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Assessing the road safety impacts of a teleworking policy by means of geographically weighted regression method

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ABSTRACT

Travel demand management (TDM) consists of a variety of policy measures that affect the effectiveness of transportation systems by changing travel behavior. The primary objective of such TDM strategies is not to improve traffic safety, although their impact on traffic safety should not be neglected. The main purpose of this study is to simulate the traffic safety impact of conducting a teleworking scenario (i.e. 5% of the working population engages in teleworking) in the study area, Flanders, Belgium. Since TDM strategies are usually conducted at a geographically aggregated level, crash prediction models should also be developed at an aggregate level. Given that crash occurrences are often spatially heterogeneous and are affected by many spatial variables, the existence of spatial correlation in the data is also examined. The results indicate the necessity of accounting for the spatial correlation when developing crash prediction models. Therefore, zonal crash prediction models (ZCPMs) within the geographically weighted generalized linear modeling framework are developed to incorporate the spatial variations in association between the number of crashes (including fatal, severe and slight injury crashes recorded between 2004 and 2007) and other explanatory variables. Different exposure, network and socio-demographic variables of 2200 traffic analysis zones (TAZs) are considered as predictors of crashes. An activity-based transportation model framework is adopted to produce detailed exposure metrics. This enables to conduct a more detailed and reliable assessment while TDM strategies are inherently modeled in the activity-based models. In this study, several ZCPMs with different severity levels and crash types are developed to predict crash counts for both the null and the teleworking scenario. The results show a considerable traffic safety benefit of conducting the teleworking scenario due to its impact on the reduction of total vehicle kilometers traveled (VKT) by 3.15%. Implementing the teleworking scenario is predicted to reduce the annual VKT by 1.43 billion and the total number of crashes to decline by 2.6%.

1. Introduction

Urbanization and population growth together with employment and motor vehicle growth largely and negatively affect transportation systems' performance. To diminish these negative impacts, different policy measures and strategies have been applied by authorities. These programs and strategies that promote more efficient use of transportation systems are generally called TDM strategies (Litman, 2003). TDM consists of several policies and strategies which aim to overcome transportation problems by means of mode shift (e.g. using public transportation instead of cars, biking for short distance trips or carpooling), travel time shift (e.g. avoiding traffic peak-hours by leaving home/the work place earlier or later) or travel demand reduction (e.g. teleworking). In general, TDM strategies are implemented to improve transportation systems' efficiency. However, their potential secondary impacts such as traffic safety or environmental effects should not be overlooked.

"Teleworking" is a general term used when application of telecommunication systems substitutes for actual travel to the work place. Teleworking is one of the most popular and effective components of commute trip reduction programs (Litman and Fitzroy, 2012). Teleworking can significantly reduce participating employees' commute travel and consequently the total distance traveled. As mentioned earlier, TDM strategies usually have consequential impacts (e.g. impacts of reduced travel demand after

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applying a teleworking strategy) such as traffic safety, which is interesting to be investigated. To the best of our knowledge, traffic safety impacts of teleworking as a TDM strategy have not been investigated before in a proactive manner. The main goal of this study is, therefore, to evaluate the road safety impacts of a teleworking scenario by coupling ZCPMs with an activity-based model for Flanders, Belgium. This way, the behavioral impact of the TDM scenario in terms of traffic demand is incorporated in the safety analysis. By assigning traffic demand to the road network, the impacts of responses to TDM, such as changes in trip planning, route choice and modal choice are incorporated into the analysis.

The most immediate and direct impacts of teleworking are on travel demand and consequently a reduction of total distance traveled. Previous research has evaluated these impacts from individual and global points of views; i.e. some studies focused on the changes of only telecommuter's behavior and their travel pattern (individual) whereas other studies investigate the effects of a telecommuting strategy on a more global level.

Henderson and Mokhtarian (1996) compared the differences in non-telecommuting days and telecommuting days for a telecommuting group. They showed that vehicle miles traveled (VMT) and the number of daily trips reduced by 66.5% and 31.9%, respectively. Koenig et al. (1996) compared participants' telecommuting day travel behavior with their non-telecommuting behavior. They concluded that the number of person vehicle trips reduced by 27% while VMT decreased by 77%. Moreover, Mokhtarian and Varma (1998) compared several travel indicators between telecommuting days and non-telecommuting days for a sample of 72 center-based telecommuters in California. An average reduction of 11.9% in person miles traveled and 11.5% in VMT was found over a five-day work week.

