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Potentials and Limitations of Implementing Linear Infiltration Systems on Urban Streets

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Introduction

Increasing infiltration systems in urban environments has become a major focus of our discipline to reduce the harmful impact of stormwater on urban watersheds. Two recent studies were conducted by the author of this paper (Sleegers and Brabec; 2013, Sleegers, 2013) with the focus on evaluating the aesthetics of linear urban infiltration systems on urban streets. Each study revealed challenges and limitations of these systems on various levels. What are the crucial criteria to propagate infiltration along streets, raise their acceptance and make them more usable? The purpose of this paper is to investigate the challenges and limitations of urban infiltration systems and propose recommendations for further implementation.

Background and Literature Review

Landscape Perception and their Qualities:

Within the body of environmental aesthetics and the qualitative assessment of designed landscapes theory, there are two primary approaches: the **design-based** approach that translates biophysical features of the landscape into formal design parameters, and a subjective **perception-based** approach that treats biophysical features of the landscape as stimuli that evoke aesthetically relevant psychological responses (Daniel 2001; Panagopulous 2009). Rachel and Stephen Kaplan (1989) categorized complex landscape aesthetic qualities in a preference matrix: coherence, complexity, legibility, and mystery. **Coherence** provides a sense of order and directing attention. Coeterier differentiates coherence from **unity**. If the parts fit together and function as a whole the landscape has the quality of unity. (Coeterier, 1996; Loidl and Bernard, 2003). The Kaplans define **complexity** in terms of the number of different visual elements in a scene, how intricate the scene is, its richness, and how much there is to look at. **Legibility** is introduced by the Kaplans with reference to Lynch. The Kaplans define legibility as a place that is easy to understand and remember, well-structured with distinctive elements such as landmarks. **Mystery** is the fourth fundamental attribute of preference explained in the model; mystery is involved if the observer is encouraged to further explore a situation or if this is not possible inspire the viewer's fancy. **Spaciousness** is describing the spatial definition of a scene through presence of distinct edges or landmarks (Kaplan S. and R., 1989). Different aspects of a landscape affect spaciousness: size and form of the open space, height of elements, texture of the surface, and composition of the elements (Coeterier, 1996; 1994). **Naturalness** is describing the biotic component of landscape perception. Its importance has been proven in the research of landscape preference; diverse public groups prefer natural scenes over artificial components or settings in the landscape (Kaplan S. and R., 1989). Naturalness should also be seen in the context of use (Ulrich, 1986).

Methods and Scopes of Landscape Perception:

Shafer and his research team measured attributes of photographs taken at eye-level to assess larger scale landscapes. This approach implies a causal link between landscapes composition and the perception of scenic value (Shafer 1969). Coeterier (1996) uses panorama photographs because they show the viewshed in a more realistic way to assess urban streets. In the application of this body of theory to landscape assessment, most tools and techniques have examined natural landscapes rather than urban landscapes (Bernasconi et al. , 2009). Little attention has been paid to the systematic aesthetic evaluation of infiltration in urban streetscapes. A study conducted by Echols and Pennypacker (2008) is a notable exception. It described aesthetic richness as a goal for the creation of amenity value through making stormwater an interesting experience of beauty or pleasure. An investigation of the inherent qualitative, perception-based attributes that give aesthetic value to users is missing in the current research.

Case study areas: Three infiltration systems from two exemplary and highly published projects of alternative rainwater management were chosen to investigate their aesthetic values: Hannover – Kronsberg in Germany (Santner, 2009), and High Point in Seattle, USA (Farr, 2008). Kronsberg and High Point are large-scale housing development projects of approximately the same size, address infiltration on higher-density residential street corridors as a strategy, and were implemented in the last ten years.

