The 3Ds of the built environment and leisure activity choice: an assessment for the Netherlands

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Abstract:

The linkages between the built environment and travel decisions have been discussed extensively in the literature of recent decades. Frequently, a significant association is found between the close environment of a consumer, and the choice of mode and distance traveled. However, travel in itself is merely a derived demand, and it is the need or preference to undertake other, stationary activities that drives travel choices. Activity patterns have changed over the years. Particularly the number of leisure activity trips has increased significantly, to almost twenty-four percent of the total number of trips in 2007. This paper studies built environment effects on leisure activity choice in the Netherlands. To clarify this relationship, we relate the 3Ds of the built environment (density, diversity, and design) to elaborate data on leisure trips in the Netherlands from the Continuous Free Time Survey 2006-2007, which was gathered by using an activity diary approach. Socio-demographic, socio-economic, and time-specific factors serve as control variables.

We deploy an alternative-specific logit model to disentangle these effects. The paper shows that residential density significantly influences leisure activity participation: residents from (very) high-dense neighborhoods for example participate more often in social entertainment activities than residents of less-dense neighborhoods, while cycling trips and walking trips attract relatively many residents of low-dense neighborhoods. The interplay of supply and demand accounts for these differences. The rate of diversity also determines activity choice: a higher rate of diversity in supply of an activity positively induces a consumer to choose for this activity. Design does not determine activity choice in this instance, if all three built environment indicators are added simultaneously to the model.

The results are relevant for (at least) two reasons. First, since we control for socio-demographic, socio-economic, and time-specific factors, we are able to capture the effects of the built environment on activity choice at a detailed level. Second, the estimates have a clear policy implication in a constantly changing and increasingly dense environment such as the Netherlands. Lack of space is imminent, and as such an optimal allocation of the remaining available space is essential, to let consumers optimally enjoy its leisure preferences within the set of constraints the consumer experiences. Hence, a study on how the environment affects leisure activity choice is warranted.

Keywords: Leisure activity choice, built environment, 3Ds, alternative-specific conditional logit

1 Introduction

The primary focus of transport planning in the Netherlands of the last three decades has been in providing adequate transport infrastructure facilities, to meet long-term needs. Growth has however not been confined to the level of transportation infrastructure. Urban areas are developing continuously in terms of size, with green areas being turned into residential areas, and a change in pattern is not expected in the near future. Particularly the Randstad area (a metropolitan region in the western part of the Netherlands, containing the major cities in the country) has full potential to grow rapidly in the next thirty years because of its appeal as financial, business, and transport centre of the country. Scarcity of open space is thus imminent, and consequently the focus of transport literature has shifted, especially in recent years, towards the integration of modeling land-use and travel behavior. Deploying a large variety of methods, a significant number of studies concludes the built environment determines travel behavior to some extent, yet no agreement exists on the extent of influence and how to model the built environment[1].

The expected development of metropolitan regions increases the need for an even more refined and efficient transport network and land-use planning, to ensure residents can organize their daily schedules as efficient as possible. As Becker (1965) convincingly notes, an individual deals with both monetary and time constraints in scheduling its activities optimally; he or she will pursue maximum utility while minimizing both cost and time. The locations of home, work/school, leisure activities, and their respective distances, play an important role in meeting individual monetary and time constraints. Travel behavior surveys, such as the Mobility Survey Netherlands, show that, within these constraints, activity patterns have changed over the years. Particularly the number of leisure activity trips has increased significantly, to almost twenty-four percent of the total number of trips in 2007. Aguiar and Hurst (2007) confirm this trend; the amount of time (and thus money) spent on leisure activities has increased in the last decades, while time spent on work-related activities shows a continuously decreasing trend.

Thus, in recent times the efficient scheduling of trips with leisure sites as destination has increased in importance. While work locations are rather fixed and insensitive to spatial substitution in the short-term, leisure activities can be expected to have a higher importance attached to proximity[2]; proximity significantly determines an individual to choose for one

[1] Bohte *et al.* (2008) provide a thorough review of recent publications on the relationship between the built environment and travel behavior, and the role self-selection plays in the decision mechanism. The review addresses the results and methodologies of the numerous studies in great detail, so we will not undertake such a study here.

[2] Some studies focus on the participation in one activity, and prove the importance of proximity. Zhang (2005) performs a study for green space recreation in Guangzhou, China. Proximity of a green space site is the most important determinant to visit a site. Maat and De Vries (2006) add that only high-quality, big-sized green space sites are able to break this pattern. As soon as reputation effects do not count anymore a potential user of green spaces will settle for the green space in the proximity of his residence.

activity site, instead of another comparable site. Largely overlooked in current literature are the substitution patterns in a set of leisure activities, and the relationship with the built environment[3]. To optimally plan the remaining, and scarce, open space it is however crucial to determine which substitution patterns exist, and especially in what way the built environment determines an individual to choose for one activity and not for the other.

Several studies, such as Cervero (2002) and Bhat et al. (2009), stress that neglecting land-use and the built environment leads to an over- or underestimation of other variables, as these variables soak up the influence of the omitted variables. However, these choice patterns provide a policy maker the necessary input to adjust policy or implement new policy. We consider the built environment here as a multi-facet concept, in line with Cervero and Kockelman (1997). According to recently popularized planning movements such as new urbanism and smart growth, three factors (the 3Ds) determine the appeal of a neighborhood. Density emphasizes compactness, and thus serves as a condition to bring origin and destination closer together. Also, some activities require a high rate of density to make it a worthwhile investment, and thus differences in population density are assumed to induce differences in activity choice patterns. The rate of diversity measures the set of opportunities a respondent has, and to what extent the diversity in supply of the leisure activities determines choice. Design, finally, pinpoints the character of a neighborhood and is thus a representation of the ease of getting to a destination.

To disentangle the relationship between the built environment and leisure activity choice we need to analyze disaggregate behavioral responses, and reflect them on various spatial characteristics. This paper will therefore study the substitution patterns between eight categories of leisure activities. To do so, we use data on outdoor leisure trip choice from the Continuous Travel Survey Database, administered by market agency TNS-Nipo, and enrich this database with spatial data. Since previous studies acknowledge the importance of socio-demographic and socio-economic variables for activity choice, these explanatory variables will serve as control variables.

Methodically this paper will use an alternative-specific conditional logit model (McFadden's choice model), in which both alternative-specific and case-specific data determine choice. We find that a higher rate of diversity in supply of one activity increases the odds the consumer chooses this one activity, while the density parameters portray significant differences in rate of participation between the eight activities; logically this points at differences in supply per type of neighborhood. Both the density and diversity indicator

[3] Studies who enlarge the set of activities to analyze activity trade-offs usually focus on different types of activities. For example, Maat and Arentze (2003) project the substation patterns of daily and non-daily shopping to time spent at work and school. Lu and Pas (1999) also perform such a study, checking for the influence of socio-demographic variables.

point at the policy relevance of the topic, as policy-makers clearly influence choice patterns of consumers by the choice of location of new leisure sites.

The remainder of the paper is structured as follows. In Section 2, we provide a review of the literature related to built environment, travel behavior, and leisure activity choice, and hypothesize some relationships. Section 3 gives a detailed description of the modeling strategy and data, while Section 4 contains the estimation results, and discusses these results. Section 5 concludes.

2 The built environment, travel behavior, and leisure activities

The past two decades has seen a considerable number of studies, at varying degrees of depth and sophistication, on travel demand. Usually these studies embody a clear policy stance; reduction of travel is necessary as life faces an increasing number of constraints. The complexity of travel decisions is noteworthy. This section discusses the interrelationships between the built environment, travel behavior, and leisure activity participation.

2.1 How to operationalize the built environment?

In making its decisions households experience several constraints. First, to fulfill its consumption needs a household gathers resources by engaging in labour, as consumption goods all come at a cost. Each household trades off the benefits of spending additional time in either production or consumption, and allocates time according to its consumption preferences. Leisure is one of the consumption opportunities the household has, according to Becker (1965). In such a case the household spends time and money on the participation in leisure activities, and thus forgoes income in the same manner as with typical consumption goods.

