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Heufke Kantelaar, Martijn; Molin, Eric; Cats, Oded; Donners, Barth; Wee, Bert van

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Willingness to use night trains for long-distance travel

Martijn Heufke Kantelaar [a], Eric Molin [b], Oded Cats [c,*], Barth Donners [a], Bert van Wee [b]

[a] Royal HaskoningDHV, Laan 1914 no. 35, 3818 EX Amersfoort, the Netherlands
[b] Department of Engineering Systems and Services, Faculty of Technology, Policy and Management, Delft University of Technology, Jaffalaan 5, 2628 BX Delft, the Netherlands
[c] Department of Transport & Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, the Netherlands

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ABSTRACT

After several decades of decline, night train services have gained momentum in recent years. However, the willingness to use night trains as an alternative to airplane travel has so far received only limited research attention. This paper addresses this knowledge gap by presenting the results of a two-stage stated preferences survey comprising of a comfort rating experiment and a mode choice experiment, an approach that is based on Hierarchical Information Integration (HII) theory. Data are collected in 2019 from 804 travellers in the Netherlands. From these data, first, a multiple regression model is estimated which indicates which basic comfort variables influence perceived comfort. Second, a Panel Mixed Logit choice model is estimated which indicates how perceived comfort is traded-off against travel time and travel cost. We found that the level of comfort is an important determinant for traveling by night train, and in particular the number of persons a compartment is shared with, hence the 'privacy' aspect is important. The results can be used by rail operators to optimize the use of night train which may contribute to the substitution of air by rail travel for long-distance journeys in Europe and therefore contribute to a more sustainable transport system. Our study is also relevant for policy makers and employers because of the insights provided in these substitution factors, and because of the importance of this substitution for environmental and financial reasons.

1. Introduction

Night train services are available in many geographically large countries, including the United States, Canada, Russia, China, India, and Australia, as well as in countries such as Vietnam, the United Kingdom, and Sweden. Starting from the 1980s and until recently, international night train usage across much of Europe has declined. Davies Gleave et al. (2017) identified several reasons for this decline: high operating costs per passenger, more staff required for running overnight services and changing social norms, limited market awareness, competition from other modes (in particular low-cost airlines), and day-time high-speed services. These reasons are also partially echoed in the bottlenecks in European rail passenger transport investigated by Witlox et al. (2022). The authors identified four groups of bottlenecks pertaining to mobility services, transport services, traffic services and the physical and digital infrastructure, which are also relevant for the international night train context.

While some of the reasons that previously caused the decline of night train usage are still valid, night train services are being relaunched in the past few years in a revised form throughout Europe. New rolling stock is entering service to cater to the different social norms (i.e. private 'mini-suites'). Train companies are joining their efforts to operate under one 'NightJet' brand. Also in government the perception is changing: the European Environment Agency asserts that night trains could be an alternative to flying (European Environment Agency, 2018) and the Europe's Green Deal and the EU Year of Rail (2021) aim to promote the train for sustainable travel. It remains however unclear if and under which conditions people are willing to use night train for long-distance trips. Traveling by night train may be attractive since it offers the possibility of sleeping during the journey and arriving rested in the morning. Notwithstanding, the journey might take significantly longer than the same journey by plane.

The literature so far has given only limited attention to the extent travelers are willing to use night trains for long-distance travel. To the best of our knowledge, there is no single study in the international scientific literature concerned specifically with night trains. Consequently, while there is a large body of research concerning the key attributes of mode choice, the importance of various determinants in the context of

* Corresponding author.
E-mail address: O.Cats@tudelft.nl (O. Cats).

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Table 1
Overview of attributes varied in the comfort rating experiment.

Attribute	Explanation	Attribute levels
Accommodation type	The accommodation type (class) of traveling on the night train.	Sleeper, Couchette, or Seat
Number of people in the compartment	The total number of passengers in the shared compartment (either strangers or acquaintances of the respondent, open for interpretation by the respondent).	2, 4, or 6 (including respondent)
Lockable compartment	Reflects if the compartment can be locked, improving privacy.	Yes or No
Catering facilities	Indicates the availability of facilities to buy any food or drinks during the train journey. In a kiosk, travelers can buy snacks/light meals, in a restaurant car people have a place to sit down and have a more extensive meal.	None, Kiosk, or Restaurant car
Shower facilities	Reflects if it is possible to take a shower onboard the train.	Yes or No
Number of stops	Reflects the number of stops the night train makes between midnight and 6 am. Stopping, boarding, and alighting passengers may influence sleep quality and therefore 'perceived comfort' level.	0, 3, or 6 stops

long-distance travel and night train versus airplane remains hitherto largely unknown. Notwithstanding, there is however a growing body of knowledge on modal preferences for long-distance travel, in particular in relation to the competition between (high speed) trains and airplanes. Van Goeverden (2009) discussed the influence of background variables such as household, person, and journey characteristics on train choice of tourists. Behrens and Pels (2012) studies the Paris-London route and also concluded that the inter-modal competition depends largely on the trip purpose. Analyzing the competition between high-speed rail and air travel for the Barcelona-Madrid route, Roman et al. (2010) found that travel time, access and egress time, reliability, headway, and comfort are the most important service choice determinants. They also found that there is a significant interaction between the comfort level and the travel time parameter for the plane. A high comfort level reduces the effect of travel time for the plane by more than half, highlighting the importance of comfort. The ex-post review conducted by Givoni and Dobruszkes (2013) confirmed the role of comfort as the most important choice determinant after travel time. The effects of competition on service offering were investigated by several studies across Europe, all of which suggest that the supply of air services is affected by the introduction of high-speed rail alternatives (Dobruszkes et al., 2014, Clewlow et al., 2014, Jimenez and Betancor, 2012).

This paper contributes to the scientific literature by investigating the Willingness to Use night trains as an alternative to airplane travel for long-distance travel in Europe. We identify how the night train alternative is traded off against airplane alternatives through a mode choice Stated-Preference experiment. Because comfort has been indicated in earlier work as an important aspect in determining mode choice, we explicitly investigate its impact on night train choice. This is done by adopting a modeling approach that is based on Hierarchical Information Integration (HII) theory, which is explained in section 2.

The data were collected in the Netherlands in May 2019, hence, well before the COVID-19 pandemic crisis. Thus, results reflect the situation and opinion towards night trains before the pandemic. In total 804 surveys were completed, majority of which drawn from the Dutch Railways (NS) customer panel. It should be stressed that the NS panel is not confined to frequent train users.