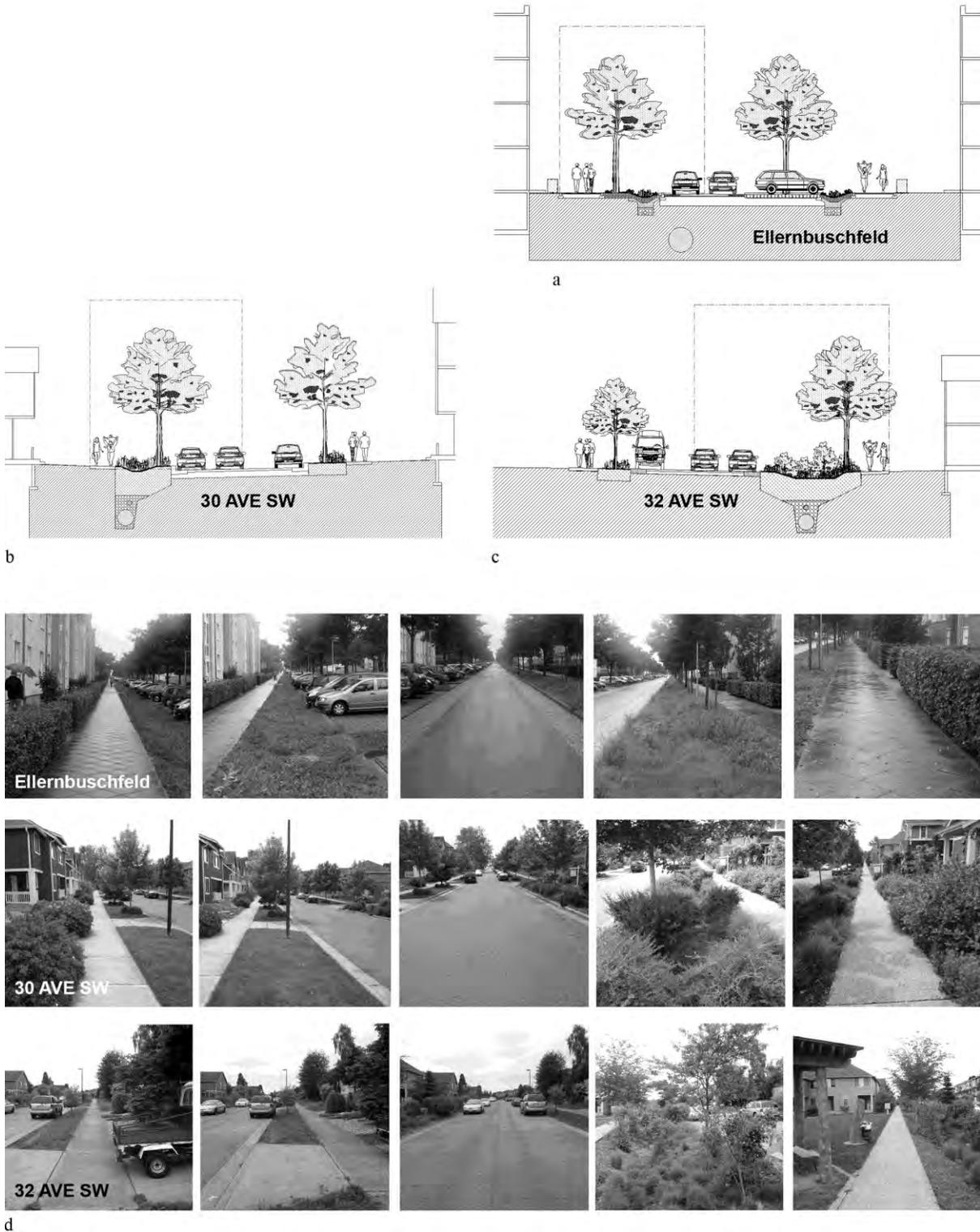


Figure 1. The three infiltration systems in sections and comprehensive sequential street views: (a) Hannover – Kronsberg, Ellernbuschfeld; (b and c) 30th Ave SW and 32nd Ave SW Section in Seattle – Highpoint. (Photos by the Author 2010 and 2012)

Goals and Objectives

This paper investigates stormwater designs through an assessment of commonly used qualitative attributes in landscape perception and reframes planning and design objectives that are relevant for the profession and the implementation of infiltration systems along urban streets.

