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Accessibility and the role of the Consideration Set in Spatial Choice Modelling: A Simulation Study

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Abstract

A recurring issue in the discourse about choice modelling is the role of consideration sets. Many scholars have proposed that consumers will follow a two-stage decision process. This paper argues that in spatial choice contexts the role of the consideration set may largely depend on the decision maker's level of access to the alternatives. It is proposed that in conditions where the decision maker's accessibility toward alternatives is constrained—for example as a result of time space feasibility—a two-stage model will perform better than a one-stage model. The more restrictive the constraints, the more important the role of the consideration set.

The paper presents a simulation analysis of the effects of geographical accessibility on consideration and choice in the context of motorists' decisions where to refuel. It simulates a grid road network where the motorists' access to petrol stations is constrained by the geographical location of the alternatives, the availability of network connections between them and the decision makers' time budgets. In this hypothetical spatial environment the study simulates consideration and choice processes for refuelling options under different conditions of petrol station access, (non-spatial) station attractiveness, and heterogeneity in the decision maker's time budget.

Keywords: Spatial Choice, Consideration Sets, Accessibility

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1 Introduction

The role of the consideration set in individual choice behaviour has drawn extensive attention from scholars in various fields of research including psychology, economics, and also in applied disciplines such as transportation and marketing. A general definition of a consideration set is given by Shocker et al. (1991) as a “a purposefully constructed set which consists of goal satisfying alternatives salient or accessible (to the decision maker) on that particular (choice making) situation” (p.183). As discussed in Roberts (1989) and Roberts and Nedungadi (1995), the consideration set is important because in more complex decision contexts the choice process is typically conceived as a two-stage sequence. First a consideration set is formed to narrow down the alternatives and then trade-offs are made between alternatives within the new set to reach the decision. This is supported by Gensch (1987) and Payne and Bettman (1992), who identified that early stages of decision making include more attribute based comparisons while later stages include more holistic trade-offs between alternatives. This means that the first stage involves a non-compensatory screening process while the second stage comprises a multi-attribute compensatory choice process. To avoid choice model misspecification it is therefore important for choice modellers to obtain an accurate definition of the consideration set.

The possibility of a stage-wise choice process becomes especially apparent in the context of spatial choice, where the decision maker and the alternatives are located in geographical space. In spatial choice contexts decision makers often face a large number of possible options. Typically many of these are impossible to reach from the current location or there may be too many alternatives to cognitively process information about. In order to simplify their choice task, decision makers therefore will employ a “hierarchical information processing” strategy. For example, in the context of consumer choice of retail destination, clusters of alternatives are initially evaluated before a specific alternative is chosen from within the selected cluster (Fotheringham 1988; Fotheringham and Pellegrini 2002). In general, this means that in spatial choice situations, the consideration stage in the two-stage choice process is realized through a spatial cognition-related process, before the decision makers proceed to the second phase where more non-spatial factors are evaluated for the considered alternatives. This is also supported by Kwan and Xiao-Dong (1997) and Decrop (2010) who suggest the formation of the consideration set is a “constraint and opportunity-driven process”, in which spatial feasibility acts as the main factor in the development of the consideration set. Taken together this reasoning implies that the spatially defined feasible set can be a good indication of the consideration set.

There is also an alternative view on the role of the consideration set, most prominently expressed by Horowitz and Louviere (1995). This view posits that the consideration stage is simply another indicator of preference and that there is not much benefit for modellers in measuring or modelling consideration separately from the choice itself. The main argument here is that individual preferences, described by their utility function, determine both the choice set composition and the final choice and hence consideration and choice information will both represent utility. Indeed, any alternative selected to be in the choice set will always have a higher utility than the alternatives not in the set. Hence knowledge about consideration sets provides no additional information for forecasting choice and there is no significance in defining a consideration set stage when modelling

choices. In the same spirit, Swait (2001) suggests that the probability of being in the 'true' choice set depends on the attractiveness of alternatives contained in it. However, even if this view is correct in arguing that consideration sets are just another manifestation of utility maximisation, there may still merit be in investigating how well a model can be estimated from data that do or do not include consideration set information.

This paper puts forward the idea that the role of the consideration set may depend on the decision maker's level of access to alternatives. Alternatives may have different physical accessibility levels due to path limitations and due to differences in individuals' mobility levels. As put forward by Hui et.al. (2009), understanding path-related issues will lead to a better understanding of consumer behaviour including the consumer decision making process. Indeed, individual choice behaviour is subject to many constraints, including *time-space accessibility*. Arentze and Timmermans (2005) studied the impact of time-space accessibility on consumers' shopping behaviour and location heuristics, positing that shopping activities are not only influenced by the store's and shopper's socio-demographic attributes but also by temporal and spatial constraints. Hägerstrand's space-time prism theory (Hägerstrand et al. 1975) has been particularly influential in this area. A string of work in Behavioural Geography (Kim and Kwan 2003; Kwan et al. 2003; Kwan and Xiao-Dong 1997; Miller 1998; Weber and Kwan 2002) uses Hägerstrand's theory to provide methodological and empirical background to the application of time-space restrictions in the development of a decision maker's consideration set in a spatial choice situation.

We present a simulation analysis of the effects of physical access on consideration in the spatial context of motorists' decisions where to refuel during their trip towards some final destination. Similar to the approach taken in the context of shopping centre choice by Borgers and Timmermans (1987), the present paper simulates a grid road network. In our network, motorists' access to petrol stations is constrained by road and traffic conditions, trip characteristics (e.g., the time budget available for that trip), the geographical locations of the refuelling alternatives as well as those of the origin and final destinations, and by the availability of network connections between them. Similar to the approach by Borgers and Timmermans (1987) to this setting we add variation in knowledge about alternatives, which accommodates for decision makers predetermining and rejecting low performing alternatives if they have sufficient knowledge about these alternatives.

