The heterogeneity of value of travel time among cyclists and implications in policy appraisal

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Abstract

The recent Norwegian value of time study (Ramjerdi, et al, 2010) addresses all modes of travel including cycle as main modes of travel. The main purpose of the cycle study was to provide estimates of the value of travel time savings, valuation of different cycling infrastructure, facilities and services as well as health effects of cycling.

Cyclists are a very heterogeneous group, at least in Norway. The focus of this paper is on the heterogeneity of value of time among cyclists and implications for policy design and appraisal. We identify distinct classes of cyclists with different values of travel time savings and consequently different valuations of cycle facilities and services. We also compare the resulting values of travel time (VTT) of a latent class model with those of a mixed logit model. The paper emphasizes the importance of identification of the different classes of cyclists.

1 Introduction

The Norwegian National Transport Plan emphasizes the promotion of cycling by investment on cycling infrastructure and facilities. Environmental concern and health benefits of cycling are the grounds for the endorsement. The share of short trips in Norway which are undertaken using bicycle as the main mode of transport is much lower than in other European countries. Hence, it is of importance to address the potential for increasing the use of bicycle among different groups of travellers with different characteristics and preferences.

The literature on the impacts the provision of cycling infrastructure, facilities and services on demand for dates back to the 90's. A recent study by Heinen (2011) provides an overview of the literature on the valuation of infrastructure, facilities and services by cyclists and their importance for the increase of the cycle mode share. Among these separate cycle path and number of stops at intersection are prevalent. Heinen also reviews the literature on the socioeconomic characteristics and attitudinal variables that tend to affect the propensity to cycle. Among these factors are gender, age, car ownership, employment status, experienced cyclists, habit, built environment, and ecological and environmental beliefs.

The recent Norwegian value of time study (Ramjerdi, et al, 2010) addresses all modes of travel including cycle as main modes of travel. The main purpose of the cycle study was to provide estimates of the value of travel time savings, valuation of different cycling infrastructure, facilities and services as well as health effects of cycling. The study relies on stated preference (SP) technique.

Cyclists are a very heterogeneous group. While some are almost fanatic about cycling, others are casual cyclist and their choices are more related to (generalised) cost of travel or their care for the environment. The focus of this paper is on the heterogeneity of value of time among cyclists and implications for policy design and appraisal.

To address the payment vehicle for cycle as the main mode of transport, the first SP experiment is designed as a mode choice exercise between cycle and the chosen alternative mode of respondents (car or public transport). The first experiment is followed by two more choice experiments for the respondents' valuation of cycle infrastructure, facilities and services. These experiments focused on the trade-offs between travel time by cycle and the provision of infrastructure, facilities and services.

The cycle questionnaire includes questions on respondents' attitudes towards physical activities as well as question on socioeconomic characteristics of respondents. It also inquires the main reason for the respondents to choose cycle as their mode of transport and the frequency of the use of cycle in a week and maximum distance they are willing to cycle as well as a convenient distance to cycle.

We identify distinct classes of cyclists with different values of travel time savings (VTT) using the data from the first SP experiment (mode choice mode) by applying a latent class model and compare the results with the results of the those derived application of a mixed logit model. The implications of the results for design and appraisal of policies for the promotion of cycling will be discussed. The paper emphasizes the importance of identification of the different classes of cyclists.

The rest of the paper is organised as follows. In section 2 we describe the latent class model used in our study followed by the description of data (in Section 3). In Section 4 we present the model specifications and estimation results. Section 5 summarises the results and recommendations for further studies.

2 Latent class choice model

The latent class model captures preference and response heterogeneity. Alternatively, the mixed logit model specifies a continuous probability density function (e.g., normal distribution) for preference parameters (Train, 2003). This approach ignores any systematic variations in preference and response across individuals Bhat (1997). However the identification of latent classes needs careful consideration including identification issues stemming from missing data, identification of the number of classes to be used and the homogeneity of the latent classes (see Collins and Lanza, 2010).

