

Analysis of Impacts of Telecommuting for Reduction of Environmental Pollution

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Abstract

Telecommuting is defined as the substitution of journeys to work by working from alternative locations using information technologies and telecommunications. Telecommuting is often stated as a solution for transport demand management and increase of quality of life. In term of environment, telecommuting can reduce gas emissions, traffic accidents, noise and traffic jams. This paper analyses positive and negative impacts of telecommuting on environment. A framework is proposed as an initiative toward model development. The framework includes a suitable definition and classification, relationship of variables and a concept diagram for development of a model which can well evaluate environmental impacts of telecommuting. Calculation equations for air and noise pollution reduction of telecommuting are developed. The paper then discusses difficulties in evaluation of impacts of telecommuting on environment and further research.

1. Introduction

Telecommuting is defined as the substitution of journeys to work by working from alternative locations using information technologies and telecommunications. The term telecommuting was coined by Nilles in 1973, [1]. There are two determinants make telecommuting viable. (1) Telecommuting helps to increase productivity while decreasing overheads for businesses. (2) Telecommuting increases quality of life and alleviates travel expenses, delay, and stress associated with urban commute trips. The above two factors make telecommuting attractive to employees and employers and therefore they have potential to increase. The growth of telecommuting is the reason that telecommuting has received attentions from researchers. 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 the transport sector, telecommuting has been expected to reduce travel and pollution particularly where traffic congestion is high as in many large cities, [1], [2].

The paper presents a study of positive and negative impacts of telecommuting on environment. A framework is proposed as an initiative toward model development. The framework includes a suitable definition and classification, relationship of variables

and a concept diagram for development of a model which can well evaluate environmental impacts of telecommuting. Calculation equations for air and noise pollution reduction of telecommuting are developed. The paper then discusses difficulties in evaluation of impacts of telecommuting on environment and further research.

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).

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, [1], [3], [4]. 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, [5]. 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. Possible environmental impacts

According to previous studies, telecommuting can reduce the number of vehicle trips, vehicle-km of travel and travel time, [6], [7]. The reduction of vehicle trips will lead to reduction of start-up emissions, traffic noise, traffic accidents, and pollutions of road construction because of saving of road space. The reduction of vehicle-km travelled leads to reduction of running emissions and also the same other impacts of the reduction of vehicle trips. The reduction of travel time resulting from commuting trip shifted from peak hours to non peak hours probably reduces emissions from the delay of vehicles by traffic congestion that occurs often in peak hours (Figure 1).

However, telecommuting may also create more pollution for local areas. Home-base telecommuting is likely to create other trips as the flexible working time may induce other activities. These additional trips will be mainly in the regional transport system. Centre-based telecommuting could also create more trips for the local transport system. In other words, it shifts the traffic congestion from CBD to suburbs or spreads the traffic congestion from central parts to other areas. Replacement of public transport trips to the CBD by car trips to telecommuting centres could also contribute to this shift. More traffic in local areas means more environmental pollution in those areas. Thus, environmental impacts at local level should be considered when developing centre-based telecommuting.

While data to evaluate impacts of telecommuting in the reduction of traffic accidents and pollutions of road construction, this paper will focus on impacts of telecommuting in traffic noise and traffic emissions.

4. Calculation methodology

Evaluating traffic air pollution impacts depends on a number of factors including vehicle-km of travel, engine starting conditions (i.e., cold or hot starts), average speed, vehicle type (including emissions equipment), ambient air temperature, and driver behaviour, [8]. As a result, it remains difficult to fully capture all of the pollution benefits from a telecommuting program. Nonetheless, we can reach a conservative approximation by calculating 1) start emissions based on start emission factors along with 2) running exhaust emissions by using estimates of vehicle-km travelled, [3].

4.1. Computation of start-up emission reduction

The reduction of start-up emissions is calculated from the reduction of starts through the reduction of vehicle trips and emissions of each start. 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 (F_i) of telecommuting type i is applied to compute the number of telecommuting occasions per weekday. Next, the transport mode share (MS_j) is introduced to calculate the average reduction of person trips of transport mode j , [6]. 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.

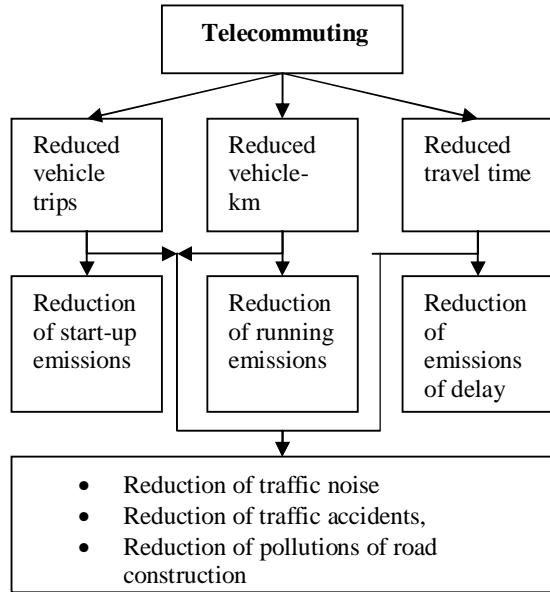


Figure 1. Relationship between possible environmental impacts and travel impacts of telecommuting

While part-day telecommuting spread traffic away from peak hours, only full-day telecommuting eliminates completely some vehicle trips. Thus, α_1 (impact factor of full-day telecommuting) is equal to 1 and α_2 (impact factor of part-day telecommuting) is zero.

