A novel representation of the noise attribute for discrete choice valuations of aircraft noise

Florian Kindermann[1]

[1] formlery WHU – Otto Beisheim School of Management, Vallendar, Germany

Corresponding author's e-mail address: Florian.Kindermann@whu.edu

ABSTRACT

We contribute to existing aircraft noise valuation research by developing a new attribute for noise representation in Discrete Choice Experiments on aircraft noise. Most previous studies place significant cognitive burden on participants by using fictional noise exposure scenarios to choose from. We exploit the differences in noise characteristics of departing and landing aircrafts and let participants choose between exclusively experiencing either scenario. Both scenarios have been experienced by participants in the weeks before the survey and potentially allow for a less abstract representation of the noise attribute in the experiment. On an individual level, we find a Willingness to pay for either landing or departing aircrafts. Although we could not find a collective preference for either landing or departing aircrafts, our findings imply the practicality of using those two scenarios as a representation of the noise attribute in future Choice Experiments to minimize cognitive burden.

INTRODUCTION

Most Stated Preference (SP) research dealing with aircraft noise valuation faces one common problem: abstract noise attribute representation presumably increases cognitive burden on participants. Asking Participants to choose from multiple scenarios that incorporate noise attribute levels such as “50% fewer planes” or “twice as many large planes” is subject to interpretation by the respondent. The more complex a choice exercise gets, the harder it becomes for participants to follow through and the more likely they drop out or make inconsistent choices [1,2]. This behavior leads to higher error variances in the results and thus to less satisfying statistical conclusions. Our objective is to find a noise attribute that is more easily understood by participants and leaves less room for individual interpretation. Finding such attribute, we suspect, increases the quality of SP experiments in the context of aircraft noise research.

We first briefly review existing literature (as of early 2019) on SP research on aircraft noise valuation. We then develop our own questionnaire for a Discrete Choice Experiment (DCE) with a novel noise attribute to capture Willingness to Pay (WTP) for a change in aircraft noise exposure. We conclude by discussing the WTP as well as our methodology in the context of existing SP aircraft noise valuation research.

LITERATURE REVIEW

Most existing research on SP aircraft noise valuation uses noise attributes that are relatively abstract and presumably require substantial cognitive effort. Two studies that came to our attention used a different approach, basing the noise attribute on actually experienced noise exposure scenarios:

Duarte [3] used a contingent valuation approach to elicit WTP for noise reductions at Barcelona's El Prat airport. In the experiment, Duarte claimed that noise can be reduced to levels prior to an airport expansion that had happened before the survey. The alternative to the status quo is hence represented by noise levels that residents have experienced.

Thanos, Wardman and Bristow [4] conducted choice experiments at two locations in Athens: two residential areas next to the city's old and new airport. The noise attribute had two levels, aircraft noise and no aircraft noise. Both noise exposure scenarios have been experienced by all respondents. The airport had been moved from an old location to a new one outside the city prior to the survey. Residents living in the old airport's vicinity have experienced aircraft noise prior to the study and its absence at the time of the study. Residents living close to the new airport have made the experience in reverse order.

Although both experiments benefit from a potentially reduced cognitive burden, they exploit scenarios that cannot be easily repeated in future research. Hence, our goal is to find a noise attribute that, first potentially reduces cognitive burden such as in the two experiments discussed above, and second is easy to replicate even without an airport expansion / closing.

SURVEY DESIGN

We conduct two Choice Experiments in Germany, one in Frankfurt and one in Berlin in 2019. We reached out to survey participants through social media (most notably Facebook) and asked for help in a study assessing the environmental characteristics that influence quality of life (QOL) as suggested by Wardman and Bristow [5] to mask the purpose of our study and potentially prevent strategic bias. Furthermore, we include a control question to test whether participants can tell landing and departing aircrafts apart as well as a socio-demographic questionnaire.

Finding a novel noise attribute

Aircrafts emit sound in many ways. Bertsch, Sminons and Snellen [6] provide a list of physical parts of an aircraft that cause noise. We can summarize the noise sources under propulsion noise and airframe noise. The propulsion noise is created by propulsion devices, i.e. either jet engines or propellers, Airframe noise is created by the remaining items proposed by Bertsch et al. [6]: landing gear, flaps, slats, lift and control surfaces, spoilers and speed brakes and leading edge devices. Bertsch et al. [6] note that noise creation depends on multiple characteristics of the parts that cause noise. But not only aircraft type matters. An aircraft's current operational configuration has an impact on sound creation. Based on the state of the flight, for instance, thrust settings and flaps deflection differ. Both, according to Bartsch et al. [6], influence sound creation by the aircraft's parts (here engine and flaps). The intuition behind this is that engines running at full thrust are louder than idle engines and flap deflection increases aerodynamic resistance that causes noise. Both, thrust setting and flap deflection vary in the different phases of the flight. They are, for instance, different in takeoff conditions than they are in landing conditions. During takeoff, propulsion equipment in most aircraft is the predominant noise source. For landing aircraft, the airframe and its aerodynamic resistance often cause most noise emissions [7,8]