Methods

This is a mixed-method that synthesizes the results of two studies: an expert-based investigation and a perception-based survey. The first study compared and assessed the aesthetic values of three linear infiltration system case studies in a comprehensive qualitative–quantitative expert-based method. It compared five common visual aesthetic criteria of landscape perception theory, including unity, complexity, legibility, mystery, spaciousness, and naturalness.

The second study investigated people’s opinion on the previously assessed three infiltration systems as a perception – based method. Do people think infiltration systems along urban streets are beautiful and why? Do they understand the function of infiltration systems and how important are ecological functions to people? What other design elements do people appreciate in the context of the infiltration system and how important is the aesthetic value of a street?

The perception-based study was conducted as a standard survey with open-ended interview techniques. Using a standard surveys and open ended-interview techniques, people on the streets of the respective case study locations - mostly residents - were asked to participate in the questionnaire. The interviews were conducted during different times of the day and week on the 400 feet long street segments. In Hanover-Kronsberg, about 30 people participated; on 30 and 32nd Ave. in Seattle the interviews were conducted to a total of 30 people on the respective streets. The survey reached out to about 40% -50% of all households and had an equal mix of genders. General questions focused on the importance of beauty and aesthetics in the streetscape and the perceived aesthetics and legibility of the swale as an infiltration system. The answers were ranked from yes, moderately/sometimes to no. More specific questions investigated the aesthetic values of specific design elements of the street and were again ranked. To obtain more precise information the interviewees were always asked to give always specific explanations and reasons for their rankings. This provided supplemental information for the qualitative assessment.

Results

Expert-based study: The findings of the first study demonstrated that the design of infiltration systems on narrow streets have the potential to engage aesthetic values through the use of basic design principles and the enhanced legibility of infiltration. The objectives of this study were to develop a landscape evaluation model for the design of surface infiltration systems on urban streets, and to identify the design parameters that can be improved, and which will enhance the aesthetic perception of the created landscapes.

The results of the comparison of the three schemes (one from the Kronsberg case and two from High Point) indicate that the design with the highest sense of **unity** is less **complex** than the most

intricate one - 32nd Ave SW. In the larger context of the development, it is problematic that the design of 32nd Ave SW is unique: the aesthetic quality of that portion of the street is not representative for the whole housing development. Even the design of the opposite side of the street has a poor aesthetic quality. All of these design aspects affect the element of **unity** as an aesthetic attribute. The case study of the residential street in Hannover – Kronsberg demonstrates the other extreme in design attributes: this design demonstrates a lack of diversity within an otherwise well-balanced streetscape. The result is a visual composition that lacks interest due to low levels of mystery and complexity. However, infiltration functions as a unifying design element within the whole development.

The results of the case studies have also shown that trees play an important role in creating the attribute of mystery, through their creation of shadow vs. light, and also partially obstructing views through branches. Trees also play an important role in the creation of spatial enclosure, an aspect of the streetscape designs that is reinforced through understory plantings. Deficits in the tree plantings on 32nd Ave SW have a detrimental effect on spatial enclosure, however the lack of understory plantings in Hannover-Kronsberg compromises the coherence of the design created by the tree canopy. Both the plant palette and planting scheme are also important for the perception of **naturalness** as demonstrated on 32nd Ave SW. On a smaller scale planting schemes of perennials and shrubs can create improve the complexity of the scheme.

Legibility of the design intent is another challenging attribute. In all of the case studies the infiltration is not legible; e.g. none of the designs showcases the flow of water, nor do they have a plant palette that that could make the idea of water part of the experience during dry periods. The landscape might be overall aesthetically very pleasing such as in the example of Seattle's 32nd Ave SW, but this is not achieved through design elements that articulate the idea of stormwater infiltration.

