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Making headway towards a better understanding of service frequency valuations: a study of how the relative valuation of train service frequency and in-vehicle time vary with traveller characteristics

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Abstract

On-going urbanization has led to greater distances between homes and workplaces and more long-distance commuting, increasing the need for efficient inter-urban transport infrastructure. For sustainability, trains are preferred to private cars.

Two key variables affecting door-to-door train travel time are in-vehicle time (IVT) and headway; however, there is often a trade-off between speed and frequency in a system.

If different categories of travellers value IVT and headway differently, their proportions on a route should affect traffic planning. Optimal system design might differ between routes carrying many commuters and routes carrying mainly passengers on single private or business trips. Knowledge of differences in relative valuations of headway versus IVT should therefore affect railway system design.

We investigate whether the relative values of headway versus IVT differ between inter-urban commuting by train and single inter-urban trips by train, whilst also examining differences between socioeconomic groups. Stated choice (SC) data from 580 Swedish respondents are used in estimation. Individuals actually commuting and individuals not commuting but imagining that they are when answering the SC questions are asked about their preferences for headway versus IVT.

Commuters are estimated to value increased headway 19 percentage points more than do non-commuters. Young people (under age 21 years) value headway more than do older people while people with children value headway less than do the childless.

JEL Classification: R4, R48, R41

1. Introduction

In recent decades, the transport sector is the only sector that has appreciably increased its total CO_2 emissions in developed countries and in the rest of the world. Besides contributing to global warming, increased transport volumes have also led to numerous other environmental problems including congestion. Over the last century, total fossil carbon emissions increased fifteen fold. For example, the transport sector is responsible for approximately 25% of the CO_2 emissions in the USA. Globally, transport sector emissions are generally in the range of 25–30% of total emissions (SOU 2008:24; US Department of Commerce, 2010). In Sweden, the transport sector accounted for 33% of the total domestic (not including international air traffic and shipping) CO2-emmisions in 2011. The private care generated almost 60% of the emissions from transport making it the largest contributor to overall emissions (19% of total emissions). In addition to CO2-emissons, responsible for global warming, transport also causes environmental problems at the local level. Road transport also generates emissions of particles causing cancer and respiratory problems, especially in cities, 25% of the particle emissions in Sweden can be attributed to road transport. When it comes to NOx, the emissions from the transport sector (not including international shipping) has been reduced by 50% since 1990 due to stricter emission standards on vehicles. Nevertheless, the transport sector emitted 61 000 tons of NOx in 2012, making it the by far the largest contributor to the total emissions (47% of total emissions).

The record high economic growth over the last century in the now rich countries has been accompanied by other crucial long-term developments, including far-reaching economic structural change, which in turn is interdependent with urbanization. This change in spatial structure is a key factor affecting the long-term development of fossil fuel demand and climate policy. According to UN population statistics, half the world's population now lives in urban areas, a concentration of importance for energy use in all economic sectors.

Somewhat unexpectedly, this concentration of economic activities and population has been accompanied by increased distances between people's homes and workplaces. This is partly due to urban sprawl, resulting in longer distances within urban areas, and partly due to an increased propensity for long-distance commuting. In 2006, almost one third of working Swedes commuted to work in another municipality (Torége *et al*., 2008). In 2007, more than 90,000 people commuted to workplaces in the Stockholm region from other regions, an increase of 50% in ten years (SCB, 2008). Of the total number of trips to work made in Sweden in 2006, more than 60% were made by car and only 14% by train (SIKA, 2007). From a sustainability viewpoint, this is troubling since travelling by train causes fewer environmental problems and is generally safer than travelling by car. In light of the environmental impacts of the transport sector, it is important to consider means to increase the market share of public transport in general (where it can be justified by demand) and of rail travel in particular. This is also central to Sweden's transport sector policy goals (Prop. 2008/09:93).

