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Estimation of Value of Travel Time Saving for Commuter Trips: A case study of Kathmandu

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Abstract
Value of travel time is one of the crucial factors in evaluating the benefits of transport infrastructure investment decisions. Value of travel time (VTT), monetary value attached to travel time, is undervalued in Nepal. The study focuses on determining value of travel time along with value attached to reliability associated with commuters in Kathmandu valley. Perception survey was conducted before collection of data by Revealed Preference/ Stated Preference (RP/SP) method. Multinomial logit model was adopted for RP data to estimate VTT. VTT from RP survey resulted in Rs. 114.73 per hour. Uncorrelated mixed logit model was adopted for SP data. VTT from SP survey resulted in Rs. 67.48 per hour and Rs. 112.38 per hour for public vehicle user and private two-wheeler user respectively. VTT for work trips was estimated as Rs. 129.64 per hour and Rs. 129.42 per hour for private vehicle user and public vehicle users respectively depicting higher value for work trips.

Keywords
Value of Travel Time (VTT), Revealed Preference/Stated Preference (RP/SP), Logit Model

1. Introduction

1.1 Background

Transportation and economic progress of a region are closely related. Socio-economic improvements as a outcome of transportation investment are higher in under-developed and developing countries compared to countries on the other end of spectrum. The concept of transportation investment as a prerequisite to economic progress is often debated. International (and historical) experiences shows that inadequate transportation system act as bottleneck to overall development [1]. Travel time saving and associated monetized benefit comprises a portion of benefit as a result of transportation investment.

The value of travel time is a critical factor in evaluating the benefits of transportation infrastructures investment and rulemaking incentives [2]. For example, in the UK, travel time savings have accounted for around 80% of the monetized benefits within cost-benefit analysis of major road scheme [3]. Without reliable methods to value travel time savings, economists continue to use vehicle operating costs as means to assess investments (exceptions are urban, inter-urban and multilateral or bilateral donor assisted rural transport projects) [4]. Little to no emphasis has been given to monetized benefit due to travel time saving during appraisal of transportation projects in Nepal.

Value of travel time (VTT) can be defined as the monetary value attached to particular travel time and the value attached to possibility to save particular amount of travel time is value of travel time saving (VTTS). Value of travel time is implicit trade-off between time and money coefficient in travel demand model. It depends on trip purpose (business, personal), personal characteristics (age, sex, education and employment), income, mode (public vehicles, private vehicles) and distance (within city, intercity), comfort. Thus, two individuals presented with same choice may respond differently. VTTS is formulated as utility maximization problem (profit maximization in case of freight), based on microeconomic theory, employing behavioral models of discrete choice theory [5].

Discrete choice problems involve the selection of alternatives from finite set of mutually exclusive and exhaustive discrete choice options [5]. Discrete choice models are based on choices made by individuals when presented with aforementioned choices. Multinomial Logit Model, Mixed Logit Model, Nested Logit Models and Multinomial Probit Model are some of the popular discrete choice models.

Revealed-preference (RP) is the choices made by decision maker in actual situation like mode of travel used. The used mode is dependent on other socio-economic and trip characteristics like income, proximity to destination, length of trip, etc. Stated-preference (SP) is choices made when presented with plenty of hypothetical choices (like altered travel time, cost, comfort, reliability, etc.) not limited by real life constraints [6]. Instead of relying on either RP or SP, combination of both is often employed for discrete choice modelling.

1.2 Research Objectives

The study deals with commuters in Kathmandu valley. The objectives can be listed as:

- To determine Value of Travel Time Saving of commuters in Kathmandu valley.
- To determine Value of Travel Time Reliability.

2. Literature Review

Several research works have been done regarding the theory and practice of estimation of value of travel time. "A Theory of the Allocation of Time", seminal work by Gary S. Becker (1965) led foundations to further research work relating to valuation of time. Value of time emerged as opportunity cost of assigning time to any activity but work and that was wage rate. Household try to maximize their utility under the constraints of time and monetary budget. Becker estimated value of travel time as two-fifth of the average hourly income. Becker used μ and λ Lagrangian multiplier for time and monetary budget constraints. The ratio μ / λ is referred as shadow price of time [7].

DeSerpa (1971) added technological constraint in addition to time and monetary budget as time and cost are not continuously substitutable but limited to the technological possibilities defined by existing travel modes. DeSerpa introduced K_i as Lagrangian multiplier for technological constraint. The ratio $(\mu - K_i)$ / λ is denoted as value of time and K_i /λ as value of saving time [8].

Troung and Hensher (1985) adopted discrete-choice models to measure travel time values and opportunity cost using both Becker and DeSerpa theory [9]. Bates (1987) highlighted the shortcomings of Troung's work caused due to a small number of crucial misunderstandings on use of technological constraints [10].