The literature on the application of latent class model in transportation is rather dispersed until recently, maybe due to appropriate software for their estimation. Kamakura and Russell (1989) formulated the simultaneous formulation of class specific choice model and class specific class membership. Gupta and Chintagunta (1994) extended the work by Kamakura and Russell by including segmentation variables in the segment membership MNL. Ben-Akiva and Boccara (1995) study mode choice behaviour of commuters, Gopinath (1995) apply latent class models for mode choice behaviour of intercity travellers and models shippers' choice between train and truck. Gopinath also integrates attitudinal indicators in the framework such that latent class model includes the measurement model for these latent class indicators. Hosoda (1999) studies shopper's mode choice. Greene and Hensher (2003) examine the performance of the latent class against mixed logit model with no decisive conclusion. Examples of the more recent studies are Walker and Li (2007) were they examine the choice of residential location by constructing latent classes based on lifestyle preferences. Zhang et al. (2009) incorporate different types of group decision-making mechanisms as latent classes into a household car choice model. Wen and Lai (2010) explore latent market segmentation for international airline passengers' preferences using stated preference data and latent class model. Arunotayanun and Polak (2011) apply both latent class and mixed logit models to study of shippers' mode choice. Wen, Wang and Fu (2012) apply latent class nested logit model for analyzing high-speed rail access mode choice. Atasoy, Glerum and Bierlaire (2011) use a latent class model that includes a class membership model and the measurement equations for psychometric indicators to estimate the mode choice (see also Hurtubia et al, 2010).

The latent class choice model presented here relies on the framework provided by Walker and Ben-Akiva (2002) who present the generalized random utility model with extensions of latent variables and latent classes. As Walker and Ben-Akiva explain, the idea of latent class model is that there may be discrete segments of decision makers that need to be identified endogenously to accommodate for unobserved heterogeneity. We use a multinomial logit formulation for modelling both segment membership as well as choice behaviour.

Given a finite and fixed number of *S* segments and assuming a particular individual *n* belong to segment *s,* the utility function of *n* for alternative *i* is

$$U_{in}^{s} = V(X_n, X_i; \beta^s) + \varepsilon_{in}^{s} \qquad (1)$$

where X_i is the attributes of the mode *i* and X_n is the individual characteristics and β^s is a set of segment specific parameters and ε_{in}^{s} is an error term. This results in a class specific choice probability for alternative *i* as:

$$P(i \mid X_n, X_i, s_n, \beta^s, \theta_\varepsilon^s) = \Pr ob\left[U_{in}^{s} \geq U_{jn}^{s}, \forall_j \in C_s\right] \qquad (2)$$

where θ_ε^s is the standard deviation of the error term in equation (2) and C_s is the choice set for class *s*.

The class membership of individuals cannot be deterministically identified. It is assumed that the probability of individual *n* belonging to class *s* is given by

$$P(s_n \mid X_n; \gamma) \qquad (3)$$

Putting these two probabilities results in the joint probability of observing choice *i* given by:

$$P(i \mid X_n, X_i; \beta, \gamma, \theta_\varepsilon) = \sum_{s \in S} P(i \mid X_n, X_i, s_n, \beta^s, \theta_\varepsilon^s) P(s_n \mid X_n; \gamma) \qquad (4)$$

Maximum likelihood estimation is used to estimate the unknown parameters. Given y_{in}^{s} is the measurement of choice defined by equation (5), the likelihood function (L) can be written as in equation (6).

$$y_{in}^{s} = 1 \quad \text{if } U_{in}^{s} \geq U_{jn}^{s}, \forall_{j} \in C_{s}$$
$$y_{in}^{s} = 0 \quad \text{otherwise.} \qquad (5)$$

$$L = \sum_{s \in S} \prod_{n} \prod_{i \in C_s} P(i \mid X_n, X_i; \beta, \gamma, \theta_{\varepsilon})^{y_{in}^{s}} \qquad (6)$$

3 Data

The 2009 Norwegian Value of Travel Time (VTT) study covers cycle as a main mode of travel (see Ramjerdi et al, 2010). This work relies on the data collected in the study.

The respondents were recruited from a representative panel, and the survey was carried out on the Internet. Incentives were offered for completed questionnaires. The minimum age of the respondents was 18 years old. The response rate after two reminders was about 20 percent. The main study was conducted between 11 June and 2 July 2009. An initial data cleaning of the date left 772 respondents in the cycle segment.