In a study conducted by Nilles (1996), it was estimated that if 10% of the workforce telecommutes on any given day, total vehicle travel would decline by 4%. Results of another study (Choo et al., 2005) indicated that estimated VMT without telecommuting would have been 1.78–3.31% higher compared to the observed VMT, with a mean impact of 2.12%. In another study, Choo and Mokhtarian (2007) found that teleworking appears to reduce VMT as little as 0.34%. In contrast to the above mentioned studies which report a relatively modest impact of teleworking on distance traveled, other studies report quite higher numbers. For instance, Vu and Vandebona (2007) estimated a reduction of 10.8–15.46% in VKT after evaluating different teleworking scenarios in Australia. Dissanayake and Morikawa (2008) investigated the reductions of VKT for car and motorcycle travel after a telecommuting policy implementation. The results revealed that the telecommuting policy proposed in their study significantly reduces congestion and vehicle usage reduces by 18–20%.

Based on the literature, it can be concluded that although teleworking seems to significantly decrease the amount of VKT, individual estimations by different studies tend to vary strongly. This uncertainty was also reported by Choo et al. (2005) who claimed that a wide range of answers to the question of "what impact on travel?" can be obtained. They concluded that although teleworking has a statistically significant impact on reducing travel demand, the magnitude of this impact would not be very extraordinary. The main focus of this paper is not to assess the magnitude of the impact of teleworking on distance traveled, however, it is important to assure that the estimates of our study are reasonable and in line with the findings of other studies.

Kochan et al. (2011) studied the effects of teleworking on total distance traveled in Flanders, Belgium. It was reported that in 2002, in Flanders, the total distance traveled decreased by 1.6% where the proportion of teleworkers that telework on a working day was 3.8% (Kochan et al., 2011). These results are in line with the findings of literature. Therefore, our study will be based on the framework presented in Kochan et al. (2011), although we simulate a 5% of the working population engages in teleworking instead of 3.8% (detailed information about implementation of this teleworking scenario is provided in the next section of the paper).

It can be concluded that the cause-effect relationship between teleworking and a reduction in VKT is well-established. Moreover, the relation between different types of exposure metrics (e.g. number of trips or VKT) and crashes has also been reported and well documented in the literature (Abdel-Aty et al., 2011a,b; Hadayeghi et al., 2010a; Lovegrove, 2005; Naderan and Shahi, 2010; Pirdavani et al., 2012, 2013) and although exposure might not be the direct cause of crash occurrence, but is a major predictive variable to estimate the number of crashes. Therefore, it is plausible to utilize the association between the teleworking scenario and the number of crashes so as to evaluating the traffic safety impacts of such TDM strategy. This will be carried out by associating the number of crashes with a number of explanatory variables like traffic exposure, urbanization level, and income level. Expectedly, different spatial variation may be observed for these explanatory variables especially where the study area is relatively large. Neglecting this spatial variation may deteriorate the predictive power of prediction models.

Spatial variation is known to be an important aspect of traffic safety analysis and particularly in crash prediction modeling. Inclusion of spatial variation in traffic safety studies has been reported by many researchers. In one of the earliest studies, the spatial relationship between activities which generate trips and motor vehicle accidents was studied and applied to the City and County of Honolulu (Levine et al., 1995). Different spatial patterns for different variables such as population, employment and road characteristics were identified. LaScala et al. (2000) found that significant spatial relationships exist between specific environmental and demographic characteristics of the City and County of San Francisco and pedestrian injury crashes. Flahaut et al. (2003) presented different methods for identifying and delimiting accidents black-zones. This was an application of spatial correlation in defining accident black-zones which share similar characteristics. A similar study was carried out by Moons et al. (2009) where the structure of the underlying road network is taken into account by applying Moran's *I* to identify crash hot zones. In another study by Flahaut (2004), it was indicated that spatial auto-correlation should be integrated in the modeling process if spatial data are being studied. He concluded that spatial models in comparison to non-spatial models, do not overestimate the significance of explanatory variables; thus, spatial variation should be considered to analyze spatial data. Geurts et al. (2005) investigated the clustering phenomenon in road accidents. This was an application of spatial analysis in traffic safety that aims to analyze the characteristics of specific zones on which more accident occur. Spatial correlation was found to be significant in injury crashes in a study conducted for the State of Pennsylvania at the county level (Aguero-Valverde and Jovanis, 2006). Aguero-Valverde and Jovanis (2008) further explored the effect of spatial correlation in models of road crash frequency at the segment level. The results of their study highlighted the importance of including spatial correlation in road crash modeling studies. The models with spatial correlation show significantly better fit compared to the Poisson lognormal models. The existence of clusters in the spatial arrangement of pedestrian crashes was reported by (Cottrill and Thakuriah, 2010). They supported their conclusions by computing Moran's *I* value and presenting the Local Indicators of Spatial Association (LISA) significance map of crashes. Huang et al. (2010) performed a county-level road safety analysis for the state of Florida. They reported that significant spatial correlations in crash occurrence were identified across adjacent counties. Given the aforementioned findings of several studies regarding the importance of considering spatial variation,