In this hypothetical spatial environment our study simulates individual spatial search for refuelling options under different conditions of petrol station access and (non-spatial) station attractiveness. The stations are spatially allocated to create different spatial competitive structures. Within a given spatial structure the simulation randomly assigns individuals to different sets of Origin-Destination coordinates, available time budgets, and levels of familiarity with each fuel station alternative. The simulation varies motorists' time budgets during their trip, which dictate their *Feasible Opportunity Sets* within the network (Kwan and Xiao-Dong 1997). This set represents the consideration set resulting from the non-compensatory screening process in the first stage of the spatial decision making process. The compensatory, or trade off stage is conducted next within this limited set, based on the non-spatial attribute in the simulation. This trade-off results in the final simulated choice.

The simulated choice data are then used to estimate various models. First, a one-stage model is estimated by treating both the spatial and the non-spatial attribute as compensatory predictors in a simple Multinomial Logit (MNL)¹. Second, a two-stage model is estimated in which the spatial attribute is treated as the non-compensatory eliminating factor in the first stage, and the trade off in the second stage is based on the non-spatial attribute (quality of fuel station). This represents the data generation process as implemented in the data simulation. To represent this two stage modelling, the Constrained Multinomial Logit (CMNL, Martínez et al. 2009) model is applied, which is an extension of the Implicit Availability/Perception Model (IAP) derived by Cascetta and Pappola (2001). Despite some limitations of the model, as put forward by (Bierlaire et al. 2010), especially in comparison to the more general Probabilistic Choice Set (PCS) model (Manski 1977), the use of this semi-compensatory model is justified for several reasons. First, the model offers flexibility to include a non-compensatory process in a regular Random Utility-based compensatory framework. Second, compared to the more explicitly stage-based models such as the PCS and the Latent Choice Set (Ben-Akiva and Boccara 1995) models, the CMNL model provides simplicity especially in conditions where there is a large number of alternatives, a situation to which the PCS is practically impossible to apply.

2 Context: Motorist Choice of Refuelling Station

The context of this paper is the choice of refuelling station by motorists. In contrast with most other shopping activities, the fuel shopping consumer is moving across the market when consuming the product (Jones and Simmons 1990). Fuel shopping is therefore not done at a specific destination point, but rather somewhere during a trip to a destination that needs to be reached for some purpose. In other words, petrol stations are rarely considered as “a destination” but rather are in-between points on a trip. It is because of this distinctive characteristic, along with the product’s homogeneity and its spatial setting, that fuel retailing has been chosen by several economists and econometricians as an object for their study (Pennerstorfer 2009).

As pointed out in Kitamura and Sperling (1987), refuelling activity can be differentiated into two general types: Routinized activities, which often are consciously planned and non-routinized activities, which include *ad hoc* search components. Both types involve different decision-making processes. In the case of routinized refuelling, the activity is coordinated with the regular out-of-home activity and the decision where to refuel is based on a process of past information acquisition, experimentation and habitation with the immediate environment, whereas in the case of non-routinized refuelling the motorist is exposed to sequential opportunities and is making spontaneous (on the fly) decisions where to refuel. Hence, the two situations comprise rather different stage-wise processes. In the case of routinized activities, motorists could be conceived as already having some preconception about their preferred and less preferred alternatives, based on their prior knowledge and experience. These preferred alternatives then constitute the motorist’s attraction-based consideration set. Decision makers will combine this information with knowledge of the spatial layout of the environment and determine which alternatives are feasible for their current refuelling need. Dingemans et al. (1986), in their study of refuelling and shopping, call this spatial knowledge the motorist’s ‘mental map’ of available options.

¹ To be consistent with previous literature in this area we refer to the model as MNL even though other sources refer to the same model as a conditional logit model.

In contrast, in the case of non-routinized refuelling, an *ad hoc* search process is started when the need arises by constructing a choice set based on the availability (or accessibility) of alternatives. In these situations the choice set may be as small as one, presenting the decision maker with a go/no go decision. Alternatively, expectations may exist about alternative options that may be available within a certain travel distance, resulting in a sequential choice problem with incomplete information.

Although non-routinized refuelling behaviour is worth exploring further, the present paper will concentrate on routinized refuelling. One reason is that, as suggested by Kitamura and Sperling (1987) based on their survey on refuelling behaviour in Davis, California, a majority of refuelling activities concerns routinized activities while only a small portion is based on a spontaneous need to refuel (running out of petrol). In Kitamura and Sperling's study the share of spontaneous refuelling was only 13.1 percent and this percentage can be assumed to be even lower for trips originating from a specific area (e.g. suburb or small town). Another reason for focusing on routinized refuelling is that these consumers are the repeat customers to whom petrol station operators will want to direct their marketing activities. Hence, it is particularly important to understand routinized refuelling behaviour.

3 Modelling issues

The modelling of a motorist's choice of fuel station presents some particular issues. Firstly, the universal or total set of available options should be reduced to a "feasible set", since most of the available fuel stations in the area will not be technically accessible because of the decision maker's "space-time" limitation. Indeed, whether planned or unplanned, the motorist has to schedule the refuelling within a restricted "travel path". Kwan and colleagues (Kim and Kwan 2003; Kwan and Xiao-Dong 1997) based on Hägerstrand's space-time paradigm provide a methodology to derive such a restricted set, which they call the Feasible Opportunity Set (FOS). The FOS defines the spatial choice set of alternatives that an individual faces, based on his or her spatio-temporal context during the travel on a road network. An alternative k is included in the FOS if it is located inside the individual's Potential Path Space (PPS), which is defined as;

$$PPS_{\alpha} = \left\{ (k, t) \mid t_i + \frac{d_{ik}}{v} \leq t \leq t_j - \frac{d_{jk}}{v} \right\} \quad (1)$$

where v is average velocity, t_i , t_j and d_{ik} are, respectively, the departure time from origin point i , the expected arrival time at the destination j and the distance between these points and the alternative k .

