Soundscapes
A Sustainability Approach to Transportation Noise Management
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The goal of environmental sustainability presents new challenges to traditional notions of how transportation systems and their components affect the quality of life. For transportation noise control, the shift to planning for sustainability advances the concept of the soundscape or sound environment. In this context, the quality of life is improved to the extent that the soundscape is deemed desirable—that is, appropriate for the location and the associated activity.

Traditional noise control strategies focus on one sound source at a time and target the intensity or loudness of that source. In contrast, the evaluation of a soundscape considers a multitude of sources and the desirability of their combinations.

Transportation design requires standards or guidelines, but few metrics are associated with soundscape desirability. To pursue desirable soundscapes as part of the transportation planning process, policy makers, engineers, and design professionals will need to understand subjective judgments about the sonic environment. Soundscape considerations are likely to alter the analysis and design processes, particularly in relation to noise barriers, quieter pavement, and source reduction.

Role of Soundscapes
The “triple bottom line” for sustainability requires a transportation project that is economical, environmentally friendly, and improves the quality of life. All transportation modes create some level of noise for those living in the vicinity. Improvements to the soundscape must address not only the undesirable aspects of noise produced by transportation but also the preservation or restoration of the desirable sounds that are covered up or masked by transportation noise. For transportation improvements or expansions to achieve the triple bottom line, the full panoply of sounds must be considered, with the goal of preserving or restoring desirable soundscapes.

The soundscape is the total sound environment “with emphasis on the way it is perceived and understood by the individual or by a society” (1). In other words, a proper analysis must understand a soundscape’s subjective meaning for the individuals who experience it.

Judgments of a soundscape may depend on its location and visual appearance (2), the type of activity or activities that occur (3), and the observer’s personal history, expectations, emotional reaction, culture (4), and age (5). Evaluating this multiplicity of factors so that decisions can be made about soundscape improvement or preservation is a formidable challenge.

Noise Control
A three-pronged approach has guided environmental noise control and management and the noise reduction strategies for highway traffic (6):

- Quieting the source,
- Reducing noise along the path of transmission between the source and the receiver, and
- Land use planning.

The first two are direct abatement strategies that for a long time have been the foundation for effec-
tively reducing the impacts of noise in communities near transportation facilities. Whether the facility is a commuter rail line, an airport, or a major highway, the overarching efforts since the landmark environmental regulations of the early 1970s have focused on these two components in the approach to noise control. Which of the two yields the most benefits will depend on the particular mode of transportation involved and on the particular situation.

Land use planning, the third prong in the approach to transportation noise control, may be viewed as a strategy of avoidance, as opposed to abatement. For example, prohibiting new residential development along a major Interstate highway will avoid a noise impact scenario; the goal is to promote or allow only development or activity that is compatible with the level of noise in an area. Noise abatement, in contrast, would require a noise barrier for the new residential development along the Interstate.

In applying the concept of soundscape to the abatement of highway traffic noise, the focus is less on the physical reduction in the level of noise and more on how the traffic noise is perceived as a component of the sonic environment. With the trend to sustainable development and sustainability, new developments tend to be more compact, urban-oriented environs, and the spaces that are created will have soundscapes that differ from those in the more traditional living spaces that characterize many suburban or rural environments. In either case, the totality of the sonic environment and the context of the various sounds indigenous to the area may be viewed in terms of their contribution to the quality of the environment.

**Quieting the Source**

Automobile and truck industry efforts have made steady progress in quieting the source. The primary subsources of noise from highway vehicles—the engine, the exhaust, and the drive train—have undergone technological advances and design improvements in the past 20 to 30 years that have resulted in some noise reductions. With these advances and increasingly stringent vehicle noise standards, a clear trend to quieter vehicles—particularly in heavy trucks—is emerging in the fleet.

In addition, the development of alternative-fuel vehicles—for example, hybrid and electric—has achieved a new level of quieting at the source. Design modifications to truck engine enclosures, improved muffler systems, and other redesigned vehicle components also have yielded noise reductions.

Tire–pavement interaction is another major subsourse of noise from highway vehicles—it is the primary source of traffic noise for most roads and for most vehicles at speeds above 30 mph (7). Although the physical quieting of many vehicle components has been accomplished gradually and through attrition—with older, noisier vehicles being replaced—quieter pavement technology has developed only recently.

A quieter pavement surface can result in immediate reductions or alterations of source noise. Quieter pavements perhaps are not an alternative to traditional noise barriers but offer an additional option in the noise control arsenal, despite issues with the longevity and durability of their quieting aspects.
Influencing Perception

These efforts at quieting or altering the character of particular sources or subsources of noise are important to the soundscape approach. Traditional noise abatement seeks to reduce offending or unwanted sounds according to established numerical criteria or limits; in contrast, the soundscape approach focuses on the human perception of the acoustic environment and on “sounds of preference” (8) that contribute to human enjoyment or well-being—that is, to quality of life.