An efficient railway system minimizes the total cost of transporting a specific volume. The total cost includes monetary cost, but this is usually overshadowed by the time cost to travellers. De Witte *et al*. (2008) demonstrated that commuters identified problems with the speed and availability of public transport as the most important reasons for choosing to travel by car instead of train. Two of the most important variables affecting door-to-door travel time by train are in-vehicle time (IVT) and headway (i.e. the time interval between departures). Although the distance travelled and technical limitations of the infrastructure and rolling stock obviously affect these variables, they are somewhat controllable by the operator (and by the rail network controller, if separated). It is crucial to acknowledge that these factors are interdependent. For example, IVT can be reduced by alternating the stations where a train stops so that no train stops at all stations along the way, but this comes at the expense of increased average headway. Reducing headway, and thereby increasing the number of trains on the track, might also require lower speeds for safety reasons. Therefore, from a planning perspective, there is often a trade-off between train speed and frequency in a system. It has been suggested that headway is more important to inter-urban commuters than to other inter-urban travellers. Based on data from a large number of British studies of inter-urban travel (50 km or longer), Wardman (2004) found that, when travelling by train, commuters attach relatively more value to headway than to IVT than do those travelling for leisure or business purposes.

In Sweden and other countries, when planning the railway system, administrators assign the same monetary values to IVT and headway regardless of the proportions of passengers commuting to work and undertaking single private trips (Swedish Transport Administration, 2012). If different categories of travellers value IVT and headway differently, their proportions on a certain route should affect the infrastructure design and traffic planning for the route. The optimal system design for routes with many commuters might differ from those for routes mainly carrying passengers on single private or business trips. Knowledge of differences in the relative valuations of headway and IVT could therefore have important effects on success in designing a sustainable and efficient railway system.

The present study therefore investigates whether the relative values of headway and IVT differ between inter-urban commuting to work by train and single inter-urban trips by train. The study uses stated choice (SC) data from 580 Swedish respondents. In this study, both individuals actually commuting and individuals not commuting but imagining that they are when answering the SC questions are asked about their preferences for headway versus IVT. This will produce a more informative basis for policy decisions. The study will also investigate whether the relative valuation of headway (in terms of travel time) differs between commuters asked about their actual trips and those asked about hypothetical trips. This might have important methodological implications, since a difference between them would indicate that people have failed to relate to the hypothetical questions.

2. Time as a resource: some theoretical underpinnings

The fact that time is at the heart of understanding individuals' transport decisions has been known to transport economists since Dupuit (1844) identified the importance of acknowledging the value of time savings when planning new infrastructure. Despite this, outside the transport sector, the time costs of consumption and time allocation have attracted little attention with a few notable exceptions. Hicks (1956) stated that:

> We ought to think of the consumer as choosing, according to his preferences, between certain objectives and then deciding, more or less as the entrepreneur decides, between alternative means of reaching those objectives. (Hicks, 1956, p. 166)

This viewpoint can be seen as predating that of Becker (1965), who articulated his famous theory of consumption in terms of household production. According to this approach, consumers should be seen as combining goods and services purchased on the market using income with their own time used to produce various commodities; for example, dish soap and time are combined to produce clean dishes, or a DVD, a sofa, and snacks are combined with time to produce a movie experience. It is from these commodities that the consumer experiences utility and not from the consumption of goods in themselves. Stated thus, it is apparent that time is potentially important for all types of consumption. It should be noted that time plays a key role in the consumption of services because they simultaneously combine consumption and production (e.g. Jansson, 2006). It is impossible to produce a public transport trip in advance, store it, and then consume it on another occasion, making time usage important for the production process and consumer of this service.

Bruzelius (1978) presents a version of DeSerpa's (1971) model that can be seen as a generalization of Becker's (1956) model and other alternative approaches. The model is as follows:

$$\text{Max } U(x_1,.....x_n,l,t_1,....,t_n,t_w) \qquad (1.1)$$

s.t. $\sum_{i=1}^{n} p_i x_i - wt_w - I \leq 0$ (1.2)

$l + \sum_{i=1}^{n} t_i + t_w - T = 0$ (1.3)

$q_i x_i - t_i \leq 0 \qquad i = 1, \ldots, n_1$ (1.4)

$q_i x_i - t_i = 0 \qquad i = n_1 + 1, \ldots, n$ (1.5)

The consumer is assumed to derive utility from consuming various goods (x_i), from the amount of leisure enjoyed, and from the amount of time spent consuming various goods (t_i). Equation (1.1) explicitly acknowledges that time spent on different activities might result in differences in the experienced level of utility. An hour spent washing dishes differs markedly from the same time spent watching a movie. Although the differences might not be as pronounced as in the previous example, it has been demonstrated that people experience a significant difference between time spent travelling on different modes of transport, for example, an hour on the train differs from an hour in a car (e.g. Wardman, 2001). Despite this, in practical applications it is not uncommon to assume the same value of time for different modes of transport.