The remainder of this paper is structured as follows. Section 2 presents the methodology and theoretical framework of the Stated-Preference experiments. Section 3 describes the results of the model estimation. Key findings, policy recommendations, limitations, and suggestions for further research are discussed in Section 4.

2. Methodology

As argued in the introduction, the level of comfort is expected to play a considerable role in night train choice. This expectation is grounded also in past empirical work on modal choice between (high-speed) rail and air travel (Román et al., 2010 and Givoni and Dobruszkes, 2013). In this study, we regard comfort not as a regular attribute such as time and cost that can directly be controlled (admittedly within limits) by a transport operator, but as a higher order attribute that potentially is influenced by many more basic attributes, which are under the direct control of an operator. Examples of such basic attributes would be accommodation type and the number of persons in a compartment. This conceptualization is based on the Hierarchical Information Integration (HII) theory (Louviere, 1984; for a review see Molin and Timmermans, 2009). In essence, this theory assumes that if a decision problem involves many attributes, not all attributes are traded-off against each other, but only attributes that belong together. To that effect, attributes are grouped into so-called (higher order) decision constructs and a separate experiment is constructed for each decision construct to examine to what extent its attributes affect its evaluation. On a higher level, the various construct evaluations are traded-off to arrive at a final decision. This decision is examined in a separate experiment. Evidence of the validity of this modeling approach is provided by Molin and Timmermans (2003).

The modeling approach applied in this paper follows a HII variant that is developed by Bos et al. (2004) and which is also applied in Molin et al. (2017). This variant involves that the final decision is not based on decision construct evaluations only, but that in transport decisions, the decision construct evaluations are traded-off with the basic transport attributes time and costs. As in Molin et al. (2017), in this study only a single decision construct is assumed, that is comfort, which is considered to be a perception variable whose score depends on the facilities/configurations of a particular night train car. Hence, to include such a perceived comfort variable in a choice model, we need to construct a second model that allows predicting its score for a particular night train configuration.

Hence, in this study, two separate experiments are constructed. The first experiment examines how the basic comfort attributes influence perceived comfort. This evaluation is measured on some measurement scale, hence, in the model estimated from this experiment perceived comfort is the dependent variable. In the second experiment perceived comfort is treated as an attribute and its levels correspond to the numbers used to capture the perceived comfort evaluation in the first experiment. This experiment is designed as a choice experiment that measures how perceived comfort is traded-off against travel time and travel costs. Both experiments are discussed in more detail in the next subsections.

2.1. The first experiment: Measuring perceived comfort

This experiment examines to what extent selected comfort determinants influence the 'perceived comfort' level of night train configurations. The attributes used in this experiment were obtained by first investigating the distinguishing characteristics of the main night train service available on the European market, i.e. the night train services offered under the brand name 'Nightjet' and operated by the national Austrian train operator, ÖBB. This was chosen as at the time of research, ÖBB had plans to operate a night service on the route Amsterdam – Vienna which was finally introduced in May 2021, therefore representing a potential real market choice.

In addition, three focus group meetings with students and experts from the field were organized to identify which attributes travelers considered important for night train comfort. In the experiment, we

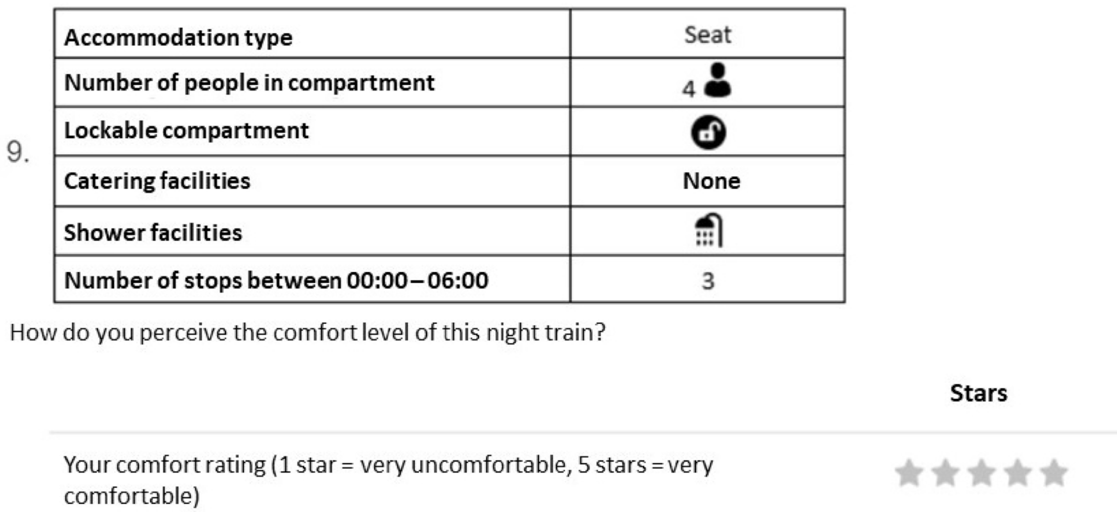

Fig. 1. Example of a comfort rating question.

Table 2
Attributes for the mode choice experiment.

Attribute	Explanation	Attribute levels
Night train travel time	This is the total in-vehicle travel time, which is based on the average distance (by rail) between Amsterdam and Vienna/Milan and varying the average speed.	11:45, 13:00 or 14:15.
Airplane travel time	Corresponds to the total travel time from arriving at the departure airport until arrival at the city center train station, including waiting time, in-flight time, transfer time at the airport, and time for the final trip leg into the city center.	05:00 or 05:30. The evening plane alternative fixed at 05:00.
Night train travel cost	One-way trip costs.	€40, €80, €120, €160
Airplane travel cost	One-way trip costs, including transfer to the city center. The evening plane is fixed to the middle level and an average cost of €120,- for a hotel night is added (PWC, 2016; 2018).	€60, €110, €160. The evening plane is fixed to €230.
Night train perceived comfort	This attribute represents the 'perceived comfort level'. Respondents have to imagine that this represents their perceived level of comfort for the particular night train vehicle they are traveling with.	1, 3, or 5 stars.

focused on the comfort aspects of the onboard experience and therefore disregarded aspects pertaining to the pre-trip experience that were mentioned in the focus groups such as information acquisition, booking system, and billing options. The selected list of attributes and their levels as varied in this experiment are shown in Table 1.