The second complication in modelling a motorist's choice of fuel station is the interplay between spatial and non-spatial factors in the choice process. In contrast with non-spatial choice contexts, in spatial choice the (geographical) accessibility plays a pivotal role in determining choice. The impact of non-spatial attributes of a petrol station (such as price, product range, or brand) is heavily "moderated" or even "dictated" by the "geographical/spatial separation" between the decision maker and the alternative. These "separation variables" (Fotheringham 1991) can be represented by (network) distance, (network) travel time or by spatial structure such as dominance measures (Cascetta and Papola 2009) or spatial competition and agglomeration effects (Borgers and Timmermans 1987).

The impact of spatial constraints on consumer behaviour in fuel retailing contexts is observed by Dingemans et al. (1986) and Kitamura and Sperling (1987). These authors observed apparent inconsistencies in consumer refuelling behaviour. They found that while, as expected, consumers profess high sensitivities toward prices, in reality they seldom choose the station that offers the lowest price in the area. The authors attribute this inconsistency to the “asymmetric knowledge” about the available alternatives faced by the consumer. They found evidence that consumers can only correctly identify small shares of the least and most expensive petrol stations available to them. They concluded that in spatial environments the consumer choice set is heavily influenced by the spatial structure. Furthermore, in their study about supermarket shopping, Arentze and Timmermans (2005) pointed out that not only spatial constraints but also temporal limitations (in terms of time budget available for the individual) affect the choice set generation process.

From the perspective of choice modelling, this inconsistency between consumer “preference” and actual choice can be explained by assuming a two-stage choice process as described earlier in this paper. In this case motorists first form their consideration sets based on feasible alternatives determined by their time space constraints. Under these assumptions it is possible that the temporal and spatial constraints prohibit high preferred (e.g., because they offer the lowest price) alternatives to enter the final choice set, which indicates that the choice set may not always be an effective indicator of preference. However, on the other hand, if the motorist is not bounded by time and space limitations, which means that he or she could access all alternatives easily, this inconsistency will be less likely to occur, and the choice set (and also the consideration set) will more resemble the consumer indicator of preference (Horowitz and Louviere 1995).

Therefore, in a choice modelling context, an effort to model such decision making should involve a direct measure of spatio-temporal limitations, especially in the choice set development stage. Failing to incorporate such measures could potentially lead to misleading results regarding the significance of non-spatial attributes. In the case of fuel station choice modelling for example, ignoring the accessibility limitation faced by the motorist will potentially lead to an overestimation of price sensitivity.

4 Rationale for the Simulations

Two simulations are developed to provide more insight into the role of spatial and non-spatial attributes, the role of attribute knowledge and physical access, as determinants of consideration set composition and final choices. The first simulation explores the effect of spatio-temporal limitation on the role of consideration set. Our hypothesis is that increases in decision makers’ spatio-temporal limitations will increase the role of the consideration set in determining the choice outcome.

In this approach a simple fixed effects MNL model is estimated for all scenarios, with both attributes (detour and attractiveness) as predictors. This represents a compensatory decision process where the decision maker trades off both attributes. The probability of an alternative j being selected by motorist i whose choice set is N is modelled as;

$$P(y = j) = \frac{\exp(c + \alpha \cdot \text{detour}_{ij} + \beta \cdot \text{attractiveness}_j)}{\sum_{n=1}^N \exp(c + \alpha \cdot \text{detour}_{in} + \beta \cdot \text{attractiveness}_n)} \quad (2)$$

The second simulation is directed to studying and comparing the effectiveness of modelling spatial choice in one and two stage approaches. We want to study whether it is worthwhile to model the first (consideration) set separately or not. In a one stage approach the spatial feasibility and the comparison of alternatives on non-spatial attributes is treated as a trade-off in a single compensatory model. In the two-stage approach, the first stage consists of the non-compensatory process of spatial feasibility screening and the second consists of the non-spatial trade-off.

The two-stage approach is modelled by adopting the Constrained MNL model (Martínez et al. 2009), in which the spatial attribute (detour) is treated as the consideration set predictor (in the first stage) and the non-spatial attribute (attractiveness) is deployed as the choice predictor in the second stage.

The formulation of the model is as follows;

$$P(y = j) = \frac{e^{c + \delta \cdot attractiveness_j + \ln\left(\frac{1}{1 + \exp(\omega(\detour_{ij} - \theta))}\right)}}{\sum_{k=1}^n e^{c + \delta \cdot attractiveness_k + \ln\left(\frac{1}{1 + \exp(\omega(\detour_{ik} - \theta))}\right)}} \quad (3)$$

where θ is the threshold representing the maximum detour that can be undertaken, based on the individual's time budget, and ω is a scale factor for the threshold value. ω indicates the steepness or "crispness" of θ ; a high value of ω is associated with a steep or crisp threshold.

Our expectation is that although our data are generated based on a two-stage procedure, a one stage modelling approach will be able to produce sufficient fit for less restrictive cases. However in more restrictive cases, where the decision maker has only limited access to the alternatives, the two-stage approach is expected to be superior compared to the one-stage approach. In this case the consideration set will contain significant information that is not completely captured by the ultimate choice. The main reason is that in those cases a model representing a purely compensatory process cannot perfectly capture the non-compensatory elimination process operating in the first stage and the impact of spatial structure on choice outcomes.

5 Simulation 1: The Role of the Consideration Set

5.1 Data Generation

A hypothetical road network is created in the form of a 6×6 grid, each grid-line representing a two-lane road and each intersection point representing the motorists' possible location points, i.e. origin or destination points. On this road network six petrol stations are available, each specified by its geographical location and an attractiveness measure (see Figure 1). The alternatives' geographical locations are designed to cover different types of spatial structure, in particular clustered structures (sites 1, 2, 3, and 4) and local monopoly structures (sites 5 and 6). The attribute "attractiveness" is a 0 – 10 scale representing the site's non-spatial attractiveness, which in real life could be represented by *floor size of the retail store*, *brand image* (e.g., based on consumer ratings), or *service capacity* (e.g., number of pumps). A graphical presentation of the simulation grid is given in Figure 1. The attractiveness levels of the alternatives are listed in Table 1.