Shires and Jong (2009) computed income elasticity of VTTS using cross-sectional data to be 0.5 for business travel, 0.7 for commuter and 0.5 for other passenger transport [11]. Abrantes and Wardman (2011) presented an GDP elasticity of 0.9 with narrow confidence interval estimated over 45 years contrasting with cross-sectional evidence [12].

Fezzi et. al. (2014) adopted revealed preference survey to estimate value of travel time for recreational purposes to be about 3/4 of average wage rate [13]. They concluded VTT to increase with income and decrease for those who are older than 60 years old. Departmental Guidelines for Conducting Economic Evaluations [2] recommends 50% and 70% of median hourly earnings as VTTS for personal travel local and intercity respectively. Similarly, 100% is recommended value for business travel. Athira et. al. (2016) estimated VTT for work trips,within range of 31% to 121% of hourly income, adopting RP-SP approach and concluded that income and travel distance had substantial influence (positive influence) in VTT [14].

Whether responses in SP are representations of actual choices is longstanding concern. Abrantes and Wardman (2011) allude strategic bias may occur where respondents quote higher or lower VTT to influence policy decisions [12]. Results obtained from RP lie in the technological frontier whilst that of SP may lie above or below the frontier.

Hensher (2006) found that VTT obtained from Multinomial Logit Model were underestimation compared to that of Mixed Logit model [15]. Mixed Logit model disentangles Independence of Irrelevant Alternatives (IIA) from Independently and Identically Distributed (IID) and enables the analyst to estimate models that account for cross-correlation among the alternatives [16].

Consultants in Transport for Rural Development (2002) adopted RP-SP method to value travel time saving in Bangladesh as 3.5 Tk/hour and 3.95 Tk/hour for in-vehicle time and walking time respectively along with value attached to comfort [4]. Athira et. al.

(2016) computed Value of Travel Time Saving to be 35.73 Indian Rupees/hour to 142.19 Indian Rupees/hour for different work trips in Calicut city India [14].

Ghimire and Marsani (2019) adopted RP method for mode choice modeling of work trips in Kathamandu valley. The tradeoff between time coefficient and cost coefficient in utility equation formulated, choosing public transport as reference category, results in 46.27 Nepali Rupees/hour for two-wheeler and 55.8 Nepali Rupees/hour for four-wheeler traveler [17] . Joshi and Acharya (2019) conducted mode choice modelling for intercity travel in Nepal, adopting RP-SP approach, and recommended 97 Nepali Rupees/hour as value of travel time [18]. Both adopted multinomial logit model. This paper uses multinomial logit model for RP and no correlated random parameter (mixed) logit model for SP.

3. Methodology

3.1 Study Area and Sampling

Kathmandu is the capital of Nepal. Kathmandu valley comprises of major part of Kathmandu, Bhaktapur and Lalitpur district. Ring road connects Kathmandu and Lalitpur and provides access to Bhaktapur as well. The daily commuter trips made include trips inside, outside and across Ring road encompassing all three districts. The purpose of trips could be for study, work, recreation, social activity, etc. The people that make such trips comprise study population. The participants entrained were commuters inside, outside and accross Ring road thus including three districts.

Choice based sampling is not applicable for Stated Preference survey [19]. Random sampling strategy was adopted for the study to avoid biases and make sample as representative as possible.

3.2 Data Collection

The study is based on willingness to pay reduce in-vehicle travel time at an increased travel cost. Thus, perception survey was carried out to assess if people are willing to pay extra to reduce in-vehicle travel time. Other parameters including willingness to pay for safety, comfort, reliability, etc. too were assessed in perception survey. Perception survey was carried out using printed forms and google forms adopting random survey technique. A total of 430 observations from Kathmandu valley commuters was collected in perception survey. Discarding the incomplete and inconsistent data, 384 observations were used for analysis.

Design of questionnaire is crucial in RP/SP survey. The questionnaire consisted of three parts viz. socio-economic character of individual, trip characteristics and alternate scenarios for stated choice part. In-vehicle travel time, travel cost and reliability were attributes selected for SP. The variation of attributes was done based on the findings of the perception survey.

Average in-vehicle speed was calculated based on the observations of perception survey. The variation on in-vehicle travel time for public vehicle was based on normal operating speed of BRT (Bus Rapid Transit), Light Rail Transit (LRT) and Rail Rapid Transit (RRT) (Urban Transit System and Technology 2007) [20]. Recommended design speed for collection and sub arterial road is 20-30 km/hour and 30-40 km/hour respectively (Nepal Urban Road Standard 2076) which was taken into consideration for formulation of alternatives for private vehicle. The fares of normal city bus, BRT and Metro were considered for variation in travel cost for public vehicles. The fares were obtained from ”The Cost of Urban Commute: Balancing Affordability and Sustainability (2019)” [21]. For private vehicles, vehicle operating cost, possibility of fuel taxes, congestion pricing, etc. were considered for altering travel cost.