The first restriction, (1.2), in which p_i represents the price of good i, w is the wage rate, t_w is the time spent earning wages, and I is non-labour income, states that the monetary spending of the consumer cannot exceed her monetary income.

In 1.3, the sum of the time allocated to leisure (l), working (t_w), and consuming various goods $\sum_{i=1}^{n} t_i$ equals the time available (T). Restriction (1.4) represents the fact that some activities ($i = 1, \ldots, n_1$) require a minimum amount of time (q_i), though one can spend more time on them if one so desires. At the same time, some activities ($i = n_1 + 1, \ldots, n$) require a fixed amount of time, no more, no less, which is represented by (1.5).

Stating the problem as a Lagrange function gives:

$$L = U(x_1,.....x_n, l, t_1,....,t_n, t_w) - \lambda\left(\sum_{i=1}^{n} p_i x_i - wt_w - I\right) - \mu\left(l + \sum_{i=1}^{n} t_i + t_w - T\right) - \sum_{i=1}^{n1} \gamma_i (q_i x_i - t_i) - \sum_{i=n1+1}^{n} \gamma_i (q_i x_i - t_i) \qquad (2)$$

Solving the maximization problem results in the following demand function:

$$x_i = x(p_1,.....p_n, w, q_1,.....q_n, I) \qquad (3)$$

Therefore, the demand for good i is a function of monetary price, the wage rate, the time required to consume different goods, and non-labour income. Since λ represents the marginal utility of income and γ_i is the marginal utility of a change in the time required for activity i (i.e. consuming x_i), the marginal value of time is (Bruzelius, 1978):

$$\frac{\gamma_i}{\lambda} \qquad (4)$$

Therefore, the marginal value of time will also be a function of I, w, p_i, and q_i.

3. Estimating the value of time

Empirically, the value of time can be estimated in various ways, but it has become increasingly common to use stated choice (SC) methods to do so. Conceptually, this approach has its origins in Lancaster (1966) and is based on the notion that goods or, more generally, activities differ in their attributes and that it is access to these attributes, and not the activities themselves, that gives rise to utility, i.e. particular modes of transport for a trip are associated with different attributes that generate different levels of utility (see also Becker, 1956). A train ride, for example, will be associated with a specific (expected) travel time, a specific monetary cost, particular views from the window, etc. The consumer will choose activities (including how much time should be allocated to work) so that her utility is maximized subject to the constraints set by the available time and the market wage.

In the present case, the activity in question is a train ride associated with specific attributes, two of which are allowed to change. The consumer, i, is asked to choose between states 0 and 1, between which in-vehicle time (t) and headway (F) are allowed to change. The choice can be described as:

$$\mathrm{U_i(F_1, t_1, X, Y) \geq U_i(F_0, t_0, X, Y) \rightarrow Choose\ state\ 1}$$

$$\mathrm{U_i(F_1, t_1, X, Y) < U_i(F_0, t_0, X, Y) \rightarrow Choose\ state\ 0}$$

where U_i is the indirect utility function for individual i. Other attributes (X), such as comfort and fares, are assumed to remain unchanged between the two states and income (Y) is also assumed to be unaffected by the choice. It is therefore assumed that no other differences in prices or expense between the two alternatives are present or taken into consideration by the individual.

Utility is assumed to consist of a deterministic part and a random part (the error term). Assuming that the utility function is linear and that the error terms are independently and identically distributed with a mean of zero, the difference in utility between the two alternatives can be described as follows (McFadden, 1974; Haab and McConnell, 2003):

$$\Delta U_i = V_i + \varepsilon_i \qquad (5)$$

$$V_i = \beta_t (t_1 - t_0) + \beta_F (F_1 - F_0) \qquad (6)$$

where ΔU_i is the net utility for individual i of having alternative 1 instead of alternative 0, $(t_1 - t_0)$ is the difference in in-vehicle time between the alternatives, $(F_1 - F_0)$ is the difference in time between departures between the alternatives, and ε_i is the random term.

