Transportation, Large Infrastructure, and Context in Urban Areas: A Review of Human-Scale Perception and Response

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ABSTRACT

The Alaskan Way Viaduct in Seattle, Washington, U.S.A. is slated for replacement due to concerns about earthquake stability. The viaduct is a high volume transportation corridor that parallels the city's waterfront – an area of increasing importance to the economic conditions and livability of Seattle. An expert workshop was convened to consider elevated structure alternatives. Since any new structure must provide a people-friendly context that connects waterfront to city center, expertise in human perceptions of outdoor spaces was recruited for the workshop. This paper is a compilation of evidence-based ideas and principles about human response to and behavior within outdoor spaces, derived from social sciences research. It is a perspective on context sensitive design that blends the on-the-ground scale of human activity with the macro scale of an elevated, high volume transportation structure. Such concepts are becoming increasingly important as many cities choose to optimize the use of on-the-ground spaces associated with transportation infrastructure. The following topics are presented: sound and noise, light and shadow, on-the-ground spatial configuration, crime prevention through environmental design, the experience of nature in cities, and driver response to nature in roadsides.

Transportation agencies build new, or expand existing, major transportation structures in order to meet increasing transportation demands in cities. In some instances such structures serve a single purpose, such as an elevated interstate freeway overpass. In other cases, a large elevated structure may serve multi-modal transportation needs such as the hub where a light rail station is located in proximity to a major arterial. At one time the right-of-way for such structures was dedicated land that largely remained idle. Some of these lands are important interface parcels that connect functional parts of the city. Some cities, due to growth pressures and increased land values, are no longer willing to dedicate large tracts to single use, or to permit only vacancy activities such as parking.

The changing dynamics of land use associated with large, elevated transportation structures suggests that greater attention should be paid to the interaction of people with such spaces. Large structures impact the character and experience of the ground surface for people who move through, work near, and reside close to such spaces. There has been little systematic investigation of the consequences of design and construction of large transportation structures for human activity and behavior.

This article is a compendium of empirical evidence that provides insight about life-on-the-ground associated with large elevated structures. The information was prepared following a design workshop that was conducted to propose and assess alternatives for a viaduct replacement in Seattle, Washington, U.S.A. As the design team deliberated on structural alternatives there was much discussion about the on-the-ground implications for diverse potential site users. My research program addresses human perceptions of urban green space and ecology, so I was asked to contribute information to the team about human perceptions and behaviors in outdoor spaces. This paper provides a brief introduction to the viaduct replacement project. It then presents a compilation of human response principles derived from social science research. Such information provides evidence-based insights concerning large structure design in many urban contexts.

SEATTLE VIADUCT REPLACEMENT PROJECT

The Alaskan Way Viaduct (or S.R. 99) is a double-deck elevated structure built in 1953. It is so named because a surface arterial, Alaskan Way, is immediately adjacent. The viaduct now supports 110,000 average daily trips. It was once the sole high speed transportation corridor running south to north through downtown Seattle. U.S. Interstate 5 was constructed several blocks to the East in the 1960s. Geographic constraints preclude alternative locations for placement of a south to north high-speed road to serve the city core.

Figure 1 illustrates location and urban context of the existing viaduct. The Seattle waterfront is located due west of the viaduct. The waterfront area started as a timber port, expanded to include other industrial uses, but in recent decades has become an urban recreation, retail, and tourism attraction. The waterfront includes docks that support regional ferry service (more than ten million passengers per year), restaurants, an aquarium, a conference center, shops, visitor activities (such as port tours), and cruise ship docking. Immediately to the east and uphill from the viaduct is downtown Seattle, including retail, commercial businesses, financial services, and high-density residences. Pioneer Square is a historic retail district located immediately west of the viaduct on the south end. The Pike Place Market, oldest and largest urban farmers' market in the U.S., is perched due west of the viaduct at its northern end.

FIGURE 1 Location and context of Alaskan Way Viaduct, Seattle (left of image is north).

The Nisqually Earthquake in February 2001 caused damage to the historic viaduct. Still in use after short-term repairs, there is a feeling of urgency about replacing the structure. Washington State Department of Transportation (WSDOT) has conducted public workshops that have generated 76 concepts (1).