The structure of the questionnaire is as follows:

- Introductory questionnaire: to collect data on socio-economic and demographic characteristics of the respondents
- Questions on a recent trip (reference trip)
- Choice experiments to collect data on the trade-offs between attributes of interest
- Final questionnaire: control questions and to collect data further data on respondents

The cycle part of the Norwegian VTT study focuses on;

- Cycle VTT as main mode of travel,
- Values of reducing number of stops at intersections,
- Value of provision of cycle path, and
- Value of upkeep of cycle route
- Value of snow removal from the cycle route

The estimation of VTT is based on trade-offs between time and cost. Since cycle modes involve a monetary transaction, it is important to find an appropriate payment vehicle for the estimation of VTT. The study relies on a mode choice study between walk/cycle and a paid mode (car or public transport). The respondents who decline car or public transport as alternative to their recent cycle trip are offered a bus alternative. Hence in a choice experiment between cycle and the chosen paid mode (car, public transport or bus) of the respondents the trade off between cost and time for Walk and Cycle can be established.

For the estimation of the valuation of other attributes we used a 3 attribute experiment. One attribute is always cycle time. These experiments establishes the trade-offs between walk/cycle time and the other attributes. The results can be transformed to a monetary basis by the use of the trade-off between time and cost from the first experiment.

The choice experiments for cycle are:

- Mode choice experiment. Four attributes is used in this experiment; total cycle time, separate cycle path (all the way or none), total in vehicle travel time in paid mode and, total cost of the trip with the paid mode.
- Route choice experiment with 3 attributes: total cycle time, upkeep of the cycle route and number of stops.
- Route choice experiment with 3 attributes: total cycle time, separate cycle path, and number of stops.
- Route choice experiment with 3 attributes: total cycle time, separate cycle path, and snow removal.

Each respondent gets three SP experiments, a mode choice experiment followed by two experiments among the experiments described above. Figure 1 shows the design of the cycle questionnaire.

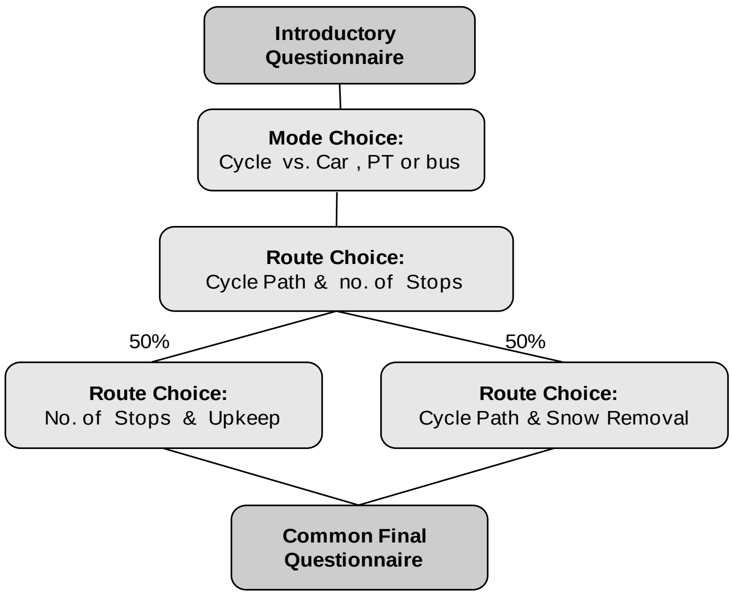

Figure 1: The design of the cycle questionnaire.

A randomised factorial design with no dominant pair is used in the mode choice SP experiment with eight binary choices. A base cycle time is randomly assigned to the respondents and the cycle time is used to construct the time and cost of the alternative paid mode (see appendix I for the design of this experiment). Figure 2 shows the presentation of a choice in this experiment.

The design of route choice experiments with three attributes follows the approach described in de Jong et al. (2007). In this approach design of the attributes are pivoted around the attributes of the reference trip by cycle. The design avoids dominant alternatives. Six binary choices are used in these experiments. The details of the designs are described in Ramjerdi et al (2009). Figure 3 show an example of a choice task in the route choice experiment.

