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Enhancing the economic benefit assessment of roadway investment through the application of value of time by trip length

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ABSTRACT

This study analyzes how the benefit assessment of roadway investment projects changes when VOT is applied according to trip length. In the theoretical study of VOT variation with respect to trip length, it was found that VOT could be changed by various effects while the direction could not be determined. Yet, the study was able to summarize that most of the empirical studies demonstrate a phenomenon of an increase in trip length. Based on the survey results in Korea, this study compares the case of applying VOT by trip length, the case of using the existing method of fixed VOT, and the results of the benefit calculation. The comparison indicates that applying the differentiated VOT by trip length tends to increase the benefit, however, the benefit yielded is not always higher than applying the fixed VOT, due to the different spatial distributions of travel demand associated with each project.

1. Introduction

The Value of Time (VOT) refers to the opportunity cost of time that a person spends on a certain activity. When the activity is accompanied by a travel which is not for its own sake, the value of travel time is the cost of time spent on transport. Thus, it is natural that the importance and the necessities of deemed activities requiring travel influence the VOT for travel. Some travel activities are considered more valuable than others (e.g. a business trip for a contract compared to an everyday shopping trip), and the different individual characteristics such as income and age incur the VOT to be varied (Hensher, 1997; Gunn, 2001; Hensher, 2001; Jara-Diaz, 2003; Jiang and Morikawa, 2004; VNTSC, 2005; Small, 2012; Shao et al., 2014).

The varied characteristics of the VOT have been supported by both theory and empirical evidence. Since Becker (1965)'s representation of the VOT using time allocation model, the theory has become sophisticated enough to represent VOT variation by the types of associated activities (Oort, 1969; De Serpa, 1971) and the tightness of the time budget (Vickrey, 1969; Evans, 1972; Jara-Diaz, 2003). An empirical survey that specified the VOT with the stated preference method (SP) has also demonstrated its diversity. Various studies have reported the wide range of the VOT in relation to income (Hensher, 2001), trip length (Hensher, 2001; Mackie et al., 2003; Daly and Carrasco, 2009), and other factors. (Kono and Morisugi, 2000).

VOT variation is not a trivial issue for the evaluation of transportation projects because the expected travel time savings are monetized via the VOT and this accrue to most of the benefits of the project (Small, 1999). This means that incorrect Valuation of Travel Time Savings (VTTS) could result in the biased evaluation of candidate projects (Berechman, 2009). However, in practice, VOT variation is not properly reflected in the evaluation of transportation projects. In case of the U.S., USDOT (2016) sets the VOT in an aggregate manner to be used in the economic analysis: $13.60/hour for personal local travel, $25.40/hour for business travel, and $14.10/hour for all purposes travel, measured in 2015 dollars. The utilization of the fixed VOT is also observed in the U.K and South Korea.

This study attempts to count VOT variation on VTTS and aims to investigate the effects of the differentiated VOT by trip length in transportation project evaluation. Among various factors associated with VOT variation, the study places a special attention to VOT variation by trip length in VTTS based on the empirical evidence. Since the study applies the varying VOT by trip length into VTTS, the literature review section focuses on the theoretical background for VOT variation in relation to trip length and its application on VTTS. Then, the paper applies the differentiated VOT using the route-based traffic assignment technique, followed by the discussion section on the issues that incur when differentiated VOT is applied. The last section concludes the paper with the direction for future research.

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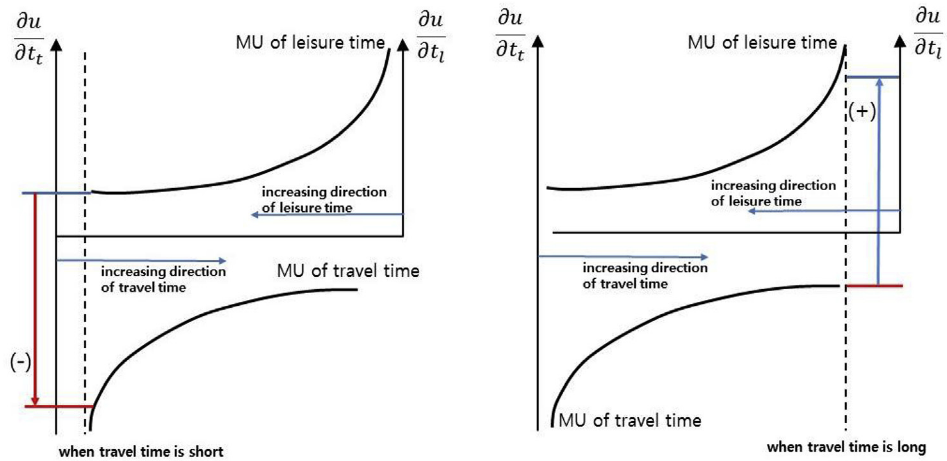

MU change when travel time is short (a)   MU change when travel time is long (b)

Fig. 1. Change of the MU of travel time and leisure time (recreated figure from Jiang and Morikawa, (2004)).