The City of Seattle is advocating for an underground tunnel. Due to cost considerations elevated structure design options are being reviewed. In July 2006 WSDOT convened the Context Sensitive Design and Architectural Enhancement Workshop for the Alaskan Way Viaduct and Seawall Replacement. Agency and consulting experts on bridge design, transportation engineering and urban design deliberated for three days to generate schematic alternatives, responding to a short list distilled from many initial concepts. Alternatives are now being refined and reviewed for engineering feasibility.

Two primary concepts emerged from the workshop. The first sets of options were variations of a double deck pre-stressed concrete girder structure (Figures 2 and 3). The main objective for this set of options is to replace the viaduct with another structure that is similar is size and shape to the existing structure. Once the new structure is in place the street level under the viaduct could become a retail outlet space, creating an additional retail block from downtown to the waterfront. It could include restaurants, coffee houses, kiosks, and retail establishments.

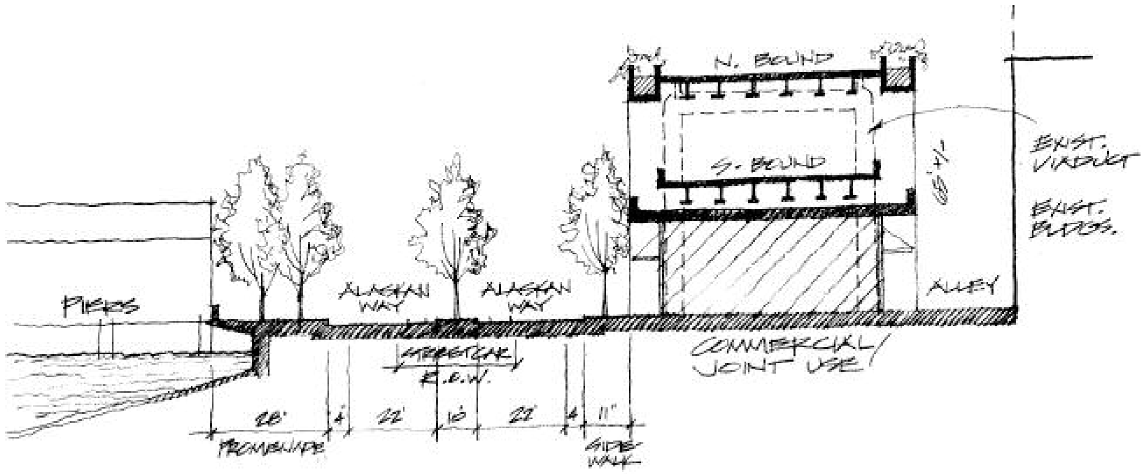

FIGURE 2 Structure design concept - concrete girder: section sketch.

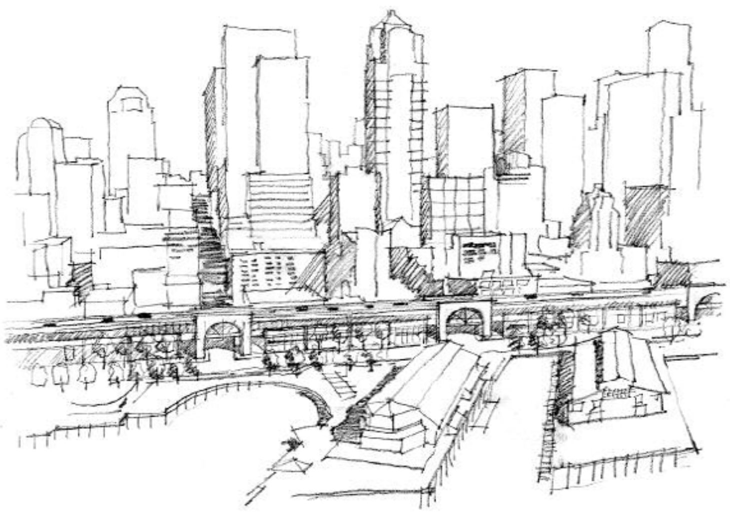

FIGURE 3 Structure design concept - concrete girder: aerial perspective sketch (left of image is north).