However, the allocation of time in production and consumption depends on numerous other constraints. For example, households nowadays spend a significant fraction of available time on travel between home, work, and leisure sites. Data on travel behavior in the Netherlands, assembled in the Mobility Survey Netherlands 2007, shows every individual on average needs twenty-three minutes per one-way trip to change location. At some point, time required to travel between locations is not within the limits of the household's time possibility set. Consequently, to limit travel time, the location of the residence relative to work and leisure sites is crucial: the location of the residence spatially constrains the opportunities of the household. Popular spatial planning strategies of recent decades, such as new urbanism and smart growth, therefore emphasize the importance of a high-diverse supply of facilities in the vicinity of the residence to limit travel time. Travel demand literature suggests that the residential location, subsequently, is automatically linked to mode choice and mode ownership, which implies the built environment determines travel behavior. For example, Bhat *et al.* (2009) find statistically significant linkages between the built environment, household vehicle holdings and usage, while Bhat and Guo (2007) confirm a negative association between the ownership of cars and the availability of a high-quality transit network in the vicinity of the residence. Dieleman *et al.* (2002) assess that mode choice and distance traveled significantly differ between households because of built environment characteristics[4].

Little agreement exists on how to estimate the built environment. Population density and, additionally, employment density frequently serve as indicator of the built environment[5]. This narrow view is however frequently criticized. For example, Handy (1996) questions whether it is really density that matters, or the factors that go along with density. Badoe and Miller (2000) add that density merely acts as a proxy for the important travel demand factors it wants to explain, such as travel time and travel cost, and that the built environment would leave us uninformed on the deeper trade-offs consumers make with respect to their set of constraints. Thus, a clear understanding of built environment effects, especially in light of the imminent lack of space to construct new leisure sites, requires a detailed framework.

Several studies probe and dissect the many ways in which urban form and neighborhood design shape travel behavior. In many studies, the indicator choice stems from urban design theories that have gathered support in recent decades as ways of limiting travel demand into the set of human, time-specific and spatial constraints. In light of the decreasing amount of available space and individual limitations, developing urban spaces efficiently is worth the while, and logically new urbanism, with its emphasis on efficient and mixed usage of open space to limit travel time, comes as a straightforward choice. Subsequently, scientific research can provide empirical justification on the most efficient set of built environment indicators. For example, Kockelman (1997) utilizes accessibility, land-use balance, land-use mix, and density as indicators. Of these four typical built environment indicators density appears to lack importance for travel behavior when the other built environment indicators are taken into account. Lee and Moudon (2006) confirm this tendency in their study on the built environment and walking behavior in an activity-based approach.

Cervero and Kockelman (1997) rationalize an optimal representation of the close environment requires indicators on density, diversity, and design (the so-called "3Ds"), as

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[4] Frequently, studies relating the built environment to travel behaviour add socio-demographic variables as control variables to the model. Recent examples of such studies are Cao *et al.* (2007) and Kemperman and Timmermans (2008).

[5] Some recent and not-so-recent studies that use population and employment density as indicators of the built environment are Bhat *et al.* (2009), Crane and Crepeau (1998), Boarnet and Sarmiento (1998), Naess (2006), Newman and Kenworthy (1989), and Fillion and McSpurren (2007). Ewing and Cervero (2001) find employment density to be a more significant predictor for the built environment than population density.

new urbanism employs these indicators as tools to structure new neighborhoods. Density serves as a condition to acquire certain services; local areas require high population density to attain basic local facilities (Naess, 2006). Subsequently, diversity promotes the easy access to a wide range of activities; a high rate of diversity in the vicinity of the residence ameliorates the odds an individual arrives at the site of his or her preferred variety within the set of constraints. Last, the design of the built environment affects the ease of reaching a location, which is a different type of accessibility than the diversity indicator. Design effectively ensures the consumer is able to enjoy the full range of diverse opportunities efficiently. The three built environment indicators together summarize the attractiveness of the close environment. Cervero and Kockelman (1997) apply a factor analysis to detect the most influential micro-level attributes of these 3Ds.

Many recent and not-so-recent applications also deploy the 3D's to analyze built environment effects on travel behavior. For example, Cervero (2002) expands the framework by including variables on both the origin and destination of the trip. Point elasticity estimates show, for mode choice, land-use intensity (density) and mixture (diversity) exert the highest influence, while the design indicators determine mode choice only to a minor extent. Ewing and Cervero (2001) perform a meta-analysis on applications of the 3Ds framework, and although the authors acknowledge the comparison is methodologically tricky, all built environment indicators exert influence on travel behavior. A recent study by Chen *et al.* (2008) confirms this finding, although here employment density at work determines mode choice most. Chatman (2008) relates the built environment to the number of non-work trips per mode, but reports different patterns per mode. In the case of car trips for example, all three built environment indicators are significant when including them separately, yet lose significance when added to the model simultaneously. Density is the only built environment indicator exerting influence at that point, although the inclusion of an interaction variable for the insignificant diversity and design indicators yields significant results. This finding confirms common belief that the built environment is a difficult topic to tackle: several combinations of these indicators are theoretically sound. This is in line with the conclusion of Cervero and Kockelman (1997), who find some degree of credibility to the claim that compact (thus, high-dense), mixed-use (thus, high-diverse), pedestrian-friendly designs can influence the number of vehicle trips and decrease the number of miles traveled. All built environment indicators seem to matter, yet the extent of influence really differs per research question.

Fang (2008) and Kinnell *et al.* (2006) criticize the simultaneous addition of three built environment indicators because of multicollinearity. Especially design and density are often prone to collinearity issues. Ewing and Cervero (2001) however reply that lumping a neighborhood into a single categorical variable leads to a concomitant loss of information.

Although some features are co-dependent – for example, many studies report higher importance to diversity when density is high – bundling variables can be a weakness because the individual effects doubtlessly differ in magnitude. The trick is to find a specification which is not prone to collinearity issues. Such high-detailed information on the linkages between the built environment and individual behavior provides essential policy information.

2.2 Activity choice and the built environment

It is righteous to claim travel is the result of a complex decision-making process by which individuals and households try to meet their needs and preferences under constraints of time, financial resources, social opportunities, and the built environment. Travel in itself is however merely a means to an end or derived demand, as it is, to a far extent, not the purpose of the individual to engage in travel itself (Lu and Pas, 1999). Individuals and households travel because of the need or preference to undertake other, stationary activities. Physiological needs, institutional needs, personal obligations, and personal preferences derive the demand for these activities (Naess, 2006). In recent years this view has been challenged by many theorists who see travel as a purpose in itself, but the scarcity of open space in the metropolitan Randstad region necessitates an activity-based approach, rather than a trip-based approach, as the preferred location of a leisure alternative is warranted.

Although several studies have linked the built environment to (leisure) activity participation in recent years, no study has implemented a detailed description of the built environment in line of Cervero and Kockelman (1997). Rather, the remaining studies frequently implement a single categorical variable to correct for built environment influences, or divide the set of respondents in latent classes. With respect to unraveling activity choice, we can distill two broad categories of studies. The first category focuses on the trade-off between a variety of activities, while the second category disentangles the motivations to participate in a single activity. For the latter, subject of study is in many instances the dissection of what determines individuals to recreate in green spaces. For example, Maat and De Vries (2006) test the compensation hypothesis of green space leisure – that is, are individuals lacking considerable amounts of green space in close proximity of the residence willing to travel a bit further to enjoy green space leisure? The study clearly dissects which influence the quality and quantity of proximate areas have on activity choice, and the degree of distance deterrence of a single activity. In the case of Arnhem, a Dutch middle-sized city, no substantial evidence was found for the compensation hypothesis. It is proximity which tailors the choice to recreate in green spaces. Likewise, Fleischer and Tsur (2003) study the value of different types of natural open spaces in Israel, and add that the type of site does not matter in site choice and participation, rather only distance towards the green space site.

The importance of proximity in activity choice is not limited to merely green space activities: participation in typical central city activities is also adjacent to the location of the residence and distance towards the activity site. Glaeser and Gottlieb (2006) explore participation in such typical central city activities, and confirm this association for cultural activities and social entertainment. Residents in suburban areas significantly participate to a lesser extent in central city activities than residents residing in central city areas, as the rate of supply is lower in the suburbs and distance reduces the attractiveness of the activity for the suburban resident. In terms of the 3Ds framework, these results suggest high density in the central city serves as an attraction force for activities to exist, while the lack of diversity in central city activities in the suburbs drives these neighborhoods' consumers to participation in another activity. Yet, the study does not separate the effects of the various features of the built environment, and only includes a dummy for the location of the residence while consumer preferences are arguably more intricate.

