Estimation of the Value of Travel Time Considering Road Accessibility and Future Conditions

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Existing roads only focus on high travel speeds and mobility. Recent rapid technological advances, however, such as autonomous driving, have increased the demand for advanced roads, and at the same time, shifted the paradigm of roads toward valuing their accessibility as a typical example of social overhead capital. Nonetheless, the evaluation system for road investment is still inadequate to reflect these changing socioeconomic conditions. Specifically, applying a uniform value of travel time (VOT) that does not reflect various travel characteristics is highly likely to create a gap in the practical benefits of roads.

This study attempted an empirical analysis to confirm that the VOT can vary according to travel-time savings, such that new VOTs can be estimated in terms of road accessibility. In addition, the study presented evidence on base data to reference in planning policies on modes of transportation by estimating the VOT according to the usage patterns of autonomous vehicles, one of the expected changes in future travel conditions.

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- National Expressway Network to Contribute to a Better Life and Economic Growth (2021–2030) (part 2). 2017. Korea Expressway Corporation.
- Management of Road Policy Research Center. 2017. Ministry of Land, Infrastructure, and Transport (MOLIT).
- Feasibility Study for Access Roads to Industrial Parks. 2016. MOLIT.
- Planning for the Medium- and Long-Term National Highway Projects. 2016. MOLIT.
- Planning for the Comprehensive National Road Networks. 2016. MOLIT.

Contents

Summary

The value of travel time (VOT) is an important factor in determining the feasibility of road projects. The current feasibility study is flawed because it utilizes a uniform VOT, however, it fails to reflect various future changes in conditions.

This study predicted future changes in conditions, such as the polarization of cities and the popularization of autonomous vehicles, and looked at ways to ensure the accessibility of roads. The expansion of metropolitan areas and the increasing cost of road projects are expected to cause problems related to the decline of smaller cities and discrimination among transportation users. It is therefore necessary to be prepared for road accessibility in terms of equity.

According to the analysis that the VOT can vary depending on the amount of reduction in travel time, it is estimated that the VOT may be up to 142% higher than the existing uniform VOT. This would have a positive effect on feasibility studies in regions with low traffic demand in terms of a high rate of bypass reduction.

The VOT for autonomous vehicles that use fully autonomous driving was calculated to be 36,744 won, whereas the VOT for autonomous vehicles that use manual driving was calculated to be 48,198 won, and the VOT for shared autonomous vehicles was calculated to be 73,884 won. Policies for the introduction of new modes of transportation need to consider various hierarchical preference trends, such as travel distance, gender, and age.

It is expected that the government will be able to increase feasibility by remaining flexible while estimating the benefits of reducing travel time. Also, the VOT of autonomous vehicles can be utilized for investment in related facilities and the development of policies linked to the activation of autonomous vehicles. Finally, the basis for applying the new VOT, such as the reduction rate of travel time with autonomous vehicles, was presented to prepare base data for the revision of guidelines.

CHAPTER I.

Introduction

1. Issues

Paradigm shifts and technological changes regarding roads. Existing roads were built with a focus on only high travel speeds and mobility, but recently, road accessibility has become a major topic, leading to changes in the public perception of roads as public goods that everyone can use together. As an act that must be accompanied by other activities, travel is an important element in our lives, along with food, clothing, and shelter. To this end, roads are a typical example of social overhead capital, as anyone has the right to enjoy an adequate level of transportation services. A disproportionate supply of road and transportation services, however, causes regional differences in transportation services and generates social demands for accessibility in the roads sector. In addition, the rapid growth of road-related technologies, such as autonomous driving, is fueling the sophistication of road infrastructure components. Alongside this trend, the behavior of people who use vehicles is also projected to largely change. Today, people increasingly want roads that offer accessibility and advanced functions, as well as safe and diverse experiences, instead of merely fast roads, as has been true in the past.

The current accessibility of roads remains at an equitable level between user segments. Although accessibility is a basic value that our society should pursue, it is mostly discussed by specific user segments due to the ambiguity of the concept. Because a road-accessibility policy in the Republic of Korea is restricted to reductions in private-expressway tolls to ease the burden on road users, it does not reflect the comprehensive value of accessibility. Future changes in the roads sector, including road-related paradigms and technologies, can disrupt equity between regions and between modes of transportation, thereby undermining road accessibility in the long run. In the face of these future changes, it is necessary to develop an evaluation system for road investment, which can establish road accessibility in a sustainable manner.

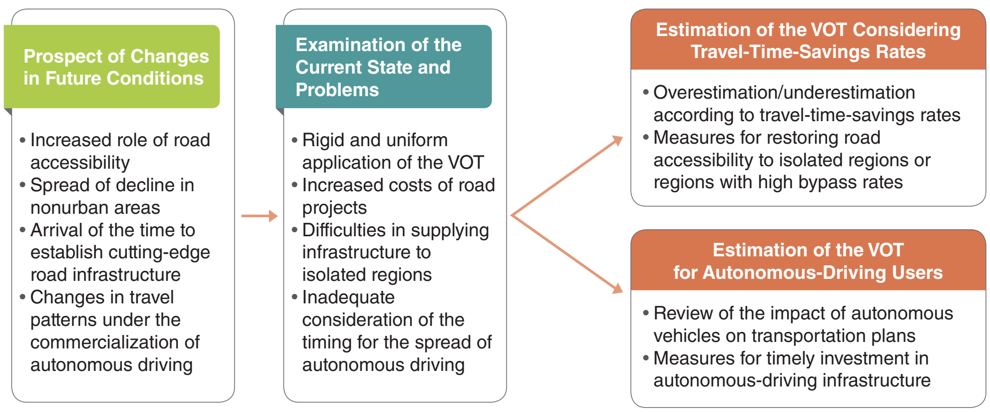
Korea has published the Standard Guidelines for Preliminary Feasibility Studies, thereby standardizing estimation methods for the benefits derived from road investment. The country is also improving the practicality of per-unit and benefit estimation methods through continuous revision and improvement. Despite these efforts, however, the methodologies and basic units for the estimation of benefits and costs do not yet fully reflect the country's socioeconomic conditions. Although various studies have focused on the segmentation of new or existing benefits, the incorporation of these results at the decision-making level remains inadequate. The current value of travel time (VOT) is highly likely to cause a gap in actual benefits by applying a uniform value that does not reflect various travel characteristics. The estimated benefits from travel-time savings, which account for over 70% of the benefits generated by the recent transportation investment projects, result from applying a uniform VOT without factoring in the characteristics of individual travelers. As a result, the accuracy of benefit estimation is not improving. At present, the benefits of travel-time savings are calculated by multiplying the reduction in travel time derived from a road project by a uniform VOT. In the future, however, the VOT will likely be differentiated by the travel time (or distance), purpose of travel, and means of travel.

It is necessary to develop improvement measures for benefit-estimation methods for transportation projects to secure road accessibility according to changes in future traffic conditions. The amount of travel time reduced by implementing road projects will determine the level of usefulness that road users perceive. For this reason, the benefits from road projects can be overestimated or estimated depending on the type of projects. In addition, more relaxed in-vehicle activities following the adoption of autonomous vehicles are projected to bring changes in the VOT perceived by road users. It is therefore necessary to suggest the direction for improving the VOT estimation methods and evaluating the feasibility of transportation projects by considering these various changes in future conditions.

2. Purpose of the Research

This study aimed to produce the VOT for each of various user segments in the country and to estimate new VOTs that consider road accessibility and changes in future traffic conditions. The study approached road accessibility from the perspective of efficiency and equity of resource allocation in the supply of road infrastructure. Based on the estimated results, the study proposed a policy alternative that is applicable in evaluating the feasibility of public projects.

Figure 1. Conceptual map of the estimation of new VOTs



Source: The author's own work.

CHAPTER II.

