Context-dependent stated choice experiments

Eric J.E. Molin
Transport and Logistics Group
Delft University of Technology
Delft, Netherlands
E.J.E.Molin@tudelft.nl

Abstract— Context-dependent stated choice experiments request participants to make choices between choice alternatives assuming that a certain context applies. This requires the construction of two experiments: a regular experiment with choice alternatives and a context experiment that varies the context variables. These are then combined by nesting the choice alternatives under the context descriptions. This extended SC experiment allows to examine how parameters estimated for attributes vary with context conditions. This approach is illustrated with an application that examines the impact of context of trip-circumstances on the parameters estimated for (multi-modal) mode attributes and alternative specific constants. It is argued that this approach is convenient to study evacuation choices.

Index Terms: Stated choice experiments, context effects, evacuation behavior

I. Introduction

In order to estimate evacuation related choice models, choices between choice alternatives need to be observed. As revealed choice data collection, hence observing what people actually have chosen, frequently face problems (e.g., i) identifying which choices alternatives where considered; ii) high multicollinearity among attributes; iii) choice alternatives of interest are not available yet; iv) behavior of interest is not very common and sufficient variation is therefore lacking), researchers often rely on stated choice experiments to collect choice data. Stated choices experiments make use of experimental designs to construct choice sets that describe two or more hypothetical choice alternatives in a number of attributes. Participants in the SC experiments are presented a series of choice sets (typically about 10) and requested to make a choice in each choice set. Hence, participants state what they would choose if the choice situation presented to them were the only options to choose from. It is generally acknowledged that the more realistic the choice experiment is, hence the more the constructed hypothetical situations resemble real world options, the more valid the observed choices are. Because of their convenience and cost-effectiveness, stated choice experiments have become a dominant data collection approach in many disciplines, like in marketing and transportation.

Typically, in stated choice experiments only the characteristics of the choice alternatives are varied across the choice sets. Hence, if there is interest in the effect of context variables on the observed choices, these context variables are typically observed in another part of the questionnaire and included in the choice model as interactions with the constants or attribute coefficients. For example, in mode choice applications often travel motive is included, hence interactions effects are estimated that indicate whether other choices are made in commute trips and recreational trips. However, one then has to assume that all observed choices are made with this context in mind. Moreover, one does not observe whether the participant would make other choices if another context would apply for him or her, hence, there is no within person variability in context effects observed. Furthermore, there may be an interest in more context variables and only observing revealed contexts as in common practice may result in too limited variation to estimate all context effects of interest.

In such situations, it is better to extend the stated choice experiment with descriptions of context situations. This requires the construction of second experiment that varies context variables and results in context profiles. The choice experiment is then nested under these context descriptions. If, for example, one is interested in modeling how the chosen evacuation mode depends on the severity and the kind of disaster, such a context-dependent stated choice experiment may be constructed. Although context-dependent experiments are proposed more than two decades ago [1], the number of applications is still very limited (e.g. [2,3,4,5]).

The aim of this paper is to introduce context-dependent stated choice experiments to the evacuation behavior community. First, the use of experimental designs to construct stated choice experiments is briefly introduced, which is followed by an explanation of the construction of context-dependent stated choice experiments. Then, an illustration is provided by presenting a study in which the effects of context of trip circumstances on (multi-modal) mode choices are examined.

II. Constructing context-dependent stated choice experiments

The challenge of stated choice experiments is to construct choice alternatives with sufficient variation across all choice sets in such a way that the intended utility function can be estimated. This implies that one first selects the attributes one likes to vary and in which levels and range. To construct choice alternative and choice sets, one has for a long time relied on orthogonal designs, which involves that the attributes de not correlate across all choice sets. This implies that each level of an attribute is combined an equal number of times with each level of all other attributes. To make this concrete: a low quality product is combined an equal number of times

with a low price as with a high price. In case a linear model is estimated, such as a regression model, it can be shown that orthogonal designs result in the lowest possible standard errors of the estimated coefficients, hence, in the most efficient models. However, the logit models one estimates from choices are non-linear models; orthogonal designs may still be applied, but do not result in the most efficient models.