Also, the imminent lack of space and, as a consequence, high importance of a spatially sound division of amenities requires in-depth analysis on the trade-off between all leisure activities, while Glaeser and Gottlieb (2006) discuss participation in activities without looking into activity trade-offs. A small number of studies reports activity trade-offs, but these studies are usually not confined to leisure activities. Lu and Pas (1998) for example analyze activity participation and travel behavior for four categories of activities, including leisure, but do not consider the built environment as a determinant in the model. Maat and Arentze (2003) discuss the trade-off between work, school activities, daily, and nondaily shopping. To correct for the supply of activity sites in the vicinity of the residence, distance to the nearest daily shopping and service facilities is added, but this measure leaves distance insignificant. The usage of cumulative opportunity measures for activities, at multiple spatial scales, produces some significant results, but it is the inclusion of the square root of the cumulative opportunity measure which marks a real improvement. These results indicate that it is important to have some shops nearby instead of a large number of shops in the vicinity, which would imply that differences in supply do not affect activity choice.

Naess (2006) however asserts it depends on the type of activity. Activities can be classified into bounded and non-bounded activities, with the former group being fixed in time and space, and the latter flexible. For some non-bounded activities the site the individual visits in itself does not matter as all sites are rather homogeneous in nature; proximity is, logically, decisive for these activities. For other activities quality differences or symbolic differences in activity sites may encourage the individual to travel further than the closest option[6]. Thus,

[6] Murdock (2006) and Von Haefen and Phaneuf (2008) provide a methodology to analyze such site-specific differences in quality. The methodology is attractive since site-specific data is not required to observe the influence of heterogeneity in activity sites.

participation in activities susceptible to quality differences likely enlarges with a high supply in the vicinity of the residence, as it implies the odds of having your favourite variety within the set of your constraints increases. Naess (2006) shows the built environment indeed determines activity participation in the Copenhagen area to some extent: central city residents trade off participation in typical central city activities, such as cultural activities and social entertainment activities, in favor of participation in green space activities. Residents of the outer suburbs on the other hand recreate more often in forests and at shores. This finding is consistent with the supply side of the area.

Kemperman and Timmermans (2008), finally, discuss consumer heterogeneity in leisure activity participation of both in-home and out-of-home leisure activities. The study establishes four latent segments in the set of consumers, and shows these latent segments self-select themselves into neighborhoods which fulfill their leisure needs easiest[7]. Thus, the degree of urbanization is significantly related to the latent class segments: participants of cultural activities to a high extent live in relatively highly urbanized areas, and the segment of traditional consumers to a large extent reside in less urbanized areas, and engages more often in both in-home activities and out-of-home green space activities. The high supply of outdoor recreation opportunities in lower urbanized areas helps to fulfill the traditionalists' recreational needs.

This study focuses on out-of-home leisure activities only, for multiple reasons. First, due to the imminent lack of space, efficient and effective usage of the remaining open space above all necessitates insights on the linkages between socio-demographics, the built environment, and activity participation in out-of-home leisure activities. After all, this type of leisure activities seizes the remaining space when new sites are established. Second, although many studies confirm the importance of out-of-home leisure activities for society, the literature lacks a study which links out-of-home activity participation to the built environment in a detailed manner. The current study is therefore a worthy addition to the literature.

2.3 Research hypotheses

Findings of previous studies guide us to hypothesize relationships between the built environment and leisure activity participation. We implement the 3Ds framework, which stress the importance of density, diversity, and design of the close environment for travel

[7] A large stream of literature discusses residential self-selection and its effects on travel behavior. Recent additions are Cao *et al.* (2007), Chatman (2005), and Pinjari *et al.* (2009), with mixed results. Chatman (2005) argues self-selection issues can be ignored as the difference in attitude to activities and travel preferences is small, and housing markets do not allow residents to freely choose a location according to its preferences. Cao *et al.* (2007) and Pinjari *et al.* (2009) however conclude residential self-selection effects play a role in travel behavior. According to Vance and Hedel (2007), the exclusion for a control of self-selection would lead to an underestimation of the built environment variables. We lack the data to control for these issues, yet we can distill some hints of residential self-selection.

choices. The 3Ds of the built environment are thought to affect activity choice in a similar manner. First, the rate of diversity of opportunities close to the residence conditions the extent of choice a consumer has to participate in leisure activities. Logically, a high abundance of one activity automatically opens up the range of opportunities, and therefore a high degree of diversity enables the consumer to find the preferred variety of the activity in the vicinity of the residence more easily. A good example is the effect of different types of restaurants in the vicinity of the residence on activity choice. When restaurants are abundant in the vicinity of the residence, they try to win customers by focusing on different types of meals. Logically, the diverse supply of opportunities tailors the heterogeneous tastes of the consumers. Having both a restaurant serving Italian food, and a restaurant serving Chinese food close to the residence increases the odds a consumer finds a restaurant which fits his or her taste rather than when the restaurants would only serve Italian food. When the latter occurs, a consumer might choose to not participate in the activity at all. Thus, an increase in supply of one activity is expected to increase the diversity of the set of opportunities for the consumer, and subsequently affects participation rates in a positive manner.

Second, the design of the built environment structures the ease at which the respondent is able to reach a leisure site. Bento *et al.* (2005) shows annual miles driven increases with road density, while Chatman (2008) confirms trip distance increases with a design encompassing a low number of obstacles. As activities differ in sensitivity to distance, the design of the close environment potentially affects activity choice. Non-bounded activities, as Naess (2006) names them, are relatively sensitive to distance and should exhibit a higher popularity in environments with a beneficial, low-obstacle design. On the other hand, an environment in which design does not promote travel is thought to lead to frequent choice for activities with a low distance threshold.

Third, density acts as a condition to acquire local activity sites. Although this indicator is seemingly related to diversity, it differs in the extent that the latter is expected to prove the consequence of having a diverse set of opportunities per activity on activity choice, while the former pinpoints which effect the rate of human concentration in the vicinity of the residence has on activity choice. Thus, do residents of very high-dense neighborhoods participate in social entertainments activities more often than residents of low-dense neighborhoods, as expected?[8] If the rate of diversity in supply matters for the respondent, then the density indicator simultaneously proves which activity is the abundant activity in the close

[8] An endogeneity issue might be at stake here. From one side, density serves as an attraction force for some activities (especially for bars, restaurants, and cultural activities), which implies areas with high densities are for example abundant in typical central-city activities. In this case, demand structures the supply of an activity. However, consumers try to fit all potential destinations in their set of individual constraints, and thus supply could also structure demand. It is difficult to separate these effects, but to show leisure activity trade-offs we can neglect the possible two-way direction for now.

environment. The three built environment indicators are thought to influence activity choice in the following manner:

H1: A rise in the rate of diversity in supply of one activity promotes participation in this type of activity.

H2: As design determines the ease of travelling to a location, a higher ease in the vicinity of the residence benefits participation rates for activities which are relatively insensitive to proximity.

H3: The rate of density is in conformity with the typical existence requirements of activities, and leads to differences in activity participation patterns between the groups of varying densities.

The three built environment indicators are expected to significantly influence activity choice if taken into account separately, but also when added simultaneously[9]. Findings of previous studies however show that the built environment is complex. Messenger and Ewing (1996) argue that explanatory variables have been treated as independent when, in fact, they almost certainly have combined effects. A neighborhood requires a combination of the three built environment indicators to optimally limit travel time within the set of constraints, and to optimally enjoy consumer's preferences. Chatman (2008) confirms this tendency, with linkages between all three built environment indicators. In our case, perhaps the rate of diversity differs per type of neighborhood, which could imply that in one neighborhood residents do not respond in the same manner to differences in diversity of supply for an activity as residents of other neighborhoods do. Such a result would have important policy implications, as it predicts a different response in activity participation once new leisure activity sites are added to an environment. Likewise, the response to the ease of reaching a leisure site might differ per rate of diversity. If the consumer lacks any opportunity to participate in one activity, then a high ease to travel might not shift activity choice towards an activity with a high distance threshold. If so, failing to investigate such interactions in analysis will yield misleading results. Thus, we also hypothesize:

H4: The simultaneous addition of the three built environment indicators retains the previously hypothesized relationships.

