Transportation-Related Noise in the United States

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Transportation-related noise affects nearly every person in the United States to some degree by limiting the ability to carry on conversations, to concentrate at work and school, and to sleep. Urban residents face the most substantial impacts. However, as existing airports grow and new ones are built, as ground-based infrastructure is expanded, and with the likely advent of high-speed rail, it is anticipated that the impacts will extend well beyond the immediate vicinity of major cities to suburban and rural communities. At the same time, much has been accomplished during the past three to four decades with regard to improving the noise climate in the United States, and many new technologies offer the potential for further improvements in the future.

Background

The field of transportation-related noise is relatively young. Significant work in the area began in the 1950s, primarily in the field of aircraft noise. Not coincidentally, the first commercial jet aircraft, the de Havilland Comet, was introduced in 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. This rapid expansion fueled the initial rise in aircraft-related noise research in the United States.

Most of the early contributions in the field of transportation-related noise date back only to the 1960s and 1970s. For example, the first federal authority to control aviation noise was established by the 1968 amendment to the Federal Aviation Act, which directed the Administrator of the Federal Aviation Administration 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 the National Cooperative Highway Research Program between 1971 and 1976, which resulted in NCHRP Reports 117, 144, 173, and 174. Some of the most highly regarded research in the area of rail noise was also conducted in the 1970s.

Aircraft Noise

During the past 25 years, the FAA has taken a three-pronged approach to aircraft noise control. This approach encompasses noise control at the source, operational restrictions, and effective land-use planning (*1*).

With regard to *noise control at the source*, in 1969 the FAA issued the first version of the Federal Aviation Regulations (FAR) Part 36, which addresses requirements for aircraft noise certification in the United States. Since its initial release, more than 20 amendments to the regulation have been issued to cover virtually all types of aircraft. Several of these amendments have increased the stringency of the requirements. The net result has been a substantial decrease in noise levels for U.S.-certificated aircraft during the past four decades. Indeed, since the 1950s, a reduction of some 25 decibels (dB) in certified noise level has been achieved, which equates to about an 80 percent reduction in perceived loudness.

The magnitude of improvements derived through aircraft source noise control has been shrinking with time, however, and this will likely remain the case for the foreseeable future. The vast majority of improvements to date have been achieved through the introduction of high-bypass-ratio engine designs. However, there are physical limitations on 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 as concerns engine/nacelle acoustic treatment, there are currently no novel approaches

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offering promise for substantial reductions in aircraft noise levels (greater than 10 dB). 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.

The FAA has effectively forced manufacturers to develop improved noise control technologies by imposing the mandatory phaseout of aircraft that failed to meet certain noise limits. In fact, the latest phaseout was complete 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.[1] This limit will likely involve a further reduction in certified noise levels of between 3 and 5 dB relative to current Stage 3 limits.

In the area of *noise control through operational restrictions*, the FAA has embarked on several recent airspace redesigns with a primary emphasis on reducing noise impacts. The main goal of such efforts is to reroute backbone flight tracks to areas away from the general population—over water where possible.[2] Comprehensive airspace redesigns recently took 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, is the watershed document addressing land-use planning issues related to aircraft noise. The FAA has dedicated a substantial budget to support noise remediation for residential structures affected by areas of incompatible land use; remediation measures include land buyouts and sound insulation programs. As of 1994, a budget in excess of $1.5 billion had been allocated for this activity, which will likely continue well into the 21st century. The FAA's Integrated Noise Model (2,3) is the tool used for Part 150 studies in the United States. Since 1978 the agency has been committed to the long-term development and improvement of this model, a trend that is expected to continue well into the next century.

[1] Noise limits for commercial jet aircraft have historically been set according to stages. Stage 1 comprises the older, noisier fleet, which has now been phased out. Stage 2 aircraft were phased out just recently, so that all commercial jet aircraft in the current fleet meet Stage 3 noise limits.

[2] A backbone flight track represents an average of many geometrically dispersed flight tracks.

In 1993 the National Aeronautics and Space Administration, with support from the FAA, initiated an important 8-year effort known as the Advanced Subsonic Technology (AST) Noise Reduction Program. The program has a total budget of just over $200 million. The rather ambitious goal of the program is to ensure no increase in aircraft noise exposure in the 21st century. In quantitative terms, the target is a reduction of 7 to 10 dB relative to 1992 technology. Like the FAA's three-pronged approach, the NASA/FAA program is focused on three areas with regard to noise control: source noise, operational restrictions, and land-use planning.

There are currently no organized plans for continuation of the NASA AST Noise Reduction Program. In 1998, however, NASA conducted a series of workshops on the reduction of aircraft noise exposure in the United States. The most significant finding of the workshops was that a 10-dB reduction in aircraft noise exposure was attainable during the next 10 years, and a 20-dB reduction was possible within 25 years. Such significant reductions are, of course, conditional on a continuing national research effort similar in magnitude to the current AST Program.