It is shown that so-called efficient designs [6,7] result in more efficient choice models. Those designs are based on the idea that one should construct choice sets in such a way that the choice maximizes the information on the trade-offs respondents make between the attributes. In contrast, a choice set that includes a dominant alternative, does not provide any information on the trade-offs. A dominant alternative has a better score, at least not worse, on every attribute than all other alternatives in the choice set. For example, a faster and cheaper train service will be preferred by everyone over a more expensive and slower train service. Hence, an observed choice for the faster and cheaper service does not provide any information on the trade-off between price and speed. Such a choice set can be avoided if one uses so-called priors to construct the stated choice experiment. Prior estimates are best guesses on the real coefficients, which may be based on small-scale preliminary research. The priors are used to create choice sets in which the alternatives have about equal utility. As by using priors dominant alternatives are avoided and choice sets are created in which utility is more balanced, each observed choice reveals maximum information about the trade-offs. It can be shown that this results in the smallest possible standard errors of the estimates. Hence, efficient designs potentially require a smaller number of respondents to arrive at statistical significance of the estimated coefficients than orthogonal designs do. The construction of efficient designs is supported by the software package Ngene.

Now we shift our focus to extending the stated choice experiment to include context variables, which may be background variables or temporal trip conditions. Oppewal and Timmermans [1] discussed the need to construct two experiments. A first experiment is constructed to vary the choice alternatives; this is a regular choice experiment. In this experiment, the attributes of the choice alternatives and/or the availability of the choice alternatives are systematically varied across the choice sets, based on an experimental design (for details on constructing such experiments see [8]). A second experiment is needed to systematically vary the context variables to arrive at a set of context descriptions. Next, the choice sets of the first experiment is nested under the context descriptions resulting from the second experiment to arrive at a set of context-choice set descriptions. Hence, as each choice set is combined with each context description, the total number of context-choice sets is equal to the number of choice sets times the number of context descriptions.

This is illustrated by constructing a simple experiment intended to examine the effects of context variables on mode choice. Imagine there is an interest in examining the effects of two context variables, type of disaster and alarm code, on mode choice. The context variables vary in the levels *hurricane* and *flood,* and in *code red* and *code orange* respectively. Combining these levels results in four context descriptions. Imagine further that choice sets are constructed to vary the availability of two public transport alternatives, bus and train. This results in 4 different choice sets: bus and train can be both available, either only bus or train can be available, or none can be available. To this, we add two base alternatives, which we assume are always available: car and walking. Nesting the four mode choice sets under the four context descriptions results in the 16 context-specific mode choice sets presented in Table 1. Note that in this simple example only the availability of alternatives is varied; it goes without saying that the choice sets can represent any set of constructed choice alternatives varying in generic or alternative-specific attributes.

TABLE 1: Example of nesting choice sets under context variants

	context 1:	**Hurricane – code orange**			
1	mode set 1	bus	train	car	walk
2	mode set 2	bus		car	walk
3	mode set 3		train	car	walk
4	mode set 4			car	walk
	context 2:	**Flood – code red**			
5	mode set 1	bus	train	car	walk
6	mode set 2	bus		car	walk
7	mode set 3		train	car	walk
8	mode set 4			car	walk
	context 3:	**Hurricane – code red**			
9	mode set 1	bus	train	car	walk
10	mode set 2	bus		car	walk
11	mode set 3		train	car	walk
12	mode set 4			car	walk
	context 4:	**Flood – code orange**			
	mode set 1	bus	train	car	walk
14	mode set 2	bus		car	walk
15	mode set 3		train	car	walk
16	mode set 4			car	walk

III. An application: the effect of trip circumstances on mode choice

To illustrate context dependent choice models a recent application of this method is provided. A series of four stated choice experiments were constructed to examine the effects of trip contexts on mode choice for trips that are made on a regular basis for daily and non-daily non-work activities within a metropolitan region. The applied methodology is described here in main lines only. For motivations and more

detail, we refer to Arentze and Molin [9]. We first briefly discuss the mode choice experiments and next consider the trip contexts and choice task.