Similarly, only drive alone mode share affects vehicle trip reduction. 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 $\beta_{2,3,\dots}$ (impact factor of other modes such as car share, bus, train) = 0. Equation (1) can now be rewritten:

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

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

Then the reduction of start-up emissions can be calculated by following equation:

$$\Delta SE_i = \Delta TR \times SE_i \quad (3)$$

where ΔSE_i is the reduction of start-up emissions by telecommuting and SE_i is start-up emission rate of gas i . According to California's EMFAC emission model, SE_i at soak time of 120 minutes can take values of 2.18, 27.69, 1.69 and 94.49 grams per start for reactive organic gases, CO, NO_x and CO_2 respectively, [8].

4.2. Computation of running emission reduction

The reduction of running exhaust emissions by telecommuting can be computed by using estimate of vehicle-km travelled reduction from telecommuting. Each full-day telecommuting occasion eliminates a round trip to work, [7]. Thus:

$$\Delta VKT = E \times TC \times F_{FDTC} \times MS_{DA} \times D \quad (4)$$

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.

The reduction of running emissions can be calculated by following equation:

$$\Delta RE_i = \Delta VKT \times RE_i \quad (5)$$

where ΔRE_i is the reduction of running emissions by telecommuting and RE_i is running emission factors of gas i . According to California's EMFAC emission model, RE_i at average speed of 35km/h can take values of 0.125, 2.06, 0.28 and 161 grams per km for reactive organic gases, CO, NO_x and CO_2 respectively, [8].

4.3. Computation of traffic noise reduction

According to Handbook of Acoustic Noise Control [9], the 50 percentile of traffic noise for speed of 35-45 mph and distances greater than 20 feet is given as:

$$L_{50} = 68 + 8.5 \log(V) - 20 \log(D) \quad (6)$$

where V is traffic volume in vehicles per hour and D is distance from the traffic lane, in feet.

Therefore the reduction of traffic noise by telecommuting can be given as:

$$\Delta L_{50} = 68 + 8.5 \log(\Delta TR) - 20 \log(D) \quad (7)$$

where ΔTR is reduction of vehicle trips by telecommuting given by equation (2).

A similar method can be applied to other traffic noise models to evaluate the impact of telecommuting on traffic noise.

5. Scenario application

The proposed models for assessment of impacts of telecommuting on air quality have been applied to four scenarios in New South Wales.

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), [7].

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 (8)).

$$D_2 = D_1 \times e^{-(t_2 - t_1)} \quad (8)$$

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_1 . Other inputs are as in scenario 1.

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.

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.

Model results show that reduction of reactive organic gases, CO, NO_x and CO_2 in 2001 are 0.49, 7.69, 0.94 and 496 tons respectively. In 2021 the reduction of CO_2 is from 1700 to 2450 tons (figure 2); the reduction of CO is from 29 to 39 tons; the reduction of NO_x is from 3.4 to 4.7 tons; and reduction of reactive organic gases is from 1.9 to 2.4 tons.

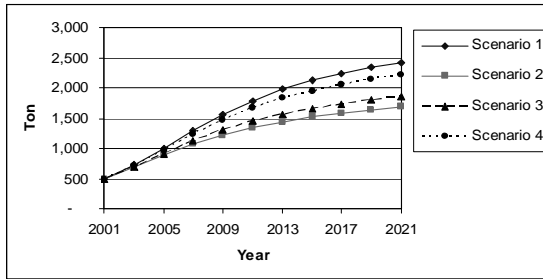


Figure 2. Reduction of CO₂ in four scenarios by telecommuting.

6. Discussion and further research

Calculation equations developed base on a number of assumptions. It was also assumed that the forgone commute would have been made in a light-duty, gasoline-powered automobile with a catalytic converter. Because a growing portion of the vehicle fleet comprises light duty trucks or sport-utility vehicles with lower fuel economies than light-duty automobiles, these assumptions will underestimate the air quality impacts of telecommuting. In other words, the current vehicle fleet almost certainly consumes more gasoline per km and produces more emissions per gallon of gasoline than that which is assumed here. Furthermore, because a constant running speed is assumed, we are neglecting any sudden acceleration and deceleration episodes which also result in higher emission rates than those assumed.

The model to calculate the reduction of traffic noise level is developed from the model to evaluate traffic noise at roadside of a specific road rather than the whole transport network. Therefore the model can be applied to assess environmental impacts of a specific road where the number of telecommuters using that road is qualified.

Adverse environmental impacts that can be resulted from the induced travel demand of telecommuting have not been taken into account in this paper. This task requires data and further research of the change of travel behaviours of telecommuters and their other family members. Reduction of traffic accidents and pollutions of road construction by telecommuting also need more work to develop the method and get data to evaluate.

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