A Discrete Choice Experiment to Elicit People's Preferences for Semi-Arid Riparian Corridors: A Multinomial Logit Model

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Abstract: The aim of this study is to examine public preferences for urban riparian corridors in arid regions using simulation and visual quality analysis scenarios. Ecological landscapes are often subject to trade-offs with aesthetic landscapes that include micro and macro environmental factors such as manicured landscapes. It is suggested that there is a preference for aesthetics in landscape design; however, it is unclear how laypeople prioritize aesthetics over different ecological factors in landscape scenes. This study uses a Discrete Choice Experiment (DCE) to elicit the preferences of current or former residents of Jeddah City, Saudi Arabia, for multiple landscape scenes. The method combines ecological landscape characteristics (adopted from the QBR index) found in the study area in Jeddah and aesthetic characteristics commonly suggested in landscape design projects. Participants in this study were exposed to a set of illustrated landscape scenes, including various aesthetic and ecological elements configurations. Participants' choices revealed the influence of their ecological and aesthetic values. Results show that people may prefer unmaintained ecological landscapes if minimal design interventions were provided. This will prevent trading off the ecological unmaintained landscape with aesthetically maintained landscapes within the study area. This study will help researchers and landscape architects advance visual preference research further into the domain of empirical studies. It presents a new powerful technique to elicit the preference of an individual element in landscape scenes, which improves the precision of community-based decision-making.

Keywords: Discrete Choice Experiment (DCE), Choice-Based Conjoint (CBC), Multinomial Logit Model (MNL), Ecosystem Services (ES), resilient green infrastructure

1 Introduction

The aim of this study is to examine public preferences for urban riparian corridors in arid regions by testing to what extent people are willing to trade off unmaintained ecological landscapes for aesthetics offered by specific micro and macro environmental factors. Landscape design reflects ecological and aesthetic values, and trade-offs are often made between the two in practice. In arid regions, water scarcity means riparian corridors are the richest landscape typology and the only blue-green links for hundreds of miles (BOGIS et al. 2021, HOU et al. 2021). Pressure from urbanization and lack of eco-literacy contribute to negative feedback loops, which present dire challenges for migrating avifauna and regional wildlife. Riparian systems with high biomass are more desirable when natural resources and biodiversity are prioritized, in which multiple deliverable ecosystem services rely on the quality and health of that ecosystem. Although this can be achieved with low or no maintenance riparian buffers, these unmaintained ecological landscapes play an intrinsic role in sustaining the global ecosystem services and are important for the survival of the avifauna (BOGIS & KIM 2021, BIAMONTE et al. 2011, MILLENNIUM ECOSYSTEM ASSESSMENT 2005). Ecological landscapes are often subjected to trade-offs with aesthetic landscapes that include micro and macro environmental factors such as manicured landscapes. It is suggested that there is a

Journal of Digital Landscape Architecture, 8-2023, pp. 502-514. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-740-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537740053.

preference for aesthetics in landscape design (KAPLAN 1977a, KAPLAN 1977b); however, it is unclear how laypeople prioritize aesthetics over different ecological factors in landscape scenes (ZHAO et al. 2017(. Learning how people make choices between alternatives will allow decision-makers to meet the best design option with the least ecological impact; thus, they can avoid trading off (replacing) ecologically unmaintained landscapes for aesthetically maintained landscapes. Therefore, this study utilizes the Discrete Choice Experiment (DCE), also known as Choice-Based Conjoint Analysis, to elicit the preferences of the residents of Jeddah City, Saudi Arabia for multiple landscape scenes. DCE is a widely used method in marketing to reveal preferences by analyzing the trade-offs people make between alternatives. Unlike the Visual Preference Survey (VPS) studies that provide the least useful information (EWING 2001), DCE helps elicit the part-worth utility assigned to each element in that scene and provides a list of the most and least preferred elements, which helps improve the precision of the decision-making (HILL 2017). This study combines ecological landscape characteristics adapted from the QBR[1] index that are found in the study area and aesthetic characteristics, such as micro and macro environmental factors that are commonly suggested in landscape design projects adapted from relevant visual preference studies (KENWICK et al. 2009, KUPER 2017, ZHAO et al. 2017). The combined DCE and VPS method and techniques used in this study established a clear connection to the "Visualization, Animation and Mixed Reality Landscapes (VR, AR)" theme. The aim of this study also contributes to the "Resilient Landscape, Global Change, and Hazard Response" theme.