Review of the Present VOT-Related Conditions

1. Overview of the VOT

The VOT signifies the monetary value of what travelers are willing to pay per unit to shorten their travel time. In transportation-facility investment projects, the VOT becomes a major factor in calculating the benefits of travel-time savings, with a decisive impact on the assessment of the respective project's economic feasibility. In the Study on Correction and Improvement of the Standard Guidelines for Preliminary Feasibility Studies in the Road/Railroad Sector (Version 5), the VOT is estimated by dividing the purpose of travel into business-related travel and non-business-related travel. Generally, the business-related VOT is calculated using the wage-rate method, and the non-business-related VOT is produced by applying a specific rate to the business-related VOT. In addition, the ratio of the non-business-related VOT to the business-related VOT is derived using the marginal-wage-rate method.

Wage-rate method calculates the VOT as the traveler's wage per working hour, based on the assumption that one's reduced travel time can be invested in production activities. The non-business-related VOT is calculated by applying a certain rate to the business-related VOT.

Business-Related VOT: $V_{business} = \frac{W}{T}$

Non-Business-Related VOT: $V_{non\,business} = \frac{W}{T} \times w_i = V_{business} \times w_i$

Here, V is the VOT, W is the monthly mean wage, T is the monthly mean working hours, and w_i is the ratio of the non-business-related VOT to the business-related VOT.

Marginal-wage-rate method calculates the VOT using the ratios for the parameters of travel time and travel cost, which are estimated by modeling travelers' behavior as the relationships between travel time, travel cost, etc. The VOT is mainly calculated using the ratios of marginal utility for travel cost and marginal utility for travel time, which are derived from establishing mode-choice models and estimating utility functions from the models.

$$U = \alpha + \beta_1 c + \beta_2 t + \cdots, \frac{\delta U/\delta t}{\delta U/\delta c} = \frac{\beta_2}{\beta_1}$$

Here, α, β_1, β_2 are parameters, c is travel cost, and t is travel time.

The country's key guidelines for feasibility assessment include the Standard Guidelines for Preliminary Feasibility Studies, enforced by the Ministry of Economy and Finance, and the Guidelines for Investment in Transportation Facilities, as implemented by the Ministry of Land, Infrastructure, and Transport.

Table 1. Guidelines for feasibility assessment

Category	Standard Guidelines for Preliminary Feasibility Studies	Guidelines for Investment in Transportation Facilities
Competent Authority	• The Ministry of Economy and Finance (The National Finance Act)	• The Ministry of Land, Infrastructure, and Transport (The National Transport System Efficiency Act)
Purpose	• To promote fiscal management, including efficient budget planning	• To establish national transportation facilities efficiently • To increase the efficiency of investment in transportation facilities, including the adjustment of investment priorities
Target Project	• Public projects with over 50 billion won in total project costs or over 30 billion won in national funds invested	• Public-transportation-facility projects with over 30 billion won in total project costs
Application Period	• The phase prior to budget planning	• The phase of establishing mid- and long-term plans or basic plans for each project

Source: The author's own work.

The two sets of guidelines are similarly organized, but the role of the Standard Guidelines for Preliminary Feasibility Studies is growing over time. They have the same analysis elements, including the benefit- and cost-estimation systems and the decision-making system for project implementation, while having differences in only certain numerical values, such as the basic unit. It is frequently observed that the implementation of projects is determined through preliminary feasibility studies and that their assessments are based on the Guidelines for Investment in Transportation. Facilities remain at the level of confirming the results of the preliminary studies. Although the two sets of guidelines have continued to update the VOT, the VOT under the Standard Guidelines for Preliminary Feasibility Studies has not changed for over 10 years, with the last update in 2008. For this reason, actual studies have converted the VOT into the current value by reflecting the consumer price index.

Table 2. Changes to the VOT by guidelines

Source: Reorganized by the author based on Standard Guidelines for Preliminary Feasibility Studies, and Guidelines for Investment in Transportation Facilities.

Category	Version	Time of Revision	VOT (Won/Vehicle)			
			Year	Passenger Cars	Buses	Trucks
Standard Guidelines for Preliminary Feasibility Studies	1st	Dec. 1999	1997	9,750	9,207	7,976
	2nd	Oct. 2000	1999	8,527	59,649	-
	3rd	Dec. 2001	2000	9,697	72,717	-
	4th	Sept. 2004	2003	12,150	83,537	-
	5th	Dec. 2008	2007	14,990	58,561	16,571
	6th	To Be Revised	2015	20,030	85,141	16,701
Guidelines for Investment in Transportation Facilities	1st	Jan. 2002	1998	9,413	50,561	-
	2nd	Dec. 2007	2005	11,049	43,927	11,913
	3rd	Dec. 2009	2007	14,587	65,493	12,492
	4th	Nov. 2011	2009	16,153	63,590	14,574
	5th	Nov. 2013	2011	15,318	58,774	15,636
	6th	June 2017	2013	19,637	83,472	16,374

When the VOTs in the previous guidelines were converted into the value as of 2015 by applying the consumer price index, the resulting VOTs were about 9% to 35% lower than the VOT in the latest guidelines. Based on the Standard Guidelines for Preliminary Feasibility Studies (Version 1), the VOT of passenger cars is 9,750 won as of 1997. When a consumer price index of 166.5 was applied to this amount, the VOT was converted to 16,234 won as of 2015. This accounts for about 81% of 20,030 won, which is the VOT as of 2015 presented in the Standard Guidelines for Preliminary Feasibility Studies (Version 6). Applying only the consumer price index without steady updates to the VOT is therefore prone to underestimating the social benefits of road projects.

Table 3. Changes to the VOT by the type of guidelines

Category	Version	Year	VOT of Passenger Cars (Won/ Vehicle)	Consumer Price Index1	VOT of Passenger Cars Converted as of 2015	Difference Between the VOT in the Standard Guidelines for Preliminary Feasibility Studies (Version 6)
Standard Guidelines for Preliminary Feasibility Studies	1st	1997	9,750	100.0	16,234	-3,796
	2nd	1999	8,527	108.4	13,097	-6,933
	3rd	2000	9,697	110.8	14,572	-5,458
	4th	2003	12,150	122.7	16,487	-3,543
	5th	2007	14,990	136.9	18,231	-1,799
	6th	2015	20,030	166.5	20,030	-
Guidelines for Investment in Transportation Facilities	1st	1998	9,413	107.5	14,579	-5,451
	2nd	2005	11,049	130.6	14,086	-5,944
	3rd	2007	14,587	136.9	17,741	-2,289
	4th	2009	16,153	147.3	18,258	-1,772
	5th	2011	15,318	157.7	16,173	-3,857
	6th	2013	19,637	163.2	20,034	4

Note: Reorganized as of 1997 based on the consumer price index.

Source: Bank of Korea's Economic Statistics System 2019.

2. Problems with the Application of VOTs in the Current Investment Assessment System

The first is the uniform application of the VOT. The VOT acts as an important factor in dividing modes of transportation and allocating routes when forecasting transport needs, as well as in assessing the economic feasibility of investment projects. The current policy decisions on preliminary feasibility studies absolutely rely on the results of the evaluation of economic feasibility (B/C), and the benefits of travel-time savings exceed 70% of the total benefits of road projects. According to an examination of the ratios of benefits by item in the preliminary feasibility studies conducted over the last five years, the benefits of travel-time savings accounted for an average of 70.4% of the total benefits. As this shows, the VOT is the key element that has the most influence on policy decisions. Uniform values have been applied, however, without a notable improvement since the methodology for producing the VOT was established. Although studies have been conducted regarding the VOT's various components, such as cargo transportation and leisure trips, no case of applying those results has been reported. More seriously, the VOT under the Standard Guidelines for Preliminary Feasibility Studies published in 2007 is more generally applied than the VOT in the Guidelines for Investment in Transportation Facilities, which has been renewed in a relatively steady manner.

The second is the increasing in road-project costs. With a paradigm shift in roads, road projects are also diversifying in their types and growing in size. A key example is underground road projects aimed at returning spaces on the ground to pedestrians and minimizing the conflict between vehicles and pedestrians. In addition, advances in autonomous-driving technology necessitate changes in the requirements for road infrastructure. European countries are highlighting the importance of road infrastructure to promote the smooth positioning of autonomous driving in the roads sector and are suggesting the direction for developing road infrastructure through the concept of infrastructure support levels for automated driving (ISAD). ISAD defines the infrastructure capable of supporting autonomous driving at five levels. For infrastructure to support autonomous driving, such physical and digital infrastructure as sensors, radars, and traffic-control centers should be built to communicate with vehicles, which is naturally predicted to increase the costs of road-facility projects.