Perception-based study: The results of the most relevant general questions, including the aesthetic perception of the swales, are displayed in Table 1; the results that focused on the specific design elements in the street are displayed in Table 2.

All interviewed persons think that the appearance of their street is important for their neighborhood. Many of the interviewees expressed that appearance relates to other aspects like perceived safety and even steady or increasing property values. Generally the residents in all of the three case studies acknowledge and value the executed ecological approach of their housing developments and think that this creates a high sense of identity. Almost concordantly do people recognize the infiltration swales and relate the function to water and infiltration. Divergences emerge concerning the overall planting and the aesthetic quality of the swale (Table 1, Question 1 and 3). The planting and the swale on Seattle's 32nd Ave SW is rated very high; the ratings for the 30th Ave SW and Hannover's residential street are lower for the quality of the planting scheme and about the same. In comparison, the swale on Hannover's street seems to have the least acceptance; many interviewed residents complained about a lack of maintenance, trash and dog excrements. The people who gave better ratings acknowledge the positive function of infiltration.

Ranking	Hannover Ellernbuschfeld	Seattle 30th AVE SW	Seattle 32nd AVE SW
1. Do you like the street planting on this street?			
yes	69%	69%	92%
moderately	21%	23%	8%
no	10%	8%	0%
2. Did you notice that the street has a swale on one side of the road?			
yes	100%	77%	100%
no	0%	23%	0%
3. Do you think the swale is a beautiful element in the street?			
yes	41%	69%	75%
moderately	28%	8%	25%
no	31%	15%	0%
4. Do you think that the appearance of this street is important for the whole neighborhood?			
yes	97%	100%	92%
moderately	0%	0%	8%
no	3%	0%	0%

Table 1: General questions. Selection of the four most relevant and revealing questions from the perception – based survey and their results in the three case study streets.

The more specific investigation about the beauty and uniqueness of specific design elements in the street expanded the more general questions. The interviewees took the opportunity to name other design elements that connote to beauty and character such as an infiltration pond in High Point or the intricate agricultural landscapes that surround the Kronsberg neighborhood and are connected through large alleys of trees and greenways.

In all of the three case studies trees are seen as the most successful design element to make the respective street aesthetically pleasing. In Seattle the existence and of saved old, mature trees was mentioned many times. The relatively low values for grasses and perennials in Hannover were again expressed in relationship to maintenance. Remarkable is that people lowered their aesthetic appreciation of the swales in comparison to the previous, more general part of the survey. In Hannover and on 30th Ave SW people complained about the swales as barriers, e.g. while carrying groceries across from the on-street parking. One resident from 30th Ave SW related the swale with a negatively connoted ditch. On Seattle’s 32nd Ave SW some of the people who gave moderate ratings for the swale expressed the desire to have more flowering trees planted within or adjacent to the swale. Others expressed that this swale offers a range of possibilities besides its infiltration function; e.g. it is used for fruit picking and playing. Visible water in the swale after heavy rainfall has low to moderate aesthetic value for the residents; on 30th Ave SW again mainly due to a reduced accessibility of the adjacent sidewalks while crossing the streets. Sometimes negative comments were articulated due to the implied collection of contaminants from the streets’ runoff. The cleansing function of swales was only articulated

by a few people. This result was also remarkable in relationship to the individually expressed aesthetic value of bigger, permanent water bodies like the nearby pond in Seattle, High Point. Almost every interviewed person appreciated the high quality of the neighborhood in relationship to their pond as a place to relax or exercise. On Hannover’s residential street the role of the water in the swale could not be answered because runoff that from the streets percolates immediately in the both-sided swales. On another note this reveals also the good function of this system. The comparatively lower overall rating of the streetscape in Hanover was also mentioned with respect to a lack of variety in the planting schemes and the impression of monotony. This stands in contrast to the highly appreciated destinations in the larger context; the green courtyards, the nearby agricultural landscapes are valued for their opportunities to relax, exercise or play. Within the street corridor the patterns of natural pavements were emphasized by some residents.