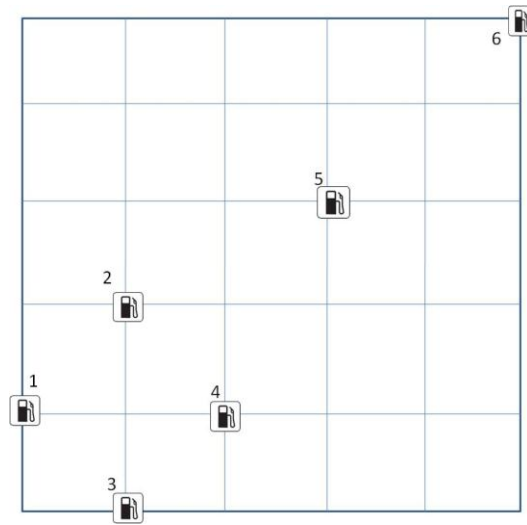


Figure 1 Hypothetical Road Network

Table 1: Petrol Station Characteristics

Alternatives	Location		Attractiveness
	X	Y	
1	0	1	6
2	1	2	5
3	1	0	7
4	2	1	6
5	3	3	5
6	5	5	7

For the simulation experiment 1000 imaginary trips were randomly generated. Individual i is assumed to be travelling from origin O_i to destination D_i . The grid coordinates for O_i and D_i are randomly generated. Each individual is only simulated for one particular trip and has a randomly assigned time budget (t_i), drawn from a uniform distribution ranging from 0 to 10 units of time.

As in Borgers and Timmermans (1987), the (subjective) perception of attractiveness is simulated by assigning normally distributed random disturbances (e_{ij}) to the (objective) non-spatial attractiveness score for each alternative. The random disturbance represents real-life variation in attractiveness based on variations in familiarity, brand perceptions or spatial cognition (e.g. closeness to home, location visibility etc.). The perceived attraction value PA is calculated by using;

$$PA_{ij} = \text{Attractiveness}_j + e_{ij} \text{ for all } j, \tag{4}$$

where e_{ij} is a normally distributed random disturbance with mean = 0 and variance = 1.

During the first stage of the decision process the individual's choice set is constrained by applying the previously discussed Feasible Opportunity Set procedure to each considered alternative, based on the individual's time budget. The time-space

accessibility in Formula (1) is operationalized by introducing the variable $detour_{ij}$, which represents the deviation from the shortest path between the Origin and Destination that needs to be taken by individual i to reach destination j , which is calculated by using formula;

$$detour_{ij} = (dist_{(orig\ i - alt\ j)} + dist_{(alt\ j - desti)} - dist_{(orig\ i - desti)}) \quad (5)$$

Alternative j is included in the FOS if it is located inside the individual's Potential Path Space (PPS), which is defined as;

$$PPS_i = \{(j, t) | detour_{ij} \leq t_i\} \quad (6)$$

In the case that none of the alternatives in the consideration set are feasible, the individual moves one grid step in the general direction toward the destination (representing the situation where the motorist continues to travel or is forced to reconsider the space time budget) and the feasible set is recalculated and updated based on the new origin position; the process is continued until the feasible set is populated with at least one alternative. Once the feasible set is generated, the (feasible) alternative with the highest perceived attractiveness PA_{ij} is chosen.

5.2 Findings

Figure 2 presents the results from the first (consideration) stage based on geographical accessibility. The graph describes the aggregate “consideration share” of each alternative under different time constraints. The share represents the percentage of trips for which an alternative is included in the individual's consideration set.

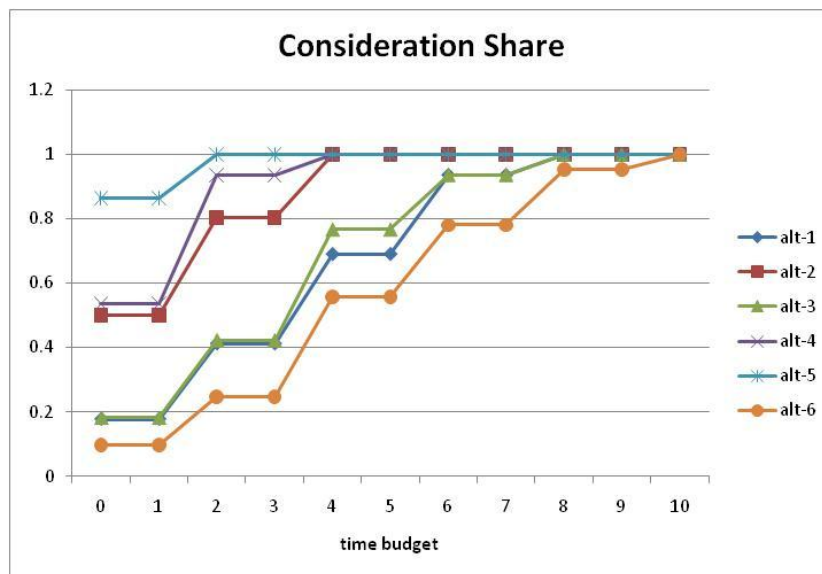


Figure 2 Consideration Shares

As expected, the impact of spatial structure on consideration set composition is substantial. Alternatives located closer to the centre of the grid (fuel stations 2, 4 and 5) are more likely to be considered than alternatives that are in the perimeter. The effect of “centrality” in an Origin Destination based choice situation has been studied previously, for example in the case of intra urban migration context by Boots and Kanaroglou (1988) and urban transportation (Sohn and Kim 2010)

Figure 3 describes the result from the second (choice) stage. As described previously, in the simulation, once the consideration set is formed, the choice is based on the non spatial attractiveness, hence the aggregate market shares under different time constraints resulting from this stage preview the increasing significance of spatial attributes (from the initial stage) in the choice outcome.