Table 4. Categorization by ISAD phase

Source: ERTRAC 2019. Reorganized by the author.

Category	Phase	Name	Definition	Information Provided by the Infrastructure			
				Digital Maps	VMS, Accid-ents Weather, etc.	Micro Traffic Condi-tions	Speed, Distance Between Vehicles, etc.
Digital Infrastructure	A	Cooperative Driving	To optimize the overall traffic flow, the infrastructure guides autonomous vehicles based on real-time information on the flow of vehicles.	O	O	O	O
	B	Cooperative Perception	The infrastructure is capable of perceiving detailed traffic conditions and providing the information to autonomous vehicles in real time.	O	O	O	
	C	Dynamic Digital Information	The infrastructure is capable of digitally offering all dynamic/static information about itself to autonomous vehicles.	O	O		
Existing Infrastructure	D	Static Digital Information/Map Support	Digital map-based information is available, including traffic signs. Autonomous vehicles should perceive traffic lights, road construction, and VMS on their own.	O			
	E	Conventional Infrastructure/No Audiovisual Support	The existing infrastructure without digital information—autonomous vehicles should perceive all information on geometric road designs, road signs, etc. on their own.				

As Table 2-4 shows, the costs of road projects are increasing, as a reflection of changing times. Thus, when project benefits fail to reflect changes of the time, it is difficult to establish the feasibility of creating road facilities to assess road projects, which can have a negative impact on the timely supply of facilities.

The third is the difficulties in establishing infrastructure in transportation-disadvantaged regions. The benefits of road projects are measured by aggregating benefits to the country's entire society. In addition, they are calculated as a whole, without factoring in certain characteristics, such as regions, income groups, and road types. Although the VOT is currently suggested and applied according to the types of vehicles, such as passenger cars, buses, and trucks, it is necessary to produce and apply more segmented VOTs that match the project characteristics. In the current environment, projects are eventually concentrated in regions with large populations and heavy traffic volume, without regard for road accessibility in relatively underdeveloped regions that are disadvantaged as far as transportation services. Despite ongoing investment in roads, such regions as Gangwon-do, Gyeongsangbuk-do, and northern Gyeonggi-do still suffer from low accessibility.

The fourth is the insufficient consideration of the spread of autonomous vehicles. Domestic and overseas companies in the autonomous-vehicle industry are increasing their investment in the development of related technologies to commercialize autonomous vehicles. Accordingly, autonomous-driving technologies are rapidly advancing. In recent years, various advanced driver-assistance systems applied to conventional vehicles have evolved into partial autonomous-driving technology. This has enabled the commercialization of autonomous vehicles. After a comprehensive review of this trend in technological development, the Korean government recently announced development strategies for the future automobile industry in October, 2019 (The Ministry of Industry et al. 2019). According to this plan, by 2024, the government is set to complete the infrastructure necessary to support the commercialization of fully autonomous driving (level four) on the country's main roads, which is targeted for 2027. Moreover, the distribution of autonomous vehicles is likely to spread rapidly, as shown by the projection that autonomous vehicles at levels three and four will acquire approximately a 50% share of the market for new cars going forward. Meanwhile, the adequate supply of road infrastructure takes a long period of time, and an analysis period of 30 years is typically set for feasibility studies. Accordingly, the distribution of autonomous vehicles should keep pace with the future development of road infrastructure. In other words, feasibility studies on road infrastructure should consider the combined implications of the calculated VOT based on existing conventional vehicles and the VOT set in consideration of autonomous vehicles. This is because the mixed presence of existing conventional vehicles and autonomous vehicles is forecasted to continue for a considerable period of time, thus requiring efforts to enhance rationality in assessing the feasibility of long-term infrastructure-supply policies in the mixed road environment. For reference, a study by Lee Backjin et al. (2017), analyzed the effects of autonomous vehicles on capacity enhancement by road type and found that high-standard roads (roads with an uninterrupted traffic flow, such as expressways) produced an overall higher level of capacity enhancement than inner-city roads. This highlights the need to establish the autonomous-driving road system in such high-standard roads as expressways in the introduction stage of autonomous vehicles. Hence, it is important to improve the investment evaluation system, such as by estimating the VOTs related to autonomous driving in view of such policy needs as feasibility evaluations related to the autonomous-driving road system in the introduction phase of autonomous vehicles.

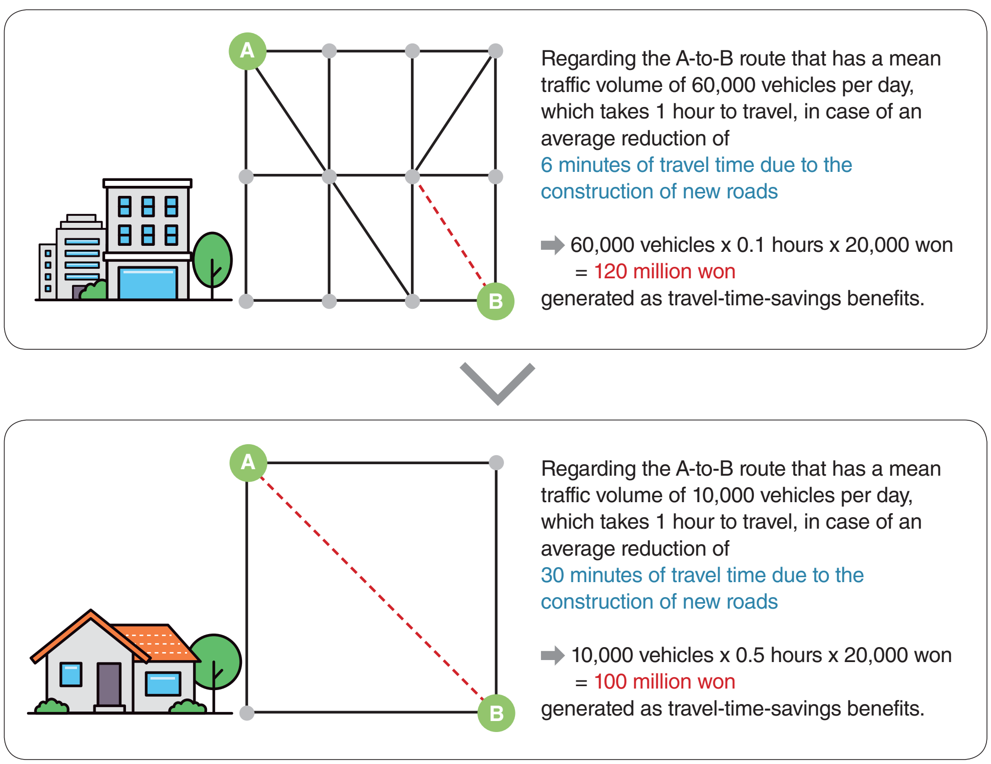
3. Derivation of Analysis Tasks

Most studies that have forecasted changes in future transportation conditions specifically expected significant changes in the use of national territory, as well as in modes of transportation and behaviors. These studies predicted that the expansion of metropolitan areas and the decline of provincial cities would widen regional inequalities and continue to increase disparities in road infrastructure and transportation services. The commercialization of autonomous vehicles is likely to generate an array of social benefits, such as increased road capacity, reduced car accidents, lowered barriers to elderly people driving, and increased mobile productivity. Mixed traffic conditions of autonomous vehicles and conventional vehicles running together, however, can cause conflicts between road users, which requires institutional and physical countermeasures in accordance with technological advancement. The gravitation of populations toward metropolitan areas and growing benefits in the road transportation sector are predicted to heighten the efficiency of resource allocation. The decline of provincial cities and discrimination against users of specific modes of transportation, however, can reduce equity in resource allocation. In response to these changing future conditions, it will be necessary to promote road accessibility from the perspective of equity.

