In telecommuting application f is the proportion of telecommuting in year t and F is the maximum proportion of telecommuting achievable by the workforce. The constants c_1 and c_2 need to be calibrated using historical data. Blackman suggested fitting a regression line to the historical data. To simplify this process, Equation (6) is rewritten in a linear form:

$$\ln\left(\frac{f}{F-f}\right) = c_1 t' + c_2 \quad (7)$$

where

$$t' = t - t_0 \quad (8)$$

t' is the period of time from the initial year to the year of interest.

Rearrangement of (7) forms the constrained logistic function that provides the proportion of telecommuting *f* as a function of time:

$$f = \frac{F \times e^{\left(c_1 t' + c_2\right)}}{1 + e^{\left(c_1 t' + c_2\right)}} \quad (9)$$

To estimate the initial year (t_0) we compared the proportion of telecommuting in Australia and in US. The proportion of telecommuting in Australia in 1994 was 3.4% (Brewer and Hensher, 1996), approximately equal to the level of telecommuting in US in 1990 (Shafizadeh et al, 2000). Thus, a four year time lag period was selected. Both Handy and Mokhtarian (1996) and Shafizadeh et al (2000) have selected 1980 as the initial year of telecommuting in US to forecast telecommuting. 1984 is our selection as the initial year that telecommuting captured a portion of workforce in Australia.

To estimate the maximum level of telecommuting we reviewed other studies. Studies from developed countries confirmed a positive trend with rapid increase of telecommuting proportion. The Canadian Telework Association estimated in 2004 that 65 per cent of jobs would be amenable to telework. ITAC also forecasted that 100 million US workers (approximately 70%) will telework by 2010.

Nilles (1988) hypothesized that 80% of information workers were potential telecommuters and 50% of workforce was composed of information workers. Then Nilles proposed that 40% of all workers were potential telecommuters. Later, other studies and surveys have shown that the telecommuters included workers other than just information workers (ECaTT, 2000; ABS, 2001). From these reasons the upper limit of telecommuting can be expected to be greater than 40% of workforce.

We selected 50% as the maximum level of telecommuting in Australia. The proportion of telecommuting in 2000 was 11% (ABS, 2001) and 2005 was 30% (Vidal, 2004 and Sensis, 2005). Using these data to calibrate Equation (9) (Figure 3), an R^2 value of 0.99 was observed and the regression line is found to be:

$$y = 0.2732\,x - 5.4397 \quad (10)$$

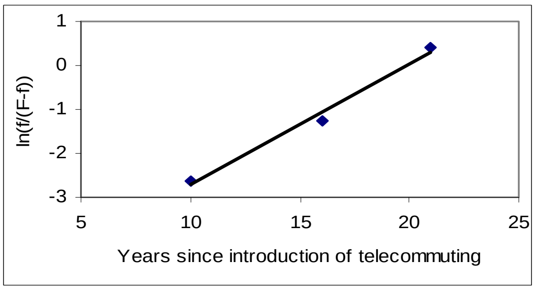

Figure 3. Calibration using linear regression.

Thus, Equation (9) can be rewritten:

$$f = \frac{0.5 \times e^{\left(-5.44 + 0.27\, t'\right)}}{1 + e^{\left(-5.44 + 0.27\, t'\right)}} \quad (11)$$

The proportion of telecommuting in Australia is forecasted as in Figure 4 using Equation (11).

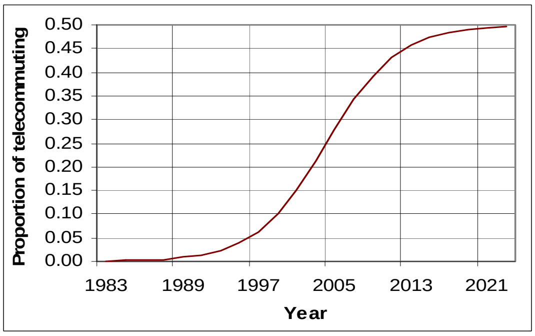

Figure 4. Simulation of growth of telecommuting in Australia.

