A1F04: Committee on Transportation-Related Noise and Vibration
Chairman: Gregg G. Fleming

Transportation-Related Noise in the United States

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Nearly every person in the United States is affected by transportation-related noise. It affects the ability of people to carry on conversations, to concentrate at work and school, and to sleep. Urban residents face the most substantial impacts, but as airports are expanded and new ones are built, as ground-based infrastructure is expanded, and with the likely advent of high-speed rail, it is anticipated that impacts will expand well beyond the immediate vicinity of major cities to suburban and rural communities.

Over the past three to four decades, much has been accomplished with regard to improving the noise climate in the United States, and there are many new technologies offering the possibility of further improvements in the future. In this paper, a brief historical perspective of past milestones in transportation-related noise control is presented, along with a discussion of the current state of the art. Some of the more promising future technologies and research areas in the field are also examined. For convenience, the three primary modal areas—aircraft, highway, and rail—are discussed separately. Because this is not only an era of shrinking research dollars but also a time in which transportation planning needs to take place on a cross-modal level, the need for sharing of resources among different transportation agencies is also discussed.

BACKGROUND

The field of transportation-related noise is relatively young. Significant work in the area began in the 1950s, mostly in the field of aircraft noise. Not coincidentally, the first commercial jet aircraft, the de Havilland Comet, was introduced in the first half of 1952, followed by the Boeing 707 and Douglas DC8 toward the end of the decade; by the late 1960s more than 2,000 commercial jetliners were in operation worldwide (*1*). This rapid expansion fueled the initial rise in aircraft-related noise research in the United States.

Most early contributions in the field of transportation-related noise date back only to the 1960s and the 1970s. For example, the first federal authority to control aviation noise was the 1968 amendment to the Federal Aviation Act, which directed the Federal Aviation Administration (FAA) administrator to establish standards and regulations for aircraft noise in an effort to protect the public health and welfare (Public Law 90-411, Section 611). The most significant early work in the area of highway-related noise was that performed in support of the National Cooperative Highway Research Program (NCHRP) between 1971 and 1976, resulting in *NCHRP Reports 117*, *144*, *173*, and *174* (*2–5*). Some of the most highly regarded research in the area of rail noise was also conducted in the 1970s (*6–11*).

AIRCRAFT NOISE

Over the past 25 years, FAA has addressed aircraft noise control through a concerted three-pronged approach, which includes noise control at the source, control of noise through operational restrictions, and control of noise through effective land use planning (*12*).

With regard to noise control at the source, FAA issued in 1969 the first version of the Federal Aviation Regulation (FAR) Part 36 (*13*), which addresses requirements for aircraft noise certification in the United States. Since its initial release, more than 20 amendments to the FAR have been issued to include coverage for virtually all types of aircraft. Several of these amendments included increases in stringency requirements. The net result has been a substantial decrease in noise level for U.S.-certificated aircraft. Figure 1 displays this trend toward substantial reduction of aircraft noise levels over the past four decades. It also shows projected future improvements in certified aircraft noise levels. The figure indicates that a reduction of some 25 dB in certified noise level has been achieved since the 1950s. The reduction equates to about an 80 percent reduction in perceived loudness.

There is a definite flattening out of the trend line in Figure 1: the magnitude of improvements in aircraft source noise technology is shrinking with time. This will likely remain the case for the foreseeable future. The vast majority of past improvements have been achieved through the introduction of high bypass ratio engine designs. However, there are physical limits to this approach to noise reduction. In simple terms, the increased dimensions associated with high bypass ratio designs often result in aircraft/engine ground clearance issues, especially for aircraft with wing-mounted engines.

With the exception of active noise control, particularly with regard to engine/nacelle acoustic treatment, there are no novel approaches offering promise for substantial reductions in aircraft noise levels (greater than 10 dB) in the foreseeable future. Even with regard to active noise control, substantial noise reductions achieved in controlled test facilities have translated to more modest reductions for in-flight applications.

FAA has effectively forced manufacturers to develop improved noise control technologies with the imposition of mandatory phaseout of aircraft that did not meet certain noise limits. In fact, the next phaseout is scheduled for final implementation at the end of 1999. In addition, there is significant international pressure to establish a new, more stringent noise certification limit in the near future. Recent negotiations between the United States and the European Community will probably result in implementation of a Stage 4 noise limit within the next 1 to 2 years. This limit will likely call for a further reduction in certified noise levels of between 3 and 5 dB, relative to current Stage 3 limits.