H5: Interactions between the three built environment indicators constitute a significant determinant, as built environment effects differ per type of neighborhood.

[9] We are unable to detect self-selection effects with this database, and thus do not hypothesize a relationship on residential self-selection and activity choice. However, we will shortly deliberate on the possibilities of our parameter estimates present for the residential self-selection hypothesis.

Thus, rather than explicitly testing predetermined expectations on interactions, we choose to keep our expectations generic. Although Boarnet and Crane (2001) criticize such a strategy, the rather diverse findings in comparable studies show the complexity of the built environment and therefore the difficulty of a solid prediction.

3 Method and data

This section reviews the econometric specification of the model, followed by a dissection of the data used in this study. The econometric model employed here is a member of discrete choice methodology[10], which predicts qualitative choice outcomes based on explanatory variables of all kinds. The theory used in the estimation of choice models is derived from two major economic theories, namely Lancaster's characteristics theory of value (Lancaster, 1966) and random utility theory (see Luce (1959) and McFadden (1974)). The discrete choice model employed here uses the random utility maximization (RUM) hypothesis, which assumes utility maximizing agents have complete knowledge of all factors that enter preferences and determine choice. However, the knowledge of these factors is incomplete, and therefore preferences and choice are random from her perspective. By treating the unobserved determinants of choice as random draws from a distribution, the probabilities of choosing each alternative can be derived.

3.1 Method

The RUM presented in this study is the alternative-specific conditional logit model, which is based on both the standard conditional logit model and the standard multinomial logit model (McFadden, 1974/1980). It measures the probability of an outcome (in this case, the selection of a leisure alternative), conditional on the various characteristics of all alternatives, and on the characteristics of the individual making the choice (Cameron and Trivedi, 2009). The utility of the individual, U_i, is treated as a random variable comprised of a systematic component, V_{ijt}, and a random component, e_{ijt}. For the random component, the key assumption here is that the errors are independent of each other. The independence of errors implies that the unobserved portion of utility for one alternative is unrelated to the unobserved portion of utility for another alternative. Although this independence of irrelevant alternatives (IIA) assumption is fairly restrictive, we believe that the model suffices to explain leisure activity choice behavior based on the systematic component of the utility function. Stated equivalently, the specification of the systematic component of the utility

[10] Train (2003) provides a terrific general overview of discrete choice methodology, while Hensher *et al.* (2005) and Scott Long and Freese (2001) extensively discuss how to implement these models into statistical software packages such as NLOGIT or Stata.

function satisfies in such that the remaining, unobserved portion of utility is essentially "white noise".

Our aim is to estimate the effect of the built environment on leisure activity choice, while controlling for socio-economic, time-specific, and socio-demographic variables at the same time. Thus, the model consists of two types of explanatory variables, namely alternative-specific (built environment variables) and individual-specific variables (built environment, time-specific, socio-economic, and socio-demographic variables). The model in such a way is an improvement of the multinomial logit model, which only takes into account individual-specific variables, and the standard conditional logit model, which only relates alternative-specific variables to the dependent variable. The utility function associated with the *j*th choice would become a combination of the utility functions of conditional logit and multinomial logit models:

$$U_{ij} = V_{ij} + \varepsilon_{ij} = z_{ij}^{'}\alpha + x_{ij}^{'}\beta + \varepsilon_{ij} \quad (1)$$

Equivalent to the conditional logit model, z_{ij} contains values of the alternative-specific explanatory variables for outcome *j* and individual *i*, and α contains the estimated parameters. Equivalent to the multinomial logit model, x_{ij} contains individual-specific explanatory variables for individual *i*, and β contains parameters for the effects on alternative *k* relative to the reference category. Thus, the model collapses into the conditional logit or multinomial logit model after the removal of one group of explanatory variables. The logit choice probability function of the model equals:

$$\Pr\left(y_i = k \middle| x_i, z_i\right) = \frac{\exp\left(z_{ik}\alpha + x_i\beta_k\right)}{\sum_{j=1}^{J}\exp\left(z_{ij}\alpha + x_i\beta_j\right)} \quad (2)$$

The probability for a leisure alternative is necessarily between zero and one, as the denominator sums up the individual alternatives' utilities. When V_{ik} increases in value, this reflects an increase in attractiveness of this alternative for the individual, as V_{ij} is held constant. The individual chooses the alternative which attains the highest utility based on both the individual-specific and alternative-specific explanatory variables. The model consists of a set of eight alternatives, namely water space activities, green space activities, walking trips, cycling trips, practicing sports, social entertainment activities, socio-cultural activities, and amusement activities. The next subsection, which describes the data, will discuss the alternatives and explanatory variables more extensively.

3.2 Data

To relate activity choice to built environment variables, socio-economic variables, socio-demographic variables, and time-specific variables, we require an extensive set of data. Consequently, the data used to estimate the model stems from multiple sources. Crucial is data which reveals individuals' activity choices. The data used here stems from the Continuous Free Time Survey (CVTO) 2006-2007, performed by Dutch market research agency TNS-NIPO in collaboration with the Dutch Bureau for Tourism and Congresses (NBTC). The survey is part of the advanced research database TNS-NIPObase, which comprises 220.000 respondents. Each week TNS-NIPO asks 350 respondents from this database to fill in online questionnaires on leisure activity participation. Naturally, TNS-NIPO ensures that the group of respondents is representative for the entire Dutch population, and all of these respondents actively keep up with their leisure activities for seven days.

The survey defines a leisure trip as a trip in which the respondent engages in a (day) recreational activity outside the own residence. A further requirement is that he or she leaves the residence for at least one hour (including travel time). As such, in-home leisure activities, such as watching television or reading, are not included in this survey. Paying visits to friends, family, and acquaintances are also not considered here. This fits the purpose of this study well, as in-home leisure trips do not matter for the optimal and sustainable distribution of new leisure sites in a densely-populated area; out-of-home leisure activities, and their respective demand patterns, do.

The database reports, on average, approximately five out-of-home leisure trips per week for each respondent. Although related literature shows the importance of trip chaining and substitution patterns in time[11], we consider each registered trip as a separate case. Every case represents a new choice situation, which is not related to previous decisions made by the individual. We neglect the chaining of trips here because of the relatively short period the respondent is asked to register his or her activity choices. After the deletion of cases with missing data, we are left with 38.237 cases.

To acquire policy-relevant results, we need to constrain the database to leisure trips which take place at sites in the relative proximity of the residence. After all, policy initiatives on new leisure sites take place at the level of the province or municipality in the Netherlands, and leisure sites are at first meant to facilitate the leisure needs of residents in the

[11] See for example Limtanakool *et al.* (2006), Golob (2000), and Ye *et al.* (2007). Trip chaining influences mode choice, and changes activity participation decisions. If an individual is able to participate in two activities for which the activity sites are close to each other, he or she is more likely to undertake such a trip rather than when the two activity sites are not close to each other. The chaining of trips in this case saves costs and time, as the distance to travel decreases. Although such trip chaining issues are also relevant for our research question, we lack data to investigate such effects. The precise location of all activity sites would have to be available.

surrounding area. The willingness to travel per activity, in terms of distance, is a solution. Thus, per activity, only leisure trips with a one-way distance smaller than or equal to the average one-way distance per activity are taken into account, which leaves us with 28.722 trips in the end.

Although the database initially consists of 112 activities, we assemble these activities into eight major activities. Table 1 in the Appendix summarizes the number of trips per activity, and the willingness to travel per activity in kilometers, or distance threshold, in the initial set of 38.237 cases. Choice frequency is highest for social entertainment activities, which includes nondaily shopping trips, and visits to restaurants and bars. Also participation in sports and socio-cultural activities (which consists of cultural activities and participation in associations) is high, while water space activities and amusement activities are relatively unpopular. Interestingly, categories with a low choice frequency also experience the highest willingness to travel: average distance to the leisure site is highest for these two categories. This already hints at a possible relationship between the environment in which the individual resides, and the choice an individual eventually makes.

We introduce the built environment by including measures on density, diversity, and design. We use population density as a measure of density here, and is just as the activity choice data extracted from the CVTO-database. The population density categories are based on the measure of the National Bureau of Statistics, who divide the Dutch population in five groups of varying densities. We sum the very low- and low-dense groups, as the high-dense nature of the Netherlands left these groups a relatively low frequency. The categories are measured at the municipality level, while population density equals the number of individuals per hectare land.