1) Task 1: Measures to improve road accessibility in isolated regions and regions with relatively high bypass rates

In the current investment evaluation system, even with effective road projects to improve the traffic system, there are difficulties regarding investing in underdeveloped regions, with low demand in terms of population, traffic, etc. In urban regions, existing road facilities have been built at adequate levels. This reduces the effect of travel-time savings from the implementation of new projects, but it makes it easier to establish economic viability thanks to expanding populations and increasing traffic volume in these regions. In underdeveloped regions, although high bypass rates increase the effect of travel-time savings from new projects, there are difficulties in demonstrating economic viability due to low demand for road infrastructure. The VOT of road users, however, is not uniform in reality. Thus, it is necessary to reevaluate the scale of travel-time savings from the viewpoint of "travel-time savings = the opportunity to switch to other activities". Accordingly, the present study intends to enhance road accessibility in isolated regions and regions with excessive bypass rates caused by a lack of directly connecting routes, by estimating the VOT resulting from travel-time savings.

Figure 2. Conceptual map of the calculation of VOT-induced benefits

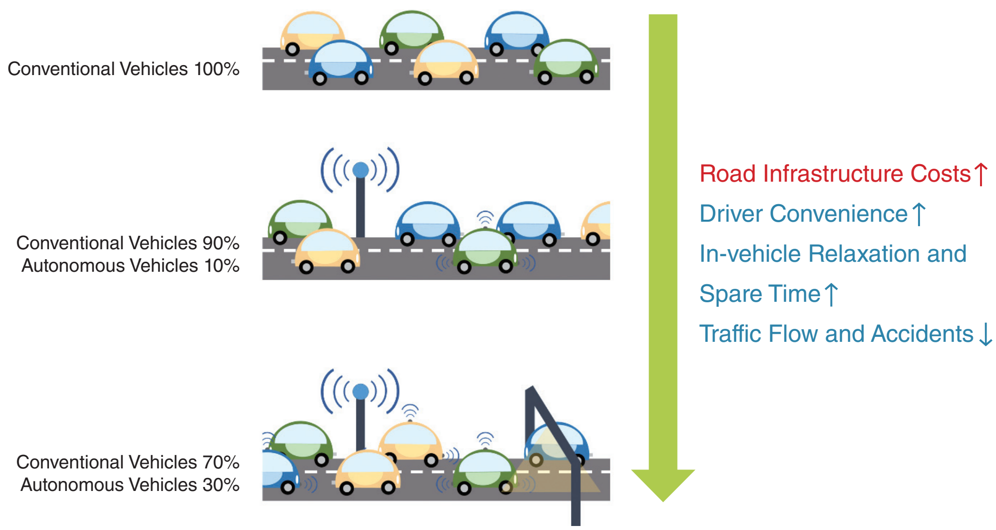


Source: The author's own work.

2) Task 2: Quantification of the value of autonomous driving time, in consideration of changing future conditions

The mixed presence of manually driven vehicles and autonomous vehicles can last for a long time, depending on the level of distribution of autonomous vehicles. This therefore necessitates investments in facilities and the establishment of policies in accordance with the trend. Various supply and operating policies are needed, including the establishment of digital infrastructure as well as of roads and lanes exclusively for autonomous vehicles. To support these investments, the VOT related to autonomous vehicles should be quantified to assess the feasibility of the introduction of autonomous-vehicle-related policies. To this end, preferences for travel using autonomous vehicles should be examined, and the quantified VOT for each of various elements should be estimated.

Figure 3. Conceptual map of the changes from the spread of autonomous vehicles



Source: The author's own work.

CHAPTER III.

Estimation of the VOT Considering Travel-Time-Savings Rates

1. Theoretical Review

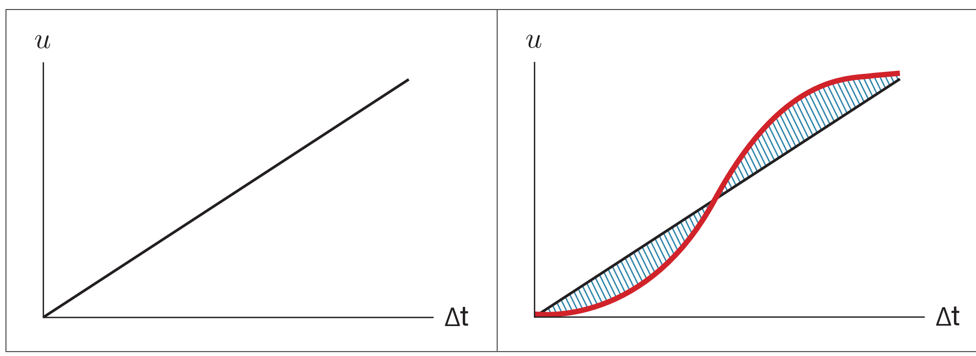
The VOT's basic theoretical structure is based on Becker's original time allocation (Becker 1965; Kim Taehee et al. 2003). Traditional consumer-behavior theories modeled only the consumption of goods based on income levels. In the 1960s, however, studies began to argue that, as a result of reduced working hours stemming from improved productivity, people no longer had indefinite hours available to raise their income, and therefore, an individual's time should be divided into the time spent on labor and the remaining time, in order to enable the adequate modeling of an individual's utility. Becker (1965) was the first scholar to model how many hours people would invest of their available time between labor, leisure, and travel. He assumed that time savings can transfer freely between labor and leisure. This means that the time saved in areas other than labor can lead to income increases through labor. This time-allocation structure was effectively modeled by De Serpa (1971) and used to calculate the VOT. An individual's utility u is comprised of the time t_k used for various activities k, time spent on dual labor t_w, income from labor, and the consumption of goods X using income. With the total available time T and the constraints of working hours and budgets, the utility function's conceptual equations can be indicated as follows:

$$
\begin{aligned}
&\max \cdot U = f(X, t_k, t_w) \\
&s \cdot t \cdot \\
&wt_w + r \geq PX \\
&T \geq \sum_k t_k + t_w \\
&t_w \geq t_w^m \\
&t_k \geq t_k^m
\end{aligned}
$$

As presented in this theoretical basis, at least a certain time scale is required for the transfer of travel time savings to other activities. If the travel time reduced by the implementation of a road project is negligible, this can hardly transfer to other activities, and ultimately, users experience little practical utility. On the other hand, the greater the amount of travel-time reduction from the implementation of a road project, the more likely it is that the reduced time will transfer to various other activities and produce an effect of increased utility as experienced by users. This suggests that users' per-unit utility can vary according to their travel-time savings. It shows that, depending on the type of projects, the benefits of projects whose average unit of time in travel-time savings is small can be overestimated, or the benefits of projects whose average unit of time is large can be underestimated.

Figure 4. Conceptual map of the utility curve of travel-time savings

Source: The author's own work.



2. Survey Design

The implementation of road projects leads to reductions in road users' travel time. This study intended to estimate the utility curve of travel-time savings as perceived by road users. It is considered that road users only very slightly perceive their travel-time savings when they are below a certain level and that they perceive them more intensely when they are above a certain level. In this regard, stated preference (SP) methods were used to analyze road users' VOT and responses regarding preferred patterns and route changes. The data used for model estimation can be divided into revealed preference (RP) data and SP data. The RP data were used to derive users' behavioral results in response to a choice of alternatives, and the SP data were used to estimate the models of users' SP regarding virtual situations. In this study, an SP-based survey was designed, because the study investigates route changes for various travel-time savings following the implementation of multiple virtual road projects.

The subjects were road users who routinely drive a car. The purpose of travel was restricted to commuting/business and leisure activities. Unemployed people and homemakers were excluded from the survey. This study aimed to suggest virtual routes with different travel-time savings and costs, based on the current travel times, and to derive each user's characteristics and responses to the variables, as well as their VOT for each travel-time savings that could be estimated from their responses. The marginal rate of substitution (MRS) method generally estimates the VOT through mode or route-choice models. The present study, however, adopted the SP-based design because it targets roads. Each respondent agreed to participate in four scenarios, with three experiments per scenario, and to have a random value set within the range of each variable as follows:

Scenario 1: Changes within 10%, Scenario 2: Changes in the range of 10% to 30%, Scenario 3: Changes in the range of 30% to 50%, and Scenario 4: Changes in the range of 50% to 70%

To minimize any biases in SP data, respondents were induced to make rational choices by providing them with information on changes in travel time and cost in order to enable an easy comparison of the attributes and service levels of alternative choices.