3.4. Consideration of adverse impacts

There are adverse impacts of telecommuting that affect the reduction of vehicle-km travelled. These effects can be grouped to (1) the change of transport mode of commuting trips of other household members of telecommuters; (2) the change of non-commuting trips of telecommuters and their household members (induced demand); (3) the travel mode change of telecommuters; (4) the travel distance increase by residential relocation; and (5) the latent demand (e.g. space freed up by telecommuters stimulates use of private transport mode).

The increase of non-commuting travel is the most likely adverse impact to occur due to travel-time saved from telecommuting. Field studies in California have shown the number of non-commuting trips increased by 0.2 to 0.5 trips per telecommuter. However, the non-commuting vehicle-km travelled decreased by 3.2 to 8.1 km (Mokhtarian 1998).

The range of influence of non-commuting travel is computed by the proportion of change of non-commuting vehicle-km and the saving of commuting vehicle-km by telecommuting. The limit of range of influence is computed from the largest increase and the largest decrease of non-commuting vehicle-km travelled. It has been estimated that the impact from the increase of non-commuting travel ranged from -5.7% to 17%. To account for influence of non-commuting travel changes on vehicle-km travelled we included variable *NCT* in the model. *NCT* receives the range of value from 0.943 (NCT^-) to 1.17 (NCT^+). These values are used as multipliers to compute ΔVKT^- and ΔVKT^+ respectively to determine lower and upper bound estimates for vehicle-km travelled (see Figure 5).

$$\Delta VKT^{-} = E \times TC \times F_{FDTC} \times MS_{DA} \times D \times NCT^{-} \qquad (12)$$

$$\Delta VKT^{+} = E \times TC \times F_{FDTC} \times MS_{DA} \times D \times NCT^{+} \qquad (13)$$

4. BASE SCENARIO FOR ANALYSIS

The proposed model has been applied to four scenarios in New South Wales. Inputs for the base scenario have been determined as follows.

Employment: According to statistical sources employment of New South Wales in 2001 was 3,044,800 and expected to increase by 50000 per year. This value has been used as an input (see Table 1) in all scenarios presented in this paper.

Telecommuting frequency: In this paper, fraction form of telecommuting frequency is used. In this form, telecommuting frequency is the ratio between the number of telecommuting days per week and the number of working days per week. In RTA (1995), Mokhtarian (1998) and Sensis (2005), telecommuting frequency has been reported to be from 0.2 to 0.3. We used 0.24 with regard to conditions of NSW, in which 0.18 was frequency of full-day telecommuting.

Private transport mode share: According to Parker (2004), the private mode share of commuters in five Australian largest cities was 80% in 2001. This value was applied in this paper for the base scenario.

Average distance of round trips of general commuters: According to TPDC (2005), average distance of round trips fluctuated slightly from 31.8 to 32.6 km between 1991 and 2003. 32.5 km is the selected distance of round work trips of commuters in 2001 for the base scenario.

Average distant saved by each telecommuting occasion: This value has been reported to be in the range of 25 to 80 km in Hamilton (2006) and 159 km in RTA (2000). 60 km is applied here as the average distance saved per occation.

Drive alone mode share: Parker (2004) reported that the drive alone mode share in five large cities of Australia, including Sydney, in 2001 was 70%. We used this result for our base scenario.

Car occupancy of work trips of general commuters: According to TPDC (2005), car occupancy in Sydney on weekdays was 1.45 in 1999 and 1.43 in 2003. Furthermore, Parker (2004) reported that car occupancy of commuters in Australia decreased from 1.21 to 1.08 between 1976 and 2001. The application of car occupancy in this paper is for work trips; therefore, we selected the value 1.08 for the base year 2001.

5. SCENARIO ANALYSIS

In the base scenario (also referred as scenario 1) full-day telecommuting frequency, drive-alone mode share, and distance saving per each telecommuting occasion are kept unchanged at the level of 2001 (base year), 0.18, 0.7 and 60 km respectively (see Table 1). Model results show that savings are over 3 million vehicle-km per day (4.2%) in 2001 and 15 million vehicle-km per day (15.5%) in 2021. The third row in Table 1 shows that the number of telecommuters in NSW was under 400 thousand in 2001, and this number would increase to almost 2 million in 2021.