With the help of the Ngene software (ChoiceMetrics, 2018), an orthogonal fractional factorial design was constructed to arrive at 36 comfort profiles (basic comfort attribute combinations). To limit respondent fatigue, this was blocked into 6 blocks of 6 profiles each. Each respondent was randomly assigned to one of the 6 blocks. Each respondent was therefore requested to evaluate each of the six profiles in terms of comfort. Since quality of accommodations is often expressed in stars, and we assume that most respondents are familiar with such a quality representation, we decided to use a rating scale expressed in stars. For this we used a five-point rating scale, in which the end points were labeled as: 1 star = very uncomfortable and 5 stars = very comfortable. An example profile and the response scale is presented in Fig. 1.

2.2. *The second experiment: Measuring the trade-off among perceived comfort, time and costs*

The main goal of the second experiment is to examine how 'perceived comfort' is traded off against basic transport attributes such as travel time and travel costs. This study investigates choices made for trips of about 12–14 h, which resemble trips between Amsterdam and Vienna or Milan.

For this experiment, choice sets were constructed that each included a night train alternative and its most likely competitor, that is a morning plane alternative. Since also evening plane in combination with a hotel stay is a viable travel alternative, this option is added as a base alternative of which the attribute levels have fixed values thus do not vary. Literature research and properties of the envisaged case are used to come up with the attributes and their levels of the other two alternatives, which were verified in the same three focus group meetings that we mentioned before. Travel time and travel cost have been included by most studies analyzing long-distance travel (van Goeverden, 2009, Román et al., 2010, Dobruszkes et al., 2014) and comfort levels have been highlighted as an important choice determinant (Román et al., 2010; Givoni and Dobruszkes, 2013). In addition, an expert from Dutch Railways was consulted to ensure that ranges of attribute levels included in the experiment were realistic. The person responsible for the introduction of international trains at the Dutch Railways reviewed the draft attribute levels. Suggestions to adjust the arrival/departure time of the train in the choice set and broaden the price range were taken into account. Consequentially, it was chosen to use a night train price attribute with 4 levels. Table 2 presents the attributes and their levels. Note that levels of the comfort attribute are expressed in stars (end points and middle value), which corresponds with the response scale as applied in the first experiment. Respondents had to assume that the presented attribute level represented their own evaluation of a particular configuration of a night train service.

Respondents needed to assume that the night train and the airplane both left from Schiphol Airport, which in addition to a big international airport is also a major domestic train station/transfer hub serviced by international trains. Since the Dutch Railways are considering to reintroduce night train services, it is of interest to them to understand to what extent arrival times affect night train choice. To examine this, two different arrival times were varied as a context variable in the choice

47.

Characteristics	Night train	Morning plane	Plane + hotel
Check-in time train station/airport	17:45	02:30	17:30
Arrival time at destination train station	08:00	08:00	22:30
Your perceived comfort level	★	Economy Class	Economy Class
Total travel time, of which:	14:15	05:30	05:00
- Time before departure	00:10	02:00	02:00
- In vehicle time train/airplane	14:00	02:15	01:45
- Deboarding/transfer	00:05	00:45	00:45
- Airport transfer	-	00:30	00:30
Total costs, of which:	€160	€110	€230
- Ticket	€160	€100	€100
- Airport transfer	-	€10	€10
- Hotel	-	-	€120

Do you choose the night train or morning plane alternative?

◯ Night train

◯ Morning plane

48. Do you choose the previously selected alternative or do you travel by airplane the evening before, plus hotel stay?

◯ The previously selected alternative

◯ Evening plane, plus hotel stay

Fig. 2. Example of a mode choice question.

experiment: 08:00 and 10:00. Since catching an early morning flight means a very early trip to the airport, respondents had to assume that travel options that allows them to arrive on time are available. Additionally, they are told that they are traveling with hand luggage only.

In order to arrive at realistic alternative descriptions, the attribute levels for travel time and travel costs were presented to respondents broken down into sub-parts. However, only total costs and in-vehicle time were varied, while the other sub-parts were fixed. Recall that the evening plane alternative was set as the reference alternative, i.e. it has fixed attribute level values that are not varied in the choice sets. Note further that check-in time is not an attribute controlled by the experimental design, but derived by distracting the total travel time from the arrival time and only presented in the alternatives as a service to the respondents.

As prior values were not available in the literature, it was chosen to apply an orthogonal design to create the choice sets (e.g., Walker et al., 2018). The resulting survey was piloted among a small group of 15 test respondents. This resulted in various small changes in the wording of questions and introduction text. The orthogonal design resulted in 36 different choice sets, which we divided into six blocks of 6 choice sets each. Respondents were randomly assigned to two of these blocks, one for each of the two different arrival time context levels (08:00 and 10:00). This means that each respondent is requested to make 12 choices: six for early arrival time and six for late arrival time. In each choice set, respondents answered two questions. First, whether they preferred night train or morning train and then whether they preferred the chosen alternative or the base alternative *evening plane*. An example choice set including the two questions is provided in Fig. 2. Responses to both questions were combine, that is, choice for the evening plane in the second question over rules the choice in the first question.

2.3. Data collection and sample characteristics

The target population of the survey is defined as 'Dutch people who traveled outside the Benelux (Belgium, Netherlands, Luxembourg) countries in 2018′. This assures that respondents are familiar with traveling abroad and can imagine making a trip like the one described in the choice experiments.

Data were collected in May 2019 in various ways: most respondents were recruited by distributing the survey link through the Dutch Railways (NS) customer panel by handing out flyers at Schiphol Airport, and by distributing the link through social media. In total this resulted in 804 completely filled out questionnaires of which 666 from the Dutch Railways customer panel, 114 through social media and Royal HaskoningDHV, and 23 from Schiphol airport. All respondents participated in both experiments. Table 3 provides information about the distribution of the background variables in the sample.

The sample consists of a high percentage (80.7 %) of people holding a bachelor's degree or higher. Almost half of the sample is a regular train traveler (47.6 % more than one day a week), an expected result given the distribution of the survey via the Dutch Railways panel. Teenagers (<20 years old) are almost absent, as they were not targeted. 61.6 % of the sample has traveled by international train in the preceding 2 years, while 80.1 % traveled by plane in the same period. Given most respondents are recruited via the Dutch Railways panel, it is likely that the sample is somewhat more in favor of traveling by train compared to the population 'Dutch people traveling abroad', although it is not clear to what extent this affects preference for night train. Nevertheless, it is best to consider this a convenience sample, which is elaborated upon in the discussion section.