There is less agreement on how to introduce design of the built environment at best in the model. Cervero and Kockelman (1997) add micro design features to the model, such as block length of the neighborhood, the presence of street trees, and the proportion of intersections that are four-way. Ewing and Cervero (2001) distill micro design features of the neighborhood, related to pedestrian facilities, landscaping, building orientation, and parking spaces. Urban design theories such as new urbanism list thirteen features to which a neighborhood should stick to optimally benefit from design, but data limitations prevent us to take into account several micro-attributes of the built environment. As an alternative, Lee and Moudon (2006) add several transportation network indicators to correct for the design of the built environment. Chatman (2008) adds network load density to correct for design. Network load density is operationalized as the number of residents per road mile, which provides an interesting route. The design indicator after all stands for the ease of reaching an activity location. We thus add a form of network load density here, namely the number of cars per total amount of land used for roads, measured on municipality level. The data stems from the free online database of the National Bureau of Statistics (StatLine), and the date of measurement for this indicator is January 1st, 2007.

Both built environment indicators are individual-specific, as the set of potential destinations for the other activities is unknown in this database. For the diversity indicator of the built environment, it is however possible to construct an alternative-specific indicator. As Kemperman and Timmermans (2008) show, the cumulative opportunity measure of Ingram (1971) represents a solid measure to include the diversity in supply the respondent experiences in the vicinity of his or her residency. The cumulative opportunity measure is defined as:

$$a_i = \sum_{k=1}^{K_i} O_K f(d_{ik}), \text{ with } f(d_{ik}) = (D_k - d_{ik})/D_k \text{ iff } d_{ik} \leq D_k$$

The cumulative opportunity measure sums, per single activity, the size of all activity spaces within an arbitrary distance threshold. We have taken the average one-way distance towards the activity site as distance threshold, and as such the average one-way distance is compared to the actual one-way distance to an activity site. Thus, the measure enables us to take into account both the size of the area used for an activity, and the distance towards this area. A relatively small area in the close proximity of the residence might, in such a case, account for a higher value than a very large area further away from the residence. The data we use here stems, again, from the National Bureau of Statistics, who measure land use in hectares for different types of uses and activities at the municipality level every three or four years. Since the activity choice data is from 2006 and 2007, we include the land use data from 2006 and all data is scaled to enable comparison between land use figures of one activity to another. One assumption with respect to the data is however required. The land use database measures the extent of land use at the municipality level, while it arguably matters whether the respondent lives at the borders of a municipality, or downtown. Postal code level data would enable us to correct for the position of the residence in the municipality, but for now we assume that land use is homogeneously distributed over the postal code areas in a municipality. The distance from one postal code area to another is measured in ArcGis, by applying PC4 data of the Netherlands provided by Geodan IT BV.

The other explanatory variables in the model are all individual-specific, and are related to either the socio-economic or socio-demographic position of the respondent, or to the day at which the respondent undertook an activity. All data is from the Continuous Free Time Survey database which also comprises the activity choices, and is in some instances recoded to ensure a better fit to the model. For example, information on life-phase of the respondent and household size is used to compute dummies for the existence of children aged zero to six years old or children aged seven to twelve years old in the household, to control for the situation in the household while not directly relating the information to the age of the respondent, which is also an explanatory variable in the model.

Also, we computed a scale for weather on the day of the activity based on several weather variables, as the introduction of the weather indicators separately in the model led to insignificant estimates. It obviously matters whether the temperature is twenty degrees Celsius with a day full of sunshine or twenty degrees Celsius with ten millimeters of rain per square meter, which justifies the introduction of a combined measure. Table 2, again in the Appendix, summarizes the socio-economic, socio-demographic, and time-specific variables in the model.

We need to make some final notes. First, we have left out the group of respondents younger than eighteen years in the database, as this group colours the estimation of some socio-demographic and socio-economic variables in the model. Furthermore, the mobility of these individuals is usually significantly lower than for individuals of eighteen years and older, which also clouds the explanatory power of design in the vicinity of the residence for activity choice. Second, age enters the model both with a 'normal' age variable and a squared age variable, to control for nonlinear age effects. Other studies have found such nonlinearities in activity participation, and our estimations also point at an improvement in model fit after adding the squared age variable to the model. To deal with collinearity, the age variable was first mean centered. Household income gets the same treatment, as income appears to affect activity participation nonlinearly.

Finally, we exclude trip and time costs from the model[12]. The model thus has only one cost variable, namely the entry costs of the activity. These costs are fixed per activity (neglecting age-related discounts for convenience), and do not depend on the location of the residence; entry costs are necessary costs to settle to be able to undertake an activity. On-site spending is however neglected from the analysis, for the same reason as with trip and time costs: it is

[12] Trip and time costs are frequently used in studies explaining travel behavior. Some noteworthy examples are Bockstael *et al.* (1987), Feather and Shaw (1999), and Englin and Cameron (1996). We exclude them here, because of the endogeneity of these variables with the trip itself. Trip costs (think of the price of gasoline you use to get to a leisure site) are the result of a choice to undertake a leisure trip to one site, instead of a determinant predicting the choice for a leisure activity. The interplay of the household situation and the available amount of income determines whether a leisure site is a viable option for the respondent. The same reasoning holds for time costs: travel cost methodology uses the Becker framework to claim that spending time in one activity automatically implies less time can be spent on another activity, and the individual thus gives up some amount of income to undertake a leisure activity. Yet, such a trade-off implies that the individual is able to influence its work schedule with great flexibility, which is usually not the case, at least not in a very short-term time-space. Another reason to delete time and trip costs from the model is data restrictions. The database collects leisure activity choices, but does not register the precise site at which the activity takes place. Thus, we cannot analyze site choice out of a group of feasible activity sites, which renders the importance of trip and time costs unimportant.

the result of the choice for an activity, and household income heavily influences spending opportunities. Taking into account on-site costs would also entail a classical endogeneity bias.

4 Estimation results and discussion

This section reflects to what extent and in which manner the built environment influences activity choice. We control for socio-demographic and socio-economic variables while observing the influence of the built environment. The hypotheses selected in the second section will serve as guidelines in the discussion of the results. Finally, we will discuss the implications of the results.

4.1 Explanatory power of the three built environment indicators

The hypothesized relationships in Section 2 point in two directions: first, the three built environment indicators should individually account for explanatory power on activity choice when taking control variables into consideration. Second, we hypothesized that the three built environment indicators constitute influence on activity choice altogether, either with or without interactions. Therefore, an exploration of partial influences of built environment indicators on activity choice, followed by a stepwise introduction of all built environment indicators to the model, is a logical strategy. At all stages socio-demographic, socio-economic, and time-specific variables serve as control variables.

Table 3, also in the Appendix, summarizes the results of the singular introduction of the built environment indicators to the model. This first step allows us to evaluate the statistical and theoretical importance of the indicators. As Table 3 immediately shows, the estimates are not very promising in every aspect. Note that we estimate the difference between one alternative and an (arbitrary) reference alternative in this type of models, thus the parameters estimate the value an explanatory variable contributes to the attractiveness of one alternative in comparison to the reference alternative, in this case social entertainment activities. The built environment indicators are highly significant if taken into account separately (the model collapses to a standard multinomial logit model when only taking into account population density dummies or the design variable), but not all parameters are of the expected sign.

The parameters for the design variable particularly raise doubts. Of the eight included leisure activities, the distance threshold is highest for water space activities, which implies that, in line with the hypothesis, this activity should experience the strongest impetus from a higher ease to travel in the vicinity of the residence. As the ease of travel gets higher, the restrictions a respondent faces in reaching a destination decrease. Simultaneously, the importance of distance towards the activity site should decrease. In comparison to the reference category, we find evidence for this relationship to hold for water space activities.

However, the estimates prove that the odds to participate increases for all activities in comparison to the reference category when design is of less concern to the respondent. Although this finding is not in conformity with the hypothesis, it is actually not very startling. Despite all being leisure activities, every activity has a different type of enjoyment; consumers opting for a green space activity pursue another experience than consumers who participate in a social entertainment activity. A green space activity particularly enables a consumer to relax in a quiet environment, while the purpose of social entertainment is to interact with other human beings in an out-of-home setting. This result points at another topic of importance for activity choice: the enjoyment of the trip towards the activity site potentially differs per activity and site. Hallo and Manning (2009) and Eby and Molnar (2002) discuss the consumptive value of a trip, and show that the usual interpretation of the financial loss of time on travel is too rigid. The enjoyment of the trip towards an activity site is heterogeneous, with knowledge on the route towards the site positively related to enjoyment and purpose of the trip as other determinant.