We suspect that the total noise of departing aircraft is greater than that of landing aircraft for any given position overflown by both departing and landing aircrafts. We validated this hypothesis for Frankfurt airport using the publicly available noise monitoring software Fra.Nom from Frankfurt's airport operator Fraport [9]. The software records noise events caused by aircrafts flying over measure points around the airport. We focused on a measure point in Neu-Isenburg (approximately 6 km east of the airport) and compared 30 noise events of aircraft of the same type (Airbus 320) for comparable weather conditions[1]: 15 departures and 15 landings. We noted down the highest single sound level (dB) caused by overflies. We indeed found a significant difference in noise levels of departing and landing aircraft. Departures are generally louder than landings.

Groups	Count	Sum	Average	Variance		
Departure	15	1005.9	67.06	2.221143		
Landing	15	962.8	64.18667	1.162667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	61.92033	1	61.92033	36.598	1.6E-06	4.195972
Total	109.2937	29				

Figure 1: Comparison of Airbus 320 Departure and Landing Noise Events

Therefore, residents living east or west of the airport are exposed to different noise scenarios depending on the airport's takeoff/landing direction which changes depending on weather conditions. Hence, we represent our noise attribute with the two levels "only landing aircraft" and "only departing aircraft" – two scenarios experienced by the participants. Our noise attribute is represented as follows:

Table 1: Representation of the noise attribute in the experiment

German (original)		English (translation)	
Attribute	Levels	Attribute	Levels
Lärmbelästigung durch einen Flughafen	- Ausschließlich durch startende Flugzeuge - Ausschließlich durch landende Flugzeuge	Noise annoyance by airport	- Exclusively by departing aircraft - Exclusively by landing aircraft

Payment vehicle

We decide for an increase or decrease in living utilities (e.g. induced by an increase in property taxes). Because in Germany most people pay their rents (and utilities) monthly, our payment duration is set to one month.

1 Wind from the north, 3-5 m/s

Control questions

Before starting the choice exercise, we ask participants whether they can distinguish departing and landing aircrafts. This question serves two purposes: One, it tells us whether the choices between the two noise scenarios are real or artificial ones (because they cannot tell a difference; those who cannot tell are disregarded in later analysis) for the participant. Two, it encourages the participant to think about the different noise exposure scenarios. We intend to increase sensitivity for this issue, before going on to the DCE.

General Noise Annoyance

We ask participants, after they have completed the DCE, how annoyed they are by aircraft noise. Based on findings from Giering et al. [10] and Fabruel and Luchini [11], we hypothesize that peoples' WTP for less annoying noise scenarios, among other factors, can be explained, among others, by their annoyance by aircraft noise in general. To measure to what degree people are annoyed by aircraft noise, we employ a translated version of the five-point ICBEN scale [12].

RESULTS

Of all completed questionnaires, 108 respondents indicated that they could tell the difference between landing and departing aircrafts (76 in Frankfurt / Rhine-Main and 32 in Berlin). Only those questionnaires are considered in the following.

We average parameter estimates for preference weights (betas) and WTP over all observations for both Berlin and Frankfurt / Rhine-Main. For the attribute of interest, aircraft noise, the betas over all regarded participants for both attribute levels are almost zero with a small tendency for a positive averaged beta and WTP for exclusively landing aircraft. The two noise attribute levels "exclusively departing (landing) aircraft" both yield negative and positive betas and WTPs for different respondents: some participants prefer departing aircraft whereas others prefer landing aircraft hence rejecting our hypothesis that landing aircraft are generally favorable. The averaged betas for both levels are close to zero because positive betas are almost offset by the negative betas. We conclude that averaging betas and WTP over all respondents in this case is of limited explanatory power. We therefore create two new measures: "preference for change_beta" and "preference for change_WTP". With these two measures we intend to capture the strength of preference (beta) and WTP for a change of the status quo to either of the attribute's levels. Using that logic, we found an average WTP for a change in the status quo of 1.65€/month (0.77€/month) in the Frankfurt / Rhine-Main region (Berlin). That is, participants were willing to pay on average 1.65€/month to change the status quo to either exclusively landing or departing aircrafts depending on preference.