2 Research Design

The one-time self-administered online survey was available from January 1, 2020, to January 31, 2020. The survey instrument consists of three parts; First, a visual choice set survey of the urban riparian corridor (DCE). Second, a survey questionnaire on attitudes toward several factors related to a) public parks, b) physical activity, c) ecology knowledge & attitude, d) the constructed concrete channels, and e) riparian corridors. Third, a series of socio-demographic questions. The demographic and attitudinal questions are designed to be used as explanatory variables to understand patterns of ecological preferences, perception, and knowledge among the participants.

The DCE in this study involves visual representations of several developed choice tasks of different design alternatives for the urban riparian corridor. Each design profile represents an independent and unique design alternative (profile) of itself. All the profiles were manipulated using the selected design attributes of the urban riparian corridor that exists in Jeddah. The essential parts of performing a DCE are the creation and arrangement of the profiles into choice sets to be evaluated by respondents. The study was structured as follows:

1) Operationalizing riparian corridor attributes

2) Designing the choice sets: Test the efficiency of the design

3) Data collection and analysis

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[1] QBR index is a riparian ecosystem index designed to provide brief data on the ecosystem condition or the habitat quality on the banks for Mediterranean rivers.

2.1 Operationalizing Urban Riparian Corridor Attributes

To conduct a discrete choice experiment (DCE), several steps must be completed including a) selecting the design attributes of interest, b) operationalizing them, and c) selecting their levels. These steps are essential because they construct the design alternatives to be assessed in the visual experiment. According to LOUVIERE & TIMMERMANS (1990), in the stated preference experiments like DCE, the selection of attributes should only i) include the salient features, ii) be simplified through combining similar attributes to reduce redundancy or confusion between them, and iii) be related to not only potential users but also to the decision-makers. It should be noted that the increase of an attribute or the levels of an attribute will exponentially increase the number of possibilities. What is most important, though, is the range of the levels. It is recommended for reliability reasons that the number of attributes should not exceed "a maximum of ten attributes with at most 15 levels per attribute" (HILL 2017, 4); however, according to some research in DCE (SUGIYAMA et al. 2008, 436-437), the number of attributes and their levels can reach 15 and 40, respectively, with no effect on the validity of the test results.

In this study, the salient attributes of the urban riparian corridor are the micro-environmental factors of the riparian buffer (vegetation cover, water's edge, ground texture, and cover, and waterscape) and the macro-environmental factors that act as land use policy adjacent to the riparian buffer zone (urban density and diversity). The selected design attributes for this study were compiled as seven main attributes and divided into three sub-attributes for five of the attributes and two sub-attributes for the other two, which bring them to a total of 19 levels of attributes (See Table 1). Next, the attributes were operationalized, meaning an explanation of what each attribute represents in this study was assigned an ecological quality (EQ) score. The EQ Score is a dummy score used to provide brief data on the ecosystem condition or the habitat quality. The researcher evaluates four main parts and sub-parts in the QBR index that represent attributes of riparian landscapes. The evaluation method includes a subjective assessment where the observer assigns a score that represents the ecological evaluation for a particular riparian landscape attribute. In this study, a 25 EQ score is the highest score that could be assigned in the evaluation process but unlike the QBR index, a negative score of no less than -25 was used to represent the possible impact of an added design attribute (design solution) in this study. This allows the researcher to evaluate the total ecological qualities of each possible design alternative that may appear in the choices task and help examine the correlation between the increase and decrease of an EQ score and people's preferences. Lastly, photograph illustrations with all possible combinations between the levels of attributes were created, yielding 972 design concepts.

Table 1: Operationalizing the attributes of the urban riparian buffer. Each level of the attributes was assigned a different ecological quality score that was adapted from the QBR* index and KENWICK et al. (2009) and aesthetic attributes adopted from different studies KUPER (2017).

