TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

INDOT Research

TRB Subject Code: 17-4 Noise and Air Quality Studies *November 2001*
Publication No.: FHWA/IN/JTRP-2001/19, SPR-2414 *Final Report*

NOISE CONTROL AND SPEECH INTELLIGIBILITY IMPROVEMENT OF A TOLL PLAZA

Introduction

Vehicular toll roads are one component of many municipal transportation systems. Personnel working at toll collection plazas are exposed to extended, continuous traffic noise. Sustained noise levels of this nature may cause hearing loss, induce fatigue or stress, and reduce worker productivity. The annoyance and discomfort related to continuous noise exposure may create an unpleasant working condition and may affect the hospitality of the tollbooth operators and their attitude toward customers. Furthermore, the noise level may hinder communication with customers and may compromise safety. Reduction of the noise level and an improvement in speech intelligibility are highly desirable.

Open communication windows, often used in tollbooths, facilitate essential communication and monetary transactions. Typical transactions between toll collectors and patrons involve charge cards, commuter cards, toll tickets, and the exchange of cash. Direct visual and physical contact between patrons and attendants is made possible by the open communication window. One disadvantage is that vehicle noise generated outside the booth is easily transmitted into the booth via the open window. The booth structure acts as a partially open enclosure, which may amplify road noise due to sound reflections off of rigid surfaces and reverberation within the enclosure.

The objective of this research is to lower the noise levels experienced by toll collection workers and increase the speech intelligibility of the tollbooth environment.

Findings

Contributions of the study include the following:

1. Surveys of toll plaza employees confirm that traffic noise creates an unpleasant work environment and frequently hampers communication.

2. A toll plaza was modeled using a beam tracing method. Toll plaza model predictions indicate that implementation of reasonable passive noise control solutions will reduce the sound level by approximately 3 dB. This is a noticeable but rather modest decrease. Results suggest that significant noise reductions can only be achieved by reducing the direct sound field.

3. Active noise control (ANC) systems were investigated to control the direct field. The potential of ANC systems to

reduce low frequency sounds within reverberant, partially open enclosures has been demonstrated in previous studies. Improvements in speech intelligibility may be possible when dominant low frequency sounds in traffic noise mask speech signals and reduce intelligibility.

4. The noise attenuation of ANC systems was investigated. The noise reduction ratings (NRR) for the ANC systems were highly dependent upon the system configurations. A sealed ANC headset achieved a NRR value of 24 dB, while some of the open systems achieved NRR values near 0 dB. Passive components, such as circumaural earcups, result in the greater attenuation found in closed headset.

5. The speech intelligibility at the toll plaza was investigated using standardized methods. Traffic noise conditions at the toll plaza were recorded. In the presence of traffic noise, the speech intelligibility was poor even for the highest vocal efforts.

6. The effects of active noise control systems on speech intelligibility were investigated. While some of the systems offer significant attenuation of noise, none of the systems improved the speech intelligibility significantly. The systems are not adaptive and do not directly alter the signal to noise ratio. The results suggest that low frequency traffic noise masking of higher frequency communication sounds is not as detrimental as in-band masking. The best systems had the greatest overall reduction, which suggests that overloading effects are important.

7. Innovative systems were modeled to improve intelligibility at the toll plaza. A sealed ANC headset with a dipole directional microphone input and level reduction provides 20% more of the speech cues to a listener under high vocal efforts. A higher order directional microphone input, creates a good communication situation (75% and greater of the speech cues available to the listener).

Implementation

Predictions of the performance of a hypothetical modified ANC system resulted in a significant increase in speech intelligibility. The next step is to build a number of prototype systems. The systems would be built to further investigate performance. In addition to the directional microphones and single channel feedback active noise control algorithms, exploration of adaptive noise control algorithms would be beneficial. Adaptive algorithms produce different system transfer functions for different signals. By selectively attenuating noise and passing speech, the signal to noise ratio could be further increased. Investigation into cost and comfort issues should be addressed.

The toll plaza model demonstrated that passive noise control solutions, which address the reflected sound field, do not substantially reduce the noise level. The modeling approach did not account for coherent reflections that cause reverberation and resonance. Due to the statistically random nature of vehicle noise, it is a reasonable approximation to use a source model assuming incoherent waves where phase is neglected. If resonance conditions occur at the toll plaza, placement of absorbing material may have a more dramatic effect than predicted by the model. It is suggested that the possible existence of resonance conditions be investigated in a subsequent study. On-site measurements at many locations throughout the toll plaza could be used to investigate the presence of standing waves. The results of the beam tracing method could be validated through on-site measurements.

Contacts

For more information:

Prof. Luc Mongeau
Principal Investigator
Purdue University
1077 Herrick Laboratories
West Lafayette, IN 47907-1077
Phone: 765-494-9342
Fax: 765-494-0787

Prof. Robert J. Bernhard
Principal Investigator
Purdue University
1077 Herrick Laboratories
West Lafayette, IN 47907-1077
Phone: 765-494-2141
Fax: 765-494-0787

Indiana Department of Transportation
Division of Research
1205 Montgomery Street
P.O. Box 2279
West Lafayette, IN 47906
Phone: 765-463-1521
Fax: 765-497-1665

Purdue University
Joint Transportation Research Program
School of Civil Engineering
West Lafayette, IN 47907-1284
Phone: 765-494-9310
Fax: 765-496-1105