Table 3
Distribution of background variables in the sample.

Background variable	Category	Percentage
Gender	Female	43.9
	Male	56.1
Highest attained education level	Pre-vocational education	2.9
	Vocational education	16.4
	Bachelor's degree	39.8
	Master's degree or higher	40.9
Age (years)	17–19	1.1
	20–39	24.6
	40–64	43.2
	65–79	30.3
	80+	0.7
Annual disposable income (Euros)	<10.000	11.9
	10.000–20.000	9.6
	20.000–30.000	18.1
	30.000–40.000	24.7
	40.000–50.000	12.7
	50.000–100.000	19.7
	>100.000	3.3
International plane travel past 2 years	0 times	17.9
	1 time	19.7
	2–3 times	30.8
	4–5 times	16.0
	6–10 times	10.1
	>10 times	5.5
Train travel frequency	Never	0.2
	<1 day a year	1.0
	6–11 days a year	17.7
	1–3 days a month	28.7
	1–3 days a week	25.5
	4 or more days a week	22.1
Employment status	Student	11.9
	Part-time worker	18.9
	Full-time worker	38.4
	Retired	28.6
	Unemployed	2.2
International train travel past 2 years	0 times	38.4
	1 time	21.9
	2–3 times	22.3
	4–5 times	9.5
	6–10 times	4.5
	>10 times	3.5

Table 4
Applied effects coding.

Variable	Parameter	Level	Effects coding	
Accommodation	Sleeper/ Couchette		Sleeper	Couchette
		Sleeper	1	0
		Couchette	0	1
		Seat	−1	−1
Catering facilities	Restaurant/ Kiosk		Restaurant	Kiosk
		Restaurant	1	0
		Kiosk	0	1
		None	−1	−1
Shower	Shower	Yes	1	
		No	−1	
Lock	Lock	Yes	1	
		No	−1	
Gender	Gender	Female	1	
		Else (Male/ Unknown)	−1	
Education	HighEdu	Bachelor or higher	1	
		Else	−1	
Income	HighIncome	High disposable income (>€40.000/year)	1	
		Else	−1	
Arrival time	Arrival time	08:00	−1	
		10:00	1	
Frequent train user	FreqTrain	Yes (>once per week)	1	
		No	−1	
Employment status	Student/ Retired		Student	Retired
		Student	1	0
		Retired	0	1
		Else	−1	−1
Purpose	Purpose	Business	1	
		Leisure	−1	

Table 5
Parameter estimations of perceived comfort model.

Parameter	**Estimate**	***t*-value**	***p* value**
Constant	4.086	61.321	<0.001
Accommodation			
- Sleeper	0.722	11.083	<0.001
- Couchette	0.285	4.276	<0.001
- *Seat*	*−1.007*		
Number of People	−0.253	−26.966	<0.001
Possibility to lock compartment	0.163	10.962	<0.001
Catering facilities			
- Restaurant car	0.148	6.810	<0.001
- Kiosk	0.116	5.532	<0.001
- *None*	*−0.246*		
Possibility to shower	0.127	8.374	<0.001
Number of stops	−0.070	−11.560	<0.001
High Income	−0.110	−6.530	<0.001
Frequent train traveler	−0.034	−2.104	0.035
Age	−0.003	−2.845	0.004
Sleeper * Age	−0.006	−5.506	<0.001
Couchette * Age	−0.003	−2.456	0.014
Education * Number of People	−0.012	−2.934	0.003
Sample size 804			
Observations 4824			
R-squared 0.286			

2.4. Model estimation

2.4.1. Perceived comfort model

In the comfort rating experiment, respondents were requested to rate their 'perceived comfort' of each presented night train configuration on a 5-star rating scale (see Fig. 1). As discussed earlier, stars were used to capture the respondent's position on the perceived comfort continuum. In the following, we assume that measurement to be of interval level, i.e. differences between any two consecutive stars are regarded to be equal by respondents.

The main motivation for this interval level assumption stems from the treatment of perceived comfort in the choice model and we have to be consistent between the models estimated from both experiments. Recall that the perceived comfort attribute in the choice experiment is varied in the levels 1, 3 and 5 stars. This attribute is assumed to have interval measurement level, which warrants estimating a continuous function that allows to interpolate results and determine the impact of the two not included levels, 2 and 4, or any real number between 1 and 5. Conversely, if we were to treat perceived comfort as ordinal, this would require estimating two dummy variables that would not allow for interpolation. More generally, the implication of assuming ordinal level for other applications of this methodology would be that then any number of the applied scale in the first experiment would needed to be included as a level in the second experiment. Hence, suppose a 10-point rating scale would be used as a response scale in the first experiment, this would involve varying 10 levels for the corresponding attribute in the choice experiment, which consequently needed to be represented with 9 dummy variables in the choice model. Such an approach would not result in a very efficient design nor in parsimonious model. Moreover, breaking down an effect in too many dummy variables results in a loss of statistical power and increases the risk of failing to find statistically significant relations with background variables and therefore would have the risk of drawing erroneous conclusions. Thus, in order to be able to estimate powerful parsimonious models, we assume that