The graph in Figure 3 shows how the spatio-temporal limitation reduces the importance of non-spatial attractiveness in determining the choice outcome. In the relaxed conditions (time budget > 5) the market share structure reflects the attractiveness levels, with alternatives 3 and 6 (as the most attractive alternatives) dominating the market. However, once the spatio-temporal conditions become more restrictive (time budget < 4) the more spatially dominant alternatives (4 and 5) become the market leaders, even though they are less attractive in a non-spatial sense. This corresponds with the results from empirical studies about refuelling behaviour of motorists (Dingemans et al. 1986; Kitamura and Sperling 1987).

The two graphs combined reveal the increasing role of the consideration set as the spatio-temporal limitations increase. The more restrictive the spatio-temporal conditions the more the “consideration set” starts to resemble the final “market share”. This suggests that in that situation the consideration set has more meaningful information compared to less restrictive situations.

The role of the consideration stage can be further analysed by observing the conditional probability of an alternative A to be chosen by individual i given that it is already included in the consideration set (CS_i). This probability can be derived using a Bayesian rule;

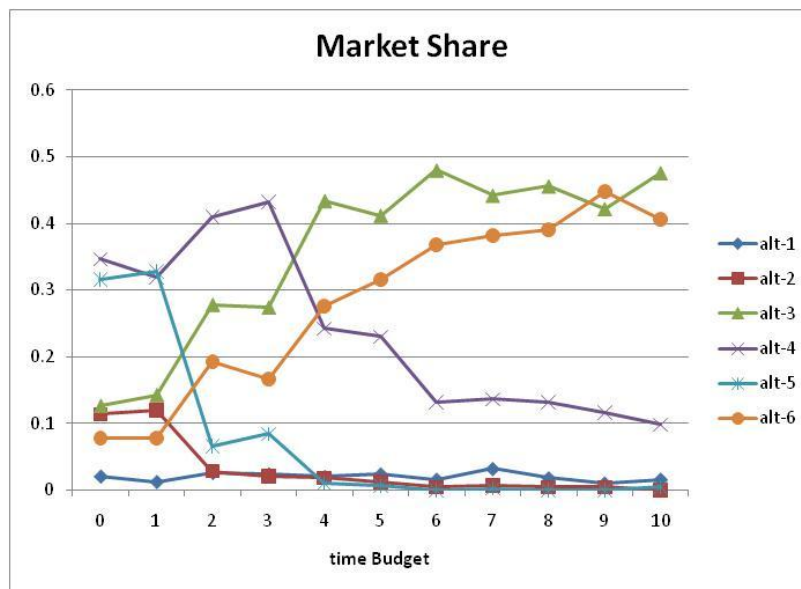


Figure 3 Market Shares

$$\text{Prob}(y_i=A|A \in CS_i) = \text{Prob}(A \in CS_i|y_i=A) \times \frac{\text{Prob}(y_i=A)}{\text{Prob}(A \in CS_i)} \quad (7)$$

and, since in this case $\text{Prob}(A \in CS_i|y_i = A) = 1$, this equation can be simplified as;

$$\text{Prob}(y_i=A|A \in CS_i) = \frac{\text{Prob}(y_i=A)}{\text{Prob}(A \in CS_i)} \quad (8)$$

Applying (6) to the simulation data gives a result as presented in Figure 4.

The graph in Figure 4 provides further indication of the impact of accessibility on the role of the consideration set. In situations where decision makers are restricted (lower time budget) the consideration set has an important role, indicated by the drastically higher $\text{Prob}(y_i = A|A \in CS_i)$ values. In less restrictive situations (time budget > 5) the probability that an alternative is chosen when we know it is already included in the consideration set relies almost entirely on the attribute that is prominent in the second stage ($\text{Prob}(y_i = A|A \in CS_i) < .50$). In this situation membership of the consideration set does not provide any guarantee that an alternative will be chosen. On the other hand, with more restrictions in accessibility this value drastically increases, indicating the probability to be chosen depends more on whether the alternative is included in the consideration set and less on the second stage attribute. The example is alternative 6. When the time budget < 2, the alternative will almost always (p=0.80) be chosen once it is included in the consideration set. In this case, the consideration set holds a significant and decisive role in determining the choice outcomes.