Mode choice

In the experiment, three possible modes for a trip are distinguished: private-vehicle (PV) based, public transport (PT) and a combination of private and public transport (multimodal or, in short, MM). In the experiments respondents are presented choice tasks for a given distance (5, 20 and 65 km) where travel options are varied in terms of the main transport mode of the trip and attributes of route components. Different experiments were developed for the various distances, which was necessary because not all modes are feasible for all distances. The experiments are constructed such that the complexity of MM and PT alternatives offered increases with distance. For example, a PT alternative involving a transfer is not a feasible option for a short distance trip. The experiments differ in terms of the mode alternatives available in the choice-set and the length of the imaginary trip (5, 20 and 65 km). The experiments were constructed in such a way that a single model can be estimated from the pooled data of all experiments.

Based on priors obtained from a pilot study, we constructed efficient designs for each of the four experiments, that had 27, 27, 45 and 45 choice sets respectively for the MM5, MM20, PT20 and PT65 experiments. Table 2 (see appendix) presents the attributes that were varied in the choice experiments.

Trip context

In order to examine the effect of trip circumstances on mode choice, the respondents were requested to imagine that a presented context applies for their trip. This context is described in terms of a number of attributes of the trip and a situational setting in the same way for all four experiments. The context attributes include purpose of the trip, flexibility in arrival time, travel party (alone or with some else), weather conditions, traffic conditions and luggage (carrying of bags). The selected trip purposes are intentionally representative for a range of discretionary and mandatory activities individuals engage in in daily life. They include paying a visit to a patient in a hospital, going out in a city (e.g., visiting a museum), important (business) meeting and paying a visit to family or friends. Commute trips to work or school are not considered; these trips tend to be special in a number of respects, such as frequency, mode dependency, price arrangements with employer, etc., and hence would ask for a special experimental treatment, which we leave for future research.

Table 3 provides an overview of context variables and the applied effect coding. It should be noted that travel party actually had only two levels, that is, 'traveling alone' and traveling with 'someone else'. The nature of the relationship of the travel party was specified depending on the available relations of a respondent. For respondents with young children the travel party always involved 'young child (younger than 12 year old)'; for respondents without young children but with a partner, this always involved 'partner', and for all others this involved 'a good friend'. Thus, travel party is a combined context and person-background variable.

TABLE 3. Context variables and coding

Label	**Effect Coding**		
	ind1	ind2	ind3
Baggage			
small bag	1		
heavy bag	-1		
flexibility arrival time			
inflexible	1		
flexible	-1		
time of day			
no rush hour	1		
rush hour	-1		
trip purpose			
hospital	1	0	0
day out	0	1	0
business	0	0	1
visit	-1	-1	-1
travel party			
with friend	1	0	0
with child	0	1	0
with partner	0	0	1
alone	-1	-1	-1
weather			
rainy & cold	1	0	0
rainy & not cold	0	1	0
dry & cold	0	0	1
dry & not cold	-1	-1	-1

To arrive at complete contextual situations, an orthogonal fractional factorial design involving 16 profiles was constructed to which its foldover design was added resulting in 32 different context profiles. By adding the foldover design, main context effects do not correlate with any two-way interaction effects of the context variables so that more valid main context effects can be estimated [1,8].

The choice task

Each respondent is presented 9 choice sets arranged in three sets with a same context setting. The combined choice-sets and contexts are generated for a respondent as follows. First a context situation is randomly drawn from the pool of context profiles. This is followed by a random draw from the pool of the mode alternative choice sets from the experiment the respondent is assigned to (see next subsection). To limit the amount of new information presented to the respondent, the same trip context applies for the following two (randomly drawn) mode choice sets as well. This procedure is repeated twice to generate the next two sets that each contain three combined context-mode choice tasks. Hence, each respondent is presented in total three different trip contexts and nine different mode choice sets.

An example of a choice task taken from the MM20 experiment is provided in Figure 1 (see appendix). In the

presentation of choice alternatives, the total (door-to-door) travel time is represented as well as travel-time components. The travel-time components shown include all stages except the main stage. The travel time of the main stage can be found as the difference between the total travel time and the shown components. Note that this is an aspect of the presentation, not of the design; the travel time components including travel time of the main stage are varied by design and total travel time follows from that. The experiments were implemented in an on-line questionnaire.