Attribute	Attributes' Operationalization	Attribute Levels	EQ*
TRVC*	This attribute may appear as 1) Low TRVC (>10%): only the native vegetation with no ground cover on the pathway, or 2) Moderate (50%): includes double the native vegetation with no ground cover on the pathway, or 3) High (>80%): includes double the native vegetation with a ground cover on the pathway.	1- Low (>10%) 2- Moderate (50%) 3- High (>80%)	5 10 25
Water's Edge	Different water's edge denotes different ecosystem services. This attribute may appear as 1) stone, 2) grass or 3) tree water's edge.	1- Stone 2- Grass strip 3- Tree	0 10 25
Complexity	Three levels under this attribute 1) Zero: denotes preferring the native plant as it is; 2) Low: denotes little design modification is required; 3) Moderate: denotes high modification is required.	1- Zero (no exotic plants) 2- Low (2 species) 3- Moderate (4 species)	25 10 5
Density	Different building heights denote different densities.	1- Three-story 2- Six-story	0 0
Diversity	Precedent studies showed a significant correlation between mixed uses and people's motivation to walk and enjoy public space. Single land use leads to more car dependency.	1- Single land use 2- Mixed uses	0 0
Trail design	1) The light trail represents a low-impact solution (boardwalk). 2) The compact sand trail will increase the flow. By increasing flow, sediment will be more likely to be transported as a result of increased stress on the bed. In addition, higher velocity also increases erosion rates as flow overcomes sediment shear stress. 3) A paved trail is an impervious pavement that will increase the chances for plants, soil, and streambed erosion.	1- Light trail 2- Compact sand trail 3- Paved trail	25 5 -25
Activities	Different activity denotes different preferences, and each may impose a different ecological impact.	1- Distant from the stream 2- Close to the stream 3- In the stream (rafting)	25 -5 -25

*TRVC: Total Riparian Vegetation Cover; EQ: Ecological Quality

2.2 Designing the Choice Sets: Test the Efficiency of the Design

Two important decisions to make when constructing choice tasks are 1) how many concepts (unique design alternatives) to present per task, and 2) how many total choice tasks to ask per participant. Showing more concepts per screen increases the information content of each task and the task difficulty. Research has shown that respondents are efficient at processing information about many concepts. To answer choice tasks with four concepts, it takes a respondent considerably less than twice the time to answer two concepts. When a large proportion of the respondents are expected to take the DCE survey on smartphones with relatively small screens, this also calls for showing perhaps just two or three concepts per task (ORME & CHRZAN 2017). This study used Sawtooth Software to generate all the possible design alternatives (concepts). Each participant was randomly assigned to a group of visual choice tasks that were controlled and organized by the software. All the attributes and the levels were equally presented in the visual choice tasks in this empirical study. To achieve the minimum standard error (≤ 0.05) and equally test all the possible design alternatives, the "Test Design" feature in the software was performed. It was found that this study must include fifteen random tasks; each task includes three concepts (design alternatives) and a none option (I would not choose any of the three options). The study must include at least 250 qualified respondents with a 15% chance of no response (for minimum standard error and to equally test the preference for every single attribute). Next, the 972 possible alternatives were created using the photo that was taken from the study area in Jeddah City to form the base that was manipulated (illustrates the attributes over) using Photoshop 2018. Figure 1 demonstrates how the choice tasks may appear for the respondents.

2.3 Data Collection and Analysis

The study follows a non-probability purposeful convenience sampling and snowball approach. This study qualified any current and former residents of Jeddah City who are over 18 years old, have a formed attitude and ascribed value toward the coastal-arid landscape of Jeddah, and have a formed attitude toward public space in the city. The recruitment invitations were sent via emails, social media, text messages, and hard copies of flyers to KAU members and the EcoFoci social media platforms. A total of 988 adults participated in the study; after data screening and cleaning, only 285 were qualified participants. The study was approved by the Biomedical Research Alliance of the New York Institutional Review Board (BRANY-IRB). According to the discussion in section 2.2, the 285 participants are enough to test the design concepts with minimum standard error.

The results of people's choices come into utility scores for each attribute. The higher the score the higher the preferences for that attribute (See Table 2). It is assumed that a respondent will choose the most preferred alternative that yields the highest utility and the best outcome. There are three estimation approaches embedded in the software. This study implemented the most widely used and robust utility estimation approach, the Multinomial Logit Model (MNL). MNL has been used for more than three decades in the analysis of DCE data. It is useful as a top-line diagnostic tool, both to assess the quality of the experimental design and to estimate the average preferences for the sample (ORME & CHRZAN 2017).