To allow commuters to have different relative valuations of headway and in-vehicle time, for the questionnaire variants about actual trips, the parameter for headway is defined as:

$$\beta_F = \beta_0^F + \sum_{i=1}^{n} \beta_i^F \qquad (7)$$

where *n* attributes affect the value produced by a change in frequency; for example, being a commuter or having children might affect the value a consumer ascribes to reduced headway. The probability that individual *k* answers "yes" is

$$P[Yes]_{ki} = P[U_{net,ki} \geq 0] = P([\beta_F \Delta F_{ki} + \varepsilon_{ki}] \geq -\beta_t \Delta t_{ki}) = P\left(\left[\frac{\beta_H \Delta F_{ki} + \varepsilon_{ki}}{-\beta_t}\right] \geq \Delta t_{ki}\right) \qquad (8)$$

An econometric model can be estimated with maximum likelihood. Assuming that the error terms are extreme value distributed, a logit-model is used and the probability of choosing the alternative with improved headway is

$$P_k \text{ of choosing alternative with improved headway} = \frac{e^{V_k}}{e^{V_k} + 1} = \frac{1}{1 + e^{-V_k}} \qquad (9)$$

All parameters are divided by an unknown scale parameter, τ, but can be interpreted as ratios. The average willingness to substitute (WTS) in-vehicle time for less headway for a specific category can be calculated as follows (Hanemann, 1989):

$$E[WTS] = \frac{1}{-\beta_t}(\beta_H) \qquad (10)$$

The result will be the relative valuation of 1 min of headway in terms of IVT. It can differ between individuals with different attributes, such as being a commuter or a non-commuter.

4. Study design

The study was undertaken using stated choice (SC) questions in which headway and in-vehicle time were varied around their current levels. SC study design and issues related to such studies are described by Louviere *et al*. (2006). The aim in designing the present study was to make it easy for the respondents to answer the questions and perceive them as meaningful and realistic, while minimizing the inclination to answer strategically. Another aim was to estimate valuations in terms of time instead of money, as in Ivehammar (2008), but instead of using actual travel time differences, time is varied hypothetically around its present level. This is a way to avoid using hypothetical and unrealistic fare differences.

SC questions with pair-wise choices are used in our study. Only two factors (IVT and headway) are varied at three levels in each variant of the questionnaire. Restricting the choice in this way makes it easier for respondents to choose. It is a realistic assumption that investments to improve train travel could reduce either in-vehicle time or headway. The nine alternatives for each variant of the questionnaire can be combined in pairs in 36 ways. The study design was fully factorial, but all combinations in which one alternative was clearly preferable were removed. All respondents had to choose between the remaining nine combinations.

Focus groups and a pilot study were used to test the questionnaire. The pilot study tested five variants of the questionnaire.[1] Four variants were sent to people living in Eskilstuna,[2] which has train connections similar to those described in the SC questions. One variant asked the respondents to imagine that they were commuting to work 100 km away five days a week. Another variant asked them to imagine travel to a specific city, i.e. Stockholm. A third variant asked them about actual trips to Stockholm. A fourth variant asked about actual trips to a destination of their own choice. In the third and fourth variants, those who did not travel by train were asked not to answer the SC questions because the answers were connected to actual train trips. The first variant was also sent to people living in Vadstena,[3] which currently lacks a train connection. The levels of in-vehicle time and headway were varied around current levels on the route between Eskilstuna and Stockholm. The levels of IVT used were 75, 60, and 45 min, while the levels of headway used were 3 h, 1 h, and 30 min. The first train departure was at 6:30 and the last at 22:30 in all variants. The pilot study revealed that the first and fourths variants sent to Eskilstuna were the most suitable for the main study, and that the attribute levels used in the pilot study were suitable. These two variants of the questionnaire were used in the main study in addition to including the 15-min headway level. An example of a questionnaire, translated from Swedish, is included as an appendix.

All questionnaires include the current headway and the current in-vehicle time on the Eskilstuna–Stockholm route as one level. In-vehicle times of 75, 60, and 45 min and headway levels of 2 h, 1 h, 30 min, and 15 min are used. In one variant, respondents were asked to imagine that they were commuting to work 100 km away five days a week. The other variant asked about actual travel to a destination of their choice as a commuter or traveller taking single trips. The respondents were asked to answer the questions while considering the actual trips. Those who did not travel by train were asked not to answer the SC questions. The current headway and current IVT levels were used as one level for all respondents.

When the headway is more than 10–15 min, travellers usually consult the timetable and arrive at the station a few minutes before departure (Jansson, 2001). In all variants, it is assumed that the travellers act this way rather than randomly going to the station to catch a train. The cost of headway can be seen as the inconvenience of not travelling at the desired time.