3. Setting the Analysis Model

This analysis intended to formulate utility functions with the variables of travel time and travel cost to estimate the VOT of passenger-car users by applying the MRS method, which is based on the theory of utility maximization. Under this theory, travelers choose the most useful alternative under given constraints. The utility of alternative i therefore consists of the observed utility V_i and the unobserved utility ϵ_i. As the error that analysts cannot observe, unobserved utility becomes a random variable. Eventually, the utility U_i itself becomes a random variable.

$$U_i = V_i + \epsilon_i$$

With this utility function applied in the present study, based on the assumption that the variables affecting the choice of routes are the travel time T and the travel cost C as shown below, the utility of the route i for an individual can be expressed as the following linear equation:

$$U_i = \theta_t T_i + \theta_c C_i + \epsilon_i$$

Here, θ_k is the weight of the variable k in the utility of the route i, and θ_t, θ_c have negative signs. This is because the utility of the route i decreases as the travel time and cost increase. Assuming that each respondent's modes of transportation are the same, and thus their perceptions of travel time and cost are the same, the time (β_{time}) and cost (β_{cost}) coefficients are set at the same values in the utility function for every route. Given the possible presence of utility that is not observed in the survey, such as familiarity with existing routes, an alternative specific constant was set in the current route's utility function to calculate the difference in unobserved utility between the current and changed routes.

$$U_{\text{present}} = \beta_o + \beta_{time} \times time_{\text{present}} + \beta_{\text{cost}} \times \text{cost}_{\text{present}}$$

$$U_A = \beta_{time} \times time_A + \beta_{\text{cost}} \times \text{cost}_A$$

$$U_B = \beta_{time} \times time_B + \beta_{\text{cost}} \times \text{cost}_B$$

When the distribution of unobserved utility ϵ for mutually different alternatives is independent and identically distributed and when the distribution of unobserved utility exhibits a Weibull distribution, this route-choice model is defined as a logit model. In a logit model, the probability of selecting the alternative i can be calculated as follows:

$$P_{ni} = \frac{e^{V_{kn}}}{\sum_k e^{V_{kn}}}$$

Here, P_{ni} is the probability of the individual n selecting the alternative i, n is the decision maker, and V_{kn} is the observed utility when the individual selected the alternative k.

The VOT refers to the value or reward that travelers are willing to pay when the travel time changes by a single unit, and it can be indicated using differential calculus as follows:

$$\text{VOT} = \frac{dC}{dt}$$

It can also be expressed as below when the chain rule is employed.

VOT = $\frac{dC}{dt} = \frac{dU}{dt} / \frac{dU}{dC}$

From the above utility function, $\frac{dU}{dt} = \beta_{time}$ and $\frac{dU}{dC} = \beta_{\text{cost}}$ can be derived. In other words, the VOT can be indicated as the ratio of the time coefficient to the cost coefficient as follows:

$$\frac{dC}{dt} = \frac{dU}{dt} / \frac{dU}{dC} = \frac{\beta_{time}}{\beta_{\text{cost}}}$$

4. Results of Model Estimation

In this study, values such as coefficients, the t-value, and ρ^2 were estimated for each alternative model using the Nlogit program, and route-choice models were estimated for each change in time and cost. The route-choice models were estimated using a total of 12,000 questions targeted at 1,000 respondents. The number of respondents who selected the current route was 8,867 (73.9%) and the number of respondents who selected alternative routes was 3,133 (26.1%). Four scenarios were created by differing the level of travel-time savings resulting from project implementation. Two alternative routes were suggested, which reduced travel time but increased travel costs compared to the current route. According to the estimation in the route-choice models, the sign for utility was adequately derived as negative for both the travel time and cost, which was also statistically significant (p-value). Given that the specific alternative constant had a positive value with statistical significance (p-value), the current route may have a higher expected value of unobserved utility than the alternative routes. This implies that the majority of people preferred the current route when the other conditions were identical. Although an increase in the travel-time-savings rate results in a corresponding increase in travel cost, the number of respondents who selected alternative routes trended upward. As a result, the VOT per person according to travel-time-savings rates ranged from 7,592 won to 19,141 won, indicating that a higher travel-time-savings rate resulted in a corresponding higher VOT. When this result was converted to the VOT per passenger car, which is typically applied in the sector, the mean VOT of passenger cars ranged from 11,844 won to 29,860 won. This VOT range accounts for 56% to 142% of 21,005 won—the VOT as of 2019, based on the Standard Guidelines for Preliminary Feasibility Studies—signifying that the existing VOT was considerably underestimated. The latest VOT in the Standard Guidelines for Preliminary Feasibility Studies is 20,030 won as of 2015. This value was recalculated in 2019 by applying 104.87, the consumer price index as of October 2019.

Figure 5. Graph on the VOT according to travel-time-savings rates

Source: The author's own work.

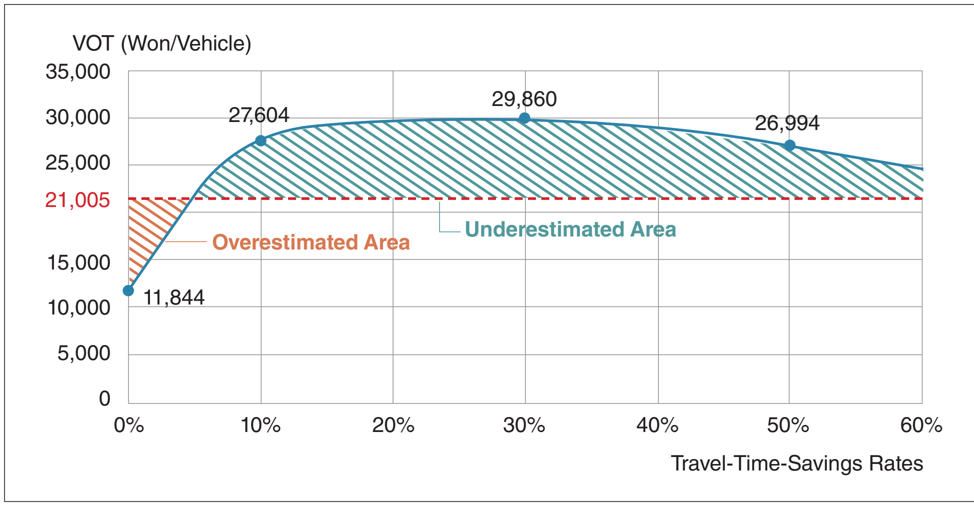


Table 5. Results of the model estimation by scenario

Source: The author's own work.

Category		Scenario 1 (Within 10%)	Scenario 2 (10%–30%)	Scenario 3 (30%–50%)	Scenario 4 (50%–70%)
Route Selection	Current Route	2,323 (77.4%)	2,317 (77.2%)	2,122 (70.7%)	2,105 (70.2%)
	Route A	428 (14.3%)	400 (13.3%)	535 (17.8%)	566 (18.9%)
	Route B	249 (8.3%)	283 (9.4%)	343 (11.4%)	329 (11.0%)
Specific Alternative Constant	Coefficient	2.63807	3.04782	2.49515	2.61065
	Standard Error	0.16055	0.19625	0.20848	0.25485
	t-value	16.43	15.53	11.97	10.24
	p-value	0.0000	0.0000	0.0000	0.0000
Time Required (10 minutes)	Coefficient	–0.57174	–0.67924	–0.44518	–0.63825
	Standard Error	0.31076	0.17422	0.16122	0.1676
	t-value	–1.84	–3.9	–2.76	–3.81
	p-value	0.0658	0.0001	0.0058	0.0001
Cost Paid (1,000 won)	Coefficient	–0.45186	–0.23032	–0.13955	–0.22131
	Standard Error	0.1014	0.06566	0.0557	0.05823
	t-value	–4.46	–3.51	–2.51	–3.8
	p-value	0.0000	0.0005	0.0122	0.0001

1) Calculated by applying 1.56 persons per vehicle, based on the number of occupants per passenger car nationwide.

