Using Landscape Visualization to Inform Streetscape Design

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Abstract: The streets of commercial districts play an important role in the social fabric of communities. A well-designed streetscape provides an opportunity for thriving commerce, aesthetic enjoyment and public forum. The purpose of this study was to investigate how different elements of streetscape design influence a person's preferences for the space. Using 3D visualizations of existing and possible future conditions, we studied the effects that infrastructure design had on perceived safety and attractiveness. Our study site was a small college town in the US. Results demonstrate that green infrastructure, including trees and bioswales, improve attractiveness and safety. Parking strategies also have an effect on safety and attractiveness – the fewer opportunities for parking, the higher the perceived safety. Participants were clear that any change would be an aesthetic improvement, but there was no strong preference between any of the non-existing conditions. 3D visualization provided an opportunity to test for perceived differences by allowing the control of environmental variables and design elements.

Keywords: 3D Visualization, streetscape, environmental perception, simulation, design

1 Introduction

Commercial districts are often the epicentre for economic and social activity within cities. In addition to the activities and amenities these places offer attractive and safe streetscapes are vital to cultivating a vibrant commercial district (JACOBS 1961, KUO et al. 1998, DU TOI et al. 2007). Streets and sidewalks are important to the fabric of commercial districts as they provide public areas for social interaction and physical activities (Kuo et al. 1998). In commercial districts, walkability is important for cultivating vibrant communities, providing a comfortable social environment, a pleasant visual experience, and potential financial benefits to local businesses (JACOBS 1995). Furthermore, streets in commercial districts can be used to augment an individual's experience by creating an atmosphere that is safe, accessible and lively (KUO et al. 1998, DU TOI et al. 2007). For these reasons, and many more, it is critical that streetscape design be a foundational element to commercial district planning. The purpose of this research study was to better understand how different elements of streetscape design influence a person's perception of attractiveness and safety. Specifically by studying how these perceptions are affected by different parking strategies, as well as the presence of vegetation, designated bike lanes and seating. The results are intended to support empirically-based design of streetscapes and further the literature on this topic.

2 Survey Design and Procedures

This study was intended to support empirically-based streetscape design by investigating the perceived effects of different combinations of streetscape elements. Specifically, how the inclusion of infrastructure in design may effect an individual's preference. The commercial district selected for this study is located in a small U.S. college town. The site is immediately adjacent to the university entrance and is frequented by students day and night. Transit to the

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district is mostly done by vehicles and on foot. The streetscape within the district consists of: one to two story buildings, few scattered trees, widespread on-street parking and one way single lane roads. Sidewalk widths are quite narrow for this type of commercial district and social seating is non-existent. Using the existing condition as a baseline, a preference survey was developed using landscape visualization techniques to model and assess possible streetscape design alternatives for a revitalized commercial district. The visualizations enabled a systematic investigation of how different design elements affected perceived attractiveness and safety across the different stakeholder groups.

2.1 Designing the 3D Visualization Survey Set

The study was developed using the psychophysical approach (DANIEL & BOSTER 1976) which aims to quantitatively assess the relationship between individual perceptions and the environment. We employed 3D visualizations to simulate a range of potential development alternatives (see DANIEL & MEITNER 2001 for questions on reliability of visualizations for related studies). The design variables for the survey include: a range of parking strategies, bike lane infrastructure, green infrastructure, and seating. The fractured factorial survey included proposed ideas of: a) four kinds of transit and parking strategies (existing condition, 60% parking on both sides, no parking, pedestrian only), b) four kinds of green infrastructure (existing, trees, bioswale, trees + bioswale), c) the presence of absence of designated bike lane, and, d) the presence or absence of seating. From these variations 40 unique landscape visualizations were produced. Some variations of infrastructure were not possible. For instance, under existing conditions there is not enough space to add seating and accommodate local regulations for sidewalk width. Likewise some variations were not included because we wanted to reduce participant expected time. An example of the rendered image of the existing condition juxtaposed to a photo of the existing condition is shown in Figure 1. Participants were only asked to rate the rendered images in the study.

Fig. 1: Left: Photo of existing condition. Right: 3D visualization of existing condition.

The first step for creating visualizations involved collecting existing geospatial data e. g. (building footprints and roads), importing this data into CAD, and then verifying the accuracy against actual measurements. With the line work completed, Sketchup was used to create the 3D models of the buildings, then photographs and textures were then superimposed onto the building faces using Photoshop. The variations of infrastructure (e. g. parking strategies and location of infrastructure) were then designed in CAD and exported into Sketchup.

The combinations of the different variables were then merged with each other and the buildings to systematically create the different scenarios. The Sketchup models were rendered using Lumion. Figure 2 shows an example of the final render and design models.