In the main study, each variant was sent to 600 randomly chosen people 18–65 years old living in Eskilstuna municipality.[4] The upper boundary of 65 years was chosen because half of the questionnaire variants specifically concerned commuting to work, and people over 65 years old are usually retired and do not commute. The train connections described in the questionnaires were similar to those in the current timetable.

The response rate was determined by counting only those completed questionnaires with answers to the SC questions. After two reminders were sent, the response rate was approximately 48%. One way to search for non-response bias is to study the response rates of different subgroups (Groves, 2006). Overall, there were no large variations in the ages, genders, and places of residence of respondents to the different variants.

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[1] The pilot study was carried out in March 2007 by sending each variant to 50 people randomly chosen from the phone book.
[2] Eskilstuna is a city in central Sweden with 95,000 inhabitants.
[3] Vadstena is a town in central Sweden with fewer than 8000 inhabitants.
[4] The study was carried out in May and June 2007 and the addresses were obtained from SPAR, the Swedish national address register managed by Infodata AB.

5. Results

A great many socioeconomic factors might affect the relative valuation of headway. In terms of estimation, these factors enter the model as the different attributes in (7). Table 1 shows the variables identified and analyzed (in addition to travel time and frequency) in the present study.

Table 1. Attributes included in original estimation (in addition to travel time and headway)

Variable	Explanation
Travel frequency	Number of trips undertaken
Commuter	Commuter or not
Car user	Respondent having a driving license and access to a car
Parent	Two variables, one indicating whether the respondent has at least one child and one indicating whether the respondent has at least one small child
Gender	Man or woman
Outskirts	Respondent living outside city centre
Age	Divided into age groups: <21, 20–36, 35–51, >50 years
Income	Income >SEK 39,999

The frequency at which an individual makes a specific trip might affect the relative valuation of headway. A frequent traveler might learn the timetable and plan her activities accordingly; as she would probably want to minimize the total time spent travelling, it is reasonable to think that such a person would value (reduced) travel time relatively higher. The same reasoning applies to commuters, but since it is not uncommon for long-distance train commuters to work during the trip, they might value travel time savings less.

When it comes to people with a driving license and access to a car, it is reasonable to assume that they will assign a relatively low value to service frequency. This is because they can be assumed to want to maximize the flexibility of their travel options and thereby be able to minimize total travel time for each specific trip. They therefore prioritize short in-vehicle time, taking the train only when the schedule fits and when they cannot use the car.

Being a parent might also affect the valuation in different ways. One might argue that parents would like as much flexibility as possible, for example, having the option to take an earlier train than planned in case a child falls ill or in case of other emergencies. On the other hand, a parent might want to minimize the time spent away from home and therefore prioritize short in-vehicle time. The latter is more likely in the case of long-distance commuters or frequent travelers, since there is likely another parent or relative present in the home town able to cover emergencies.

Many studies of travel time valuation observe a difference between men and women, possibly because women have traditionally assumed the main responsibility for running the household. We therefore expect women to value in-vehicle time more than do men, in order to minimize the time spent away from home.

The study also tested for a difference between those living in the city center, near the train station, and those living on the outskirts of the city or in the surrounding countryside. Since those living in the countryside may be dependent on the frequency of buses to their homes, higher train frequency may be less important for them.

Among the socioeconomic variables tested are age and income. Although peoples' preferences may change as they age, any effect of the age variable is likely because it reflects differences in the work and family situations not captured by other variables. At the same time, income likely captures differences in the type of work and employment situation facing individuals.

These variables enter the model as interaction terms of the headway variable, i.e. they comprise the components of (7).[5] The estimation procedure starts by estimating a model that includes all variables (i.e. in-vehicle time, headway, and the variables presented in Table 1). Statistically insignificant variables are then eliminated, starting with the one with the lowest *t*-value. In each step of the procedure, the previously removed variables are reintroduced to rule out their previous removal having been due to multicollinearity (Neter *et al.*, 1996).

Table 2 shows the results of estimating equation (8) using data obtained from the survey about actual travel behavior.