Because the soundscape concept focuses on the identification, perception, and characterization of sounds in the total aural environment, the ability to alter the character of the contributing sounds presents an opportunity to influence the perception of the sound or noise in a positive way. In an environment in which multiple sources may contribute to the overall sound energy, the perception of dominant sounds, which are judged as negative or undesirable, and of sounds that are masked or overwhelmed complicates assessments of an individual’s annoyance or satisfaction.

For example, human-made sounds—such as traffic noise—that mask the natural or desirable sounds indigenous to an area or community would typically be viewed as degrading the environment. Sounds are processed differently according to an individual’s culture or experience, so that the same acoustical event can yield different meanings and interpretations, depending on the situation (9).

Path Control

Noise reduction at the source or subsource level can be effective, depending on the transportation mode. Reductions in the overall noise effects of aircraft, for example, have resulted principally from design improvements to the engine and airframe to quiet noise, as well as from operational modifications during take-offs and landings. In contrast, highway traffic noise abatement has relied on noise barriers as the primary and most effective approach.

As noted earlier, the concept of sustainability and sustainable development fosters a design philosophy and characteristics, conditions, and practices different from more traditional development scenarios. Suburban sprawl—that is, suburban development that is centered on the single-lot, single-family dwelling—comes with a closer-to-nature atmosphere of open space, wooded areas, and backyards.

Noise barriers target the single primary noise source—for example, an adjacent highway—and provide a means of restoring or improving the soundscape by reducing the intrusive and typically dominant traffic noise and by simultaneously unmasking other desirable natural sounds in the community, such as birdsong or rustling leaves. Although not eliminated, the traffic noise can be relegated to a background component.

In a sustainable development scenario, however, a more urbanized, compact approach to housing, along with a more pedestrian and public transit orientation, fosters greater use of public spaces, producing a more complex soundscape. Multiple sound sources affect audibility and may vary in time and duration, making the assessment of the soundscape’s contribution to the quality of life challenging and complex. An assessment must include not only the A-weighted sound pressure level but also the link with psychoacoustic parameters to accommodate the multidimensional nature of perception (10).

Acceptable Noise

For soundscapes, the context or prevailing environment can have a substantial effect on how a particular sound is perceived. For example, a study of a major urban district in Kyoto, Japan, found that traffic noise was generally considered a positive sign of commercial activity, and rarely was characterized as an annoyance (11). Would traditional noise abatement strategies yield substantial benefits? In a suburban or rural context, that same traffic noise more likely would be viewed negatively, and abatement measures would be highly valued.

As the example suggests, inhabitants of more urbanized places may perceive transportation noise as less of an annoyance and perhaps more acceptable within the soundscape. As a result, the desire for transportation noise abatement in urban settings may be expected to be reduced or at least altered, depending on the characteristics of the area.

In addition, the physical parameters of the development—for example, the presence of multisitory, high-rise residences—may preclude the effective use
of such traditional abatement measures as noise barriers, although absorptive or quieter pavements may be effective in reducing the prominence or at least in altering the character of the traffic noise.

Assessing Community Impact
In the suburban setting, the traditional approach to traffic noise abatement is focused on substantially reducing the noise level from the highway source. In the majority of circumstances, this approach will yield meaningful and beneficial results for the community. But when the soundscape is more complex and varied, with both positive and negative contributory sources, additional attention may be needed to preserve or enhance the soundscape according to the community's preferences. An assessment of the total soundscape, beyond the numerical noise levels, would be informative.

This more integrated approach would require more effort in assessing community impacts. Studies on soundscapes often involve surveys and questionnaires that probe the attitudes, expectations, and preferences of the community residents. The studies have found that the context of the various sounds, including both visual and sonic cues, has a major effect on the judgment of sound quality. Soundscape studies also can involve laboratory-based experiments with recorded data and statistical analysis of feedback from study participants.

Researching Soundscapes
Research comparing field measurements of quieter pavements has revealed that shifts away from the higher frequencies, to which the human ear is more sensitive, could translate into a more positive rating or perception of traffic noise as a component of the soundscape. Similarly, changes in the frequency characteristics of the traffic noise that reflects or echoes off of a building facade or other structure also could affect the perception. These shifts in frequency often are perceived as a change in the character of the noise source.

In 2004, a laboratory-based soundscape experiment explored perceptions of the effects of a roadside traffic noise barrier (12). Participants listened to recordings of conditions before and after a roadside noise barrier was built and were asked to determine if the randomly selected sounds were with or without the noise barrier. In addition, participants were asked to describe the cues they used to discriminate between the with-barrier and without-barrier samples.