Fig. 2: Example image set of rendered image (top left), design representation (top right) and plan view (bottom) to illustrate a single alternative scenario

2.2 Survey Delivery and Procedures

The study and survey were developed using the psychophysical approach, employing Likert scale questions and requiring individuals to rate each image on a scale of 1-7 (low – high) for safety and attractiveness. The volunteer participants were identified through convenience sampling from local businesses along the selected street. Participants took the internet-based survey on an iPad tablet. Before rating each image, participants were prompted with a set of nine sample images as a preview of the kinds of images and infrastructure they would be seeing in the survey. They were not explicitly told about the kinds of infrastructure. The order of the survey images was randomized and the rating mechanism maintained throughout. At the top of the page, the user would be shown on of the images, and below the images were two rows of Likert scales (scales were presented as seven radio buttons). The first row prompted the user to rate attractiveness (1-7), and the second, safety (1-7). In total 31 participants from the public took part in the survey. 14 males and 16 females were surveyed with ages ranging from 19 to 78 (mean = 27.2, standard deviation = 13.2).

3 Analysis and Results

Analyses were conducted to identify study variables causing statistically significant effects on perceived attractiveness and safety. Age was shown to be a significant covariate for both attractiveness and safety ratings, but is eliminated from further analysis because of a weak r^2 (.056 attractiveness, .064 safety) and a weak correlation coefficient (.23 attractiveness, .25

safety). Gender influenced both attractiveness and safety, with males showing higher mean ratings across all images. Tables 1 and 2 include gender as a variable, along with the other four factors and those interaction effects that were statistically significant.

Table 1: ANOVA results of streetscape design infrastructure on attractiveness ratings

	Variable	df	Mean Square	*F ratio*	*p*	Partial η2
Attractiveness	*Gender*	*1*	*55.943*	*25.450*	***.000****	*.022*
	Street Parking	3	11.982	5.451	**.001***	.014
	Green Infrastructure	3	192.399	87.529	**.000***	.191
	Seating Area	1	1.228	.559	.455	.001
	Bike Lane	1	3.071	1.397	.237	.001
	Gender x Street Parking	3	8.041	3.658	**.012***	.010

* Statistically significant results at $p = 0.05$ level. Only statistically significant results shown for interactions.

There are four different statistically significant effects for attractiveness (Table 1). Green Infrastructure has the largest effect: $F(3,40) = 87.529$, $p < 0.000$, $\eta^2 = 0.191$. Figure 3 (Left) shows that no green infrastructure is statistically lower than bioswale alone, which is statistically lower than trees only. There is no difference between trees only and the combination of trees and bioswale. Street Parking also had an effect: $F(3,40) = 5.451$, $p < 0.001$, $\eta^2 = 0.014$. Figure 3 (Right) shows the existing condition as a lower mean rating than any of the other designs. A post-hoc analysis (Tukey HSD) was conducted to determine the exact statistical difference within each variable. For instance, there is no statistical difference between pedestrian only and 60% parking designs. There is also no statistical difference between the latter and no street parking, but the pedestrian only design is statistically higher than no street parking. Gender also had an effect, with males evaluating all images slightly 0.5 points higher than females. The interaction of gender and street parking has slightly different results, with females rating the pedestrian only design more attractive than males, and males rating the 60% parking higher than no parking or pedestrian only designs.

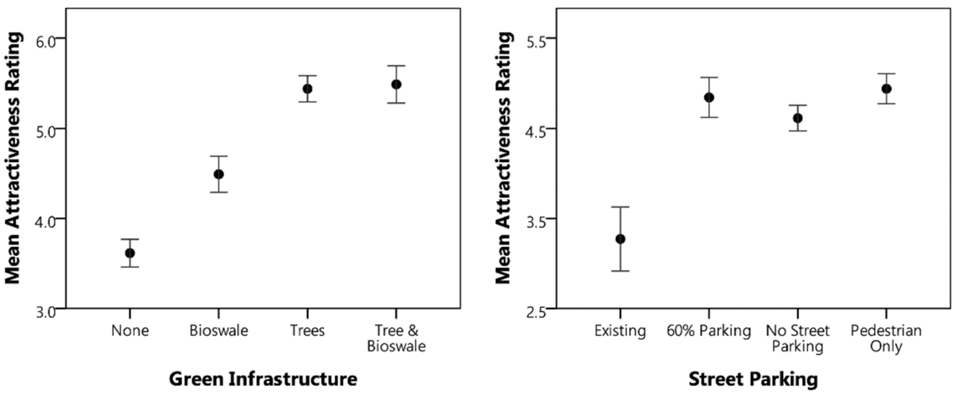


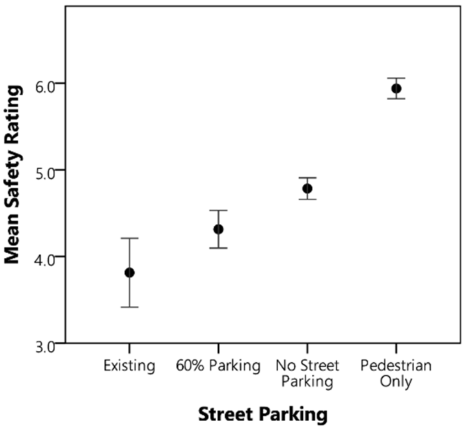
Fig. 3: Mean Attractiveness Ratings for Green Infrastructure (Left) and Street Parking (Right). Mean values shown as black dots with confidence interval (95 %) as bars.