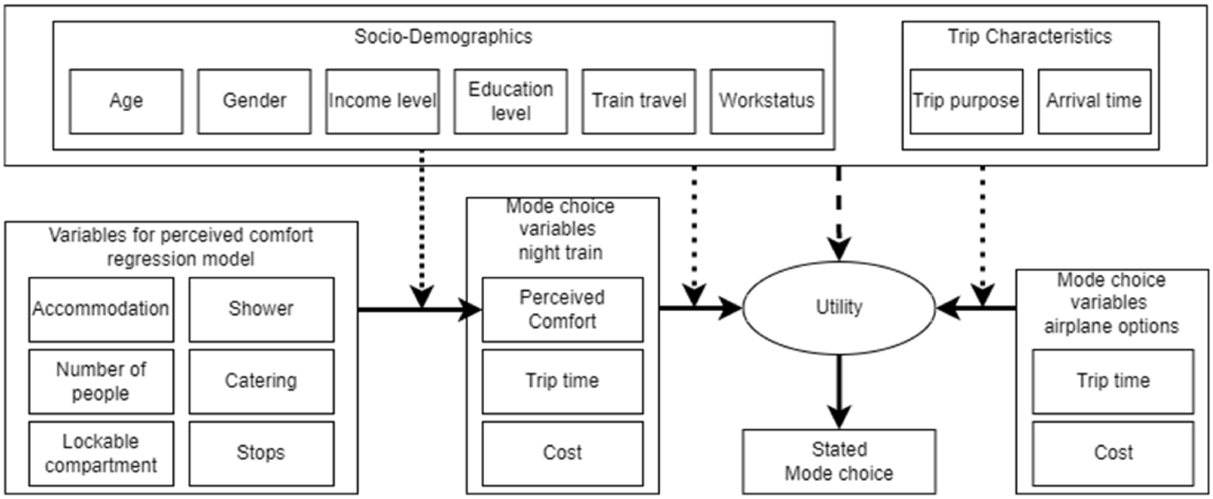

Fig. 3. An overview of model structure.

Table 6
Parameter estimates of the Panel Mixed Logit models.

	Night train			Morning plane		
	est.	*t*-value	p value	est.	*t*-value	p value
ASC (Alternative Specific Constant)	4.17**	5.86	<0.001	3.19**	7.56	<0.001
travel costs (per 100 euro)	−0.962**	−13.6	<0.001	−1.19**	−12.1	<0.001
travel costs * purpose	0.214**	3.05	0.002	0.153	1.58	0.115
travel time (per 5 h)	−0.651**	−5.05	<0.001	−1.45*	−2.41	0.016
comfort	1.44**	21.2	<0.001			
comfort*purpose	0.242**	3.64	0.002			
sigma comfort	−0.978**	−20.8	<0.001			
arrival time	−0.0717	−1.88	0.061	0.108*	2.43	0.015
gender	0.429**	3.48	<0.001	0.616**	4.35	<0.001
high education	−0.184	−1.24	0.216	−0.436**	−2.56	0.010
high income	−0.151**	−4.09	<0.001			
purpose	−1.63**	−7.26	<0.001	−1.41**	−6.04	<0.001
frequent train traveler				−0.708**	−4.33	<0.001
student	−0.265**	−4.89	<0.001			
age				−0.0256**	−10.00	<0.001
error component_morning	4.58**	24.6				
Parameters		24				
Sample size		804				
Observations		9648				
Initial log-likelihood		−10599.41				
Final log-likelihood		−6550.74				
McFadden rho squared		0.382				
AIC (Akaike Information Criterion)		13149.47				
BIC (Bayes Information Criterion)		13262.02				

perceived comfort is of interval level measurement.

We also test empirically for the validity of our assumption by estimating also an ordinal regression model and comparing it to the results of our linear regression model, details of which are provided in the appendix. We find that the ordinal and linear regression models yield similar estimates, while the predictions based on the linear regression model fit the data better than those based on the ordinal regression model. This offers empirical evidence in support of our assumption that the respondents regarded the differences between consecutive stars as equal across the entire scale.

A multiple regression model is therefore used to analyze the results of the comfort rating experiment. Effects coding is used to include categorical attributes, the coding of which is shown in Table 4. We explored to what extent the background variables that are included in Table 3 either directly affected the perceived comfort evaluation or interacted with the attributes. For reasons of parsimony, background variable parameters were removed if not significant at 95 % reliability level. The estimates are presented in Table 5 and interpreted in the results section.

2.4.2. *Mode choice model*

From the choices observed in the choice experiment, a Panel Mixed Logit model is estimated for which we applied PandasBiogeme (Bierlaire, 2018). Recall that this experiment varied attributes for night train and morning plane, while evening plane functioned as a base alternative of which the utility is fixed to 0. Categorical variables are included using effects coding, which is shown in Table 4. In the same fashion as in the perceived comfort regression model, the effects of background variables are explored as main effects and interaction effects with the attributes. In principle, all effects that are statistically significant at the conventional 95 % reliability level are kept in the model and otherwise removed from the model. In addition, the main effects and interaction effects of arrival time (AT) were explored: recall that this context variable was varied in two levels (08:00 and 10:00).

It is hypothesized that the utility contribution of an additional comfort star decreases with increasing comfort level, i.e. the utility contribution of upgrading from 1 to 2 stars is larger than the utility contribution of upgrading from 4 to 5 stars. This decreasing marginal utility of upgrading to a higher comfort level can be modeled by adding a quadratic component to the utility function. For reasons of parsimony, we estimated a single parameter for the natural logarithm of comfort instead, which gives exactly the same utility contributions for each comfort level and these loglikelihood values for the estimated model, but with one parameter less.

Furthermore, we explored whether alternatives share unobserved factors by adding additional error components to the model. We tested for different nests that were formed by mode type (both airplane alternatives), alternatives that departure in the evening (night train and evening plane) and the alternatives that both arrive in the morning (night train and morning plane). Only the latter error component turned out to be statistically significant. Hence, an additional error component ($\sigma_{Morning}$), assumed to be normally distributed with a mean of 0, was included in the final model. The final Panel Mixed Logit model was estimated with 800 Halton5-draws from a normal distribution. Fig. 3 summarizes the studied variables and their assumed relationships, which formed the bases of our analysis.

3. Results

3.1. Perceived comfort model

Table 5 shows the parameter estimates for the multiple regression model of the comfort rating experiment. All comfort attributes included in the experiment are found to be statistically significant at the conventional 95 % reliability level and all have the expected sign. The R-square of the model is 0.286, which is relatively low and indicates there is considerable heterogeneity in the observed rating scores which is not captured by the model. Arguably, heterogeneity may be attributed to a variety of explanatory factors which we did not take into account in our study, such as differences in assumed travel circumstances by different respondents (e.g. travel company: alone or with co-travelers, with kids), differences in perceptions about night train attributes we did not vary in our experiment, such as inside climate (availability of heating and/or air conditioning) and Wi-Fi access (Molin et al. 2020), and different perceptions of traveling by night train in general (ease-of-sleeping, health and hygienic considerations) (Shelat et al. 2021).

The ‘Number of People’ in the compartment has a strong effect on the perceived comfort rating. The difference between sharing with 2 and 6 persons is about 1 star (=4*0,252). It reflects that people dislike sharing their accommodation on a night train with other persons. Interactions with background variables shows that this effect is stronger for people who are highly educated.