Table 2. Results of estimating equation (8) using data on actual travel behavior

Variable	Coefficient	Std. error	*z*-statistic	Prob.
RESTID	0.080485	0.005439	14.79801	0.0000
F	–0.022247	0.002748	–8.097039	0.0000
F*(Commuter)	–0.015276	0.002519	–6.063316	0.0000
F*(MAN)	–0.006179	0.002292	–2.695711	0.0070
F*(Age <21)	–0.009194	0.004098	–2.243479	0.0249
F*(Parent)	0.005447	0.002277	2.392635	0.0167

Mean dependent var.	0.594833	S.D. dependent var.	0.491079
S.E. of regression	0.448831	Akaike info criterion	1.185557
Sum squared resid.	318.4910	Schwarz criterion	1.205858
Log likelihood	–934.7398	Hannan-Quinn criter.	1.193099
Deviance	1869.480	Restr. deviance	2142.612
Avg. log likelihood	–0.588998		
Obs. with dep = 0	643	Total obs.	1587
Obs. with dep = 1	944		

A coefficient with a negative sign indicates that an increase in the variable in question reduces the probability of choosing the alternative with better (less) travel time. It can therefore be seen that being a commuter, male, and under 21 years old all increase the probability of choosing a relatively high-frequency alternative, i.e. they value decreased headway relatively higher than do other groups. At the same time, being able to drive, being older than 20, and

[5] It would be equally viable to have the variables enter the model as interaction variables of the in-vehicle time variable, but this would not affect the relative valuation of headway versus in-vehicle time.

having small children are not included in the model, since they were not statistically significant.

The results can be further illustrated using the results from Table 2 in equation (10) to calculate the valuation of frequency relative to travel time. The baseline for comparison is a woman 20–35 years old (note that people over 50 years old are found to have the same valuation of frequency) without children. Although all possible combinations could be calculated, only the effects of changing one variable at a time are shown here.

Table 3. Illustrative examples of relative (to travel time) valuations

Based on actual trips	Value of headway (in relation to travel time)	**SE**
Woman, no children, commuter	0.466211	0.032
Woman, no children, commuter, age <21	0.580444	0.058
Man, no children, commuter	0.542983	0.034
Woman, no children, non-commuter	0.276412	0.026
Woman, children, commuter	0.398534	0.033

In this case, no difference is found between those having older versus younger children. People with children value frequency less than do those without children. This might seem counterintuitive, as one might assume that parents would value the flexibility of having more departures to choose from in case of emergencies. However, as discussed earlier, given that many parents having a long commute probably have another parent working closer to home who can cover emergencies, this result is perfectly natural. When making longer trips and/or commuting, parents instead value short travel time and probably plan their trips according to existing departures.

In this case we find that commuters do value frequency more than do non-commuters, which could be expected as flexibility is more important if one travels often. When making single trips on special occasions, however, it is not that inconvenient to plan one’s departure according to a low-frequency schedule.

The reference person used as a baseline for comparison values a 1-min reduction in headway at 0.47 min of reduced travel time. Interestingly, young people appear to value the flexibility offered by higher frequency while parents assign the least relative value to reducing headway. The latter is perhaps because parents prioritize low travel times to maximize time with family, relying on a spouse (or someone else) closer to home to handle emergencies.

Table 4 shows the final results (after eliminating non-significant variables) from the estimation of equation (8) using data obtained from the survey asking about a hypothetical situation.

Table 4. Results of estimation of equation (8) using data on hypothetical travel behavior

Variable	Coefficient	Std. error	*z*-statistic	Prob.
TID	0.073635	0.004326	17.01982	0.0000
F	–0.035021	0.002560	–13.67998	0.0000
F*(Car user)	0.003820	0.001123	3.402302	0.0007
F*(Parent)	0.014667	0.002695	5.441870	0.0000
F*(age <21)	–0.014169	0.004363	–3.247631	0.0012
F*(age 35–51)	–0.005059	0.002431	–2.080631	0.0375
F*(young children)	–0.012403	0.002309	–5.372190	0.0000
Mean dependent var.	0.553826	S.D. dependent var.		0.497202
S.E. of regression	0.456652	Akaike info criterion		1.215020
Sum squared resid.	480.8724	Schwarz criterion		1.232410
Log likelihood	–1398.170	Hannan-Quinn criter.		1.221358
Deviance	2796.340	Restr. deviance		3179.641
Avg. log likelihood	–0.604483			
Obs with dep = 0	1032	Total obs.		2313
Obs with dep = 1	1281			

In this case, it can be seen that being under 21 years old and having small children increase the probability of choosing the higher-frequency alternative, i.e. those groups assign a relatively high value to frequency. The relative value of frequency also appears to be higher for people aged 35–50 years than for those aged 20–35 years. On the other hand, being able to drive (i.e. having a driving license and access to a car) or having older children has the opposite effect.