Consider two alternative trips Cycle & by Public Transport	
Trip A: Cycle Total time: T_c minutes Cycle Path: all the way	**Trip B: Public Transport** Total time: T_{PT} minutes Total cost: C NOK
Given everything else the same, which one do you prefer? ☐ **Trip A**	☐ **Trip B**

Figure 2: An example of a choice task in the mode choice experiment

Consider the following two trips as Cyclist	
Trip A Total walk time: T_A min Separate Cycle Path: T_CP_A min No. of Stops: S_A	**Trip B** Total walk time: T_B min Separate Cycle Path: T_CP_B min No. of stops: S_B
Given everything else the same, which one do you prefer? ☐ **Trip A**	☐ **Trip B**

Figure 3: An example of a choice task in a route choice experiment

4 Model specification and estimation results

The latent class model used in this study comprise of a latent class and class specific discrete choice models as described in section 2.

We focus on two classes of cyclist (active and casual). Individuals' characteristics are used to explain class membership. The results of the estimations will be compared with a results derived from a mixed logit formulation. The results of the estimation of a model with 3 latent class model are described in the appendix.

For the estimations of the models in this study, the extended version of the software package BIOGEME (Bierlaire (2003) is used, extensions partly being explained in Bierlaire and Fetiarison (2009). All estimations are based on 10000 Halton draws. The panel structure of the dataset has been accounted for in all models.

4.1 Latent Class model specifications and estimations

In the model with two classes (active and casual), individuals' characteristics are used to explain class membership. The structural equations are built for the two latent classes and the probability of belonging to each class is defined with a binary logit formulation. The class membership model is given by:

$$V_{active} = \gamma_{Max\,Dis}(MaxDis > 40) + \gamma_{ComfDis}(ComfDis > 30) + \gamma_{No.of.cycle/week}(No.CycleTrip / week > 10) + \gamma_{Speed}(Speed > 15km / hr) \gamma_{age}(Age < 39) + \gamma_{environment}(Environmnet) + \gamma_{exercise}(Exercise) \quad (7)$$

$$V_{casual} = ASC + \gamma_{No.of.cycle/week}(No.CycleTrip / week < 5) + \gamma_{Education}(Education\_Univ)$$

All variables are dummy variables. *MaxDist* stands for the maximum distance a respondent is willing to cycle (in km) and *ComfDis* stands for a comfortable distance a respondent likes to cycle (in km). *No.CycleTrip/week* stands for number of cycle trips per week. Respondents were asked to state the reason for the choice of the mode. *Environment* and *Exercise* were among the 5 specified reasons in the questionnaire. Other specified reasons were "inexpensive", "fast" and "flexible". The respondents had a choice to specify other reasons with possibility to write down what the "other reasons" were. The most frequent responses were "all the above (meaning fast, flexible, environment and physical activity), ""wife took the car" and "planned to drink". "Male" did not turn significant among the variables in the classes, neither car ownership in the household. *Education* stands for those with four or more years of college or university education. *Speed* is calculated from the information on the reference trip of the respondents.

The utilities of alternatives are simply explained by the modal attributes in this study for each class as described by equation (8). Assuming extreme value distribution for the error terms associated with the utility function of the alternatives, the class-specific choice models will be multinomial logit model. Therefore, for each class *s*, the probabilities of choosing alternative *i* is given by equation (9).

$$\begin{aligned} V^s_{cycle} &= \beta^s_{T\_cycle\_NoCP} T_{NoCP} + \beta^s_{T\_cycle\_W\_CP} T_{CP} \\ V^s_{car} &= ASC^s_{car} + \beta^s_{\cos t} C_{car} + \beta^s_{T\_car} \\ V^s_{PT} &= ASC^s_{PT} + \beta^s_{\cos t} C_{PT} + \beta^s_{T\_PT} \\ V^s_{bus} &= ASC^s_{bus} + \beta^s_{\cos t} C_{bus} + \beta^s_{T\_bus} \end{aligned} \quad (8)$$

$$P^s_i = \frac{\exp(V^s_i)}{\sum_{j \in C_s} \exp(V^s_j)} \quad (9)$$

The utility for cycle include travel time with no cycle path (T_{noCP}) and travel time with cycle path all the way (T_{CP}). The utilities for other modes; car, public transport (PT) and bus include travel time and travel cost by the modes.

Table 1 shows the result of the estimation of the latent class model. The latent segmentation we obtained in this study strongly suggests that the population is heterogeneous in terms of value of travel time.