In the area of control of noise through operational restrictions, FAA has embarked on several recent airspace redesigns with a primary emphasis on reducing noise impacts. The main goal of such studies is to reroute backbone flight tracks to areas away from the general population, preferably over water where possible. Comprehensive airspace redesigns have recently taken place in New Jersey and Illinois, and a third is being initiated in the Virginia-Maryland area.

A significant amount of work has also been undertaken with regard to land use planning. FAR Part 150, which was officially issued at the end of 1984 (*14*), is the watershed document addressing aircraft noise-related land use planning issues. FAA has dedicated a substantial budget to support noise remediation for residential structures subjected to areas of incompatible land use; remediation measures include land buyouts and expansive sound insulation programs. This activity will likely continue well into the next century. As of 1994, a budget in excesss of $1.5 billion has been allocated for this activity. FAA's Integrated Noise Model (INM) (*15,16*) is the tool used for Part 150 studies in the United States. Since 1978, FAA has been committed to the long-term development and improvement of the model, a trend that is expected to continue well into the next century.

In 1993 the National Aeronautics and Space Administration (NASA), with support from FAA, initiated an important 8-year effort known as the Advanced Subsonic Technology (AST) Noise Reduction Program (*17*). The program has a total budget of just over $200 million. The rather aggressive vision of the program is to ensure no increase in aircraft noise exposure in the 21st century. In terms of quantification the program is targeting a reduction goal of 7 to 10 dB relative to 1992 technology. Similar to the above-stated FAA approach, the joint NASA/FAA program identified three areas to target with regard to noise reduction technologies: source noise, noise control through operational restrictions, and land use planning.

There are currently no organized plans for continuation of the NASA AST Noise Reduction Program. However, in 1998 NASA conducted a series of workshops that focused on the reduction of aircraft noise exposure in the United States. The most significant vision resulting from the workshops was that a 10-dB reduction in aircraft noise exposure was attainable over the next 10 years, and a 20-dB reduction was possible within 25 years. Such significant reductions are of course provisional on the continuation of a concerted national research effort of a magnitude similar to that of the current AST Program (W. Wilshire, personal communication, May 1999).

The Society of Automotive Engineers (SAE) Committee A-21 on aircraft noise, which was responsible for many significant contributions (*18,19*) to the state of the art in aircraft noise prediction methodologies in the 1970s and 1980s, has been revitalized. In fact, the group is actively researching areas having to do with aircraft noise modeling (including lateral attenuation of aircraft sound and empirical modeling of aircraft performance), aircraft noise monitoring, atmospheric absorption of sound, and other aircraft-related noise issues. It is likely that the concerted efforts of A-21 (made up of members from academia, industry, and government) will guide the state of the art with regard to aircraft noise into the next century.

HIGHWAY NOISE

Much like FAA, the Federal Highway Administration (FHWA) has used a three-pronged approach to highway noise reduction, including control at the source, control through effective land use planning, and highway project mitigation (*20*).

With regard to reduction of noise at the source, it is clear that improvements have been made. The emission levels developed in support of the FHWA Traffic Noise Model (FHWA TNM) (*21*) indicate that truck noise emissions at typical highway speeds have decreased by 3 dB since the last comprehensive national noise emission level study was undertaken in the mid-1970s. Although a 3-dB decrease is barely perceptible to the human ear, a 3-dB decrease in truck noise emission levels effectively offsets a doubling of the U.S. truck population. Since the growth of the registered U.S. truck fleet has historically averaged about 3 to 4 percent per annum (*22*), the 3-dB decrease equates to about 18 to 23 years of growth without an associated increase in noise level. On the downside, smaller vehicles in the automobile category have actually grown slightly noisier over the past two decades. However, this trend is more a function of the increasing number of sport utility vehicles on the road today and the higher RPMs that are typical of today's smaller cars, rather than a lack of improvement in vehicle source noise technology.

What does the future hold in terms of vehicle source noise technology? In many ways, air quality issues are driving the development of future highway-based vehicle technologies. From the standpoint of energy efficiency, hydrogen fuel cell technology is the most promising, followed by methanol, diesel, electric, and compressed natural gas (*23*). With the exception of electric car technology, these approaches all use internal combustion engines and, therefore, offer little promise with regard to improvements in the noise environment in the vicinity of roadways. Electric vehicles offer some hope, at least for vehicles traveling at relatively modest speeds, where engine/exhaust noise is the primary contributor. At speeds above about 30 mph, electric vehicles, as well as other planned technology, offer little benefit with regard to noise, because at such speeds noise generated by tire/road interaction is the primary contributor to the surrounding noise environment.