Additional proposals focused on the concept of an Extrados cable stayed/concrete segmental structure (Figures 4 and 5). One and two pier variations were considered. The structure would be built using a single spine, with beams perpendicular to the spine. Cables would be attached to the beams, and the segmental portion would be built between the beams. This would allow light to penetrate between the segments. The surface streets would be designed around the central column, with Alaska Way north bound being on the easterly edge of the column. This would allow a wider promenade to be built along the waterfront, and maximize the uncovered area along the waterfront.

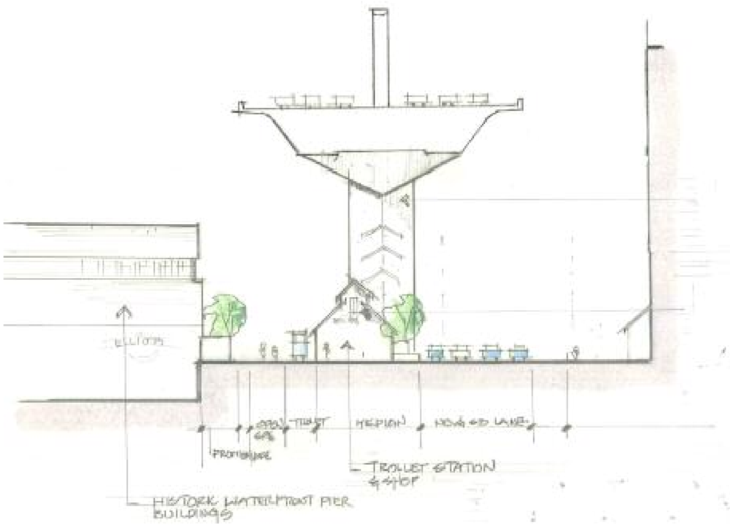

FIGURE 4 Structure design concept 2 - cable-stayed concrete segmental: section sketch.

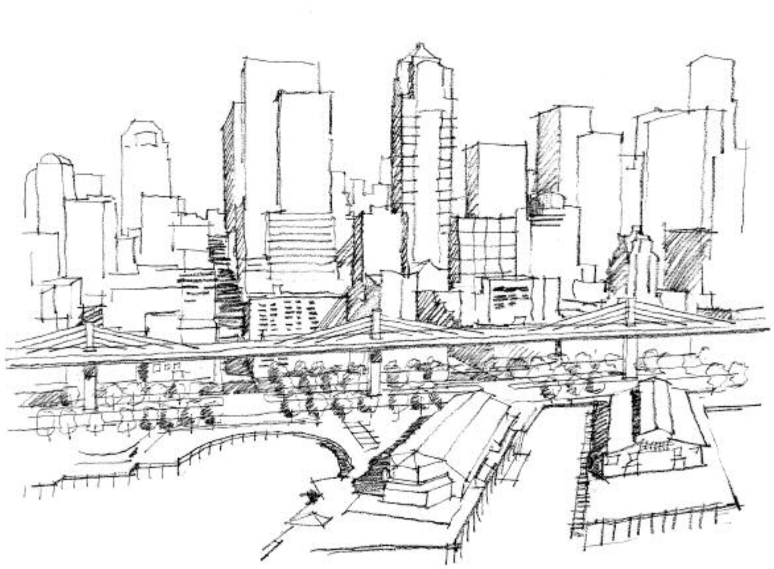

FIGURE 5 Structure design concept 2 - cable-stayed concrete segmental: aerial perspective sketch (left of image is north).

The elevated structure designs would have many consequences for diverse users of the outdoor spaces in and around the viaduct. The City of Seattle has accepted “7 Framework Principles for Waterfront Planning.” The principles fall within an overarching principle – the need to balance and integrate multiple and potentially competing purposes for the waterfront area.

The design discussions during the workshop and the City of Seattle’s goals for the Central Waterfront have addressed many dynamics of human response and perception. This paper is an effort to provide current empirical evidence concerning the human experience of spaces like those associated with elevated viaduct proposals. Social science investigators in environmental psychology, architecture, urban planning, geography, transportation, and landscape architecture have contributed to the evidence-based literature.