The two classes that we identified (active and casual cyclists) seem plausible with respect to the variables that describes them. Active cyclist are under 39 years old, they are experienced cyclists (with more than 10 cycle trips per week), their maximum cycle distance and comfortable cycle distance is above the average so is their reported speed for the reference cycle trip. They state "environment" and "exercise" as their main reasons for cycling The casual cyclist are those with higher education and cycle less than 5 times a week.

Table 1: Estimation results, latent class model

No. of estimated parameters:	28	Sample size:	7141
Init log-likelihood:	-4032.161	Final log-likelihood:	-3185.483
Likelihood ratio test for the init. model:	1693.358		
Rho for the init. model:	0.210	Rho bar for the init. model:	0.203

Parameter	Affected utility		Class		Value	Robust t-test
	1	2	1.Active	2.Casual		
Name					**Value**	**Robust t-test**
ASC				x	2.9	7.32
Age < 39			x		0.457	2.2
MaxDist > 40 km			x		1.3	4.54
ComDist >30km			x		1.28	5.74
No of Cycle/Week >10			x		1.29	5.12
No of Cycle/Week <5				x	1.08	2.91
Exercise			x		0.415	1.82*
Environment			x		1.08	2.69
Education: university				x	0.383	1.71*
Speed > 15 km/hr			x		0.389	2.06
Time, cycle without CP	x				-6.81	-13.23
Time, cycle with CP	x				-5.17	-8.6
ASC, car	x				-4.1	-11.7
Time, car	x				-1.59	-1.23
ASC, PT	x				-3.66	-6.41
Time, PT	x				-4.65	-3.15
ASC, bus	x				-3.9	-2.75
Time, bus	x				-1.4	-0.25*
Cost	x				-0.0429	-4.57
Time, cycle, without CP		x			-10.9	-17.37
Time, cycle, with CP		x			-7.55	-11.93
ASC, car		x			-1.59	-6.56
Time, car		x			-5.47	-6.49
ASC, PT		x			-2.05	-7.61
Time, PT		x			-4.46	-3.86
ASC, bus		x			-2.18	-2.13
Time, bus		x			-3.29	-0.59*
Cost		x			-0.0557	-10.09

(* Statistical significance < 95%)

The "Casual" class membership probability is 0.185, compared to "Active" class membership probability of 0.815. The class membership probabilities are used to calculate VTT for cycle, car, public transport and bus.

Note that bus time did not turn significant in either of the classes. Only 29 respondents had bus as an alternative. Also note that the cost coefficients in the indirect utility of the two segments are not significantly different.

The derived VTT for the two segments and for the whole population is presented in Table 2. Cycle VTTs for the "casual cyclists" are significantly lower than those for the "active cyclists". Also note that VTT for paid modes for all cyclists are plausible and similar in size to those estimated in the Norwegian VTT study.

The difference between cycle VTT with no cycle path and with cycle path all the way is about 41 NOK/hr, suggesting a significant benefit for providing a connected cycle path network.

Table 2: Value of travel time (NOK/hr); comparison of derived values based on latent class and mixed logit model

Mode	latent class			Mixed logit Model
	Active class	Casual class	All cyclists	
Cycle, no cycle path	158.7	195.7	163.8	174.3
cycle, cycle path all the way	120.5	135.5	122.6	139.5
Car	37.1	98.2	45.5	82.1
Public Transport	108.4	80.1	104.5	97.9
Bus	32.6	59.1	59.1	86.9

4.2 Mixed logit model formulation and estimation

The mixed logit model is specified by equation (11)

$$\begin{aligned} V_{cycle} &= \beta_{T\_cycle\_NoCP} T_{NoCP} + \beta_{T\_cycle\_W\_CP} T_{CP} \\ V_{car} &= ASC^{s}_{car} + \beta_{\cos t} C_{car} + \beta_{T\_car} \\ V_{PT} &= ASC_{PT} + \beta_{\cos t} C_{PT} + \beta_{T\_PT} \\ V_{bus} &= ASC_{bus} + \beta_{\cos t} C_{bus} + \beta_{T\_bus} \end{aligned} \qquad (10)$$

We have assumed normal distributions for coefficients $\beta_{T\_cycle\_NoCP}$ and $\beta_{T\_cycle\_W\_CP}$. Table 3 shows the results of the estimation. The derived VTT from the mixed logit formulation is presented in Table 2. Note that the VTTs derived from latent class and mixed logit models for all cyclists are similar.