2. Literature review

The literature review explores both the theoretical and empirical aspects of VOT variation.

2.1. Trip length and VOT variation

There is an apparent relationship between trip length and VOT variation (Wardman et al., 2007). In the case of the VOT change due to trip length, it is necessary to focus on the behavioral and cognitive aspects of the passenger rather than the VOT change due to the intrinsic characteristics of the derived demand. The following section summarizes the existing studies that identify why the VOT varies with trip length.

In theory, the VOT is measured by the substitutional rate between the Marginal Utility of Cost (MUC) and the Marginal Utility of Time (MUT).

$$value\ of\ travel\ time\ (VOT) = \frac{\partial\mu_t}{\partial\mu_c} \quad (1)$$

where,

$\partial\mu_t$ marginal utility (μ) with respect to trip length
$\partial\mu_c$ marginal utility (μ) with respect to cost

Eq. (1) leaves the possibility of a bi-directional change of the VOT with trip length. When trip length increases, MUT and MUC both change. If the change rate of each Marginal Utility (MU) is different, the VOT increases or decreases. The increasing VOT is due to the relatively insensitive travel cost (so-called the damping effects) for longer trips. Various studies (Wardman et al., 2007; Daly and Carrasco, 2009; Daly, 2010) reported the declining cost sensitivity from their VOT estimation. The cost damping effects observed in the VOT estimation are well annotated by Daly (2010). Recently, Hjorth and Fosgerau, 2012 approached the issue with the prospect theory where travel time losses and gains are valued differently, which also found the diminishing sensitivity stronger for cost than for travel time.

However, VOT variation cannot solely be attributed to the relative sensitivities of the MU of cost and time. The size of the travel time savings also affects the VOT (Wardman et al., 2007; Ojeda Cabral, 2014). People tend to place a much higher value when travel time savings exceed a certain amount. The issue may be interpreted with the following questions: Are 30-second time-slices good enough? Can travelers perceive small time savings? Do the savings have any resource value? Mackie et al. (2003) reported that the value of small time savings was not observable up to 6 min. On the contrary, Small (1999) pointed out that even for the savings of 30 s, people adjust their schedule to utilize the savings in the long run. A comprehensive review of the valuation of small travel time is provided by Daly et al. (2014). Jiang and Morikawa (2004) approached the issue mathematically using the utility function consisting of the cost of leisure activities, leisure time, and travel time assuming no utilities for work time. The core of variation is the possible bi-directional changes (+, -) of the MU and its magnitude depending on trip length. They identified that the VOT increases when the MU of trip length decreases. On the other hand, the VOT decreases temporarily and increases with trip length when the MU of trip length decreases. The paper concludes that the case of short travel time is more applicable to short trip length because travel time is much shorter than leisure time. However, the study does not provide the threshold for short travel time (see Fig. 1).

In addition, the directions of the travel time changes affect the VOT in different ways. In other words, the impacts of the same amount of travel time savings and the increased trip length to VOT variation are asymmetric: the impact due to increased trip length is stronger than the one due to travel time savings. The equations in Fig. 2 illustrate the three effects: different sensitivity for cost and time, the size effects, and the sign effects.

Not counting the three effects, Daly and Carrasco (2009) found the reason for the problem in the data. They identified that VOT variation by trip length is due to the heteroskedasticity in the survey data with respect to trip length. They (2009) confirmed that the non-linear cost variable represented by the log cost function cannot be considered better than the model reflecting heteroskedasticity in cost.

2.2. Empirical evidence

It is not easy to clearly declare that the VOT increases with trip length because the theory provides the ground for the bi-directional change of VOT with trip length (Gunn, 2001; Hensher, 1997). This section attends to the empirical survey results from various research.

In 1994, the Swedish Institute for Transport and Communication Analysis reported (Algers et al., 1995) that the VOT is significantly different for short and long trips. Especially, a considerably higher VOT is observed in the mode of car. Existing studies attribute the higher VOT of long-distance trip to the fatigue from driving. The increasing pattern of the VOT with respect to travel time is represented by elasticity. In the U.K., AM&HCG (1996) estimated the VOT elasticity as 0.37, which means that 1% increase in travel time is associated with 0.37% increase in the VOT. Mackie et al. (2003) also made a conclusion that the VOT increases with a positive elasticity of 0.26 based on the data of AM&