An important result is that the commuter variable is not statistically significant in this case. This is as it should be, since the respondents in this case were asked about hypothetical trips in which they were to imagine that they were commuters. Had the commuter variable been significant, that would indicate an inability to picture oneself in that position, which would cast doubt on studies using hypothetical questions.

In Table 5, examples of valuations have been calculated to enable comparison with the previous model. To make the valuations as comparable as possible, the baseline person is in this case a person aged 20–35 (or over 50) years without children and unable to drive a car (no access to car and/or having no driving license).

Table 5. Example interpretations of the results

Based on hypothetical trips	Value of headway (in relation to travel time)	**SE**
Age 20–35, age >50, no children, non-driver	0.48	0.027
Age <21, no children, non-driver	0.67	0.071
Age 36–50, no children, non-driver	0.54	0.042
Age 20–35, age >50, small children, non-driver	0.44	0.035
Age 20–35, age >50, older children, non-driver	0.28	0.039
Age 20–35, age >50, no children, driver	0.42	0.019

The reference person in this case values a 1-min reduction in headway at 0.48 min of reduced travel time. This is obviously very close to the findings of the model using data on actual travel habits. This further emphasizes the robustness of the use of hypothetical data. As before, young people appear to value the flexibility offered by higher frequency, while parents with older children put the least (relative) value on reducing headway. The latter is presumably because they prioritize low travel times to maximize time with family, but they do not need the flexibility that parents of small children might.

6. Conclusions

Overall, the present results agree with those of Wardman (2004): for inter-urban trips, the relative valuation of headway versus train IVT is higher for commuters than for non-commuters. In addition, differences in relative valuation were found between different socioeconomic groups. For example, young people under the age of 21 years assign a higher value to headway than do older people, and people with children value headway relatively less than do those without children. To achieve an efficient transport system, this difference in valuation should result in different prioritizations of headway versus in-vehicle time on different routes, to reflect their different traveller compositions.

It is estimated that a commuter values increased headway 19 percentage points more than does a non-commuter. Another important finding is that when people are asked to imagine that they are commuting, there is no measurable difference between those who actually commute and those who do not (but asked to imagine being commuters). This is an important methodological finding, as it strengthens the trustworthiness of findings based on hypothetical data.

In terms of practical applications, some advice could be given. When planning commuter trains, on which there are a large proportion of commuters, priority should be given to increase headway and thereby reduce waiting time compared to speed and travel time. On relations where a larger proportion of the travelers are non-commuters, travelling less frequently, speed is more important than headway. This might seem trivial; however there are a lot of occasions where there is a conflict of interest between long distance (faster) trains and short-distance commuter trains when track capacity is limited. In such cases it should be taken into account that it is important to maintain high frequency on the regional network and if necessary allow for fewer long distance trains as long as they are allowed to pass with high speed. This recommendation is further strengthened by the fact that the commuter trains, at least in Sweden, often have a large proportion of young passengers, who also was found to give a relatively high priority to frequency over speed.

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APPENDIX – Questionnaire translated from Swedish

QUESTIONNAIRE (Please fill out and return in the stamped addressed envelope)

Your travel habits by train

Do you commute (travel several days each week) by train?

- ☐ Yes
- ☐ No, not now, but I've done it before
- ☐ No, I've never done it

How often do you travel by train?

- ☐ I commute (see above)
- ☐ I do not commute, but travel by train about .... times per ....
- ☐ I never travel by train

Commuting by train: What do You prefer?

When traveling by rail, the frequency (how often the trains run) and travel time (how long the journey takes) can vary. Improvements for passengers when traveling by rail can be implemented in different ways. Investment and capacity expansion can either improve the frequency of service (trains run more frequently) or reduce travel time (the journey is faster).

Imagine you commute daily (travel every day from Monday to Friday) by train to your place of work, which is located 100 kilometres away. Even if you currently do not commute by train or do not work, we would like you to try to imagine yourself in this situation.