Table 3: Estimation results, mixed logit model

No. of estimated parameters:	11	Sample size:	7205
Init log-likelihood:	-6091.788	Final log likelihood:	-3099.102
Likelihood ratio test for the init. model:	5985.371		
Rho for the init. model:	0.491	Rho bar for the init. model:	0.489

Coefficient	Value	Robust t-test
Bicycle time, no CP, Mean	-1.45	-20.01
Bicycle time, no CP, var	0.680	13.21
Bicycle time, with CP, Mean	-1.16	-17.85
Bicycle time, with CP, var	0.520	11.76
ASC_car	-3.64	-11.38
Time,car	-0.683	-7.09
ASC, PT	-3.64	-9.87
Time,PT	-0.814	-5.66
ASC,bus	-3.69	-2.29
Bus, time	-0.723	-0.49*
Cost	-0.499	-10.32

(* Statistical significance < 95%)

4.3 Estimation results of the route choice SP experiments

Mixed logit models have been applied to data from the three cycle route choice SP experiments. "Cycle time" is always one of the attributes among three attributes used in these experiments.

Table 4 shows the result of estimation of the cycle route choice SP experiment with "Cycle Travel Time", "Cycle Travel Time on Cycle Path (CP)" and the "No. of Crossings". All coefficients are assumed to be normally distributed.

Table 5 shows the result of estimation of the cycle route choice SP experiment with "Cycle Travel Time", "Upkeep of the Cycle Route" and the "No. of Crossings". All coefficients are assumed to be normally distributed.

Table 6 shows the result of estimation of the cycle route choice SP experiment with "Cycle Travel Time", "Cycle Travel Time on Cycle Path" and "Snow Removal". Only the coefficient for "Cycle time" is assumed to be normally distributed.

Table 4: Estimation results based on from SP experiment with attributes "Cycle Time", "Cycle Path" and "No of Crossings"

No. of estimated parameters:	7	Sample size:	5034
Init log-likelihood:	-3856.182	Final log likelihood:	-2402.230
Likelihood ratio test for the init. model:	2907.905		
Rho for the init. model:	0.377	Rho bar for the init. model:	0.375

Coefficient	Value	Robust t-test
Cycle time, Mean	-3.55	-13.76
Cycle time, var	3.23	12.26
% of cycle time on CP, mean	1.18	16.05
% of cycle time on CP, var	0.908	13.03
No. of crossings, mean	-3.45	-13.69
No. of crossings, var	2.37	9.05
ASC	-0.0607	-1.10

Table 5: Estimation results based on from SP experiment with attributes "Cycle Time", "% of Upkeep of cycle Path" and "No of Crossings"

No. of estimated parameters:	7	Sample size:	2754
Init log-likelihood:	-1930.352	Final log likelihood:	-1930.615
Likelihood ratio test for the init. model:	1219.419		
Rho for the init. model:	0.316	Rho bar for the init. model:	0.312

Coefficient	Value	Robust t-test
Cycle time, mean	-4.08	-10.43
Cycle time, var	3.04	8.25
% of cycle route up kept, mean	0.800	11.32
% of cycle route up kept, var	0.671	9.90
No. Of crossings, mean	-3.29	-8.83
No. Of crossings, var	2.52	-.14
ASC_R	-0.128	-1.80*

Table 6: Estimation results based on from SP experiment with attributes "Cycle Time", "Cycle Path" and "Snow Removal"

Coefficient	Value	Robust t-test
Cycle time. mean	-0.385	-6.22
Cycle time. var	-0.5.36e-12	0
% of cycle time on CP	0.238	9.60
Snow removal. small part	4.55	2.74
Snow removal. mostly	26.2	14.84
Snow removal. all the way	37.9	16.95
ASC	0.0158	0.24

The results presented in Tables 4-6 provides some indications that that the population is heterogeneous in terms of their valuations of cycle infrastructure, facilities and services. Note that the standard deviations of most random coefficients are fairly large. This call for applying latent class models for the estimation of these values.