Respondents were recruited from an existing large national panel in the Netherlands owned by Intomart Gfk. This panel involves about 110.000 persons that on a regular basis are requested to fill out questionnaires, mainly for marketing research purposes. Intomart Gfk claims that this panel is representative for the Dutch population in terms of regular background variables such as gender and age. In total 2,746 respondents participated in the survey and were included in the analysis.

Model estimation

A comprehensive multi-modal travel choice model is estimated across the four experiments and added the statistically significant interaction terms constructed for the effect-coded context variables (see Table 2) and all estimated parameters. To be more specific, a MNL model including four error components and scaled parameters for the four experiment is estimated. In total, the model included 35 main parameters for alternative specific constants and attributes, and 62 interactions of context variables and mode choice parameters. The final Log-Likelihood of the model is equal to -21,246 and has an adjusted Rho-square value of 0.214. We refer to Arentze and Molin [9] and Molin and Arentze [5] for more details on the modeling estimation procedure and the presentation of all results.

IV. Results

The estimated main-effects for the mode attributes may be regarded as averages across the different contexts. We discussed these parameters in Arentze and Molin [9], in which we argued that the parameter estimates are within the value ranges that can be found in the literature and concluded that these show face validity. The estimated interaction effects indicate how the context variables modify these main-effects. As effects coding is applied, these effects are expressed as deviations from the main parameters. These interaction effects are discussed in Molin and Arentze [5], in which we concluded that most effects are in expected directions and those who were not provided interesting new insights.

In this paper, we present only a small part of the results with the sole purpose to demonstrate what type of results the context-dependent stated choice experiments may produce. More specifically, we discuss the main parameters estimated for car travel time and the significant interaction effects of this parameter with the context variables.

Table 4 shows that the main parameter for car travel time is equal to -0.080, which indicates that for every minute longer travel time by car, the utility that is derived from car decreases by 0.080 utility points. The other result indicate how this parameter is modified by the context variables luggage, arrival time flexibility, rush hour, and weather.

The results for luggage indicate that if the traveler needs to carry a heavy bag, the car travel time parameter becomes less negative (-0.080+0.008=-0.072). This suggests that travelers less mind traveling by car if they have to carry heavy stuff. In contrast, every minute car travel time weighs more heavily (-0.088) if a traveler does not need to carry heavy stuff.

The results for arrival time flexibility, indicate that car travel time weighs less heavily (-0.070) if one needs to arrive on time, while it weighs more heavily (-0.090) if there is no need to be on time. Together with the results for luggage, a more general picture emerges: if constraints apply for a trip, travelers less mind spending time in the car, which suggest a tendency to choose car more often compared to other modes of transport in those circumstances.

Furthermore, the rush hour results suggest that travel time weighs a little less in rush hours compared to non-rush hours (-0.075 vs. -0.085), which seems to suggests that people accept that travel time in rush hours is a little longer. The weather results suggest that especially in dry conditions, cold weather plays a role: if it is cold, car travel time weighs more heavily (-.102), while it weighs less heavily if non-cold conditions (-0.065). In rainy conditions, cold has a different effect: a minute travel time weighs less heavily (-0.073) when it is cold compared to non-cold conditions (-0.080).

TABLE 4. Example estimation results: car travel time

	value	t-value	p-value
Travel time car	**-0,080**	-12,7	0,00
small bag	-0,008	-4,7	0,00
heavy bag	0,008		
Inflexible	0,010	5,9	0,00
Flexible	-0,010		
no rush hour	-0,005	-1,9	0,06
rush hour	0,005		
rainy & cold	0,007	2,3	0,02
rainy & not cold	0,000		
dry & cold	-0,022	-5,9	0,00
dry & not cold	0,015		

V. Conclusion

In this paper, we have shown the possibilities of context-dependent stated choice experiments to model the effect of context variables on attribute parameters and constants. The construction of those experiments is briefly explained and an application is provided to illustrate the type of results such experiments can provide.

It may be argued that context-dependent stated choice experiments are a useful data collection procedure to observe evacuation choices. In this field, contexts may for example describe the type and severity of a disaster, how this is communicated, the time left until the disaster hits, etc.. The choices alternatives to choose from may involve the modes one can choose from, the routes one can take and/or the decision to evacuate in the first place.

It is hoped that this paper contributes to a more richer and more realistic construction of stated choice experiments in evacuation choice studies.

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