Another important determinant is the comfort class. ‘sleeper’ is valued highest (0,722) and ‘Couchette’ class (0,285) is valued about half a rating star lower. The ‘seat’ accommodation (-1.007) is valued a full star lower than the mean of accommodation type (which is 0 by definition for all effects coded variables) and about 1,7 stars lower than ‘sleeper’.

People do value a non-stop sleeper train: decreasing the number of stops from 6 to 0 increases the comfort rating by almost half a star (6*0.070 = 0.420).

Providing the option to get food or beverages onboard the train increases comfort. However, the difference between the ‘restaurant car’ (0.148) and ‘kiosk’ (0.116) is relatively small, i.e. people see little added value in upgraded food facilities.

Including background variables in the model provides insight into the extent to which comfort rating differs between several user groups. We find that on average older people give a lower comfort rating to the night train (−0.003*age; hence, a person aged 20 gives on average a 0.15 higher comfort rating than a person aged 70). Additionally, interaction effects between age and accommodation type show that with increasing age the perceived increase in the comfort level of the sleeper (−0.006 per year) and couchette (−0.003 per year) accommodation type declines. This also means that with increasing age, the difference between seated accommodation and couchette declines. People with a high disposable income on average give the night train a lower comfort rating. While the survey has not inquired about respondents attitudes’, it is possible that some of the relations observed are cofounded by attitudes that correlate with socio-demographic variables that are relevant for the perception of night train attractiveness as an alternative mode of long-distance transport (e.g. environmental awareness).

An unexpected result is that the parameter indicating whether someone is a frequent train traveler in daily life is negative, i.e. frequent travelers on average award the night train a lower comfort rating. An explanation might be that frequent train travelers unintentionally retrieve their commuter train experience, which is, in general, less comfortable than a night train, to imagine the night train travel experience, resulting in a lower comfort rating. This result also suggests that our sample that is mostly recruited from frequent train travelers does perceive night train to be more comfortable as earlier expected.

3.2. Mode choice experiment

Table 6 shows the parameter estimates for the Panel Mixed Logit model. All main parameters have the expected sign. In the following we first discuss the estimation results for the alternative-specific attributes followed by the individual-specific attributes.

3.2.1. Alternative-specific attributes

The comfort attribute in the natural logarithm form reflects the decreasing marginal utility with higher comfort levels. Meaning the utility difference between 4 and 5 stars is, as hypothesized, smaller than the difference between 1 and 2 stars. This concurs with our expectation that satisfying a basic level of comfort is more important than improving an already good level of comfort. Sigma comfort (=−0.978; note that the minus sign should be ignored), which is the standard deviation of assumed normal distribution of the comfort parameter, indicates that there is a significant amount of unobserved taste heterogeneity for the comfort parameter. In addition, the interaction with the travel purpose (0.242) is statistically significant and positive, indicating that comfort matters more for business travelers than for leisure travelers.

The cost parameter of morning plane (−1.19) has slightly higher value than that of nigh train (−0.961), suggesting a somewhat higher price sensitivity to plane compared to night train. The positive parameter for the interaction between purpose and travel costs (0.214) indicates that business travelers are somewhat less sensitive to cost than leisure travelers. This is a well-known effect as costs of business travel are often either paid for or reimbursed by the employer (e.g. Buehler, 2011; Román et al., 2010). A similar effect is found for morning plane (0.153), however this effect is smaller and not statistically significant at the conventional 95 % reliability level.

The travel time parameter of night train (−0.651) has a considerably smaller value than that of morning plain (−1.45), indicating that travelers are less sensitive to travel time changes in night train compared to plane.

The parameters estimated for arrival time (AT) indicate to what extent utility increases if arrival time is 10:00. The negative AT parameter for night train (−0.0717) suggests that the 10:00 arrival time slightly decreases its utility and consequently the early arrival time of 8:00 slightly increases its utility. The effect is reversed and somewhat stronger for morning plane (0.108). Morning plane becomes a bit more attractive when the arrival time is 10:00 and less attractive when the arrival is 8:00.

Interestingly, we find that choices for the two alternatives that lead to arriving in the morning - night train and morning plane are correlated rather than alternatives that involve using the same travel mode (i.e. the two plane alternatives, evening and morning). The significant and relatively high value of the related error component (4.58) suggests that respondents clearly either like arriving in the morning with either night train or morning plane of prefer traveling by evening plane in combination with staying in a hotel.

3.2.2. Individual-specific attributes

Background variables show that the travel purpose has a very strong effect on the utility of the different modes. Business travelers prefer less the morning plane (−1.41) and even more so night train (−1.63); hence, they clearly have a much higher preference for evening plane and staying in a hotel than leisure travelers, probably because being more rested is more important to them and also because the additional hotel costs are probably covered by their employer.

While past studies report that women are more reluctant to travel by public transport during the night (D'Arbois De Jubainville and Vanier 2017), this effect could not be found in this study; being a woman even contributes positively to the utility of both night train (0.429) and morning plane (0.616). With increasing age, there is a growing disutility for morning plane. In other words, preference for either the night train or the evening plane increases.

Highly educated people prefer evening plane over morning plane (−0.436) and also over night train (−0.184), although the latter effect is not statistically significant at the conventional 95 % reliability level. Hence, the latter result does not confirm the finding of earlier research that highly educated people choose the train more often in the Netherlands (as implied by the composition of the sample reported in Ton et al. 2022). Being a student (−0.265) or having a high income (−0.151), results in disutility for night train.

Finally, we are interested in the effect of train use frequency on respondents' choices. Notably, the results do not indicate that frequent travelers prefer night train over evening plane more than the non-frequent travelers do. Notwithstanding, frequent train travelers prefer less the morning plane (−0.708). Given that frequent train travelers are likely over represented in our sample, our model will probably underestimate the share of morning plane (but not the evening one) compared to night train if our model would be applied to predict market shares.

3.3. Societal implications of estimated models

Our findings can support train manufacturers and service providers in designing the comfort level of a night train service. Examples of such choices include setting the number of people in different accommodation types and including catering facilities. Up to now, there has been no scientific evidence regarding choice determinants and comfort ratings among potential travelers.

The results of the comfort rating experiment show that the privacy aspect is very important for people. Combining the estimations from the comfort rating model leads to the conclusion that a night train with basic facilities (i.e. no shower, no food/beverages) but with more private compartments (2 people), has a higher comfort rating than a night train that does have these facilities but with shared compartments with 6 people.