Category	Scenario 1 (Within 10%)	Scenario 2 (10%–30%)	Scenario 3 (30%–50%)	Scenario 4 (50%–70%)
LL(*)	–1,877.958	–1,855.649	–2,160.011	–2,105.599
LL(0)	–3,295.837	–3,295.837	–3,295.837	–3,295.837
Likelihood Ratio (ρ^2)	0.4302	0.437	0.3446	0.3611
Number of Observations (n)	3,000	3,000	3,000	3,000
VOT (Won/Person Hour)	7,592	17,695	19,141	17,304
VOT (Won/Vehicle Hour)[1)]	11,844	27,604	29,860	26,994

CHAPTER IV.

Estimation of the VOT for Autonomous-Vehicle Users

1. Needs for Estimating the VOT

The spread of autonomous vehicles is likely to shift the concept of travel time from "consumption" toward "use" (Lee Backjin et al. 2016). In other words, autonomous vehicles will bring changes to the existing concept of travel time within the framework of mere costs, because they enable drivers to carry out various activities on the move (e.g., leisure, business, rest). While using an autonomous vehicle, a driver can create new value through various activities, which would likely increase the mean travel time. The significance of autonomous vehicles, including the effect of travel-time savings, is predicted to be lower in the cost-benefit analysis as well. Given that the significance of the effect of travel-time savings is reduced and that autonomous vehicles are based on electric vehicles, the benefits of reductions in environmental contamination would also drop to an insignificant level. If car sharing based on autonomous vehicles is expanded, applying the existing benefit-estimation methods without upgrades can result in the overall problem of underestimation, including reductions in the benefits of parking-cost savings.

The spread of autonomous vehicles is projected to have diverse impacts on transportation plans, particularly on the feasibility assessment system, such as cost-benefit analysis. It is therefore an urgent matter to identify consumer preferences for and the characteristics of autonomous vehicles. In this regard, this study intended to perform a preference survey on autonomous vehicles and estimate the VOT based on the survey results.

2. Survey Design

The introduction of autonomous vehicles is predicted to have a major impact on future transportation conditions. Specifically, driver convenience will increase, giving rise to the need to reevaluate the VOT by mode of transportation. Drivers' utility derived from autonomous-driving technology is deemed to increase in line with the increase in travel distance, from short and medium to long distances. Ashkrof et al. (2019) also investigated preferences for autonomous-driving services according to travel distance and purpose and found that the preference for them was relatively high for long-distance and leisure trips. Hence, this study attempted to conduct an SP survey to estimate the VOT of autonomous vehicles in consideration of travel distance. The SP survey was adopted because fully autonomous vehicles at level four or above, as defined by the Society of Automotive Engineers (SAE), have not been introduced in Korea.

The subjects were limited to the citizens of Seoul. The purpose of travel was restricted to commuting/business. Unemployed people and homemakers were excluded from the study. The respondents' socioeconomic and travel characteristics were investigated to identify the groups that prefer autonomous vehicles. Socioeconomic characteristics. Gender, age, occupation, residential address, driver's-license ownership, total number of household members, number of family members, income levels, total number of cars owned, parking place of car owners, etc. Travel characteristics. Workplace address, primary modes of transportation used for commuting, total cost incurred by car users for commuting (e.g., fuel costs, tolls, parking fees), total cost incurred by public-transportation users for commuting, departure time to go to the office, etc. The levels of autonomous-driving technology were based on the SAE's levels, from zero to five. This survey assumed a situation where a level-five autonomous vehicle (the highest level for autonomous driving) was introduced, which enabled the driver to perform various in-vehicle activities, because their involvement in driving itself was rarely required.

Table 6. SAE levels

Source: SAE International 2018.

SAE Level	Definition	Details	Steering Acceleration/ Deceleration	Monitoring the Driving Environment	Responses to Problems	Support for System Functions
Driver monitors the driving environment carefully						
0	Nonautonomous Driving	The driver controls every aspect of driving	Driver	Driver	Driver	None
1	Assistance by the Driver	Even if the system assists in driving (steering or acceleration/ deceleration), the driver should be allowed to intervene at any time	Driver System	Driver	Driver	Some Driving Modes
2	Partial Autonomous Driving	Even if the system assists in driving (steering and acceleration/ deceleration), the driver should be allowed to intervene at any time	System	Driver	Driver	Some Driving Modes
Autonomous-driving system observes the driving environment carefully						
3	Conditional Autonomous Driving	The driver's intervention is required in case of necessity	System	System	Driver	Some Driving Modes
4	High-level Autonomous Driving	Driving is enabled without the driver's proper intervention	System	System	System	Some Driving Modes
5	Fully Autonomous Driving	The autonomous-driving system controls every aspect of driving	System	System	System	All Driving Modes

A preference survey regarding the services of autonomous vehicles according to travel distance was conducted through a comparative analysis of the travel-distance models—15 km, 30 km, and 150 km.

① Intracity travel (within Seoul, 15 km), ② Wide-area travel (Seoul → Gyeonggi-do/ Incheon, 30 km), or ③ Interregional travel (Seoul → Daejeon/Sejong, 150 km)

Modes of transportation were broadly divided into four categories: autonomous vehicles (fully autonomous driving), autonomous vehicles (driver driving), shared autonomous vehicles, and public transportation (buses). This study excluded such modes of transportation as bicycles and walking in considering the study's limited scale and after referring to the classification of modes of transportation in a study by Steck et al. (2018). Subjects are 500 people. Any deviation caused by the diversity of respondents was minimized by restricting the subjects to office workers residing in Seoul.

The scenario for each mode of transportation was set after referencing an existing study (Steck et al. 2018). In total, 27 scenarios were created by setting three levels for each cost element, and each set of three scenarios was presented to the respondents. It is important to set reference values by cost element for each mode of transportation according to different travel distances (intracity, wide-area, and interregional travel). In setting the reference values, the survey intended to induce more realistic and empirical results based on the data that match with the characteristics of each travel distance. For intracity travel, Seoul's statistical data on vehicle travel speeds were used to set the mean travel speed, and parking fees were based on the city's fees for Public Parking Lot 1. The subjects were instructed to select their preferred modes of transportation by comparing the conditions of four modes of transportation: autonomous vehicles (fully autonomous driving), autonomous vehicles (driver driving), shared autonomous vehicles, and public transportation (buses). The conditions included in-vehicle travel time, out-of-vehicle travel time, and total travel costs. Of the methods for expressing preferences (selection, ranking, and evaluation), this survey employed the selection method, in which respondents can express their preferences by choosing the most-preferred alternative from among at least two alternatives. Each subject was provided with three questions for each of the three scenarios given, such that they answered to nine choice alternatives in total.

3. Defining the Analysis Model: Mixed Logit Model

The logit model, which is used to identify the probability of the selection of a mode of transportation (discrete variable), is a quantitative-analysis method based on travel times and costs. The mixed logit model is a combination of the multinomial and conditional logit models. This model can be used for every distribution of random coefficients, unlike the existing models, which are limited by the independence of irrelevant alternatives (IIA) and assume a Weibull-normal distribution of error terms. The mixed logit model is known to overcome the following three limitations of the existing logit models:

① Limitation 1: Random taste variation

The standard logit model's "taste" coefficient β is fixed, resulting in the same value for every individual. The mixed logit model uses β_n to randomly set a different value for each individual.

② Limitation 2: Unrestricted substitution patterns

Because the mixed logit model does not have the restrictive IIA characteristic (assuming that the ratio for the probability of choosing two random options is fixed), it exhibits an unrestricted general substitution pattern. The following equation for the probability regarding a specific variable can be formed when considering changes to the probability of the mth characteristic of other variables.

$$E_{nix_{nj}^m} = -\frac{x_{nj}^m}{P_{ni}}\int \beta^m L_{ni}(\beta) L_{nj}(\beta) f(\beta) d\beta = -x_{nj}^m \int \beta^m L_{nj}(\beta) \frac{L_{ni}(\beta)}{P_{ni}} f(\beta) d\beta$$

③ Limitation 3: Correlations in unobserved factors over time

It can be problematic to use panel data that present repeated choices over time. This equates to assuming that, whenever a person makes a choice, unobserved variables that are new each time affect this choice, the probability of which is indeed very low. As mentioned earlier, this model is based on the utility function, as a combined form of the multinomial and conditional logit models.