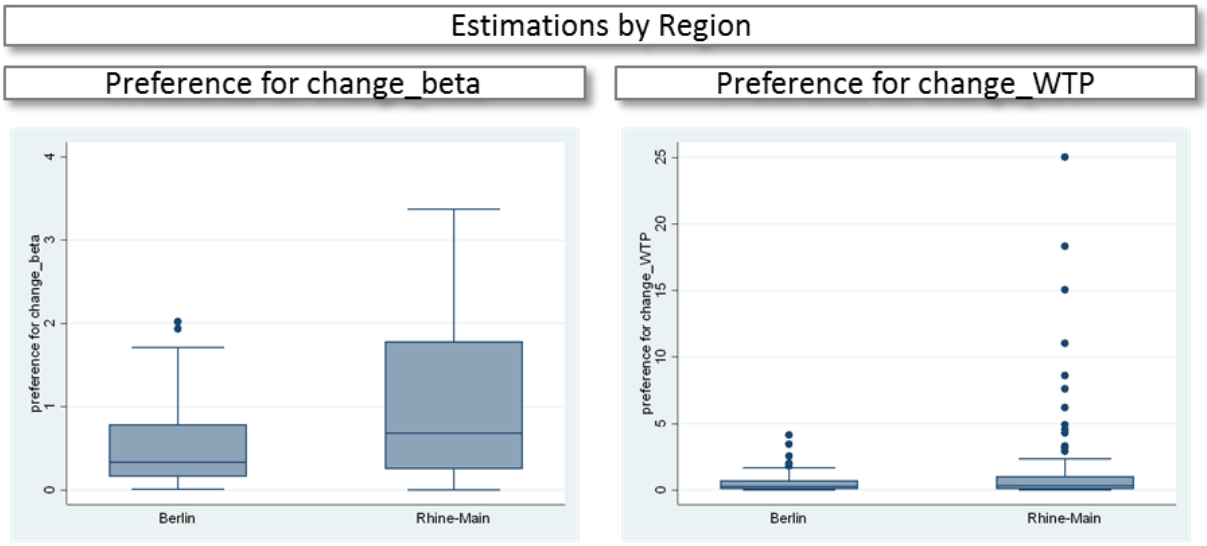

Figure 2: Results: Preference for Change and WTP per Region

For observations in the Frankfurt / Rhine-Main region, we find one significant predictor for “preference for change_beta”. Seven percent of the variance in “preference for change_beta”, the desire to change the status quo to either exclusively landing or exclusively departing aircrafts, is explained by the self-rated aircraft noise annoyance (p-value: 0.021). The sign of the effect is intuitive (coefficient: -.261) and in line with existing evidence: the more respondents are annoyed by aircraft noise, the higher the utility they draw from altering the aircraft noise exposure to their preferred scenario.

For WTP in Frankfurt / Rhine-Main, we find two significant predictors: self-rated noise annoyance by aircraft (p-value: 0.045) and household income (p-value: 0.005). Both effects were as expected in direction. Higher noise annoyance and higher income both return higher WTP for altering the aircraft noise status quo to a preferred alternative, either exclusively landing or departing aircraft (R-Squared: 0.155).

We cannot, however, confirm either finding for our Berlin model. We do not find any other predictors there either.

DISCUSSION

The WTP we found for a change in the noise exposure scenario seems reasonable in size. Thanos et al. [4] found a monthly WTP of 13.12€ to terminate aircraft noise altogether. Considering that our study does not propose a complete offset of aircraft noise but only a change to a better/worse scenario, a monthly WTP of 1.65€ (0.77€) seems in line with the evidence from Thanos et al. [4] that found a WTP about eight (seventeen for Berlin) times larger for a complete noise offset. The same is true for a comparison with Duarte [3]. Duarte found a WTP of 9.95€ to change the noise exposure to a level before the opening of a new runway. Similarly, since we do not investigate values for a complete on- or offset, our values of 1.65€ (0.77€) fit in reasonably well.

A higher WTP to change the status quo to either exclusively landing or departing aircraft and higher betas suggest that participants in the Frankfurt / Rhine-Main region are more concerned with aircraft noise than people in Berlin. We can think of two explanations:

One, Frankfurt Airport is by far larger than any of the two Berlin airports at the time of our experiment and hence accounts for more aircraft movements. Shifting the status quo to a more favorable noise scenario affects more noise events than it does in Berlin.

Two, Frankfurt Airport features more intercontinental routes that use larger and therefore louder planes. Shifting one noise event of a large aircraft to a more favorable scenario hence provides higher utility than shifting one noise event of a small aircraft.

Our study contributes to existing aircraft noise valuation research mainly by providing a new approach to represent the noise attribute. Whereas other studies use somewhat abstract representations of the noise attribute (e.g. “50% noise reduction”) or a complete noise offset [4], we use variations in noise exposure that participants can relate to because of actual experience. We show that there are indeed preferences for either departing or landing aircraft, however not collectively. Whether and why people prefer departing or landing aircraft remains beyond our study. We suspect however, that the location of the residents’ houses and hence the specific noise exposure in each scenario, plays a significant role in whether landings or departures are preferred: depending on each respondent’s location, landing or departing aircraft might be more disturbing.

LIMITATIONS AND FUTURE RESEARCH IMPLICATIONS

We cannot generalize our findings in that we compute a €/dB value for noise reduction WTP. The difference in noise exposure between landing and departing aircraft is different for every location around an airport. Whereas for our measurement landing aircraft are quieter than departing aircraft, for other locations the opposite may be true as departing aircraft often circumvent locations that landing aircraft overfly. To be able to calculate a WTP per dB, we would have had to collect the location of every participant and model actual noise exposure for both scenarios, an effort well beyond the means of this research.

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