Employees with longer commuting distance adopt telecommuting earlier, compared to general workforce as their utilities are greater. When the number of telecommuters increases, the average distance saving of each telecommuting occasion tends closer to the average commuting distance of general commuters. For this reason, in scenario 2, the distance saving of each telecommuting occasion is generated by a negative exponential function (Equation (14)).

$$D_2 = D_1 \times e^{-(t_2 - t_1)} \qquad (14)$$

D_2 is the distance saved per telecommuting occasion at time t_2. D_1 is the distance saved per telecommuting occasion at time t_I. Other inputs are as in scenario 1. According to this method, the distance saved per telecommuting occasion reduces from 60 km in 2001 to 41.86 km in 2021, when the proportion of telecommuting increases from 0.13 to 0.49. The saving in scenario 2 reduce to 14 million vehicle-km per day in 2021, equivalent to 10.8% of total vehicle-km travelled by car of general commuters.

Table 1. Computation process for scenario 1.

Variable	Estimated value		Units
	2001	2021	
E	3,044,800	4,044,800	
TC	0.13	0.49	
E x TC	395,824	1,981,952	
FDTCF	0.18	0.18	
D	60	60	Km
DA	0.7	0.7	
ΔTR	66498	332968	Veh-trips/day
NCT+	1.17	1.17	
NCT-	0.943	0.943	
ΔVKT	3,050,292	15,058,964	Vehicle-km/day
$\Delta VKT+$	3,568,841	17,618,988	Vehicle-km/day
$\Delta VKT-$	2,876,425	14,200,403	Vehicle-km/day
PR	0.8	0.8	
O_c	1.08	1.08	
D^*	32.5	32.5	Km
VKT	73300741	97374815	Vehicle-km/day
S	**4.16**	**15.46**	**%**

In scenario 3, while other inputs are the same as in scenario 2, the input value of drive-alone mode share is increased along with the proportion of telecommuting and reaches 0.77 in 2021. According to model results, the reduction of vehicle-km is almost 12% in 2021.

In scenario 4, the frequency of full-day telecommuting is also assumed to increase along with the proportion of telecommuting. For this, the frequency of telecommuting is increased from 0.18 in 2001 to 0.22 in 2021. This means in 2021 telecommuters will telecommute 1.1 day per week in average. Results show the reduction of vehicle-km of scenario 4 is 14.1% in 2021 (Figure 5).

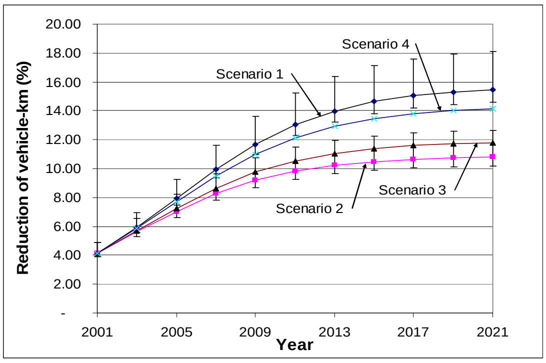

Figure 5. Savings of vehicle-km travelled.

6. CONCLUSIONS

A computation model to evaluate impacts of telecommuting on vehicle-km travelled has been developed. For this purpose, a new framework with time-based classification of telecommuting is proposed. The classification identifies full-day and part-day telecommuting as two categories with different impacts on the transport system. The framework and structure of the model have been designed so that the model can be expanded to examine impacts of telecommuting on network travel-time, traffic congestion and environmental pollution as well. This paper has focussed on impacts on vehicle-km travelled.

The main target of this research work has been to develop a forecasting model that enables estimation of savings of vehicle-km travelled using data available from published sources.Impacts of telecommuting on vehicle-km travelled are computed based on the number of employees, proportion of telecommuting, frequency of telecommuting and transport network performance measures including travel distances, mode share and vehicle occupancy. Adverse impacts of telecommuting on savings of vehicle-km travelled have been also taken into consideration in the model. The simulation of the growth of telecommuting has adopted the logistic function to forecast the substitution of a new technology. The function has been calibrated using a curve fitting method.

The model has been applied to four scenarios in New South Wales. Plausible input values have been selected from previous studies. The literature reflects that telecommuting proportion and telecommuting frequency have a real world potential to increase with time. The model has shown that savings of vehicle-km travelled would increase rapidly when telecommuting proportion and telecommuting frequency are encouraged to increase.

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