This appears to be one of the first documents in transportation policy to consider the impacts of large-scale urban infrastructure on non-driver human response. It is not an exhaustive literature review. Readers with knowledge of additional relevant studies or research are urged to contact the author.

DEFINITION OF EXPERIENTIAL SPACES

Empirical studies of human response to environments typically begin with a definition of a particular environment. Human response studies have primarily addressed small-scale situations. Examples include stations in the workplace, the structure and function of residences, arrangement and functionality of hospital treatment spaces, and so on. Few studies have addressed the complex interactions of spaces affects associated with large-scale urban infrastructure. This is probably due to combined factors of lack of fiscal support, and logistical constraints of data collection.

For the purposes of this briefing we can consider the viaduct zone as a series of overlapping, and interacting experiential spaces. These spaces are of different volumes, contain different activities, are "inhabited" by diverse users, and are differentially impacted by traffic on the viaduct.

The zones are, moving from west to east:

- **Waterfront –** more intimate scale with user attention focused on attractions and water views or activities. Uses include public attractions (e.g. aquarium), shops, hotel, restaurants, and public buildings. Users are regional residents and out-of-town visitors. Periodic surges of visitors occur with festivals and cruise ship scheduling.

- **Alaskan Way –** heavy use arterial that supports waterfront access, commuting traffic, and freight transport from a large port facility in the south to industrial businesses of the north. Associated bicycle and pedestrian paths provide downtown recreation opportunity.

- **Viaduct Superstructure –** Major S/N limited access highway serving commuters and freight vehicles, and providing a vivid glimpse of the Puget Sound region for passengers. At ground level the large volume space will vary substantially in character depending on choice of elevated structure design. Dimensional width and height of road bed, method of road bed support, and overall height of structure will greatly impact human perception and response.

- **City Edge –** highly varied building form and massing, with on-street access to shops, professional offices, high-density residences, and civic buildings. There is a varying degree and success in interface with the other zones. It is assumed that users include a diverse mix of residents, merchants, office workers and city visitors, but no systematic assessment has been done.

DIMENSIONS OF RESPONSE AND PERCEPTION

While bridge projects and studies have considered context-sensitive structure design (2, 3, 4, 5, 6) few efforts have addressed on-the-ground human response to a project of the scope and scale of the Alaskan Way Viaduct replacement. Indeed, studies of environmental psychology have infrequently addressed transportation systems (7). Thus the following evidence-based reports are taken from more limited study settings, and are extrapolated to viaduct spaces.

Two general dimensions of human response are reported. On one hand studies report on the physiological response of people to external stimulus and conditions. Measures might include heart rate, hearing capacity or visual acuity. Such studies typically evaluate whether changes or differences in an environmental condition are associated with measurable response differences. An individual may or may not be aware of changes in response.

The second dimension of studies includes perceptual aspects. Perceptual responses include self-reports of behavior that are then analyzed for relationships (correlational or causal) with an environmental condition or a stimulus change. Other perceptual responses are evaluative, in that a person is asked to make a judgment or express an attitude about an environmental condition. Such responses are analyzed for categories or clusters of response, as well as the conditions that earn high and low ratings. In both perceptual response types an individual is called upon to consciously consider or recall their changes in response. Underlying reasons for response may not always be apparent.

PERCEPTION AND RESPONSE EVIDENCE

Empirical evidence is summarized. Interpretations and application of the evidence to the experiential spaces and viaduct design options will be done as design refinement proceeds.

Sound and Noise

Sound is received by the human ear, and may be judged to be pleasant or unpleasant. Noise is generally a judgment by the listener of sensations that are unpleasant, and deemed unwanted and disturbing (8). Loudness is measured on a decibel scale (which increases logarithmically such that a 10 decibel increase represents a doubling of volume). Decibel levels for common sounds are: 20 for whispers, 60 average conversation, 80-90 for noisy restaurants and New York subways, rock concerts 110-120, jet take-offs at 150.

Loud sounds can impair hearing, after continuous exposure (generally at greater than 85 decibels) or after a single instance of a particularly loud sound. Everyday environments are becoming ever louder. Downtrends in hearing ability are particularly noted for children and older adults.