The estimates for the other built environment indicators, density and diversity, are intuitively plausible. The positive parameter for built environment indicator diversity shows that consumers respond to the rate of supply of the eight activities in the vicinity of its residence. Thus, a rise in supply of an activity (which reflects a higher diversity for the consumer) enlarges the odds the consumer chooses this increasingly-abundant leisure activity. The built environment in this respect matters for the respondent, as the set of opportunities constrains the respondent in its delight of undertaking an activity. An insignificant coefficient would have meant that the rate of supply does not matter to the consumer, and merely one option per leisure activity is enough to satisfy the consumer's needs. Consumer preferences thus do seem to be fairly heterogeneous, even when it comes to participation in one activity. The built environment indicator density shows interesting patterns per activity. For example, in comparison to social entertainment activities, you are much less likely to find residents of very high-dense neighborhoods at all activities than residents of moderate-dense neighborhoods. Residents of high-dense neighborhoods show similar activity choice patterns. On the other hand, in comparison to social entertainment activities, residents of low-dense neighborhoods are more likely to participate in all other activities than residents of moderate-dense neighborhoods.

Thus, the rate of density is clearly linked to activity choice, and the expected differences in participation frequency show up. Social entertainment activities are relatively popular in high-dense and very high-dense neighborhoods, while cycling and walking trips are sought-after choices of residents of low-dense neighborhoods. A natural question is whether these patterns persist when the other built environment indicators are taken into account simultaneously with density, as the design of the environment and diversity of activity opportunities in the vicinity of the residence might be related to the rate of density of the neighborhood.

4.2 The 3D framework and activity choice

Table 4, which is printed in the Appendix, displays the results on the simultaneous use of the diversity indicator, population density dummies, and design variable in the model. The estimates point at a remarkable loss in significance of the design variable, and a considerable decrease in magnitude of the parameters. Collinearity between the density and design variable would be an obvious explanation as previous studies have reported such a linkage, but the official tests for collinearity do not point out to a high correlation between the two built environment indicators[13]. Intuitively the shift in the design coefficient is theoretically implausible, as these results imply that a higher ease to reach a location leads a consumer to participate less frequent in water space activities, in comparison to social entertainment activities. As mentioned before, the distance threshold is highest for water space activities, which leads to the contrary expectancy.

The number of cases is fairly high in this database, and as such the simultaneous addition of design and density would lead to a more precise estimation of density influences despite the problems arising with the design variable. Omitting the design variable would imply the estimates can be subject to the usual omitted variables bias. However, popular urban design theories underline design consists of many facets, as every choice of mode requires specific conditions to optimally benefit from the structure of the environment. Capturing the effects of design in one variable is a formidable task, and could explain why the hypothesized relationship and change in parameter sign shows up here. This, in line with a Wald test on the combined addition of the density and design indicator which shows no significance, would call deletion of the design indicator a viable option for now. The likelihood ratio test of the full model in comparison to the nested model (which deletes the design indicator) also indicates an improvement in model fit with the smaller model. In addition, the significance level of the diversity and density indicator is still up to standards, while the magnitude of the parameters only marginally changes in comparison to the singular addition of the diversity and density indicator. Thus, in this case our estimates confirm earlier findings of Fang (2008) and Kinnell *et al.* (2006): design and density are too much linked[14]. We acknowledge the

[13] Although the method was initially developed for ordinary least squares regression, it is quite common for studies applying non-linear models to use the variance inflation factor and the condition index to detect multicollinearity in the set of explanatory variables. Here, the variance inflation factor for the density and design indicator do not exceed the critical value of 2.5, while the condition index for the entire set of explanatory variables is within limits. Thus, the official tests for multicollinearity do not provide relevant information concerning the loss in significance and coefficient sign change of the design variable.

[14] Of course, there are multiple ways to interpret these linkages. The first option is that the linkage between density and design indeed exists, and that the ease of getting to a location depends on the density of

likelihood that design of the environment matters for choices persists, but we require a higher-detailed level of data to fully capture the effects of this indicator.

As the simultaneous addition of density and diversity does not lead to notorious changes in parameters or significance levels, the linkages between activity choice and the built environment persist. The significant parameters for the density groups show that, despite the addition of the diversity parameter and all socio-demographic, socio-economic, and time-specific control variables, differences in activity choice can be partially explained by the rate of density of the neighborhood in which the respondent resides. The significant diversity parameter shows that a diverse set of opportunities for one activity in the vicinity of the residence affects the participation rate in this activity.

Recent studies point at possible interrelations between built environment indicators, which would imply merely adding density and diversity indicators is not sufficient. For example, Chatman (2008) proves that the addition of an interaction variable of two previously insignificant built environment indicators renders all variables significant again. Theoretically, such an addition also provides quintessential information. Glaeser and Gottlieb (2006) have shown typical central-city activities are present in (very) high-dense neighborhoods, as these activities require a large set of potential users to subsist. Studies on green space recreation have shown that residents of high-dense areas have similar green space activities needs as residents of low-dense areas. Thus, to meet the central city resident's demand to some extent, we can expect the supply of inner-city green spaces and outdoor recreation activities at the borders of the high-dense municipality to be relatively high. On the other hand, lack of space is not as imminent in low-dense neighborhoods as it is in (very) high-dense neighborhoods. Low-dense neighborhoods are often found to have a reasonable amount of space available for green space activities, and lack typical central-city activities. An increase in supply for such typical central-city activities, and thus in diversity of choices, could lead to a different response to diversity per type of neighborhood, as absolute differences in supply between the eight activities are higher in low-dense neighborhoods than in (very) high-dense neighborhoods. A market always exists for activities in high-dense neighborhoods while low-dense neighborhoods do not measure up to the necessary density level to make some leisure activities a worthwhile venture.

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population in the vicinity of the residence. This would automatically imply that the measures for the built environment indicators are valid. However, if the measures for design and density are not valid, then these linkages result from specification errors. The option that the introduction of several micro-level attributes would prove the importance of the design of the built environment then still persists. So a safe conclusion for now is that this measure of design of the built environment does not add explanatory power to the differences in choices individuals make.

The last column in Table 4 presents parameter estimates on the addition of an interaction variable between built environment indicators density and diversity[15]. The interaction terms are in this case also alternative-specific, as the diversity indicator contains alternative-specific data. All three interaction terms prove to be insignificant, which implies no conclusive evidence exists in this database that diversity in supply of these activities plays a different role in the three included types of neighborhoods, in comparison to moderate-dense neighborhoods. Stated equivalently, every respondent acts in the same manner to the (loosening of) restrictions on diversity as respondents in moderate-dense neighborhoods. The combination of the estimates on diversity, density, and the interaction terms in this case show every type of neighborhood has to deal with over- and underrepresentation of activities, and individuals tune its leisure activity participation choices according to these constraints. Increasing the diversity in supply ameliorates participation rates, and this pattern exists for each activity. Of course, this result has policy implications, as the addition of new leisure sites can change activity choice patterns massively.

4.3 Hypothesis tests and discussion

Although we have already hinted at the implications of the estimates, a discussion of the hypotheses allows us to focus on what is essential: in which precise way does the built environment constrain everyday human life? The list of hypotheses, constructed in Section 2, allows us to answer these questions step by step.

The first three hypotheses deal with the individual effects of the three built environment indicators on activity choice. To recapture, a rise of diversity in supply of an activity is expected to increase popularity of this activity. The rate of density is thought to be in line with theoretical expectations on how all leisure activity sites are distributed across space. Thus, one type of neighborhood attracts the site for one activity easily because of the rate of density in the neighborhood. Last, design represents the ease of reaching a location, and a higher ease is thought to benefit activities with a high distance threshold; thus, activities with a high average distance increase in popularity due to the decreasing importance of distance.