Below are nine questions with selection options. We ask you to select which of the two options (option 1 or option 2) you think is best in each of the nine questions. Everything but the service frequency and journey time is exactly the same in the two options. Your expenses for travel, the comfort of the train (e.g. how comfortable the seats on the train are and how much legroom there is), and punctuality (whether the train leaves and arrive on time) are the same. We therefore ask that, when making your choice, you only take into account differences in travel times and frequencies between the two alternatives described. The service frequency described means that there's a train going in both directions at the specified intervals. Travel time applies for a journey in one direction.

Place a check mark under the option you think is the better of the two described.

Question 1

	Alternative 1	**Alternative 2**
Travel time	60 min	75 min
Service frequency	A train every two hours 6.30, 8.30, … ,20.30, 22.30	One train per hour 6.30, 7.30, … , 21.30, 22.30
I prefer	☐	☐

Question 2

	Alternative 1	**Alternative 2**
Travel time	75 min	60 min
Service frequency	Two trains per hour 6.30, 7.00, … , 22.00, 22.30	A train every two hours 6.30, 8.30, … , 20.30, 22.30
I prefer	☐	☐

Question 3

	Alternative 1	**Alternative 2**
Travel time	75 min	45 min
Service frequency	One train per hour 6.30, 7.30, … , 21.30, 22.30	A train every two hours 6.30, 8.30, … , 20.30, 22.30
I prefer	☐	☐

Question 4

	Alternative 1	**Alternative 2**
Travel time	45 min	60 min
Service frequency	A train every two hours 6.30, 8.30, … , 20.30, 22.30	One train per hour 6.30, 7.30, … , 21.30, 22.30
I prefer	☐	☐

Question 5

	Alternative 1	**Alternative 2**
Travel time	75 min	45 min
Service frequency	Two trains per hour 6.30, 7.00, … , 22.00, 22.30	A train every two hours 6.30, 8.30, … , 20.30, 22.30
I prefer	☐	☐

Question 6

	Alternative 1	**Alternative 2**
Travel time	45 min	60 min
Service frequency	A train every two hours 6.30, 8.30, … , 20.30, 22.30	Two trains per hour 6.30, 7.00, … , 22.00, 22.30
I prefer	☐	☐

Question 7

	Alternative 1	**Alternative 2**
Travel time	75 min	45 min
Service frequency	Two trains per hour 6.30, 7.00, … , 22.00, 22.30	One train per hour 6.30, 7.30, … , 21.30, 22.30
I prefer	☐	☐

Question 8

	Alternative 1	**Alternative 2**
Travel time	60 min	75 min
Service frequency	One train per hour 6.30, 7.30, … , 21.30, 22.30	Two trains per hour 6.30, 7.00, … , 22.00, 22.30
I prefer	☐	☐

Question 9

	Alternative 1	**Alternative 2**
Travel time	60 min	45 min
Service frequency	Two trains per hour 6.30, 7.00, … , 22.00, 22.30	One train per hour 6.30, 7.30, … , 21.30, 22.30
I prefer	☐	☐

It is interesting to know whether different groups of people have different opinions. Therefore, we will also ask a few questions about you:

10. Where do you live?

☐ Right in the centre of the urban area
☐ Fairly centrally in the urban area
☐ On the outskirts of the urban area
☐ Outside the urban area

11. Do you currently commute by any mode of travel?

☐ Yes, by train (see above)
☐ Yes, by car
☐ Yes, by bus
☐ Yes, by other modes of transport, namely, ………………….
☐ No

If yes, how long is the trip?

………minutes each way

12. Do you have a car driving license? ☐ Yes ☐ No

13. Do you have access to a car for private use? ☐ Yes ☐ No

14. Are You: ☐ Male ☐ Female

15. Your age: .... years

16. In my household, besides myself there are (insert number)

…….. people aged 0–6 years ………people aged 7–17 years

...…… people aged 18 years or older

17. Approximately how much income does your household receive in total per month after taxes? Calculate total income in the form of student aid, wages, unemployment compensation, pension, maternity benefits, housing benefits, child benefits, social assistance, etc., after tax.

☐ SEK 0–4000
☐ SEK 4001–8000
☐ SEK 8001–12,000
☐ SEK 12,001–16,000
☐ SEK 16,001–20,000
☐ SEK 20,001–24,000
☐ SEK 24,001–28,000
☐ SEK 28,001–32,000
☐ SEK 32,001–36,000
☐ More than SEK 36,000

If there is anything you would like to add, you are welcome to do so below.

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

Thanks for your participation!