Design Medium	Ranking	Hannover Ellernbuschfeld	Seattle 30th AVE SW	Seattle 32nd AVE SW
Trees	Adds a lot of beauty	100%	85%	92%
	Adds some beauty	0%	8%	8%
	Adds no beauty	0%	8%	0%
Grasses and Perennials	Adds a lot of beauty	45%	77%	92%
	Adds some beauty	45%	15%	8%
	Adds no beauty	10%	8%	0%
Turf	Adds a lot of beauty	0%	38%	25%
	Adds some beauty	97%	54%	75%
	Adds no beauty	0%	0%	0%
Swale	Adds a lot of beauty	21%	54%	67%
	Adds some beauty	59%	23%	25%
	Adds no beauty	21%	23%	8%
Water after Rain	Adds a lot of beauty	n.a*	23%	50%
	Adds some beauty	n.a	23%	50%
	Adds no beauty	n.a	54%	0%

* none of the interviewees had observed standing water in the swales. An evaluation was not applicable.

Table 2: Specific results from the perception – based survey investigated selected design elements of the infiltration system and their perceived impact on beauty. Which element adds the most beauty to this street – what makes it unique?

Discussion and Conclusion

The results are primarily discussed with a focus on affirmative and diverging results in comparison of the two methodologies – expert-based and perception-based; secondarily the complementary outcomes of the two methodologies are highlighted; finally conclusions are made for the planning and design of infiltration systems along urban streets.

Affirmative and diverging results: Some of the results of the expert-based evaluation were confirmed by the perception-based approach. These are the lack of complexity and mystery in Hanover's residential street. Not surprising is the high appreciation of the continuous street tree plantings in Hanover. In all three case studies does the design element of trees get a far superior rating than the swales. The people who gave better ratings acknowledge the positive function of infiltration; it is not clear though if this is seen as an unavoidable compromise towards a higher aesthetic quality. 32nd Ave SW was the infiltration system that offered, in comparison, the most complexity, sensation of naturalness and opportunities for other uses. The expert-based approach revealed a lack of legibility of infiltration in the streetscape. Surprisingly in this context is the comparatively negative image of visible water in the swale after heavy rainfall that was identified by the residents.

Complementary results: The relatively moderate acceptance of the infiltration systems in Hanover and 30th Ave SW seem to relate directly to utility values and maintenance. These were findings that were revealed through the survey. Other results revealed the importance of context; the overall high quality of the public open space system in the two neighborhoods seems to balance even some deficits of function or maintenance.

Conclusion: In conclusion the evaluation of the investigated design of infiltration systems along urban streets demonstrated the following potentials and limitations:

1. Infiltration systems can add to the complexity, mystery and naturalness of residential streetscapes; specifically wider infiltration corridors can offer more choice for people to use them as playscapes and edible landscapes.
2. The beauty of streets is very important and affects the reputation and value of a whole neighborhood. e.g. trees and specifically old trees that have been saved during development are considered to have high aesthetic value.
3. The design of the streetscapes system creates a high sense of identity affected the positive perception of the landscape.
4. Lack of maintenance of infiltration system has a considerably high impact on the aesthetic qualities.
5. Impediments created by the infiltration systems, e.g. standing water, that impede daily functions diminish the aesthetic value.
6. Standing water in an infiltration system is perceived negatively; larger water bodies such as ponds with permanent water very positive responses.

7. The lack of legibility of the design intent that was identified by the first study was not a relevant factor for aesthetic value. The legibility of a landscape's ecological functions does not seem to be important to people.

The applied combination of an – expert-based and perception-based methodology is a valuable approach to evaluate urban landscapes in a comprehensive way. Further research is necessary though with focus on legibility in designed landscapes that approach ecology.

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