Certainly, control at the source is the most desirable noise mitigation approach. Given that most highway noise problems exist next to busy thoroughfares, where typical speeds are in excess of 55 mph, it appears that a better understanding of tire/road noise is essential. On that front, things are promising in the United States. For the past two decades, tire/road noise has been a neglected area of research in the United States, with piecemeal work conducted by various universities, state highway agencies, and consulting firms. Why has there not been an organized national research effort in this area similar to what has been done in Europe for the past 20 years? There is not one simple answer to this question, but issues such as pavement safety and durability probably have much to do with it.

The country appears to be at an important turning point with regard to tire/road noise research. An increasing number of organized tire/road noise research efforts are ongoing, probably the most notable at the University of Texas (*24*), the Maryland State Highway Administration (*25*), the University of Central Florida (*26*), and recent work supported by the Wisconsin Department of Transportation (*27*). Certainly, the most promising effort has recently been initiated at Purdue University's Institute for Safe, Quiet, and Durable Highways. The charter of the institute is to "focus initially on developing a fundamental understanding of tire/road interaction noise and transferring this technology to practice. As the Institute grows, emphasis will be expanded to include traffic management strategies (e.g., night time speed limitations, use of Intelligent Transportation Systems technology for identification and removal of worst noise offenders, etc.) for quiet highway environments and other modes of transportation"(*28*).

As encouraging as the institute and its charter are, only so much can be accomplished in the area of tire/road noise. On the basis of European research, reductions of as large as 10 dB may be realized (*29*). Reductions of that magnitude would be considered a major accomplishment, but they would come at a considerable cost and would require a fundamental change in the prevailing philosophy in the United States with regard to pavement design and construction. Unfortunately, even with such changes, the highway noise problem would not be eliminated, since tire/road noise is the dominant noise at typical highway speeds.

Effective land use planning is another important component of successful reduction of the highway noise problem. The state highway agencies should expand their effort of encouraging local jurisdictions to enact noise ordinances and land use regulations to guide new, noise-compatible development adjacent to major highways. Although noise-compatible development through effective land use planning and control is traditionally an area of local responsibility, FHWA has established noise criteria for different types of land use activities adjacent to highways (*20*). For certain types of federally aided highway projects, states must conduct noise analyses to identify potential highway traffic noise impacts. If impacts are identified, noise abatement measures must be considered and implemented, if determined to be both reasonable and feasible. Among the various types of possible abatement measures, the construction of noise barriers is most commonly used.

Highway noise barrier construction will continue to be a growth area in the United States. As of 1995, the number of linear miles of barriers constructed in the United States had tripled over the previous 10 years alone, eclipsing 1,300 linear miles by the end of 1995 (see Figure 2), and there are no signs that this trend will be significantly altered (*30*). Because of anticipated growth and the fact that highway noise barriers typically cost approximately $1 million per linear mile, it is critical that highway noise barrier design be as efficient and cost-effective as possible. For this reason, FHWA released, in March 1998, an entirely new, state-of-the-art model for predicting noise impacts in the vicinity of highways, the FHWA TNM (*31,32*). It uses advances in personal computer hardware and software to improve on the accuracy and ease of modeling highway noise, including the effective and cost-efficient design of highway noise barriers. FHWA is committed to continued improvement and long-term development of TNM.

As SAE A-21 is integral to continued successful advances in the state of the art for aircraft noise into the next century, TRB's Committee on Transportation-Related Noise and Vibration is expected to play a similar role in the area of highway noise.

FHWA has demonstrated a substantial commitment to the improvement of its guidance and educational tools. In the past 3 years alone, the agency has released a guidance document on highway noise measurement (*33*) and two educational videos, one on highway noise barriers (*34*) and the other on the acoustics of highway noise (*35*). In 1999, FHWA plans to release a suite of tools, which will assist in the design and construction of noise barriers.

RAIL NOISE

Compared with aircraft and highway noise, more modest accomplishments have been achieved in the area of rail noise. The most substantial recent accomplishment has been the publication by the Federal Transit Administration of a guidance manual (*36*). This document provides the first standardized procedure for preparing noise and vibration sections for environmental compliance documents for transit projects.