Fig. 1: Example of the visual choice tasks

3 Results

Table 2 shows the logit utility estimations (N=252) where the least (-) and most (+) preferred levels of attributes (β) are presented. An overall average relative importance[2] analysis was performed to reveal the total sample preferences for the attributes of the urban riparian corridor. The average importance for those attributes can be arranged into three groups: 1) high (Complexity & Water's Edge), 2) moderate (TRVC, Trail, & Activities), and 3) low average importances attributes (Density & Diversity) (See Figure 2). Even though people's preference decreases as the number of unmaintained landscape increases, the results show that they will most likely accept any design alternative that includes any number for the unmaintained landscape than choosing the none option (See Table 2). The findings of this study showed that there are many ways to minimize or even prevent trading off unmaintained ecological landscapes with consideration of meeting people's preferences (See Figure 2). Figure 2 illustrates the most and least preferred design attributes. It also reveals that urban density and urban diversity attributes show no significant effect on people's choices compared with the other micro-environmental factors (i. e., water's edge, vegetation complexity, trail design, and type of activities).

Figure 3 illustrates the most preferred design alternative for the target population. The most preferred design profile includes zones with a low number of unmaintained plants, grass water edge that is minimally modified by adding 4 exotic-maintained plants, a boardwalk, and is surrounded by a low urban density of mixed land uses (See Figure 3). Even though people are culturally accustomed to the maintained landscape over the natural, messy ecosystems (NASSAUER 1995) results of this study show that people are willing to accept a highly ecologically unmaintained landscape (natural, messy) if minor landscape design interventions are made (See Figure 4) (See Table 2).

Results show that minimal design interventions would prevent trading off the ecological unmaintained landscape with three distinct groups of preferences (high, moderate, and a low average of importances) for the seven selected attributes affecting the appeal for the riparian corridor in Jeddah City (See Figure 2 & Table 2). Table 2 shows more details about the most and least preferred attributes. A positive larger β *score* denotes a higher preference for a particular level of an attribute or a design option, and a negative or smaller β *score* denotes less preference in comparison to the other design options under that level of attribute.

[2] Average importance is calculated by the difference in average part-worth utilities between the most and least preferred levels of an attribute as known as the "attribute utility range" (ORME 2010). Then, the attribute importance is calculated by dividing the "attribute utility range" by the sum of the "utility range total" and multiplied by 100. The results come in a percentage. The degree of preference given to a particular level of an attribute is illustrated by average part-worth utilities that are similar to a beta-value (β) obtained from linear regression analyses (ORME 2010). The greater the importance of an attribute, the greater the impact on the choices.

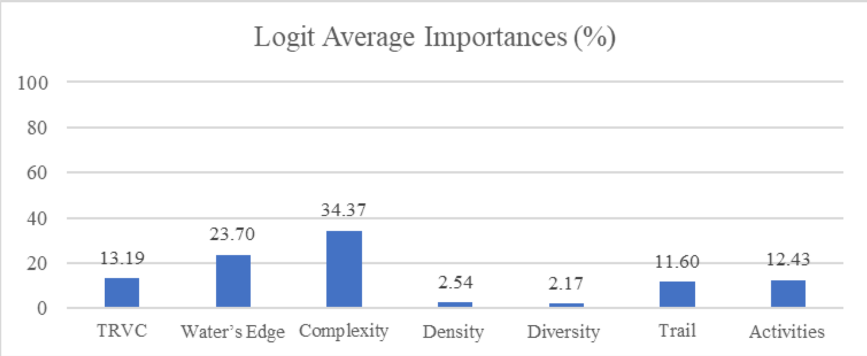

Fig. 2: This figure illustrates the attributes' average importances

Fig. 3: The most preferred design for the total sample

Fig. 4: The highly ecologically unmaintained landscape with minor landscape design intervention

Table 2: Shows the logit utility estimations (N=252) where the least (-) and most (+) preferred levels of attributes (β) are presented

		β	**Std Error**	**t-stat**
Constant		0.92	0.05	17.46***
TRVC	1- Low TRVC (>10%%) [EQ=0]	0.12	0.03	4.31***
	2- Moderate TRVC (50-80%%)[EQ=10]	0.11	0.03	3.97***
	3- High TRVC (>80%%)[EQ=25]	-0.22	0.03	-7.82***
Water's Edge	1- Stone water's edge [EQ=0]	0.17	0.03	6.24***
	2- Grass water's edge [EQ=10]	0.22	0.03	8.24***
	3- Tree water's edge [EQ=25]	-0.39	0.03	-13.12***
Complexity	1- None [EQ=25]	-0.43	0.03	-14.28***
	2- Low complexity [EQ=10]	-0.02	0.03	-0.89
	3- Moderate complexity [EQ=5]	0.45	0.03	17.21***
Density	1- Three-story building	0.03	0.02	1.68*
	2- Six-story building	-0.03	0.02	-1.68*
Diversity	1- Single use	-0.03	0.02	-1.44
	2- Mixed uses	0.03	0.02	1.44
Trail design	1- Light (Board walk) [EQ=25]	0.18	0.03	6.58***
	2- Moderate (Compact sand) [EQ=5]	-0.12	0.03	-4.32***
	3- Heavy (Paved) [EQ=0]	-0.06	0.03	-2.03**
Activities	1- Light (away from water) [EQ=25]	-0.10	0.03	-3.72***
	2- Moderate (close to water) [EQ=-5]	0.21	0.03	7.91***
	3- Heavy (in the water) [EQ=-25]	-0.11	0.03	-3.81***
LL(β)		-4654.95768		
LL(0)		-5240.19269		
Chi-Square		1170.47002		
Degree of freedom		13		
P-value		27.69***		
Number of observations[b]		3780		