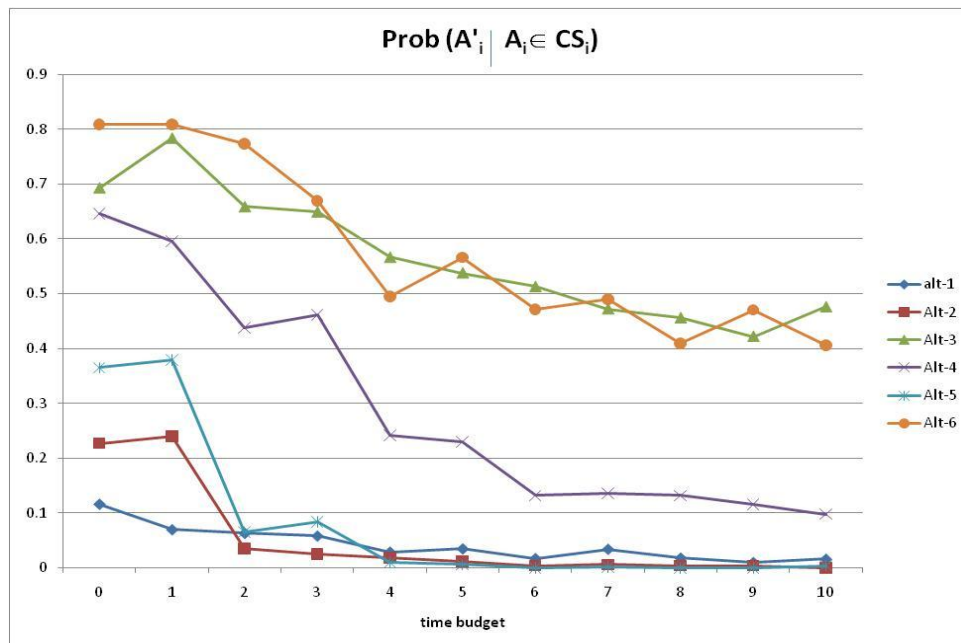


Figure 4 Market Shares Conditional on Consideration

The result highlights that the effectiveness of stage-wise choice modelling, at least partially, depends on the level of accessibility toward alternatives. In the less restrictive conditions, with time budget ≥ 4 , more than half of the decision makers are able to access all available alternatives (see Figure 2). It seems in this condition the choice process can effectively be modelled as a single compensatory process with trade-offs between spatial (detour) and non-spatial (attractiveness) attributes. However in restrictive situations (time budget < 4) the stage-wise modelling becomes more relevant, since the non-compensatory nature of the spatial attribute becomes more apparent and the effect of the spatial attribute becomes more dichotomous (feasible or not feasible) rather than a continuous distance based effect. In this case, modelling the process as a single compensatory trade-off could potentially lead to misspecification, especially an overestimation of the effect of the spatial attribute. This is well illustrated by the stark difference in market shares of two similarly attractive and closely located alternatives (1 and 4) between the restrictive (time budget < 4) and non-restrictive (time budget ≥ 4) conditions.

6 Simulation 2: Time Budget and Network Connectivity Effects

6.1 Data Generation

This simulation is done in the same setting as the first simulation, including the grid and the random generation of individual trips. The main difference is that in this simulation individuals are placed in three different traffic scenarios representing three conditions of travel speed and congestion (Table 2). The basic idea is that an individual's accessibility within a transportation network depends not only on individual specific time budgets but also on the network connectivity. A greater connectivity will provide access to a greater number of alternatives. Average travel speed is usually considered a realistic measure of network connectivity (Miller, 1998; Weber and Kwan, 2002) and (Neutens et al. 2008) therefore different scenarios of network connectivity can be simulated by assigning different levels of travel speed.

Similar to the previous simulation, the choice process consists of two stages: first the determination of the *feasible set* based on formula (1) and next the determination of *the actual choice*, which is based on a trade-off among alternatives in terms of their non-spatial attractiveness. A Random Generation Process is implemented similar to the first simulation. The only substantive difference is in the definition of the Feasible Opportunity Set (FOS), which now includes different average speed levels. Alternative j is included in the FOS if it is located inside the

Table 2 Traffic Scenarios

Scenario	Setting	Average speed (V_x)
1	Off peak hour (low density)	1.00 grid/unit of time
2	Weekdays peak hour (medium density)	0.75 grid/unit of time
3	End of business week peak hour (high density)	0.50 grid/unit of time

individual's Potential Path Space (PPS), which is now defined as;

$$PPS_i = \{(j, t) | detour_{ij} \leq t_i * V_x\} \quad (5)$$

6.2 Model Estimation

MNL and CMNL models as described earlier are estimated for each of the three scenarios. The estimation results from simulation 2 are listed in Table 3,

Table 3 Estimation result for Simulation 2

Scenario-1				
	MNL		CMNL	
	Coef.	(t_{asvmp})	Coef.	(t_{asvmp})
Constant	0.048	(0.514)	0.048	(0.514)
Detour distance	-0.331	(-19.857)		
Attractiveness	0.881	(20.072)	0.878	(18.899)
Scale (ω)			0.344	(8.821)
Threshold (detour)			-5.971	(-0.697)
LL	-1184.904		-1184.826	
AIC	2.546		2.548	
BIC	2.562		2.569	
Scenario-2				
Constant	0.244	(2.155)	0.230	(2.037)
Detour distance	-0.586	(-20.887)		
Attractiveness	1.067	(20.648)	1.039	(19.771)
Scale (ω)			0.696	(13.588)
Threshold (detour)			0.043	(0.060)
LL	-1082.026		-1077.970	
AIC	2.177		2.170	
BIC	2.191		2.190	
Scenario-3				
Constant	0.339	(2.312)	0.285	(1.932)
Detour distance	-0.888	(-22.628)		
Attractiveness	1.103	(18.451)	1.056	(17.589)
Scale (ω)			1.262	(16.172)
Threshold (detour)			1.171	(5.453)
LL	-838.401		-813.321	
AIC	1.874		1.820	
BIC	1.890		1.842	

As expected, the models show increased levels of fit for the two-stage approach compared to the one-stage approach with the addition of more spatial restrictions, as indicated by the higher reduction in Loglikelihood, AIC and BIC values for CMNL compared to MNL in the most restricted scenario (scenario 3) compared to the more relaxed situations (scenarios 1 and 2). A stark contrast can be observed between scenario 1 and scenario 3. In scenario 1 where there are the least limitations, the CMNL basically collapses into the regular MNL, indicated by the almost perfect similarity in estimated coefficients (attractiveness and constant) and also the goodness of fit values. In scenario 3, however, one can easily observe the superiority of CMNL over MNL in model fits.

Furthermore the results confirm the finding from the previous simulation regarding the increased effectiveness of stage-wise modelling with the increase of spatio-temporal limitations. This is indicated by the increased significance of the scale (ω) value and the significance of the threshold value in the CMNL estimated for scenario 3. This indicates how the two-stage model effectively captures the increase in the crispness of the elimination process in the first choice stage, as caused by the greater restriction in accessibility. As described in the previous simulation, this effect could be spotted in the different choice outcomes between two similarly attractive and closely located alternatives.