Table 7 shows the summary of cyclists' valuations of infrastructure, facilities and services. The valuation is based on an average cycle VTT of 163 NOK/hr (average of VTT without cycle path and with cycle path all the way) derived from the latent class model. The average cycle VTT derived from mixed logit model is 160 NOK/hr, with almost no significant effect on these valuations.

It should be pointed out that the results of the cycle study in the Norwegian Value of Time Study (Ramjerdi et al, 2009) was based on an entirely different approach to the modelling of the mode choice experiment. A simple logit model with two alternatives, cycle and the paid mode was used in the Norwegian VTT Study and simple logit models were applied to data from the route choice experiments. The cycle VTT derived from the latent class model or the mixed logit model is significantly higher than those reported in the Norwegian VTT study (163 or 160 compared to 130 NOK/hr).

Table **7.** Summary of cyclists' valuations of infrastructure, facilities and services

Valuation of attributes at Cycle VTT: 2.71 NOK/min (163 NOK/hr)	Experiment: Upkeep & No. of Stops	Experiment: Separate Cycle Path & No. of Stops	Experiment: Separate Path & Snow Removal
Value for upkeep in NOK: Base: Upkeep 10% of the way			
Upkeep: 1%	0.53		
Value of one stop reduction, NOK			
	2,19	2,63	
Value of 1% increase in separate walking path, NOK			
		0,90	1.67
Value of snow removal , NOK Base: No snow removal			
Partly Mostly All the way			32.03 184.42 266.78

5 Conclusions and further research

The latent segmentation we estimated in this study strongly suggests that the cyclists are heterogeneous in terms of value of travel time. The two classes that we identified (active and casual cyclists) seem plausible with respect to the variables that describe them. Active cyclist are under 39 years old, they are experienced cyclists (with more than 10 cycle trips per week), their maximum cycle distance and comfortable cycle distance is above the average so is their reported speed for the reference cycle trip. They state "environment" and "exercise" as their main reasons for cycling The casual cyclist are those with higher education and cycle less than 5 times a week.

We could have benefited from additional attitudinal data as well as data related to the built environment of the residence of the cyclists in this study.

We have also presented a three latent class model in the appendix. While the estimation results seem plausible, labelling segment was not without difficulty. Further work using factor analysis is necessary for the identification of the classes.

The results also point to richness of the latent class model in the context of value of travel time studies. However, it is not very common to include attitudinal attributes in VTT studies. Obviously attitudinal attribute have significant impact on VTT and it is important to address them in the design of a study.

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Appendix

The 3 class membership model is described as.

$$
\begin{aligned}
V_A &= \gamma_{Age<40}(Age40) + \gamma_{No.CycleTrip/week<5}(No.CycleTrip/week \le 5) + \\
&\quad + \gamma_{Cycle\_dis \le 5}(Cycle\_dis \le 5) + \gamma_{No.ofStops/km>2}(No.Stops/km > 2) \\
V_B &= ASC_B + \gamma_{environment}(Environmenr) + \gamma_{education}(UniversityEducation) \\
V_C &= ASC_C + \gamma_{Male\&Age<39}(Male\ \&\ Age < 39) + \gamma_{MaxDist>40}(MaxDist > 40km) + \\
&\quad \gamma_{Excercise}(Excercise) + \gamma_{No.CycleTrip/week>10}(No.CycleTrip/week > 10) + \\
&\quad \gamma_{ComDist>30}(Com.Dist > 30) + \gamma_{Car2+}(No.ofCar > 2) + \gamma_{CycleDis+}(CycleDis > 10)
\end{aligned}
$$

Table I1 shows the estimation results. All variables are dummy variables. *MaxDist* stands for the maximum distance a respondent is willing to cycle (in km), *ComfDis* stands for a comfortable distance a respondent likes to cycle (in km), *No.CycleTrip/week* stands for number of cycle trips per week and *Fast&Flexible* stands for the reasons a respondent had chosen to cycle. Other reasons for choosing to cycle specified in the questionnaire were for “Environment” and “Excercise”. The respondents had a choice to specify other reasons with possibility to write down what the "other reasons" were. The most frequent responses were "all the above (meaning fast, flexible, environment and physical activity), ""wife took the car" and "planned to drink". Other variables that are used in these models are "Male", “Age” and “Male & Age < 39”, two or more cars in the household “No. of Car>2”, those with 4 years or more of college/university education “Education” and the reported cycle distance “CycleDis”. No of stops per kilometre, “No. Stops/km” has been used as a proxy for built environment.