Though more difficult to measure, noise has been proven to have impacts on physiological and psychological well-being (known as nonauditory effects). Unwanted, uncontrollable and unpredictable sounds can be annoying and disturbing, resulting in physiological stress responses, such as a rise in blood pressure, excessive levels of certain hormones, change in heart rhythm, and a slowing down of digestion. Sustained noise-induced stress can result in negative responses of immune, circulatory, cardiovascular, or gastrointestinal systems. Children exposed to noises may be especially vulnerable (9).

Within a list of annoying noises, urban traffic continues to be the most significant source of annoyance (10, 11), with secondary effects. Based on correlations between public surveys and sound measurements, one study found that urban residents in noisy area were at higher risk for sleep disturbances, and such disturbances were significantly and positively related to personality traits of neuroticism, subjective noise sensitivity, and noise annoyance (12). Sleep is required for physical and mental recuperation. Sleep loss can impair daytime task performance at work or school. Based on interviews, 81 percent of adults working around major streets in one city were annoyed by traffic noise, and the noise also interfered with daily routine activities (13). Also, studies find that chronic loud transit noise exposure was associated with poorer reading performance by school children (8).

Traffic noise, largely generated from tire to pavement contact of thousands of vehicles on the viaduct, is a strong influence on human user experience of each of the experiential zones.

Decibel abatement and mitigation techniques are possible for an elevated structure, and based on empirical studies of noise and sound, should be implemented where possible.

Light and Shadow

Studies have demonstrated the importance of adequate lighting in both physiological health, and human perceptions. Recommended indoor illumination levels range from 20 foot candles (fc) for general use areas, to 50-60 fc for task lighting, and up to 100 fc for focused detail work such as laboratories. Outdoor night lighting recommendations are based on human use intensity and safety, and range from 0.8 to 3.6 fc. Full, unobstructed sunlight has an intensity of 8,000 to 10,000 fc. An overcast day will produce an intensity of around 1,000 fc. The intensity of light near a window can range from 100 to 5,000 fc, depending on the orientation of the window, time of year and latitude.

Shadow is a lower light condition that is common in cities and is a consequence of structure height and massing in relationship to pedestrian areas and public places. Some cities have regulations that address the extent of shadow caused by new buildings, and mitigation requirements. For instance, California has a Solar Rights Act and many cities in the state have code for solar access protection. The laws address illumination of solar energy systems.

Little research appears to have been done on human response to large shaded areas in cities. One important issue is personal safety. Actual and perceived personal danger in urban public spaces is inferred from physical and social cues. Improving lighting seems to be one of the most common suggestions for crime prevention by design, yet empirical studies are inconsistent in their conclusions about increased lighting and crime reduction. Arrangement and configuration of spaces (such as confinement, concealment or impeded sight lines) interact with lighting levels to affect crime perception (14). In a study of public response to urban alleys the presence of shadow was significantly associated with danger, while displays of setting care reduced judgments of danger (15).

Viaduct elevated alternatives provide for varied light and shadow footprints around structures. We have limited understanding concerning the daily or seasonal response of on-the-ground users to lighting conditions.

Spatial Configuration at Pedestrian Level

The spatial layout or configuration of outdoor spaces can positively or negatively affect human comfort and functioning. People are not passive receivers of information. They actively explore their surroundings (physical, social, and digital) and seek understanding. The outdoor environment is an important source of information for people seeking to understand the purpose, affordances and opportunities within a setting. Here are some of the highlights of research in cognitive psychology on human response to outdoor environments (16):

- **Large Expanses of Undifferentiated Ground Plane (-)**. Large areas that have little to focus on are not preferred. A quick view over such a space suggests that nothing is going on. The apparent sameness of the space, particularly if large, may make it difficult to keep one's bearings.

- **Dense Edges and Obstructed Views (-)**. A setting that has a rough boundary and a dense amount of unorganized material (such as looking into a bramble area) may provide more interest. But such a setting may lack a clear focus or suggest the possibility of getting lost. Both physical and visual access is inhibited. It is also not preferred.