Table 7. Composition of the mixed logit model

Source: The author's own work.

Composition	Combination
Multinomial Logit Model	Mixed Logit Model
$Prob(y=j) = \frac{e^{\sum_{t=1}^{k} \beta_k x_t}}{1 + \sum_{j=1}^{J-1} e^{\sum_{t=1}^{k} \beta_k x_t}}$	$Prob(y=j) = \frac{e^{\sum_{k_1=1}^{K_1} \beta_{k_1} x_{t_1} + \sum_{t_2=1}^{K_2} \alpha_{t_2} x_{k_2}}}{\sum_{j=1}^{J} e^{\sum_{k_1=1}^{K_1} \beta_{k_1} x_{t_1} + \sum_{t_2=1}^{K_2} \alpha_{t_2} x_{k_2}}}$
Conditional Logit Model	
$Prob(y=j) = \frac{e^{\sum_{t=1}^{k} \alpha_t Z_k}}{\sum_{j=1}^{J} e^{\sum_{t=1}^{k} \alpha_t Z_k}}$	

In this study, the choice alternatives included autonomous vehicles (fully autonomous driving), autonomous vehicles (driver driving), shared autonomous vehicles, and public transportation (buses). It was not considered that conventional vehicles could eliminate any preconceptions about differences in purchase costs between autonomous and conventional vehicles.

4. Estimation Results for the VOT

Shared autonomous vehicles produced the highest VOT, followed by autonomous vehicles (driver driving), public transportation (buses), and autonomous vehicles (fully autonomous driving), in order of value.

Table 8. Estimation results for the VOT

Mode of Transportation	VOT (Won/Hour)
Autonomous Vehicles (Fully Autonomous Driving)	36,744
Autonomous Vehicles (Driver Driving)	48,198
Shared Autonomous Vehicles	73,884
Public Transportation	45,273

Source: The author's own work.

According to the VOT estimation by income level, the middle-income group showed the highest VOT, followed by the high-income group, and the low-income group, in that order. In general, VOT is proportional to income level, but it can differ according to the characteristics of each traveler and the nature of the travel. In terms of the VOT of transport modes by income level, all the groups exhibited the highest VOT for shared autonomous vehicles, followed by autonomous vehicles (driver driving), public transportation, and autonomous vehicles (fully autonomous driving), in that order.

Table 9. Estimation results for the VOT by income level

Mode of Transportation	VOT (Won/Hour)		
	Low Income	Middle Income	High Income
Autonomous Vehicles (Fully Autonomous Driving)	14,949	43,960	25,517
Autonomous Vehicles (Driver Driving)	19,636	57,743	33,517
Shared Autonomous Vehicles	29,899	87,921	51,034
Public Transportation	18,424	54,178	31,448

Source: The author's own work.

Table 9 shows that the high-income group had a lower VOT than the middle-income group. Thus, the model was subsequently reestimated by dividing the participants into two groups based on the income threshold of 6 million won. As a result, the new higher-income group produced an overall 28% greater VOT than the new lower-income group.

In addition, the VOT for autonomous vehicles (fully autonomous driving) was about 12% lower than for autonomous vehicles (driver driving). This is similar to the findings reported by Steck et al. (2018) that autonomous driving can have a relatively low VOT.

Table 10. Reestimation results for the VOT by income level

Source: The author's own work.

Mode of Transportation	VOT (Won/Hour)	
	Below 6 Million Won/Month	6 Million Won/Month or More
Autonomous Vehicles (Fully Autonomous Driving)	38,672	49,500
Autonomous Vehicles (Driver Driving)	43,828	56,100
Shared Autonomous Vehicles	71,719	91,800
Public Transportation	39,000	49,920

The estimated model confirmed the following points regarding autonomous driving[1]: Respondents who owned their own cars showed a stronger preference for autonomous driving than those who did not. Given their direct experience of road congestion and long-distance driving, car owners may have been more aware of the benefits of autonomous driving. Short-distance travelers (intracity travel) exhibited a relatively low preference for autonomous driving. This coincides with the general view that autonomous driving will have greater benefits for middle- and long-distance trips. Elderly travelers aged 60 or older preferred public transportation (buses). Regardless of the way autonomous vehicles were operated, they were inclined to continue using their existing modes of transportation, such as buses. Given that new modes of transportation, such as autonomous vehicles, show different VOT levels from conventional modes of transportation, they are likely to change future travel behaviors. The acceptance of autonomous vehicles varies by gender and age. Particularly, policy-based considerations are needed for certain demographic groups, such as women and the elderly, who are unlikely to be active in using this new mode of transportation.

1) Analyzed only significant variables at a significance level of 10%.

Table 11. Comprehensive estimation results of the models

Name of Variable	Value	Standard Error	t-test	p-value	Rob. Standard Error	Rob. t-test	Rob. p-value	Other
ASC_AV (Autonomous Vehicles)	–0.255	0.169	–1.510	0.130	0.168	–1.520	0.129	
ASC_AVD (Autonomous Vehicles/ Driver Driving)	–0.611	0.185	–3.290	0.001	0.188	–3.250	0.001	***
ASC_AVS (Shared Autonomous Vehicles)	–0.273	0.190	–1.440	0.150	0.192	–1.420	0.156	
AVD_AGE_OLD (Autonomous Vehicles/ Driver Driving, Age 60 or Older)	–0.115	0.085	–1.350	0.176	0.085	–1.350	0.178	
AVD_FEMALE (Autonomous Vehicles/ Driver Driving, Female)	–0.125	0.059	–2.110	0.035	0.060	–2.090	0.036	**
AVD_JOB_WORKER (Autonomous Vehicles/ Driver Driving, Office Workers)	0.058	0.068	0.850	0.395	0.068	0.847	0.397	
AVD_NO_CAR (Autonomous Vehicles/ Driver Driving, No Car Ownership)	–0.534	0.120	–4.470	0.000	0.120	–4.440	0.000	***
AVD_SHORT_DIST (Autonomous Vehicles/ Driver Driving, Intracity Travel)	0.080	0.078	1.020	0.310	0.080	1.000	0.317	
AVS_AGE_OLD (Shared Autonomous Vehicles, Age 60 or Older)	–0.026	0.086	–0.309	0.757	0.087	–0.304	0.761	
AVS_FEMALE (Shared Autonomous Vehicles, Female)	0.191	0.061	3.140	0.002	0.061	3.150	0.002	***
AVS_JOB_WORKER (Shared Autonomous Vehicles, Office Workers)	0.110	0.070	1.570	0.117	0.072	1.530	0.125	
AVS_NO_CAR (Shared Autonomous Vehicles, No Car Ownership)	–0.014	0.104	–0.129	0.897	0.102	–0.132	0.895	
AVS_SHORT_DIST (Shared Autonomous Vehicles, Intracity Travel)	–0.043	0.076	–0.566	0.571	0.077	–0.558	0.577	

Note: *Statistical significance 10%, **Statistical significance 5%, ***Statistical significance 1%

Source: The author's own work.