Obviously, the estimates on the design indicator cause the hardest discussion. This measure of design insignificantly contributes to activity choice, while the measure in itself seems collinear with the density variable. A question we cannot answer is whether the design indicator would also prove to be insignificant if the hints of collinearity would not show up. Economically, the Netherlands is a prosperous country, and while the metropolitan Randstad

[15] We have also tested interactions on the design indicator and the other two built environment indicators, but no substantial differences in the estimates appear. The interaction terms between design and very high-dense and high-dense neighbourhoods are significantly different to zero according to the Wald test, but the original design indicator remains insignificant. We stick to our conclusion that this measure of the design of the close environment is too much interrelated with the other two built environment indicators.

region unarguably attains the highest wealth in the country, differences remain considerably small. The set of socio-economic constraints are rather similar across the country, which could imply all residents experience rather similar average opportunity sets to travel: every part of the country has a similar level of infrastructural development in comparison to the number of residents in the neighborhood. However, based on current evidence we have to reject the hypothesis on indicator design.

The hypotheses on density and diversity are both accepted. The rate of diversity matters for activity choice in the sense that when an individual lacks a diversified set of opportunities in one activity, the activity is a rather unpopular choice. The consumer is frequently unable to find the variety of the activity he or she prefers. The density indicators follow the hypothesized relationship, in such that residents of high-dense neighborhoods participate in typical central-city activities more often, and residents of low-dense neighborhoods undertake relatively more outdoor leisure activities. Naturally, these differences in participation rates are linked to the supply rates of all activities in the vicinity of the residence. Typical central city activities require high-dense neighborhoods to be able to attract enough participants, and end up with participants of high-dense neighborhoods as residents of low-dense neighborhoods do not experience enough opportunities within an appropriate distance from the residence. The significant diversity parameter proves the participation rate of residents in low-dense neighborhoods would increase if the rate of supply in low-dense neighborhoods, and thus the diversity in the set of activity opportunities, would increase[16].

If the diversity parameter would not be significant, this would put the residential self-selection hypothesis for activity choice under pressure, as we would detect real differences in preference, and residents would then not appear to self-select in neighborhoods which fits their individual preferences. In the most extreme case, one facility of a leisure activity within the distance threshold would suffice for all consumers. In such a case, residential self-selection would at most matter to a minor extent, as the reason to self-select in one neighborhood (the diversity of opportunities for one activity) clashes with the finding that the rate of supply does not matter. On the other hand, we lack information within this framework to confirm the residential self-selection hypothesis. Although the diversity parameter signifies respondents participate frequently in abundant activities because of the increasing likelihood to find an option that fits the consumer's preferences perfectly, it is unclear

[16] Narrowing down the set of activities and relating the location of a low-dense neighbourhood to the nearest high-dense neighbourhood would allow us to study the effects of 'attraction poles'. Obviously, the current diversity indicator draws a circle as large as the distance threshold around the postal code area, and it matters whether the low-dense neighbourhood only has one high-dense neighbourhood in the vicinity, or several. Although supply is probably not very diverse when only one high-dense neighbourhood is close, we might find some differences in participation in comparison to low-dense neighbourhoods with no high-dense neighbourhood in the close proximity.

whether this participation rate is the result of intentional choice, or merely the result of other factors which now constrain the respondent in making optimal leisure activity choices. Such information is valuable for policy makers, as the allocation of new leisure sites across scarce space depends on patterns in demand, and if there is no clear pattern between supply and demand allocation of new sites would become a wild guess and not based on theory.

Of similar importance, the insignificant estimates for the interaction terms between density and diversity prove the homogeneous response across the entire country on differences in supply: although the signs of the parameters might point at some minor relationship, the difference in response in comparison to residents of moderate-dense neighborhoods is not statistically different from zero. The distinction in various types of neighborhoods shows that diversity in supply plays a similar role for every resident, even though the various neighborhoods clearly differ in which activity is the abundant choice. Again, whether this difference exists because of a deliberate choice to live in a neighborhood which facilitates these leisure needs, or because the resident settles with the set of opportunities once he or she lives in the neighborhood, is unknown. The last two hypotheses thus have to be rejected, since interaction terms do not play a decisive role in activity choice, and not all three built environment indicators appear to matter simultaneously.

5 Conclusion

The aim of this study was to investigate in which way and to what extent the built environment matters for leisure activity choice. Human beings experience an increasing number of constraints in daily life nowadays, and are therefore forced to make choices between several opportunities they desire. Leisure is one of these opportunities, and to limit travel within the set of constraints of the individual an optimal allocation of new leisure sites across scarce space is warranted. We have adopted the 3Ds framework of Cervero and Kockelman (1997) here to represent the built environment: density, diversity, and design are used to explain current out-of-home leisure activity choices of residents. All three elements of the 3Ds framework correspond to one facet which potentially determines the final choice an individual takes. We use population density to estimate the effects of density, while design (measuring the ease to reach a location) is represented by a variable of traffic density. Built environment indicator diversity has an alternative-specific measure, in which we estimate the effect of an increase in supply and thus in diversity of the eight categories of leisure activities that are present in the database. Socio-demographic, socio-economic, and time-specific explanatory variables serve as control variables, to see if the effect of the built environment persists. We deploy an alternative-specific conditional logit model to estimate these effects.

Of the three built environment indicators density and diversity matter here for leisure activity choice, and the hypothesized relationships show up. Consumers respond to differences in supply when making a choice: abundance of a leisure alternative determines the participation rate in an activity. Such a finding is not startling, as a high abundance more or less automatically produces an extent of variety within the set of opportunities of one activity available to the individual in the vicinity of the residence. As a result, the likelihood an individual finds a leisure activity site which fits his or her preferences increases. Moreover, although we do not measure this effect, a higher rate of diversity in the opportunity set of one activity automatically implies the odds of having an ideal option of this activity in the vicinity of the residence also increases relative to having an ideal option for the other activities. This could induce a shift in activity choice.

The density indicators show which activities residents of the various neighborhoods undertake frequently. As expected, social entertainment activities and socio-cultural activities attract many residents of very high- and high-dense neighborhoods, while cycling trips and walking trips are frequent choices for residents of low-dense neighborhoods. The differences in participation rates which show up with the density indicator can be explained by differences in supply of the eight activities; thus, typical central-city activities such as social entertainment activities and socio-cultural activities indeed become popular choices for residents of (very) high-dense neighborhoods because of the high supply in the vicinity. Amusement activities, which include visits to amusement parks and zoos, not surprisingly has insignificant parameters for all density categories. A logical explanation is that this type of activity consists of only a small number of activity sites (yet large in size), and participation in such an activity usually takes a full day instead of just a couple of hours, tightly scheduled in between other activities. Socio-demographic, socio-economic, and time-specific variables determine the rate of participation for this type of activity, although the significant diversity parameter implies that once the supply of this type of activity starts to increase in the vicinity of the residence, it will have its consequences for the participation rate.

This paper is prone to some limitations. As in every paper, the available set of data limits the elegance of the model. For example, the diversity indicator is measured on municipality level, while the set of opportunities for the respondent equals the activity sites within the distance threshold, measured around the centroid of his or her postal code area. To measure the opportunity set of a postal code area, we require an assumption on the homogeneity of supply of leisure activity sites across the municipality, while postal code area data or other increasingly micro-level data would correspond better with the cumulative opportunity measure, and with the actual distribution of supply. Furthermore, the usage of land-use statistics on some activities, such as social entertainment activities and socio-cultural activities, is not as detailed as warranted, as such activity sites frequently have multiple floors, and differing customer policies. Although improvements in the data are logical, we expect that the significance of the estimates would persist (at least for density and diversity) if estimated with a higher-quality description of the built environment; the estimates would rather become more accurate. Particularly the design variable requires an improvement in quality. For now, data limitations prevent the design indicator to materialize as significant determinant of leisure activity choice. Micro-level design attributes might fit the 3D-framework better, as some studies have shown the importance of these micro-level design attributes for travel choices.

At this point the estimates on the density and diversity indicator already have quintessential policy implications. Policy-makers can affect consumer's choices by the choice of location of a new leisure site. Either the set of interested consumers will adapt to the location of the new leisure site and self-select themselves into neighborhoods close to the activity site, or the current residents close to the new leisure site will participate in this activity, as the activity becomes abundant and thus the odds that one variety of the activity fits the consumer's preferences perfectly increases[17]. Also, the significant density parameters prove that the rate of density can be associated with the choice of an activity, which implies the interplay of supply and demand of various types of activities structures trade-offs in activity choices. The location of a new leisure site changes the interplay between supply and demand, and therefore logically influences the activity trade-off every consumer makes.