While the estimation result of this model seems rather satisfactory, it is rather difficult to label the cyclists classes in this case. Not finding suitable labels, we refer to the classes simply A, B and C.

In the three class case, the membership probabilities of class “A”, “B” and “C” are 0.134, 0.836 and 0.03 respectively. The class membership probabilities are used to calculate VTT for cycle, car, public transport and bus.

Note that while the cost coefficients in the indirect utility of the two segments in the two class model were not significantly different, the cost coefficients in the three class model are.

The derived VTT for the segments and for the whole population is presented in Table I2. Cycle VTTs for the "casual cyclists" are significantly lower than those for the "active cyclists". Also note that VTT for paid modes for all cyclists are plausible and similar in size to those estimated in the Norwegian VTT study.

The difference between cycle VTT with no cycle path and with cycle path all the way is 50 NOK/hr compared to 60 NOK/hr to the corresponding value in the 2 latent class. .

Table I2: Estimation results, 3 latent class model

No. of estimated parameters:				41	Sample size:			7104
Init log-likelihood:				-3694.706489	Final log-likelihood:			-3007.128474
Likelihood ratio test for the init. model:				1375.156				
Rho for the init. model:				0.186	Rho bar for the init. model:			0.175
	Affected utility			Class			Estimated results	
Parameter	1	2	3	1.A	2.B	3.C	Value	Robust t-test
Age <39				x			0.696	3,18
No. of Cycle/Week ≤5				x			-0.466	-2,09
Cycle distance ≤5				x			-0.941	-4.43
No. of stops/km ≥2				x			0.382	1,67*
ASC, 2					x		0.590	2,54
Environment					x		0.336	0.93*
Education University					x		0.574	2,81
ASC, 3						x	1,02	2,72
Male & Age <39						x	0.476	1,94*
Max dist >40 km						x	-1.07	-4.55
Com. Dist >30 km						x	-0.783	-2.62
No. of Cycle/Week > 10						x	-1.01	-3.58
Exercise						x	-0.901	-3.77
Car 2+						x	0.439	1,92*
Time, cycle no CP	x						-6.37	-7.91
Time, cycle with CP	x						-5.13	-5.56
ASC, car	x						-5.05	-11.17
Time, car	x						-1.52	-0.82*
ASC, PT	x						-4.62	-7.22
Time, PT	x						-3.30	-2.07
ASC, bus	x						-4.86	-3.26
Time, bus	x						-0.559	-0.12*
Cost	x						-0.0338	-1.93*
Time, cycle, no CP		x					-11.6	-19.78
Time cycle, with CP		x					-7.78	-15.63
ASC, car		x					-2.53	-10.02
Time, Car		x					-5.82	-6.38
ASC, PT		x					-2.74	-8.93
Time, PT		x					-4.82	-3.09
ASC, bus		x					-3.26	-5.91
Time, bus		x					-3.22	-1.68*
Cost		x					-0.0734	-10.13
Time, cycle, no CP			x				-17.4	-8.31
Time, cycle, with CP			x				-14.3	-6.73
ASC, car			x				-1.34	-1.83*
Time, Car			x				-11.0	-3.90
ASC, PT			x				-2.43	-2.89
Time, PT			x				-8.05	-2.37
ASC, bus			x				-2.40	-2.45
Time, bus			x				-4.24	-0.96*
Cost			x				-0.0606	-3.37

(* Statistical significance < 95%)

Table I2: Value of travel time (NOK/hr); comparison of derived values based on 3 latent class and mixed logit model

	latent class				Mixed logit
Mode	A	B	C	All cyclists	Model
Cycle, no cycle path	188.5	158.0	287.1	166.0	174.3
cycle, cycle path all the way	151.8	106.0	236.0	116.0	139.5
Car	45.0	79.3	181.5	77.7	82.1
Public Transport	97.6	65.7	132.8	72.0	97.9
Bus	16.5	43.9	70.0	41.0	86.9