The following example will explain how a two-stage model better captures this effect compared to a one-stage approach. Let's again compare the similarly attractive alternatives 1 and 4. Imagine a decision maker i whose trip composition is such that a detour to these alternative costs 4 and 3 time units, respectively. It is obvious that, from decision maker i 's point of view, alternative 4 is slightly better located therefore will have better chance to be chosen. Figure 5 describes the odds ratio of the two alternatives (choice probability of alternative 4 over probability of alternative 1) in different scenarios based on a one-stage MNL and two-stage CMNL

As indicated in simulation 1, the increase in accessibility restrictions will dramatically increase the choice probability of a spatially superior alternative, as indicated in the jump of the market share (see Figure 2). The significant jump in odd ratios calculated from the CMNL when restriction is applied compares to a more

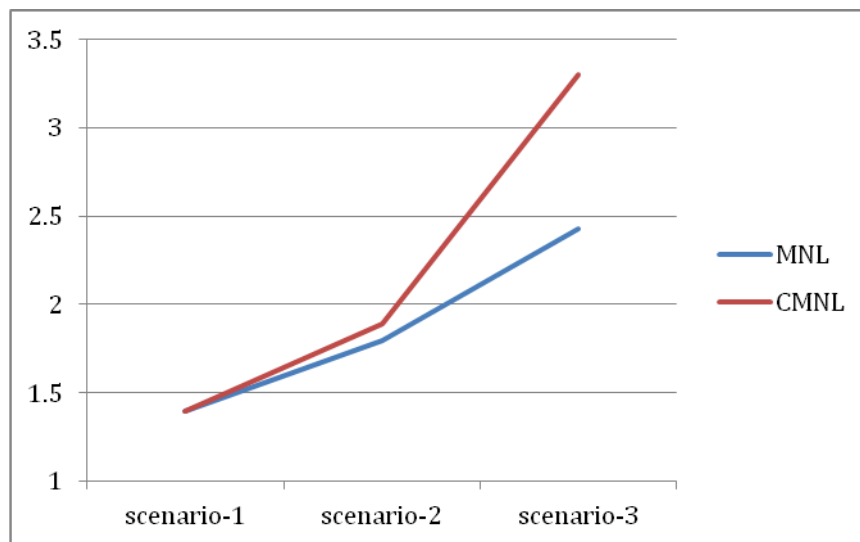


Figure 5 odds ratio of two similarly attractive and closely located alternatives

modest increase in the MNL, indicating the better ability of the two-stage model in capturing the effect.

For the more restricted scenarios (2 and 3) the two-stage model (CMNL) provides relatively lower estimated values of attractiveness than the one-stage MNL model, whereas in scenario 1 the estimates for attractiveness are almost similar in both models. This is in line with the findings from our previous descriptive analysis that in a spatially restricted condition the choice outcome is much less affected by the non-spatial (attractiveness) attribute.

This indicates that ignoring the two-stage process in modelling will lead to greater misspecification when accessibility restrictions increase. The results seem to indicate that when a decision maker's ability to access the alternatives becomes more limited, more information is contained in the consideration stage of the choice process, which increases the importance of modelling the process in a stage wise manner.

7 Discussion and conclusion

There are three important findings from the simulations presented in this paper. Firstly, the role of the consideration set depends on the underlying context, which in this paper is based on the decision maker's level of access to alternatives. The more restrictions are imposed on access, the more important the consideration set becomes in setting the outcome of the choice process. This finding may help reconcile the two different streams of thinking regarding the role of consideration set in the choice process.

Secondly, in the condition where decision makers go through their choice decision in a stage-wise manner, with a non-compensatory process in the first stage and a compensatory trade-offs in the second stage, it is quite natural to think that a two-stage model will provide better fit compared to a one-stage approach model. However, this seems to be only true if the decision maker has limited access to alternatives. In the condition where the accessibility limitation is minimal (or non-existent) a one-stage model performs at par with the two-stage model.

Thirdly, spatio-temporal limitations faced by the decision maker potentially reduce the importance of non-spatial attributes, especially in highly restricted conditions. These effects explain why the chosen alternative is not the most attractive one in general. It appears that fuel consumers' choices do not necessarily reflect their "true" preferences, as also observed in previous studies (Dingemans et al. 1986; Kitamura and Sperling 1987), however this is caused by model misspecification due to misspecification of the choice set. In the constrained simulation, the individuals face limited choice sets that exclude more attractive but inaccessible alternatives that were included previously in their consideration set. The results suggest that, for such constrained conditions, an analyst who relies only on the choice data is likely to misinterpret consumers' refuelling preferences. It is only by incorporating the analysis of the consideration stage that such misinterpretation can be avoided.

The findings of this study indicate that access influences choice outcomes and model estimates. In conditions where access is limited, for example in a path dependent situation such as in the context of petrol station choice, where the motorist's movements are channelled by the road traffic network, it is likely that a two-stage decision making process is based on the operation of feasibility criteria. In such situations the consideration set may hold significant additional information regarding the consumer's preferences, since it consists of alternatives that the motorist actively considered in his evoked set (Narayana and Markin 1975; Spiggle and Sewall

1987). The findings suggest that in a constrained situation such preferences may not be able to be uncovered by only analysing the choice data.

The results further indicate that ignoring the impact of spatial measures in such contexts will create overestimation on the non-spatial attribute. This finding highlights the importance of adequately incorporating the effects of spatial accessibility in behavioural modelling. One way to accomplish this is by applying the concept of Feasible Opportunity Set as an alternative choice set definition as shown in this paper.

From a modelling perspective, this indicates that uncovering the antecedents of consideration sets is as important as analysing the choice decision itself, since, as shown in the results, some factors which possess obvious importance to the decision maker (e.g. attractiveness in constrained situations), may not be uncovered, if the analyst is only modelling the choice without putting effort in modelling the consideration set. The consideration set may provide useful additional information after all.

Finally, the simulation also provides an example of the effectiveness of the implicit approach in the two stage choice model, both in formal simplicity, the efficiency of estimation process and its effectiveness in reconciling the non-compensatory process in a Random Utility Framework.

The paper bears several important limitations. First, due to this being a simulation study, the external validity of the findings will require scrutiny with empirical data. Secondly, the paper limits itself to the assumption that each attribute only operates in either of the two stages, while there might be a possibility that it could operate in both stages. We explored extending our simulation to situations where both attributes could operate in both stages, however technical limitations of the CMNL model in dealing with multi-collinearity precluded analysing results for such conditions. Analysing effects of attributes operating in both stages therefore remains an issue for further research, possibly by a more robust approach such as the Probabilistic Choice Set model is needed to overcome this limitation. Thirdly, this paper was limited to exploring accessibility effects for routinized refuelling behaviour; future research should also start exploring access effects on non-routinized “on the fly” decision making. Related to this, future research could also further explore the role of variation in knowledge about alternatives, which was here simulated by assigning normally distributed random disturbances to alternatives. Disturbances could for example vary with distance to represent better knowledge of closer alternatives.