In another important development, Society of Automotive Engineers Committee A-21, Aircraft Noise, which was responsible for many significant contributions (4,5) to the state of the art in aircraft noise prediction methodologies in the 1970s and 1980s, has been revitalized. This committee, made up of representatives of academia, industry, and government, is actively researching such issues as aircraft noise modeling (including lateral attenuation of aircraft sound and empirical modeling of aircraft performance), aircraft noise monitoring, and atmospheric absorption of sound.

Highway Noise

The Federal Highway Administration also has taken a three-pronged approach to noise reduction. FHWA's approach involves source control, effective land-use planning, and highway project mitigation.

With regard to *source control*, improvements have clearly been made. According to estimates developed in support of the agency's Traffic Noise Model (6), truck noise emissions at typical highway speeds have decreased by 3 dB since the last comprehensive national noise-emission study was undertaken in the mid-1970s. Although a 3-dB decrease is barely perceptible to the human ear, such a decrease in truck noise emissions 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, the 3-dB decrease equates to about 18 to 23 years of growth without an associated increase in noise level. On the down side, smaller vehicles in the automobile category have actually grown slightly noisier during the past two decades. However, this trend is more a function of the increasing number of sport utility vehicles currently on the road and the higher revolutions per minute (RPMs) that are typical of the engines in today's smaller cars than of 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, the hydrogen fuel cell is the most promising technology, followed by methanol, diesel, electric, and compressed natural gas. With the exception of electric car technology, however, these approaches are all based on the internal combustion engine and therefore offer little promise of improving the noise environment in the vicinity of roadways. Electric vehicles offer some hope for noise reduction, at least for vehicles traveling at relatively modest speeds, when engine/exhaust noise is the primary contributor. At speeds above about 30 mph, electric vehicles, as well as other planned technologies, offer little noise reduction benefit because noise generated by tire–road interaction becomes the primary contributor to the noise environment.

Given that most highway noise problems occur next to busy thoroughfares where typical speeds are in excess of 55 mph, a better understanding of tire–road noise would appear to be essential. On that front, the situation in the United States is promising. For the past two decades, tire–road noise has been a neglected area of research in this country, with piecemeal work being 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 that which has been ongoing in Europe for the past 20 years? There is no simple answer to this question, but issues such as pavement safety and durability probably have much to do with the explanation.

The nation appears to be at an important turning point with regard to tire–road noise research. An increasing number of organized research efforts in this area are now under way. The most notable efforts are probably those being conducted by the University of Texas, the Maryland State Highway Administration, and the University of Central Florida, along with recent work supported by the Wisconsin Department of Transportation. The most promising research was recently initiated at Purdue University's Institute for Safe, Quiet, and Durable Highways. The institute's charter is to focus initially on developing a fundamental understanding of noise due to tire–road interaction and on applying this understanding to practice. As the institute grows, its efforts will expand to encompass traffic management strategies, such as nighttime speed limitations and use of intelligent transportation systems for identification and removal of the worst noise offenders.

As encouraging as the institute and its charter are, however, only so much can be accomplished in the area of tire–road noise. Results of European research indicate that reductions of as large as 10 dB may be realized through efforts in this area. Yet reductions of that magnitude would come at considerable cost, and would require a fundamental change in the prevailing philosophy in the United States with regard to pavement design and construction. Even with such changes, the highway noise problem, although substantially mitigated, would not be eliminated.

With regard to *effective land-use planning*, state highway agencies need to expand their efforts in 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 various kinds of land-use activities adjacent to highways.

In the area of *highway project mitigation*, states must conduct analyses to identify potential highway traffic noise impacts for certain types of federally aided highway projects. If such impacts are identified, noise abatement measures must be considered and, once determined to be both reasonable and feasible, implemented. Among possible abatement measures, the construction of noise barriers is most common. Indeed, construction of highway noise barriers will continue to be a growth area in the United States. As of 1995, the number of linear miles of such barriers constructed across the nation had tripled during the previous 10 years alone, exceeding 1,300 linear miles by the end of 1995 (see Figure 1), and there are no signs of a change in this trend.

Given anticipated growth in highway traffic and the fact that highway noise barriers typically cost approximately $1 million per linear mile, it is critical that the design of such barriers be as efficient and cost-effective as possible. For this reason, in March 1998 FHWA released an entirely new, state-of-the-art model for predicting noise impacts in the vicinity of highways—the Traffic Noise Model (7,8). This model uses advances in personal computer hardware