- **Smooth Ground Plane with Spaced Trees (+)**. The combination of a negotiable ground plane (such as grass, or interesting pavings) combined with sizeable interspersed trees (or suitable built elements) is preferred. The combination provides clear focus, provides a sense of depth for way-finding, and invites entry. Within these general conditions legibility and moderate complexity are favored.

- **Experience of Mystery (+)**. A sense of mystery is one of the most consistently expressed traits associated with landscape preference. Mystery is defined as promise that one can find out more as one continues into and through a setting. The suggestion that there is more to see (and learn or experience) becomes compelling.

- **Enclosure and Coherence (+)**. Having several clearly identifiable areas or regions within a larger space enhances preference. A large area can be divided into smaller areas (or "rooms") using vegetative or built features, and repeated textures and materials suggest connectedness. Enclosure may be perceived, rather than literal barriers. Opportunities for 'prospect and refuge' are also enjoyed (17). Landmarks provide a sense of the whole while within distinct spaces.

- **Views and Vistas (+)**. Most principles above address human interaction from within or adjacent to a space. Passive views, even at some distance from the view target, reveal the extent of a large setting, supplying the overview that helps a person to put the pieces together and aids way-finding. Views enhance understanding and inform exploration. Focal points within a vista direct attention to important or guiding features.

Crime Prevention through Environmental Design (CPTED)

Crime prevention through design has gone through three phases since the 1960s (18). The first phase acknowledged the link between features of the physical environment and crime (19). Jane Jacobs pointed out the importance of having "eyes on the park" and "eyes on the street," asserting that the most successful urban spaces are those that have life swirling through them (20). If public spaces do not have people passing by during all times of the day, they must offer "demand goods" or facilities and events that attract visitors.

Jacobs observed the elements that make successful and safe public park spaces:

- **Intricacy**. Various focal points, groupings of trees and changes in grade comprise intricacy. These subtle expressions of difference are amplified when people are among them.

- **Centering**. Good small parks have a center (or large parks may have multiple centers). The centering element is the place that most would call the center of the park, and may be a pausing point, a climax of experience, or the intersection of paths.

- **Sun and Enclosure**. These two elements are interrelated. Sun should be shaded in the summer; but buildings should not completely cut off the sun from a park or open space. Buildings help to enclose the space.

First generation CPTED further acknowledged that criminal behavior occurs where opportunities present themselves. Therefore, altering the physical environment in specific ways can reduce criminal behavior (21). Core principles are:

- **Natural Surveillance**. Placement of activities, physical features and people should make the site readily observable by those within the site and adjacent to it. Lighting is important for late hour use (22).

- **Access Control**. Access control is the physical guidance of people as they enter and exit a place, achieved with use of fencing, signs, landscaping, lighting and other features. Barriers can be real or symbolic. Access control makes trespassing and unacceptable entry more noticeable.

- **Territorial Reinforcement**. An expression of ownership, territorial reinforcement includes the installation of art, signage and landscaping that tells a visitor that someone cares about a space. Expression of ownership reinforces territoriality, which in turn, can deter illicit behavior.

- **Target Hardening**. Target hardening involves typical crime prevention techniques that make the target of an offender less accessible, and may include locks, fences, safes, alarm systems and other locking devices. These tactics are often inapplicable in park design except in large assembly areas, as public parks are intended to be generally accessible.

- **Order Maintenance** (23). Damaged features (such as broken windows or graffiti) must be repaired quickly or they socially telegraph a lack of attention to maintenance, and a general feeling that no one cares about the public space. Without "order maintenance" users may experience fear and avoid a place. Low-level offenses occur, with possible escalation to more serious crime.

The third phase of crime prevention through design, called Second Generation or Situational CPTED, is a holistic approach maintaining that sustainable crime deterrence requires social and economic changes within the context where crime problems are likely, along with physical environment changes (24). Key principles include:

- **Physical Design**. All design elements and programming that can prevent crime (above) should be employed.

- **Context of Public Space**. Any space should be regarded as an ecosystem, so that crime prevention planning integrates social and economic factors, and involves all entities that have jurisdiction over a space.

- **Community CPTED** (25). Use of problem solving process that includes identification of problem areas (by analyzing spatial patterns and crime reports), a field survey of users and public input for solutions.