Acknowledgment

This paper was written in the context of the NWO Sustainable Accessibility of the Randstad (SAR) program, in the project "The value of recreation: now, and in a completely different future".

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[17] To what extent the rate of diversity is allowed to augment until satiation starts to play a role is unclear. We believe that at some point the (diversity in) supply becomes so high that it is not able to attract enough potential participants anymore. Yet, the possibility set of all activities matters in this extent, since individuals do not only trade-off the relevant options within the set of one activity, but within the set of all activities.

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Appendix

Table 1: The dependent variable and distance threshold

Type of leisure activity	Frequency	Percentage	Distance threshold
Water space activities	941	3.3	21.88
Green space activities	1,068	3.7	15.68
Walking trip	3,916	13.6	7.56
Cycling trip	1,322	4.6	11.84
Performing sports	5,576	19.4	9.69
Social entertainment activities	9,529	33.2	15.42
Socio-cultural activities	4,863	16.9	12.01
Amusement activities	1,507	5.2	20.92
	28,722	100.0	

The distance threshold equals the average one-way distance to the activity site, and is measured in kilometers.

Table 2: Descriptive statistics of explanatory variables

Explanatory variable	Mean	Std. Dev.	Min.	Max.
Built environment variables				
Very high population density	0.204	0.403	0	1
High population density	0.317	0.465	0	1
Moderate population density	0.230	0.421	0	1
Low population density	0.249	0.433	0	1
Diversity	0	0.746	-1.089	6.351
Density	0.682	0.386	0.251	3.004
Socio-demographic variables				
Age	48.314	16.923	18	98
Male	0.533	0.499	0	1
Female	0.467	0.499	0	1
0% non-native	0.848	0.359	0	1
50% non-native	0.096	0.295	0	1
100% non-native	0.055	0.229	0	1
Respondent has a life-partner	0.746	0.435	0	1
Household with child aged 0-6 years	0.130	0.336	0	1
Household with child aged 7-12 years	0.164	0.370	0	1
Socio-economic variables				
Free hours per week	60.265	17.219	36	80
Household income	4.224	2.563	0.2	26.1
Entry costs activity	0.820	4.236	0	300
Time-specific variables				
Weather	40.172	7.510	15.8	56.9
Weekend day	0.347	0.476	0	1

All explanatory variables have N=28722, except for diversity which has N=229776. The diversity indicator is furthermore mean-centered.

Moderate population density, Female, and 100% non-native will be deleted to omit perfect collinearity.
Free hours per week equals 80 hours minus hours worked, while household income is measured in units of 10.000 euro's. Entry costs are measured in euro's. The weather variable is computed by adding the values for average temperature and precipitation in millimeters. The values for precipitation in millimeters is first substracted from a value of 30.

Table 3: Singular addition of the 3Ds

	(1)	(2)	(3)
Alternative-specific variables			
Diversity			0.090*** (0.013)
Water space activities			
Very high population density	-0.389*** (0.107)		
High population density	-0.543*** (0.096)		
Low population density	0.118 (0.094)		
Design		0.308*** (0.088)	
Green space activities			
Very high population density	–0.229** (0.098)		
High population density	-0.395*** (0.089)		
Low population density	0.025 (0.091)		
Design		0.322*** (0.084)	
Walking trip			
Very high population density	-0.168*** (0.060)		
High population density	-0.176*** (0.053)		
Low population density	0.302*** (0.055)		
Design		0.442*** (0.050)	
Cycling trip			
Very high population density	-0.131 (0.094)		
High population density	-0.244*** (0.084)		
Low population density	0.422*** (0.083)		
Design		0.524*** (0.072)	
Performing sports			
Very high population density	-0.310*** (0.053)		
High population density	-0.167*** (0.047)		
Low population density	0.157*** (0.051)		
Design		0.336*** (0.046)	

Socio-cultural activities			
Very high population density	-0.128**		
	(0.055)		
High population density	-0.211***		
	(0.050)		
Low population density	0.271***		
	(0.053)		
Design		0.403***	
		(0.048)	
Amusement activities			
Very high population density	-0.154*		
	(0.089)		
High population density	-0.040		
	(0.077)		
Low population density	0.147*		
	(0.083)		
Design		-0.029	
		(0.115)	
AIC	96998.21	97096.17	97173.47
BIC	98439.65	98421.9	98670.02
Chi2	5929.15	5803.18	4260.05
p-value	0.000	0.000	0.000
Log Likelihood	-48373.1	-48436.09	-48480.73
Number of observations	28722	28722	28722
Number of iterations	7	7	5

Standard errors in brackets. Statistical significance: * p< 0.10, ** p< 0.05, *** p<0.01

The reference category is social entertainment activities. The omitted density dummy variable is "moderate population density". We suppress the socio-demographic, socio-economic, and time-specific explanatory variables here. All suppressed explanatory variables are of the expected sign, and are statistically significant.

Table 4: Simultaneous addition of the 3Ds

	(4)	(5)	(6)
Alternative-specific variables			
Diversity	0.071*** (0.017)	0.074*** (0.016)	0.104*** (0.034)
DiversityXVeryhighdensity			-0.024 (0.048)
DensityXHighdensity			-0.066 (0.043)
DensityXLowdensity			0.002 (0.051)
Water space activities			
Very high population density	-0.404*** (0.113)	-0.329*** (0.108)	-0.330*** (0.113)
High population density	-0.572*** (0.099)	-0.524*** (0.096)	-0.550*** (0.097)
Low population density	0.212** (0.108)	0.096 (0.094)	0.087 (0.094)
Design	-0.265** (0.126)		
Green space activities			
Very high population density	–0.089 (0.106)	-0.096 (0.102)	-0.090 (0.118)
High population density	-0.363*** (0.091)	-0.370*** (0.089)	-0.394*** (0.090)
Low population density	-0.017 (0.106)	0.002 (0.091)	-0.007 (0.092)
Design	0.046 (0.122)		
Walking trip			
Very high population density	-0.037 (0.067)	-0.058 (0.065)	-0.054 (0.082)
High population density	-0.138** (0.055)	-0.154*** (0.053)	-0.177*** (0.055)
Low population density	0.234*** (0.064)	0.275*** (0.056)	0.263*** (0.056)
Design	0.093 (0.072)		
Cycling trip			
Very high population density	0.007 (0.101)	-0.003 (0.098)	0.001 (0.115)
High population density	-0.208** (0.086)	-0.217** (0.084)	-0.247*** (0.086)
Low population density	0.369*** (0.095)	0.394*** (0.083)	0.382*** (0.083)
Design	0.058 (0.104)		
Performing sports			
Very high population density	-0.283*** (0.057)	-0.299*** (0.053)	-0.295*** (0.054)

High population density	-0.160*** (0.048)	-0.172*** (0.047)	-0.161*** (0.047)
Low population density	0.130** (0.058)	0.157*** (0.051)	0.156*** (0.051)
Design	0.061 (0.066)		
Socio-cultural activities			
Very high population density	-0.077 (0.059)	-0.109* (0.055)	-0.103* (0.056)
High population density	-0.191*** (0.052)	-0.212*** (0.050)	-0.201*** (0.051)
Low population density	0.227*** (0.061)	0.279*** (0.053)	0.282*** (0.053)
Design	0.115* (0.068)		
Amusement activities			
Very high population density	-0.099 (0.094)	-0.118 (0.089)	-0.118 (0.092)
High population density	-0.017 (0.080)	-0.031 (0.077)	-0.045 (0.078)
Low population density	0.103 (0.096)	0.136 (0.083)	0.131 (0.083)
Design	0.074 (0.106)		
AIC	96982.39	96979.03	96981.7
BIC	98368.8	98292.83	98326.53
Chi2	4485.72	4475.49	4478.61
p-value	0.000	0.000	0.000
Log Likelihood	-48357.19	-48362.52	-48360.85
Number of observations	28722	28722	28722
Number of iterations	5	5	5

Standard errors in brackets. Statistical significance: * p< 0.10, ** p< 0.05, *** p<0.01

The reference category is social entertainment activities. The omitted density dummy variable is "moderate population density". We suppress the socio-demographic, socio-economic, and time-specific explanatory variables here. All suppressed explanatory variables are of the expected sign, and are statistically significant.