Table 2: ANOVA results of streetscape design infrastructure on safety ratings

	Variable	df	Mean Square	*F ratio*	*p*	Partial η2
Safety	*Gender*	*1*	*21.879*	*11.673*	***.001****	*.010*
	Street Parking	3	180.333	96.216	**.000***	.206
	Green Infrastructure	3	5.120	2.732	**.043***	.007
	Seating Area	1	.014	.007	.932	.000
	Bike Lane	1	9.475	5.055	**.025***	.005
	Gender x Street Parking	3	6.558	3.499	**.015***	.009
	Street Parking x Bike Lane	3	5.099	2.720	**.043***	.007

* Statistically significant results at $p = 0.05$ level. Only statistically significant results shown for interactions.

There are six statistically significant effects for safety. Street parking has the largest effect: $F(3,40) = 96.216$, $p < 0.000$, $\eta^2 = 0.206$. Figure 4 (Left) depicts the differences in strategies, with the existing condition rated the lowest and the pedestrian only strategy the highest. A post-hoc analysis (Tukey HSD) revealed no statistical difference between the existing condition and 60 % parking ($p = .071$). There is, however, a difference between no street parking and the two other parking options. The most dramatic difference is the increase in perceived safety rating of the pedestrian only option. The other five effects, while statistically significant, had smaller effect sizes. Figure 4 (Right) shows confidence intervals and mean ratings with regard to different levels of the factor green infrastructure. The existing condition, again, was rated lower. Bioswales are rated higher than trees (though not significantly), and the combination of trees and bioswale is statistically higher than trees alone ($p = 0.010$). Gender also had an effect with males rating safety nearly 0.35 points higher than females.



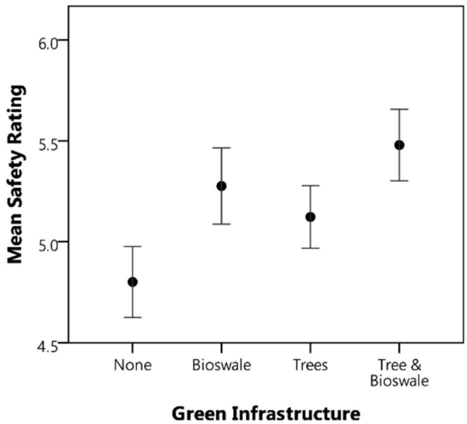


Fig. 4: Mean Safety Ratings for Street Parking (Left) and Green Infrastructure (Right). Mean values shown as black dots with confidence interval (95 %) as bars.

The interaction of gender and street parking reveals a similar trend to that of Figure 4 (Left), with males rating the pedestrian only design nearly 1 point higher on average. The effect of bike lanes, while not large, is curious. According to the results, the presence of bike lanes lowers the perceived safety of the design (Figure 5, Left). The interaction of bike lane and street parking is a bit more nuanced. There is a clear difference in perceived safety when there is or is not bike infrastructure for the pedestrian only option compared to all other combinations. There is also a statistical difference within this scenario, where the shared bike lanes without markings is perceived as safer. There is also a statistical difference with respect to the no street parking scenario relative to the other two options. This difference shows a perceived increase in safety regardless of shared or segregated lanes. What is also interesting to note is there is not statistical difference of 60 % parking or the existing condition.

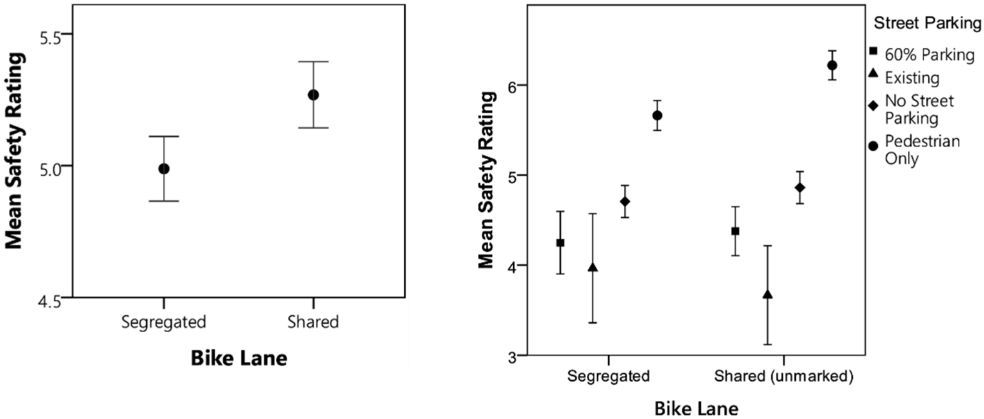


Fig. 5: Mean Safety Ratings for Bike Lane (Left) and Bike Lane by Parking (interaction, Right). Mean values shown as black dots with confidence interval (95 %) as bars.