The results indicated that the noise barrier caused perceivable changes in the soundscape and that the changes could be interpreted as positive (13). The primary finding was that the noise barrier made the traffic noise in the soundscape more homogeneous, or less variable, which in general is perceived as more desirable. The noise barrier reduced higher frequency sound but made difficult the identification of single vehicle pass-bys and of changes in directionality—that is, the perceived relative position of single vehicles and their direction of movement.

Land Use and Soundscapes
The consideration of prevailing environmental noise conditions in land use planning—the third prong in noise reduction strategy—seeks to design or direct development compatible with the prevailing noise environment. The strategy is an exercise in avoidance—that is, avoiding the introduction of noise-sensitive activities into an already noisy environment. The approach also tends to focus on the negative aspects of the sonic environment and does not seek to change it but to adapt to it.

In applying the concept of the soundscape, the goal is to improve the relationship between the aural space and the people in the living environment (13). The soundscape approach includes management of the elements of the acoustic environment that are of high quality and value to people, either through acoustic design or by management of the outdoor space, much in the same way that landscape design is applied to improve visual perception of the environment (8).

Crafting Soundscapes
In summary, sustainable development practices require the consideration and assessment of how the
Judging Soundscapes

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Soundscapes are complex. A soundscape is the all-encompassing, audible environment experienced in a specific location. In considering a soundscape’s effect on quality of life, the question to answer is “How can the soundscape be judged in a way that will facilitate improvement?”

Improving Soundscapes

For decades, efforts to improve soundscapes have focused on noise control, treating a single source at a time, seeking improvement by minimizing annoyance, limiting noise as quantified by a single noise metric, such as the day–night sound level or the community noise equivalent level. This approach has been successful, so that fewer numbers of residents are exposed to higher noise levels and presumably experience less annoyance.

But consideration of the entire soundscape needs to address multiple sources, some undesirable, some desirable. The noise control approach focuses on one undesirable source at a time and does not consider desirable sounds or judge which undesirable sound most needs quieting. Improving soundscapes means reducing the noise from undesirable sources and permitting the desirable ones to be heard.

Judging Soundscapes

Just as the concept of annoyance has been used to summarize the multiple adverse effects of transportation noise on people, a simplifying subjective judgment may emerge to summarize the human factors, experiences, and emotions that influence a person’s reaction to a soundscape. For instance, a soundscape’s contribution to quality of life could be summarized by rating the components of the soundscape on a scale of desirability.

One method of collecting this information is to survey residents to identify the sounds they hear and to rate each sound. Desirability could serve as the rating scale, ranging from −4 or extremely undesirable to +4 or extremely desirable. Figure 1 (page 37) shows hypothetical results from a survey of residents that readily distinguishes the sounds people like and those they do not. The values are cumulative, moving from undesirable at the left to desirable at the right. The more rapidly the cumulative value increases, the less desirable is the sound. Birdsong is desirable for most people, but most rate road traffic noise as undesirable.

References

1. Truax, B. (ed.) Handbook for Acoustic Ecology. ARC Pub-
Guidance for Action
Two additional questions need to be asked about the ratings in Figure 1:

◆ What are the objective sound levels from each source that each respondent is rating?
◆ For each source, what is the threshold sound level separating an undesirable rating from a desirable rating?

The answers can provide noise control design goals for each source.

The type of data shown in the figure could be acquired through a mail survey, but important questions would remain unanswered:

◆ Are all respondents hearing the same sounds?
◆ What are the levels of the sounds that respondents hear?
◆ What time of day, week, or year do the ratings represent?

Proper identification of the respondent’s location—and careful survey wording—could resolve some of these questions, but determining objective sound levels for each source for each person is an expensive and complicated, if not impossible, proposition.

Laboratory Trials
Although collecting desirability ratings and sound levels in situ would be the gold standard for soundscape analysis, laboratory studies could associate human reactions to soundscapes with metrics of sound. Researchers have had success bringing an outdoor experience into a laboratory setting to judge outdoor sounds. The technique of using various combinations of audio and visual reproductions in the laboratory has yielded subjective evaluations that correlate closely with evaluations made in the field.

Laboratory tests could employ high-definition videos and high-quality sound to learn how people rate the components of different soundscapes, and to test the correlation of various sound metrics with the ratings.¹ The soundscapes would be constructed in the laboratory setting, from separate recordings of individual sources and of different ambient backgrounds. Patching the soundscapes together would permit accurate determination of the sound metrics of each contributing source—a disaggregation not always possible with in situ measurements.

Laboratory results, especially acquired from subjects who are not familiar with a specific soundscape, may differ from the results that derive from people who live within that soundscape. But work in the laboratory could help develop a general understanding of how people subjectively evaluate different soundscapes and the component sound sources and could test the utility of different noise metrics.

¹An example has been uploaded to http://youtu.be/NjOIfUrFrR8. Listen with high-quality headphones for full effect.

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