It can be expected that efforts will be initiated to incorporate a rail noise prediction module into the FHWA TNM. The TNM is essentially ready-made for a rail module. All of the propagation components encountered during a typical rail noise study are already included in TNM. The most substantial effort would likely be the development of a fundamental noise level data base. This effort would likely entail a significant amount of work in assembling and normalizing existing data, as well as in collecting additional data. Resources would have to be invested into the design and implementation of a user-friendly graphical user interface to support the module and the development of an empirical algorithm for modeling source noise directivity.

SOME FINAL THOUGHTS

Will the future bring some holy grail of noise control technologies? Probably not. More than likely, the coming years will be similar to those past—incremental improvements will continue to accumulate. However, substantial improvements are likely in at least a few areas in the coming years. The first is transportation noise modeling. For example, a major weakness in all current models is that none accounts for meteorological effects, such as wind effects and temperature lapses and gradients. Incorporation of meteorological effects will substantially improve the accuracy of current models, by as much as 20 to 30 dB in certain instances (*37*). It is also possible that substantial gains can be made in the area of active noise control.

With regard to both improved modeling capabilities and active noise control, computer processing power will continue to be a major obstacle. Currently, the two most commonly used prediction models in the United States, the INM and the TNM, are often faced with compromises that result from the need for practical run times. Until substantial advances in computer processing can be achieved, many of the more advanced algorithms planned for inclusion into such models will have to wait. Similarly, with regard to active noise control, although the theory is well defined and understood, many practical engineering hurdles must still be overcome.

Looking toward the future, it is evident that a more coordinated approach to transportation-related noise control is necessary. In an era of shrinking budgets, pooling of federal resources and cooperation among agencies with similar objectives must become a reality. Along those lines, there is currently active legislation to examine the feasibility of developing an integrated transportation noise prediction model—a model that can take into account the combined effects of aircraft, highway, and rail vehicles. This is a particularly important need in urban areas, where residents are affected by the combined noise from multiple transportation sources. Some of the groundwork for this effort is already in place, since FAA’s INM and FHWA’s TNM both use the same noise contouring module, the U.S. Air Force’s NMPLOT program.

Coordination and communication among organizations with similar objectives will be necessary in the coming years. The Federal Interagency Committee on Noise plays this important role with regard to the design, planning, and evaluation of aircraft noise research, including research in the area of human response to noise. In addition, for the first time, there is a concerted effort to establish a noise review board made up of members of all the modal areas within the U.S. Department of Transportation.

Substantial advances have been made in transportation-related noise over the past 40 years. In addition, many promising, new activities are ongoing in the field. Finally, as the new millennium approaches, the Committee on Transportation-Related Noise and Vibration will continue with fervor its mission of research promotion and technology transfer.

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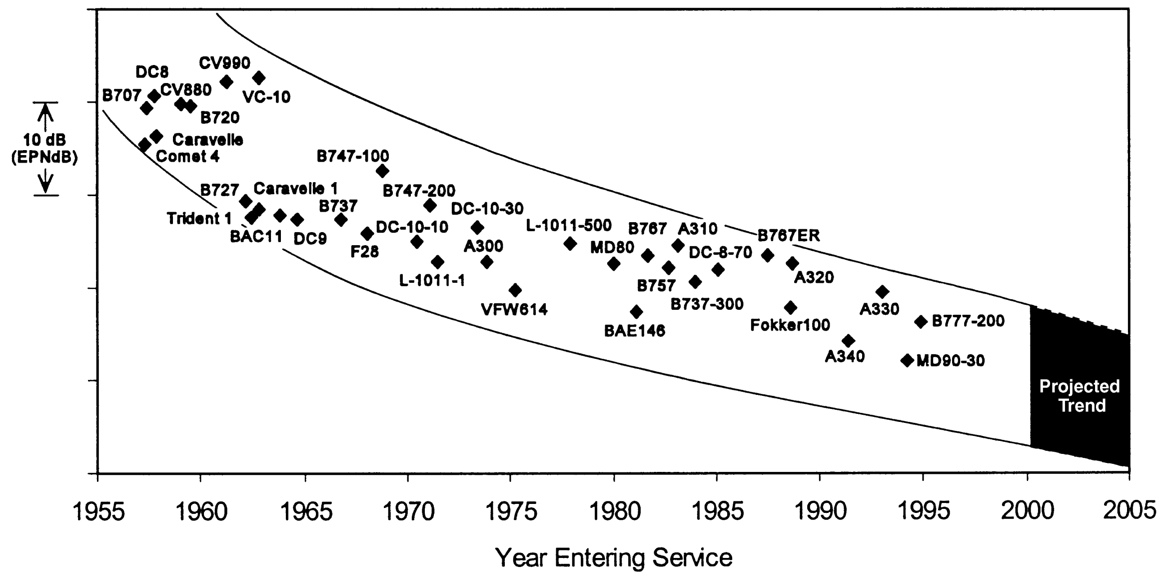