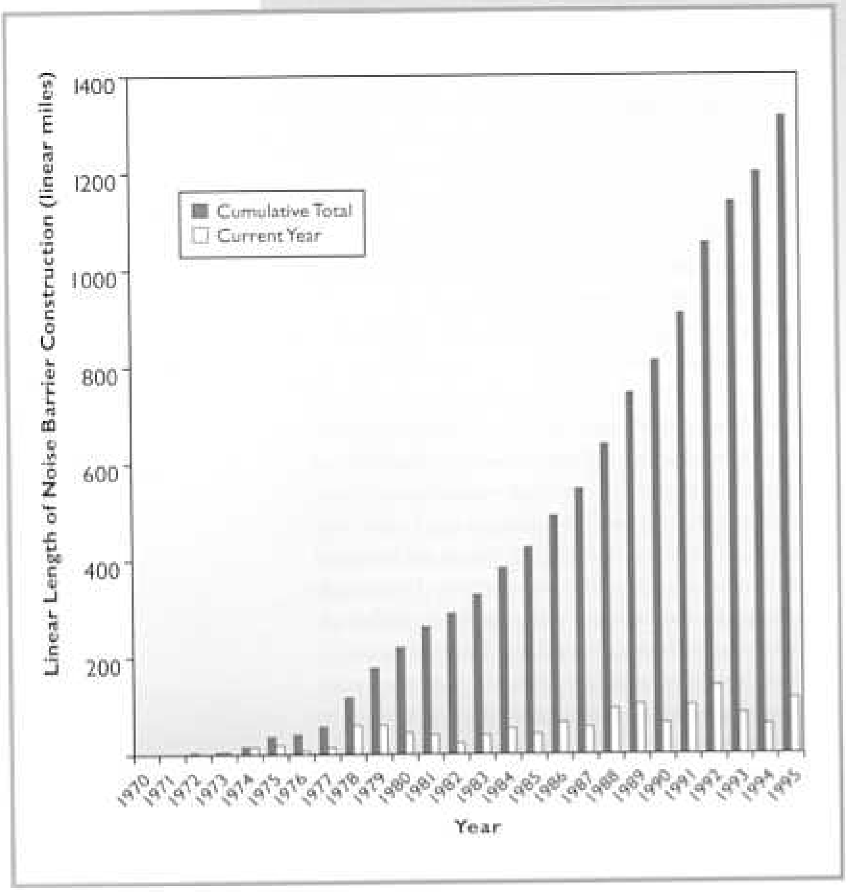

FIGURE 1
Noise barrier construction by year.

and software to improve the accuracy and ease of modeling highway noise, including the effective and cost-efficient design of highway noise barriers. FHWA is committed to the model's continued improvement and long-term development.

Indeed, FHWA has demonstrated a substantial overall commitment to the improvement of its guidance and educational tools in the area of highway noise. In the past 3 years, the agency has released a guidance document on highway noise measurement (*9*) and two educational videos—one on highway noise barriers (*10*) and the other on the acoustics of highway noise (*11*). In 2000 the agency plans to release a suite of tools that will assist in the design and construction of noise barriers.

Finally, just as the work of SAE A-21 is integral to continued advances in the state of the art for the reduction of aircraft noise, the Transportation Research Board's Committee on Transportation-Related Noise and Vibration is expected to play a similar role in addressing highway noise. Traditionally, members of this committee have been responsible for the development of the tools and techniques used for measurement, assessment, and abatement of highway noise.

Rail Noise

As compared with aircraft and highway noise, more modest accomplishments have been achieved in the area of rail noise. The most significant recent effort was the Federal Transit Administration's publication of a guidance manual (*12*) that provides the first standardized procedure for preparing the noise and vibration sections of environmental compliance documents for transit projects.

It can be expected that work will be initiated on incorporating a rail noise prediction module into the FHWA Traffic Noise Model. All of the propagation components encountered during a typical rail noise study are already included in the model. The most substantial effort would likely be the development of a fundamental noise-level database. This effort would probably 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 in the design and implementation of a user-friendly graphical user interface to support the module and in the development of an empirical algorithm for modeling source noise directivity.

Final Thoughts

In the future as in the past, improvements in noise control are likely to be achieved incrementally. However, substantial advances can be anticipated in at least a few areas. The first is transportation noise modeling. For example, a major weakness in all current models is that none accounts for meteorological effects, such as those of wind and temperature lapses and gradients. Incorporation of meteorological effects would substantially improve the accuracy of current models, by as much as 20 to 30 dB in certain instances. Substantial gains may also be possible in the area of active noise control.

With regard to both improved modeling capabilities and active noise control, however, computer processing power will continue to be a major obstacle. Currently, use of the two most commonly employed prediction models in the United States—the FAA's Integrated Noise Model and FHWA's Traffic Noise Model—is frequently limited by the need for practical run times. Until substantial advances in computer processing are achieved, many of the more advanced algorithms planned for incorporation into such models will have to wait. Similarly, although the theory of active noise control is well defined and understood, many practical engineering hurdles remain.

Looking to the future, it is also 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 these lines, the Office of the Secretary, U.S. Department of Transportation, recently released a report (*13*) addressing the feasibility of developing an integrated transportation noise prediction model—a model that could 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 the Integrated Noise Model and Traffic Noise Model both use the same noise contouring module, the U.S. Air Force's NOISEMAP plotting program (NMPLOT). In addition, the Federal Interagency Committee on Noise is playing an important coordination role with regard to the design, planning, and evaluation of aircraft noise research, including research in the area of human response to noise. There is also a concerted effort to establish a noise review board comprising representatives of all the modal administrations within U.S. DOT.

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