References

- Arentze, T. A. and H. J. P., Timmermans, 2005. An analysis of context and constraints-dependent shopping behaviour using qualitative decision principles. *Urban Studies*, 42(3), 435-448.
- Ben-Akiva, M. and B., Boccara, 1995. Discrete choice models with latent choice sets. *International Journal of Research in Marketing*, 12(1), 9-24.
- Bierlaire, M., R., Hurtubia and G., Flötteröd, 2010. Analysis of implicit choice set generation using a constrained multinomial logit model. *Transportation Research Record*, 2175, 92-97.
- Boots, B. N. and P. S., Kanaroglou, 1988. Incorporating the effects of spatial structure in discrete choice models of migration. *Journal of Regional Science*, 28(4), 495-507.

- Borgers, A. and H., Timmermans, 1987. Choice model specification, substitution and spatial structure effects: A simulation experiment. *Regional Science and Urban Economics*, 17(1), 29-47.
- Cascetta, E. and A., Papola, 2001. Random utility models with implicit availability/perception of choice alternatives for the simulation of travel demand. *Transportation Research Part C*, 9(4), 249-263.
- Cascetta, E. and A., Papola, 2009. Dominance among alternatives in random utility models. *Transportation Research Part A*, 43(2), 170-179.
- Decrop, A. 2010. Destination Choice Set: An Inductive Longitudinal Approach. *Annals of Tourism Research*, 37(1), 93 - 115.
- Dingemans, D., D., Sperling, and R., Kitamura, 1986. Mental maps and refueling behavior of vehicle drivers. *Transportation Research Record*, 1096, 1-10.
- Fotheringham, A. S., 1988. Consumer store choice and choice set definition, *Marketing Science*, 7(3), 299-310.
- Fotheringham, A. S., 1991. Statistical modelling of spatial choice. *Research in Marketing*, (5), 95-119.
- Fotheringham, A. S. and P. A., Pellegrini, 2002. Modelling spatial choice: a review and synthesis in migration context. *Progress in Human Geography*, 26(4), 487-510.
- Gensch, D. H., 1987. A Two-Stage Disaggregate Attribute Choice Model. *Marketing Science*, 6(3), 223-239.
- Hägerstrand, T., 1975. Space, time and human conditions, In A., Karlqvist, L., Lundqvist and F., Snickars (Eds), *Dynamic Allocation of Urban Space*. Farnborough: Saxon House, 3-15.
- Horowitz, J. L. and J. J., Louviere, 1995. What is the role of consideration sets in choice modeling? *International Journal of Research in Marketing*, 12(1), 39-54.
- Hui, S. K., P. S., Fader and E. T., Bradlow, 2009. Path data in marketing: An integrative framework and prospectus for model building. *Marketing Science*, 28(2), 320-335.
- Jones, K. and J., Simmons, 1990. *The Retail Environment*. London: Routledge.
- Kim, H.-M. and M.-P., Kwan, 2003. Space-time accessibility measures: A geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration. *Journal of Geographical Systems*, 5(1), 2012, 71-92.
- Kitamura, R. and D., Sperling, 1987. Refueling behavior of automobile drivers *Transportation Research Part A*, 21(3), 235-245.
- Kwan, M. P., D. G., Janelle and M. F., Goodchild, 2003. Accessibility in space and time: A theme in spatially integrated social science. *Journal of Geographical Systems*, 5(1), 2012, 1-4.
- Kwan, M. P. and H., Xiao-Dong, 1997. Network-based constraints-oriented choice set formation using GIS. *Journal of Geographical system*, 5, 139-162.
- Manski, C. F., 1977. The Structure of random utility models. *Theory and Decision*, 8 (3), 229-254.
- Martínez, F., F., Aguila and R., Hurtubia, 2009. The constrained multinomial logit: A semi-compensatory choice model. *Transportation Research Part B*, 43(3), 365-377.
- Miller, H. J., 1998. Measuring space-time accessibility benefits within transportation networks: Basic theory and computational procedures. *Geographical Analysis*, 31(1), 1-23.
- Narayana, C. L. and R. J., Markin, 1975. Consumer behavior and product performance: An alternative conceptualization. *Journal of Marketing*, 39(4), 1-6.
- Neutens, T., N., Van de Weghe, F., Witlox and P., Maeyer, 2008. A three-dimensional network-based space-time prism. *Journal of Geographical Systems*, 10(1), 89-107.

- Payne, J. W. and J. R., Bettman, 1992. Behavioral decision research: A constructive processing perspective. *Annual Review of Psychology*, 43(1), 87-131.
- Pennerstorfer, D., 2009. Spatial price competition in retail gasoline markets: Evidence from Austria. *Annals of Regional Science*, 43, 133-158.
- Roberts, J. and P., Nedungadi, 1995. Studying consideration in the consumer decision process: Progress and challenges. *International Journal of Research in Marketing*, 12(1), 3-7.
- Roberts, J. (1989). A grounded model of consideration set size and composition. *Advances in Consumer Research*, 16(1), 749-757.
- Shocker, A. D., M., Ben-Akiva, B., Boccara and P., Nedungadi, 1991. Consideration set influences on consumer decision-making and choice: Issues, models, and suggestions. *Marketing Letters*, 2(3), 181-197.
- Sohn, K. and D., Kim, D. 2010. Zonal centrality measures and the neighborhood effect. *Transportation Research Part A*, 44(9), 733-743.
- Spiggle, S. and M. A., Sewall, 1987. A choice sets model of retail selection. *Journal of Marketing*, 51(2), 97-111.
- Swait, J., 2001. Choice set generation within the generalized extreme value family of discrete choice models. *Transportation Research Part B*, 35(7), 643-666.
- Weber, J. and M. P., Kwan, 2002. Bringing time back in: A study on the influence of travel time variations and facility opening hours on individual accessibility. *Professional Geographer*, 54(2), 226-240.