One final result worth consideration is the correlation coefficient of attractiveness and safety. When looking across all rated images by all individuals, the correlation is 0.47. While this is not particularly high, it may suggest some similarity of perceptual equivalency between the two rating criteria.

4 Discussion

The results from this study continue previous work on the effects of green infrastructure on attractiveness and landscape value (DONOVAN & BUTRY 2010) and safety (KUO et al. 1998). Most importantly our study supports similar frameworks for systematically investigating how design elements affect perceived safety and attractiveness (e. g. DU TOI ORLAND & VINING 1992; STAMPS 1997). Our findings, while limited in their scope of design expression and to one example site, indicate that green infrastructure can increase the perception of safety and attractiveness. This finding supports previous literature of the value of trees along streets in urban studies. For instance, that the presence of trees is usually preferred over no trees, and that trees improve the attractiveness of a walking environment (see KAPLAN 1989, JACOBS 1993, WOLF 2005, FORSYTH & SOUTHWORTH 2008, KELLY et al. 2011, ADKINS et al. 2012). The inclusion of streetscape bioswales in the study provides evidence for their improved effects on perceived safety and attractiveness.

The perception of safety was an additional aspect of the survey that has provided direct empirical knowledge on the influence of the four elements tested. We did not anticipate any outcome from changes in seating, but were somewhat surprised by the various interaction effects. Clearly the effect of parking strategy had the most significant effect on perceived safety. The effect of green infrastructure on safety was weaker as an effect, but does demonstrate that any kind of green infrastructure in this study increased perceived safety. This evidence supports arguments for the value of placing a buffer between the road and pedestrian right of way (LANDIS et al. 2001). The data does support preliminary evidence that individuals may feel safer from the defined boundary or edge (NADERI 2003), regardless of the type of infrastructure. More directly, there is evidence showing that some kinds of crashes are reduced with the presence of trees (BURDEN et al. 2002). One important note on the results pertains to the perception of bicycle infrastructure. While there is general consensus that shared, unmarked, bike lanes increase safety it is possible that participants were responding to a different visual que than the infrastructure. The visual representations that were created showed only a silhouette of a cyclist when there was infrastructure. This means that it is possible individuals were responding more to the presence of a cyclist than that of the infrastructure. Even given this potential response, it is worth noting the interaction of parking strategies and cycling infrastructure. The difference between shared and segregated lanes does not state for all parking strategies.

As many designers move toward empirically-based design, there is need for more useful and applicable empirical data to support design constructs. One finding of this study is that bioswales are perceived as being attractive and providing increasing perceived safety. These social benefits are a win-win for design because bioswales also provide significant ecological function by slowing run-off and mitigating pollutants in waste streams (PATAKI et al. 2011). While findings, such as these provide supporting evidence for design, there is a critical need to pursue additional, more generalizable, studies. BAIN et al. (2012) argue that streetscape design for vibrant streets involves the interplay of numerous design elements. This study provides a framework for investigating design elements. Moving forward studies of these kind, should investigate the physical and place-based contexts in order to make the study robust for design application. In addition, the expansion of this study by increasing participation toward a wider audience would improve the reliability. Furthermore, the variations of design elements and characteristics (e. g. materials, texture, spatial arrangement, scale, proportion, etc.) should be investigated because they may affect perceptions and inevitably design implementation.

5 Conclusion and Outlook

The purpose of this research study was to better understand how different design strategies could effect and individuals preference both on attractiveness and perceived safety for a small commercial district streetscape. We investigated the impact of varying street and parking strategies, coupled with different green and bike infrastructure and the presence of seating. The empirical data point toward the influence of green infrastructure on attractiveness and safety, but the degree of influence differs based on the kind of infrastructure. Trees clearly influence attractiveness and safety, but with the later are not perceived differently than bioswales alone. A shift from the existing condition toward any of the alternative parking and street design increased attractiveness and perceived safety. While the results provide helpful evidence for one context, there is a need to further this kind of “what-if” research in order to investigate how designs may influence public perceptions. 3D visualization provides a robust way to represent space realistically and simultaneously model future scenarios. This kind of research can be used by designers and decision-makers to identify design strategies for improving the character of commercial districts.

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