Simulations using the estimated Panel Mixed Logit model show the effect of varying the comfort level on the mode choice. When the comfort level is increased from 1 to 5 stars, keeping the other attributes fixed at the middle level (or 2nd level in case of 4 levels), the estimated night train market potential increases by 30 percentage points, from 41.0 % to 70.9 %. These bounds are for a night train trip that takes 13 h as opposed to a train trip of 5 h, and trip costs of € 80 by night train as opposed to € 100–110 with the morning plane and € 230 with the evening plane. The lower and upper bounds correspond to the cases in which the night train has 1 and 5 comfort stars, respectively. These results are only valid for this sample and under these specific choice conditions.

Reducing the travel time of the night train by up to 2.5 h has a relatively minor effect, ceteris paribus, of only a 5 % increase in the estimated market potential. We, therefore, suggest prioritizing investments in comfortable train designs (e.g. interior, layout, facilities, privacy). While in public debates it has often been argued that the night train may compete with low-cost flights (e.g. Airport Watch, 2019), our model suggests that when comfort and price are reduced to levels comparable with low-cost carriers, the estimated market potential plummets by 20 percentage points. The night train appears thus to cater to travelers who are willing to spend a bit more on travel comfort.

4. Discussion and conclusion

This study estimates the Willingness to Use night trains for long-distance travel, as an alternative to flying. This study integrates information from two Stated-Preference experiments: a comfort rating and a mode choice experiment. In total 804 complete surveys were collected in May 2019 from a convenience sample and used to estimate a Panel Mixed Logit model.

The comfort level was found to be an important determinant of the mode choice alongside travel cost and travel time. These findings are in line with those reported in other studies focusing on long-distance travel (Román et al., 2010, Givoni and Dobruszkes, 2013). The travel time parameter of the night train is lower in (absolute) magnitude (factor 2.2) than of the morning plane, meaning that travelers are less sensitive to travel time changes for the night train than for the morning plane. Traveling for business brings along a strong dislike for both the morning plane and night train alternatives: business travelers prefer traveling the day before and staying in a hotel. This is expected as business travelers are more sensitive to potential schedule delays and have a lower price sensitivity (e.g. Proussaloglou and Koppelman, 1999). Given that one arrives early in the morning (i.e. 08:00) there is a slight preference for traveling by night train compared to flying in the early morning. If the arrival time is later in the morning (10:00) then there is a reverse preference which is slightly stronger, i.e. the morning plane is preferred over the night train. Frequent train travelers have a preference for either the evening plane or the night train and are less likely to choose the morning plane.

The comfort level of the night train itself is most heavily influenced by the number of people a traveler has to share the accommodation with. A basic night train with no facilities with more private accommodation for two people would attain a higher comfort rating than a night train with several facilities (such as showers and a restaurant car) but with accommodation for six people. Our model application results suggest that when comfort and price are reduced to match low-cost flights, the estimated market share of the night train alternative is sharply reduced.

In our convenience sample, frequent train travelers are likely over-represented. The results mainly indicate a dislike of this group for morning train, however, this group does not have a stronger preference for night train over evening plane. Our findings further suggest that frequent train travelers are not overly positive towards the night train. They on average award the night train with a lower comfort score than their counterparts. Furthermore, in our opinion, the prime market for night trains are consumers that already have gained experience with train usage. These results suggest that he overall bias due to the over representation of the frequent train travelers is rather limited.

Our research findings lead to recommendations for train operators and policymakers. Our findings indicate that people seem to be especially sensitive to the number of people in shared accommodation. Therefore, train operators could consider introducing more private compartments to attract more travelers. Furthermore, to better cater to the needs of the business traveler they might want to further study the requirements of this user group and introduce a suitable product offering. Leisure travelers seem to be willing to use the night train and exhibit lesser concerns about shared accommodation. Therefore, it is recommended for night train operator to team up with travel agencies to offer city trips including the night train, increase awareness to their services and making it easier for travelers to opt for this alternative (e.g. through their inclusion in online travel information and ticket purchasing platforms). Our research is also relevant for policy makers and employers because of the insights provided in substitution factors. Policy makers can include these insights in negotiations and contracts with train operators, especially if they receive subsidies. Employers can use these insights in developing policies that reduce flying of employees. Future research may identify the user segments that are more willing to accept shared spaces or that are interested in travelling in groups (couples, families, friends) and tailor offers for travel parties. Finally, the possibility to perform a range of activities on-board is a potential key factor in attracting prospective travelers. This is expected to be an even more important factor than the findings reported by Molin et al. (2020) for short- and mid-distance train travel. Malichova et al. (2022) found that people who traveled by train for their long-distance trips were almost three times more likeley to view their trip as worthwhile than those who did so by car or plane. Their findings indicate that enjoyment during long-distance travel is of prime importance for users of all travel modes and regardless of the trip purpose.

This study applied the Hierarchical Information Integration modeling approach to address the problem that many attributes play a role in the decision to use night train. We modeled this as a two-stage process in which we first examined how basic comfort attributes like accommodation type, the number of people and number of stops, the possibility to lock the compartment, catering, and shower influence the perceived level of comfort. Then we examined how comfort is traded-off against travel time and travel costs to arrive at util overall utility derived from night train. Hence, under this modeling approach the basic comfort attributes are not directly traded-off against travel costs and time, but rather indirectly via the comfort evaluation. This raises the question of whether the same results would have been found if instead of this two-stage modeling approach all comfort attributes varied in the comfort rating experiment would have been included in the choice experiment. This could be tested in follow-up research, however, in case the results of both approaches would differ, it would not be clear which of the two approaches would be more valid. The reason is that if the same attributes would be used as selected in this study, this would involve varying eight attributes in the choice experiment and many researchers warn against including more than seven attributes in a choice experiment because many people can only process a maximum of seven elements in their working memory, hence, the validity of an experiment including many attributes can be questioned. Obviously, such a model comparison approach requires some external validation criterion, that is real-world behavior. Hence, such a study could be planned right before a new service is introduced. Furthermore, such a study would offer possibilities to combine Revealed-Preference with Stated-Preference data to calibrate the choice model.