Two levels in each attribute was considered which resulted in full factorial design of 8 alternatives. Higher number of alternatives results in better information if the responders make choice after deliberate consideration. With increased number of choices, it is not likely that each choices are considered with same deliberation. So, four alternatives were designed removing alternatives with higher cost and less reliability. Different attribute level for private and public vehicle users were selected. Selected attributes and corresponding levels are in table 1 and table 2.

Table 1: Attribute and level: Private

Attributes	Level 1	Level 2
Travel Time	Reduced by 20%	Reduced by 40%
Travel Cost	Increased by 20%	Increased by 40%
Reliability	Reliable	Not reliable

Table 2: Attribute and level: Public

Attributes	Level 1	Level 2
Travel Time	Reduced by 25%	Reduced by 50%
Travel Cost	Increased by 25%	Increased by 50%
Reliability	Reliable	Not reliable

A sample choice set is presented in table 3.

Table 3: A sample choice set

Attribute	Present	Alternative
In-vehicle travel time	TT	0.6 * TT
Travel Cost	TC	1.4 * TT
Reliability	Current	Reliable
Choice		

450 observations was collected in RP/SP survey of which 46 was discarded due to incomplete answers. The summary of collected data is in table 4

Table 4: Summary

		Number	%
Gender	Male	299	74.0
	Female	105	26.0
Marital Status	Married	93	23.0
	Unmarried	311	77.0
Type of Vehicle	Bus	136	33.7
	Four-Wheeler	20	5.0
	Micro	41	10.1
	Tempo	17	4.2
	Two-Wheeler	190	47.0
Age	15-24	184	45.5
	25-34	188	46.5
	35-44	21	5.2
	45-60	10	2.5
	60+	1	0.2
Distance	0km - 10km	242	59.9
	10km - 20km	122	30.2
	20km - 30km	18	4.5
	>30km	12	3.0
Family_Income	<15	17	4.2
('000)	15-30	66	16.3
	30-45	74	18.3
	45-60	73	18.1
	60-75	47	11.6
	75-90	52	12.9
	>90	65	16.1
	Not shared	7	1.7

3.3 Data Processing

The collected data was manually entered in Excel and then processed in statistical software R. The data was converted to wide format as required by mlogit package.

3.4 Estimation of Value of Time

Value of travel time is estimated as ratio of time coefficient to cost coefficient in the utillity equation. Reliability was denoted by 0 for not reliable and 1 for reliable. Let the attributes be:

- In-vehicle travel time TT [in hour].
- Travel Cost TC [in Rupees].
- Travel Time reliability TR [0 for reliable or 1 for non reliable travel time]

The utility function of alternative has the form:

$$U_t = \beta_c Tc + \beta_t TT + \beta_r TR + \varepsilon \qquad (1)$$

The β parameters were estimated by maximum likelihood method using R software. The ratio of β_t / β_c gives value of time in Rs. per hour

4. Data Analysis and Result

Mode choice modelling, multinomial logit model, was performed on RP data taking "Public Transport" as reference category. VGAM package in R was used for multinomial logit model. Total travel time (walking time to station, from station, waiting time and in-vehicle travel time) was adopted for RP data. The result from RP survey is in Table 5 :

Table 5: Model from RP data

	Estimate	z-value	Pr(> |z|)
(Intercept)	1.7167	0.3880	0.0000
Cost	0.0396	0.0064	0.0000
ReliabilityInconsistent	-0.0364	0.3083	0.8980
T_Time	-0.0696	0.0083	0.0000
Value of travel time = Rs. 114.73 per hour			
Log-likelihood = -100.0489			
Pseudo R^2 = 0.6386			

The revealed preference data results in VTT as Rs. 114.73 per hour. Reliability was not found to be significant variable.

In-vehicle travel time, travel cost and travel time reliability were considered during analysis for SP observations. Multinomial logit model, uncorrelated random parameter mixed logit model and correlated mixed logit model were formulated using "mlogit" package in R. For mixed logit models, time and reliability were considered random with normal distribution.

Likelihood ratio test assess goodness of fit of two competing statistical model. The test was performed for comparison of correlated mixed logit model and multinomial logit model and then correlated mixed logit model and uncorrelated mixed logit model.

Score test, Lagrange Multiplier (LM) test, checks whether a restriction imposed on a model estimated by maximum likelihood is violated by data. The test was performed on correlated and then non-correlated mixed logit model.

Linear hypothesis test was performed to check if elements of correlation matrix are zero.

Wald test (Wald χ^2 test) evaluates significance of explanatory variable. The test was performed on mixed logit model setting correlation true and then false.