FIGURE 1 Trends in U.S.-certified aircraft noise levels.

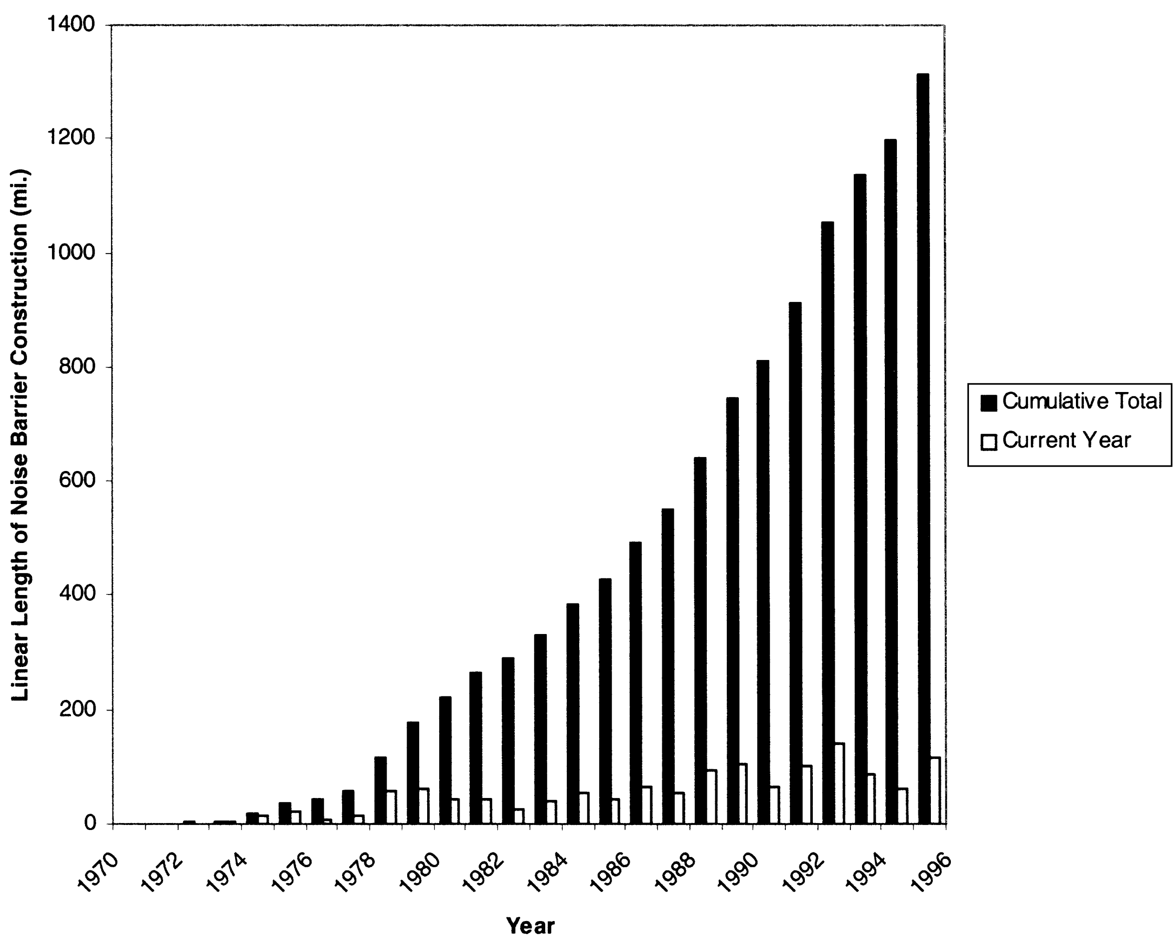

FIGURE 2 Noise barrier construction by year.