Name of Variable	Value	Standard Error	t-test	p-value	Rob. Standard Error	Rob. t-test	Rob. p-value	Other
AV_AGE_OLD (Autonomous Vehicles, Age 60 or Older)	–0.048	0.073	–0.661	0.508	0.073	–0.664	0.507	
AV_FEMALE (Autonomous Vehicles, Female)	0.055	0.052	1.050	0.293	0.052	1.050	0.294	
AV_JOB_WORKER (Autonomous Vehicles, Office Workers)	–0.081	0.058	–1.390	0.165	0.059	–1.390	0.166	
AV_NO_CAR (Autonomous Vehicles, No Car Ownership)	–0.252	0.095	–2.660	0.008	0.094	–2.670	0.008	***
AV_SHORT_DIST (Autonomous Vehicles, Intracity Travel)	–0.127	0.070	–1.820	0.069	0.070	–1.810	0.070	*
COST_LOW_INC (Travel Cost, Below 6 Million won)	0.000	0.000	–1.130	0.260	0.000	–1.120	0.262	
COST_MED_HIGH_INC (Travel Cost, 6 Million won or more)	0.000	0.000	–0.875	0.382	0.000	–0.839	0.401	
PT_AGE_OLD (Bus, 6 Million won or more)	0.190	0.065	2.920	0.004	0.065	2.910	0.004	***
PT_FEMALE (Bus, Female)	–0.121	0.048	–2.500	0.012	0.048	–2.500	0.012	**
PT_JOB_WORKER (Bus, Office Workers)	–0.086	0.054	–1.610	0.107	0.054	–1.610	0.107	
PT_NO_CAR (Bus, No Car Ownership)	0.799	0.073	10.900	0.000	0.073	10.900	0.000	***
PT_SHORT_DIST (Bus, Intracity Travel)	0.091	0.069	1.310	0.189	0.069	1.320	0.188	
TIME_AV (Travel Time, Autonomous Driving)	–0.008	0.001	–6.850	0.000	0.001	–6.660	0.000	***
TIME_AVD (Travel Time, Autonomous Vehicles/ Driver Driving)	–0.009	0.001	–6.980	0.000	0.001	–6.700	0.000	***
TIME_AVS (Travel Time, Shared Autonomous Vehicles)	–0.015	0.002	–9.080	0.000	0.002	–8.580	0.000	***
TIME_PT (Travel Time, Bus)	–0.008	0.002	–4.860	0.000	0.002	–4.850	0.000	***

CHAPTER V.

Policy Recommendations and Conclusion

1. Policy Recommendations

1) Contribution to enhancing feasibility in terms of accessibility in promoting road projects for underdeveloped regions

In the current investment evaluation system, there is difficulty in establishing the feasibility of new projects with large travel-time savings attributed to high bypass routes for underdeveloped regions with low traffic demands. The VOT estimation results with a focus on accessibility presented in this study will help establish the feasibility of implementing road projects for underdeveloped regions.

2) Useful base data in evaluating the feasibility of autonomous-driving-related policies

The study's estimation results for the VOT of autonomous vehicles will provide useful base data for evaluating the feasibility of autonomous-vehicle-related policies. This study aimed to maintain objectivity while presenting optimal evidence to set realistic reference values for various selection factors by mode of transportation and distance, in order to build mode-choice models that consider autonomous vehicles. The analysis and comprehensive consideration of trends in preferences for autonomous vehicles for each of various user segments, based on car ownership, distance, gender, age, etc., will help in designing more effective, customized autonomous-driving-related policies. Moreover, amid the mixed presence of autonomous vehicles and conventional, manually driven vehicles, it is necessary to incorporate the mixed ratio for these different modes and the VOT for autonomous vehicles into evaluations on the feasibility of policies for supplying roads (or lanes) exclusively for autonomous vehicles. This effort will support rational decision-making in the evaluation process.

3) Academic contribution to related basic research, such as revision of the Standard Guidelines for Preliminary Feasibility Studies

Feasibility studies on large-scale public facilities provide a key basis for decision-making on public-investment policies. Detailed provisions in the existing guidelines, however, such as the Standard Guidelines for Preliminary Feasibility Studies, have shown very limited accommodation of changing conditions with the times, as well as of the effects or value of public projects that are now generating a wide range of social discussion. Reflecting some of these demands, the present guidelines allow adjustment of the VOT, but only for weekend trips. The Standard Guidelines for Preliminary Feasibility Studies (Version 6) provided guidelines to allow the application of separate VOTs to weekend trips and transfer penalties, without factoring in modes of transportation or travel characteristics. The estimation results for the VOT that reflect accessibility and for the VOT related to autonomous driving will likely make an academic contribution as base data to help improve the systems related to the VOT that have not been incorporated institutionally to date. In doing so, the estimated results will contribute to increasing flexibility in the Standard Guidelines for Preliminary Feasibility Studies by reflecting the various effects and value of road projects, which are currently being discussed from various angles in feasibility evaluations, as well as contribute to enhancing rationality in evaluating the feasibility of public projects. When it comes to proposing new VOTs, however, it will be necessary to continue related basic research, coupled with constraints to maintain objectivity regarding new benefits, by presenting clear evidence for added value, thereby making the evaluation methods more sophisticated and enhancing the consistency of the evaluation results.

Table 12. Improvement measures for the VOT (example)

Category	Passenger Cars		Buses		Trucks		Autonomous Vehicles	
	Business	Nonbusiness	Business	Nonbusiness	Business	Nonbusiness	Business	Nonbusiness
In-Vehicle Occupants (People)	0.34	1.22	1.74	9.85	1	-	0.34	1.22
VOT (Won)	22,775	9,748	17,260 22,775	5,011	16,374	-	20,096	10,493
VOT (Won/Vehicle·Hour)	7,744	11,893	34,114	49,358	16,374	-	6,833	10,493
Mean VOT (Won/Vehicle)	19,636		83,472		16,374		17,326	

Note: The data of autonomous vehicles in category were produced by applying the difference in VOT between autonomous vehicles (fully autonomous driving) and the driver driving (12%), as estimated in this study, to existing passenger cars.

Source: The author's own work.

2. Conclusion and Future Tasks

It is an essential and urgent task to enhance the feasibility evaluation system according to paradigm shifts in road services in the wake of new social demands, such as road accessibility, as well as according to future technological changes, such as autonomous vehicles. Regional disparities in road and transportation services are projected to undermine the equity of road services and largely transform the behavior of road users following the proliferation of new technologies, such as autonomous vehicles. The feasibility evaluation system should be improved in consideration of these changing future conditions, in order to establish road accessibility and promote rational decision-making about public investment.

The benefits of travel-time savings are the foremost element in evaluating the feasibility of road projects, but the existing uniform application of the VOT can hamper rational estimations. Notably, the current estimations of travel-time-savings benefits do not take into account changes in the VOT according to travel-time savings. Moreover, there is a lack of base data on VOT estimation for autonomous vehicles, which could be useful for evaluating the feasibility of autonomous-vehicle-related policies in preparation for their rapid supply.

The present study therefore aimed to confirm that the VOT can vary according to travel-time savings through an empirical analysis and aimed to facilitate the rational estimation of travel-time savings. In the study, the mean VOT according to travel-time-savings rates ranged from 11,844 won to 29,860 won per passenger car, which amounted to about 56% to 142% of the VOT under the existing uniform Standard Guidelines for Preliminary Feasibility Studies. This suggests that the existing VOT was considerably underestimated.

This study also intended to establish its objectivity as a relevant basic study through such efforts as setting well-grounded reference values for the mode-choice models to estimate the VOT according to the usage patterns of autonomous vehicles, and it proposed the estimated VOTs by analyzing various user segments' preferences. The VOT of autonomous vehicles was estimated at 36,744 won for autonomous vehicles (fully autonomous driving), 48,198 won for autonomous vehicles (driver driving), and 73,884 won for shared autonomous vehicles. According to an examination of preferences regarding autonomous vehicles by user segment, car owners showed a relatively stronger preference, suggesting that they were more conscious of the benefits of autonomous driving due to their own experience of road congestion and long-distance driving. In the case of short-distance travel (intracity travel), road users exhibited a low preference for autonomous driving, which may explain the generally expected pattern that the benefits of autonomous driving will be greater for long-distance trips. In addition, women preferred shared autonomous vehicles, and elderly people aged 60 or older preferred public transportation (buses), which highlights the need for policy-based considerations that incorporate the preference trend by user segment when promoting the policy for introducing new modes of transportation, such as autonomous vehicles.

The limitation of this study was that the survey was performed on a small scale, due to time and budget constraints. Hence, various future studies are required to cover wider regional scopes, to segment survey questions and diversify variables for the further segmentation of users, and to explore various ways to apply the VOT to feasibility evaluations. Specifically, it will be necessary to estimate the VOT regionally by expanding the survey's target region to the entire nation of Korea, and it will be necessary to further segment survey questions by including a wider range of factors, such as socioeconomic variables, driving behavior, and purpose of travel. An investigation into concrete and detailed methodologies that the VOTs derived from the present study can be applied to for actual feasibility evaluations, such as how to set the mixed ratio for autonomous vehicles and existing conventional vehicles, will also be included in a primary follow-up research project.

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