The tests elucidated the presence of randomness but not correlation. Tables 6, 7, 8, 9 and 10 summarize the logit models.

Positive signs are expected for coefficients. Increase in variable *reliability* implies less reliability in terms of travel time reliability. The coefficients cannot be interpreted directly, but dividing them by the price coefficient, monetary values are obtained.

Table 6: Model: Public Vehicle User only

	Estimate	z-value	Pr($>|z|$)
price	0.0974	3.4013	0.0006
time	6.5762	4.5761	0.0000
reliability	0.0659	0.2893	0.7723
log-likelihood	-454.51		
Pseudo R^2	0.1542		
VTT(Rs/hour)	67.48		

Table 6 summarizes the logit model for public vehicle users as a whole. Time and price coefficients are significant and have positive sign as predicted. The value of travel time for public vehicle users is Rs. 67.48 per hour. As the reliability coefficient is not significant, no value could be attached to travel time reliability. This could be due to in-vehicle travel time being a part of total journey time.

Table 7: Model: Private Vehicle - two wheeler

	Estimate	z-value	Pr($>|z|$)
price	0.0188	3.4557	0.0005
time	2.1193	2.3945	0.0166
reliability	2.0963	3.5186	0.0004
log-likelihood	-451.72		
Pseudo R^2	0.2131		
VTT(Rs/hour)	112.38		
VOR (Rs.)	111.16		

Table 7 summarizes the logit model for private vehicle users (two-wheelers only). All the coefficients are significant and have positive sign as predicted . Dividing time coefficient by price coefficient results in the value of travel time for two wheeler users as Rs. 112.38 per hour. Monetary value of Rs. 111.16 could be attached to increased reliability (i.e. consistent travel time for each trip).

Table 8: Model: Work Trip - Public

	Estimate	z-value	Pr($>|z|$)
price	0.0810	2.1364	0.0326
time	10.4931	3.4119	0.0006
reliability	-0.5009	-1.1632	0.2447
log-likelihood	-186.97		
Pseudo R^2	0.169		
VTT(Rs/hour)	129.42		

Table 8 summarizes the logit model for work trips (public vehicle users only). Time and price coefficients are significant and have positive sign as predicted. The value of travel time for work trips (public vehicle user) is Rs. 129.42 per hour. As the reliability coefficient is not significant, no value could be attached to travel time reliability. This could be due to in-vehicle travel time being a part of total journey time.

Table 9: Model: Work Trip - Private

	Estimate	z-value	Pr($>|z|$)
price	0.0345	2.5324	0.0113
time	4.4741	2.2001	0.0278
reliability	2.7542	3.8265	0.0001
log-likelihood	-301.65		
Pseudo R^2	0.2262		
VTT(Rs/hour)	129.64		
VOR (Rs.)	79.80		

Table 9 summarizes the logit model for work trips (private vehicle users only). All the coefficients are significant and have positive sign as predicted. The value of travel time for work trips (private vehicle user) is Rs. 129.64 per hour. Monetary value of Rs.

79.8 could be attached to increased reliability (i.e. consistent travel time for each trip).

Table 10: Model: Study Trips - Public

	Estimate	z-value	Pr(> $\|z\|$)
price	0.1453	2.8612	0.00422
time	3.8357	2.4030	0.01626
reliability	0.3339	1.1693	0.24229
log-likelihood	-245.27		
Pseudo R^2	0.1266		
VTT(Rs/hour)	26.39		

Table 10 summarizes the logit models for study trips (public vehicles only). All the coefficients are significant and have positive signs as predicted. The value of travel time for study trips (public vehicle only) is Rs. 26.39 per hour. As the reliability coefficient is not significant, no value could be attached to travel time reliability. This could be due to in-vehicle travel time being a part of total journey time.

Except model consisting of public transport users only, reliability was a significant variable. The pseudo R^2 value seems acceptable. Value of travel time for different income group was performed and the value of travel time was comparable. The work trips had much higher value of travel time than other purpose.

5. Conslusion

The paper estimates the value of travel time saving of commuters in Kathmandu valley applying RP/SP approach. VTT from PR survey resulted in Rs. 114.73 per hour. VTT from SP survey resulted in Rs. 67.48 per hour and Rs. 112.38 per hour for public vehicle user and private two-wheeler user. VTT for work trips was estimated as Rs. 129.64 per hour and Rs. 129.42 per hour for private vehicle user and public vehicle users respectively depicting higher value for work trips. VTT from survey resulted in Rs. 22.39 per hour for study trips for public vehicle users. A number of trips for study purpose being made in public transport could be the reason VTT for public vehicle user being a bit low compared to others. The obtained value of travel time could be used in decision making process while appraising projects.

6. Recommendations

The following could be looked into in further studies

- Study considering the factors like comfort and safety.
- Use of correlated mixed logit models.

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