This study found that the number of persons in a compartment is the most important comfort attribute. However, it is likely that this attribute is valued differently depending on the travel party. For example, if one travels alone, a 6-person compartment is probably considered as not very attractive, while if one travels as part of a travel party, this may be less of a problem. This issue can be taken into account in follow-up research by conducting a context-dependent experiment (e.g. Bos et al., 2004). Adopting such an approach implies that the experiment is extended by constructing different context profiles that vary travel circumstances such as travel party and travel purpose. The constructed choice sets then need to be nested under these context profiles in a balanced way. This allows estimating interaction effects of context variables with choice alternative attributes that indicate to what extent attributes have different impacts under different travel circumstances. Furthermore, further research may explore the effect of reliability which has been found in past studies to be a relevant factor for mode choice, especially in relation to transfers (e.g. Román et al., 2010) for long-distance travel. The impact of individual travel time components, i.e. waiting time, access time, in-vehicle time, and egress time, on travelers' choice between night train and morning plane can additionally be studied. We hope that our findings can support market positioning and the further development of attractive and viable night train services which operate in a difficult business environment.

CRediT authorship contribution statement

Martijn Heufke Kantelaar: Data curation, Formal analysis, Investigation, Writing – original draft. **Eric Molin:** Conceptualization, Supervision, Writing – review & editing. **Oded Cats:** Conceptualization, Supervision, Writing – review & editing. **Barth Donners:** Supervision. **Bert van Wee:** Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix:. Ordinal or interval?

An ongoing debate among researchers is about the level of measurement of response scales like the one used in this paper. In the comfort rating experiment, we used a five-point scale to administer the respondents' evaluations of each of the presented night train configurations. The scale ranges from (1) very uncomfortable to (5) very comfortable. We assume these responses to be of interval measurement level, while other researchers may consider this to be of ordinal measurement level. Consequently, we believe that these responses can be analyzed by means of a linear regression analysis, while others believe an ordinal regression model should be estimated. If the scale is ordinal like some researchers argue, then an ordinal regression model would result in substantially different estimates than a linear regression model.

Table A1
Coefficients of the linear regression model.

	B	Std. Error	*t*-value	p-value
(Constant)	3.999	0.044	90.949	0.000
Accom1	0.380	0.021	17.716	0.000
Accom2	0.133	0.022	6.147	0.000
People	−0.261	0.009	−28.376	0.000
Lock	0.160	0.015	10.629	0.000
Catering1	0.149	0.022	6.769	0.000
Catering2	0.115	0.021	5.376	0.000
Shower	0.128	0.015	8.287	0.000
Stops	−0.070	0.006	−11.429	0.000

Table A2
Coefficients of the ordinal regression model.

Treshold	B	Std. Error	Wald	p-value
[Stars = 1]	−3.941	0.233	284.935	0.000
[Stars = 2]	−2.489	0.210	140.020	0.000
[Stars = 3]	−1.057	0.194	29.711	0.000
[Stars = 4]	0.740	0.205	13.054	0.000
Accom1	0.629	0.094	45.137	0.000
Accom2	0.259	0.093	7.743	0.005
People	−0.448	0.042	114.920	0.000
Lock	0.282	0.065	19.035	0.000
Catering1	0.263	0.094	7.827	0.005
Catering2	0.181	0.092	3.900	0.048
Shower	0.225	0.066	11.624	0.001
Stops	−0.120	0.026	20.475	0.000

Table A3
Rescaling the 'Interval coefficients'.

attributes	'Ordinal Coefficients'	'Interval Coefficients'	factor (ordinal/ interval)	'Interval Coefficients' rescaled
Accom1	0.63	0.38	1.66	0.66
Accom2	0.26	0.13	2.00	0.23
People	−0.45	−0.26	1.73	−0.45
Lock	0.28	0.16	1.75	0.28
Catering1	0.26	0.15	1.73	0.26
Catering2	0.18	0.12	1.50	0.21
Shower	0.23	0.13	1.77	0.23
Stops	−0.12	−0.07	1.71	−0.12
average factor			1.73	

Table A4
Correlations (N = 804).

	pred_interval	pred_interval_rnd	pred_ordinal	comfort_rating
pred_interval	1	0.887	0.943	0.513
pred_interval_rnd	0.887	1	0.863	0.479
pred_ordinal	0.943	0.863	1	0.473
comfort_rating	0.513	0.479	0.473	1

Moreover, the ordinal regression model would then better fit the data. In the following, we compare the estimates of both models and their fit to the data. In order to have a clean comparison and to keep things simple, we only include the attributes as predictor variables to explain the observed comfort ratings (Table A1. Table A2).

Obviously, the magnitudes of the coefficients differ between both models because these are expressed on different scales. Table A3 indicates that on average the coefficients of the ordinal regression model are a factor 1.73 bigger than the coefficients of the linear regression model. If we rescale the parameters of the linear regression model with this average factor of 1.73, then it becomes clear that the estimates of the ordinal regression model and the estimates of the interval model are very close to each other. What is more, if the correlation between the estimates of both models is calculated, this turns out to be a 0.999. This is a staggering high value, which corroborates the similarity between the estimates of both models. Hence, that both models produce similar results means that respondents consider the difference between consecutive stars as equal across the entire scale. Or in other words, the observations have interval level measurement.

To examine whether the ordinal regression model better fits the data than the linear regression, we predicted the observed scores for the 36 night train profiles we presented to respondents in the comfort rating experiment by both models The correlation table, Table A4, shows that the predictions based on the linear regression model (pred_interval) have a higher correlation with the observed comfort ratings than the predictions based on the ordinal regression model (pred_ordinal). Even if the regression model predictions are rounded to the nearest integer value (pred_interval_rnd), the predictions of the regression model remain better (though the difference is very small). Hence, these results suggest that the linear regression model better fits the data, despite having 3 fewer parameters (only 1 constant instead of 4 thresholds). Hence, should the choice model be applied for forecasting, the regression model will better predict the scores for a particular night train configuration, which then serves as the value for the comfort attribute.

To summarize, the coefficients of the ordinal and linear regression models produce virtually the same coefficients (up to a scale factor), while the predictions based on the linear regression model fit the data better than those based on the ordinal regression model. These results suggest that the linear regression model is the better model, which gives empirical evidence for our assumption that the respondents regarded the differences between consecutive stars as equal across the entire scale. To conclude, we believe that our assumption that the applied measurement in the comfort rating experiment is of interval measurement level is valid.

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