Vegetation is a desired feature of public open spaces in cities. Some crime prevention specialists have supported removal of most, if not all, vegetation in potential problem areas. However, the relationship between vegetation and crime prevention is more complicated than originally thought. Dense vegetation can obscure sightlines, may support criminal acts and increase fear (26, 27). However, in a series of studies residents of public housing having trees and lawn (with open views), as compared to paved common spaces, reported fewer incidents of vandalism, graffiti, and other low level nuisances (28). Crime reports were also less in greener housing settings (29). Investigators suggest that the negative relationship between landscape and crime was due to increased surveillance and better social functioning, as people are more inclined to spend time with friends and neighbors in green outdoor spaces.

Nature Experience Benefits

The benefits and functions that trees in urban areas has been researched for several decades. Studies have documented environmental, social and economic benefits for communities, municipalities and regions (30, 31).

Specific findings concern the human response to everyday or nearby nature in urbanized environments (16). People of all ages, and of all cultures prefer natural views to built settings. Large trees and water views, in particular, contribute to visual quality of urban environments.

Cognitive scientists have studied the restorative capacities of natural settings. Tasks and work that demand focused attention (typically done in office or school settings) for a lengthy period can result in mental fatigue, which can be expressed as irritability, physical tiredness, and inability to concentrate. Brief interludes in natural settings have been found to be restorative (32). Studies demonstrate the importance of nature and mental functioning for urbanites. Inner-city girls with more natural views at home have greater concentration and self discipline (33). Desk workers who have a view of nature report greater job productivity and satisfaction, and reduced absenteeism (34).

Psychologists with an interest in human physiology also report benefits of natural settings. Hospital patients who have a view of nature recover faster from surgery and require less pain medication (35). Views of nature reduce physiological stress response (36). Preliminary research suggests that urban forests contribute to more walkable cities and increase recreation benefits (37, 38). More active lifestyles combat obesity, improve cardiovascular health, and increase longevity (39).

Urban Trees and Driving Response

Earlier transportation publications promoted trees. In 1949 Neale proposed “trees have undoubtedly saved many lives and prevented many accidents in intangible ways.” (40) He observed that well-spaced trees might improve driver comfort by providing relief from the sun and wind. Trees can help keep drivers alert, and add beauty to harsh roadways. Trees can reduce stormwater runoff and soil erosion, as well as keeping dust levels low on roadways. Trees in medians can cut cross-glare. Zeigler also reported benefits: shade, windbreaks, visual buffer, physical protection for pedestrians from run-off-the-road vehicles, and contributions to historic character (41).

Investigators have systematically examined some of the specific benefits of the roadside urban forest. Trees are associated with improved visual quality of roadsides (42), and positive judgments of community character (43). Drivers encountering natural roadside views display reduced physiological stress response compared to those viewing built settings (44). Highway drivers with views of natural roadsides display higher frustration tolerance (45) (which perhaps reduces road rage). Reports of speed reductions or traffic calming are of great interest and have some empirical support (46, 47). A study in Toronto, Canada found that street landscape improvements reduced accidents by 5 to 20 percent (generating significant public costs savings) and boosted pedestrian use of urban arterials (48).

CONCLUSIONS

While direct empirical evidence is limited for the specific situation of the Seattle viaduct aerial structure, it is important to consider human response in the design decision process. The viaduct replacement project offers an interesting pre/post situation to evaluate human response to large-scale urban infrastructure. The information in this briefing (and potential research) is important as human experience of resulting spaces has consequences for:

- **Public Health –** noise, air quality, water quality, active living opportunity.
- **Retail Economic Vitality –** retail dynamics of the Pike Place Market, the waterfront, and downtown merchants is dependent on the quality and duration of waterfront patronage.
- **Safe and Pleasant Multi-Modal Transportation –** impacts of the intersection of viaduct, surface traffic, ferry traffic, bicycle, pedestrian, and trolley transportation modes can be aided and mitigated by perceptual influences.
- **Vibrant Cities and Growth Management –** a vital waterfront zone attracts residents to high-density downtown development, perhaps reducing development demand on outlying rural landscapes.

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