***p < 0.01., **p < 0.05, * p<0.1. [b] Each respondent completed fifteen choice tasks.

4 Discussion

There are two key findings in this study. The first is related to how people make choices and how we (designers and decision-makers) can avoid design options that lead to removing such an important ecological landscape to accommodate a highly-urbanized maintained landscape.

The second key finding in this study is related to the implemented analysis model which does not differentiate between different socio-demographic groups by only describing average overall preferences for the design attributes for the target population. Both key findings are explained as follows:

The first key finding is related to how people's choices and how avoiding trade-offs in ecological landscapes can be interpreted from the relatively high average importance attributes. These results show how minimal design intervention can influence the choices of people to accept high ecological unmaintained landscapes. Such landscapes with ecological characteristics are believed to be the reason why migrant birds and all connected ecosystems exist and successfully evolved. For example, the high average importance attributes were attached to two attributes, which are the vegetation 'complexity' attribute (number of exotic maintained plants) followed by the 'water's edge' attribute (See Table 2). The vegetation 'complexity' attribute was the most preferred environmental factor to influence people's choices upon choosing the most preferred riparian corridor design alternative in Jeddah City. The preference increases as the number of exotic plants increase, which supports the findings from the precedent landscape assessment studies (KUPER 2017, MAULAN 2006, NASSAUER 1989, 1995, NASSAUER & FAUST 2013, ZHAO et al. 2017) that suggest that people's preference increases as the vegetation complexity increases. However, the low number of exotic plants (2 species) shows no significant effect on people's preferences; rather, people would choose an option with no exotic plants or the highest number of exotic plants in a scene (4 species). In other words, to increase the acceptance of the ecologically unmaintained plants, the decision-makers may have two choices to increase the number of the manicured landscape to the maximum number used in this study (4 species) or to leave it as it is (only the ecological unmaintained plants with zero exotic plants). However, it should be noted that increasing the number of exotic manicured plants may potentially increase the net Global Warming Potentials (net GWPs) due to the required regular upkeep work (i. e., irrigation, mowing, fertilizing and clipping, etc.) (GU et al. 2015). The second most important attribute was attached to the 'water's edge' (See Figure 2). Results show that the lower the ecological score (EQ) for this attribute the higher the chances to improve people's preferences for a design alternative (See Table 2). It seems that people prefer the 'grass water's edge' solution slightly more than 'stone water's edge'. Both grass and stone design solutions (low EQ scores) are significantly preferred over the 'trees water's edge' (high EQ score) that was assigned with a negative value (mostly not preferred) (See Table 2). The reason behind refusing the trees as a water's-edge alternative could be that the local trees (Prosopis Juliflora) are seen as highly enclosed scruffy trees that may make people feel less stable and secure (KIM 2015, 132-133) by closing the visual access to the trail from both sides of the stream. Prosopis Juliflora is a widely spread local plant in the study area (well known) with very low transparency that it is almost impossible to see through in most of the spots it was found at. From biological and evolution theories perspectives, APPLETON (1975) based his argument that people tend to prefer an environment (scene) with a prospect and a refuge. He explained that panoramic (prospect) environments offer places to see, while enclosed (refuge) environments offer places to hide. This concept is very important because it explains the reason why people prefer environments where they can see (prospect) without being seen (refuge). From the safety-concern perspective, "A person with the ability to see and hide has great advantages over a person who cannot do so" (MAULAN 2006, 28). People from Jeddah may value dense vegetation from a distance but would not necessarily like to be in a dense landscape due to the unfamiliarity. The visual obstruction resulting from this dense landscape may make people hesitant to be within it.

Additionally, the low transparency imposed by the foliage of Prosopis Juliflora at the edge of the water would prevent people from enjoying the water scene and the aquatic birds. The chances to take a clear photo of the stream or even see through the tree to watch the migrant birds is near zero. Visitors may struggle to find access through the thorns that cover all the branches to get a closer look or access to the water scene. The tree is covering a wide area along the water's edge, and this blocks the scenery for the visitors. However, these characteristics are the key reasons for migrant birds to inhabit the study area due to the safe habitat and perfect hiding spots that these characteristics offer. Even though the Juliflora trees at the water's edge may decrease people's preference due to the lack of human made landscapes (i. e., maintenance or designed trail), a minimum design intervention (adding exotic plants) would improve the preference for this attribute. Lastly, the stone as a water's edge solution was found to be the second most preferred design solution. Stone and grass water's edge solutions are both preferred over the tree as a water's edge option. In terms of ecosystem services, grass and especially trees are more valuable than the stone solution. However, accommodating people's preference for stone as a water's edge solution may increase the erosion issue, change the stream morphology, increase the sediment deposit to the stream, and most likely will not perform as well as the other options in controlling urban-washed pollution (absorb and biotreat). Accordingly, replacing or removing a tree water's edge may affect the ecosystem and the habitat, and thus may affect the existence of the current avifauna and the overall biodiversity (BIAMONTE et al. 2011, MENDENHALL et al. 2016). Any influence on this ecosystem may force the migrant birds that play a very important ecological role to change their traveling route and thus may lengthen the total flying distance to the next stop (BIAMONTE et al. 2011). This may lead to endangering the number of traveled species which eventually would affect the global ecosystem and the associated ecosystem services (MILLENNIUM ECOSYSTEM ASSESSMENT 2005). If there is a need to trade-off the local trees at the edge of the water to provide better access to the water physically or visually, it is recommended to reduce the density of these trees in a few spots by moving the trees to another area around the site. The majority of the local plants must remain protected from being touched to provide a safe traveling path for migrant birds as well as a safe habitat for all faunas (BIAMONTE et al. 2011). This may benefit both stakeholders (wildlife and human) and keep the trade-off activities at a minimum level. This study also shows that some attributes (i. e., Urban density and urban diversity) have no significant effect on people's choices compared with the other micro-environmental factors (i. e., water's edge, vegetation complexity, trail design, and type of activities) (See Figure 2). Accordingly for future research, it is suggested to eliminate the insignificant attributes from the choices and focus on increasing the number of those attributes of a similar scale (i. e., micro-environmental factors).

The second key finding in this study is related to the implemented analysis model (Multinomial Logit Model (MNL)) that assumes that there are no different groups which can result in a different group of overall preferences based on socio-demographics. Therefore, different design solutions and decision-making should be accommodated based on the targeted population. Achieving sustainability requires addressing people's socio-economic needs while democratically engaging them to determine their fate (RANDOLPH 2004, 5). Mismatching public preferences on the restoration of such sensitive landscapes will negatively affect the success of preservation or restoration efforts. The ecological quality of the unmaintained landscape and its relative attractiveness (public preference or acceptance) are two essential objectives of landscape design. Both are necessary to achieve successful restoration projects (ZHAO et al. 2017, 107). Even though MNL has been used for more than three decades in the analysis of Discrete Choice Experiment (DCE) data, it is only useful as a top-line diagnostic tool to assess the quality of the experimental design and to estimate the average preferences for the sample. For future research, it is important to test if there are any significant differences between different socio-demographic groups in their preferences or values assigned to the attributes and levels of attributes used in this study. This study suggests resuming the data collection to obtain more comprehensive data of the target population and see whether there are any significant differences in the results compared to the current results.

5 Conclusion and Outlook

The intent of this study was not to draw a general idea about the target population preferences, but rather to test the efficiency of the DCE method and whether people will accept the minimum intervention made for the unmaintained ecological landscape. However, for more accurate results, it is recommended to resume data collection. The study showed that there are many ways to minimize or prevent trading off unmaintained ecological landscapes while meeting people's preferences and protecting the natural habitat. This replicable study will help researchers and landscape architects advance visual preference research further into the domain of empirical studies. It showcases an example of the hybridization of different methodologies and approaches in supporting an empirical study. It combined two research techniques from marketing and visual preference studies. The method and techniques used in this study established a clear connection to one of the Digital Landscape Architecture Conference themes and provided an example of an approach to protect, restore, or develop a resilient infrastructure.

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