Acoustic expectations, health effects, and design techniques in the urban environment

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Abstract

The motivation for new urbanism brings with it potential challenges that designers may not have been forced to consider in the past including acoustics. An occupant's expectation for acoustic privacy challenges the perceived success of the design of multi-family and mixed-use facilities in urban environments. By not addressing how the inhabitants of the spaces will be affected by noise control issues, a designer risks imposing noise related annoyance and even illness. Fortunately, design techniques to reduce annoyance and improve acoustic satisfaction in the urban environment exist and have been proven through various research studies.

Introduction

Members of the design community and building industry must constantly strive for innovation to serve the needs of the user. In 2000, over three-quarters of the United States population was defined as living in metropolitan areas and it is expected to continue to rise. With increased population density comes the integration of various types of users within a finite area, and as a result, noise control becomes more of a design challenge. Too often when planning projects in the building industry, acoustic consideration is reserved for extreme situations—high-end performance halls or extremely loud industrial facilities. However, as new urbanism promotes a paradigm shift in the way developments are planned, it is important to consider: What are the acoustic expectations of occupants and users? What are the health effects of noise? How does the existing design and construction process need to change to address these acoustic concerns?

Urban expectations

In 2000, over 80% of home owners in the United States were living in single-family houses[1] with minimal acoustic disturbances from neighbors. As urbanism increases, people will be moving from single-family, detached homes to multi-family buildings, and they will likely bring with them their single-family expectations of privacy. With higher population density comes exposure to more occupant noise and less control over its production. Urban noise sources include transportation noise from airplanes, trains, and vehicles; noises from other occupants; mechanical noise from nearby buildings; and pedestrian noise from people on the street. An occupant's expectation for acoustic privacy challenges the perceived success of the design of multi-family and mixed-use facilities in an urban environment.

To better understand the acoustics in the built environment, industry standards have been developed to quantify the sound insulation between two spaces including both air-borne noise (e.g. someone talking) and structure-borne noise (e.g. someone walking). Two commonly used acoustic quantities for air and structure-borne noise are sound transmission class (STC) and impact insulation class (IIC), respectively. STC and IIC are single-number ratings commonly cited as the criteria for sound insulation in the building codes. However, the code requirements are a minimum design standard and are often inadequate for the intended use of most occupied, urban buildings. Without effective sound insulation from the various noise sources originating from inside and outside the building, the occupants can be adversely affected by noise—even to the detriment of their health.

Health effects of noise

Over the past five decades, research has shown that exposure to environmental noise can effect quality of life and physical health resulting in annoyance and even illness. Many of the early studies focused on physically harmful noise levels (i.e., typically above 85 dBA) which can result in hearing loss. Residential and commercial environments are generally not exposed to such high noise levels causing physical damage to the ear. However, researchers continue to find stress-related illnesses associated with chronic urban noise and identify noise as a leading contributor to annoyance in the urban environment.

The World Health Organization states, "Noise can cause hearing impairment, interfere with communication, disturb sleep, cause cardiovascular and psycho-physiological effects, reduce performance, and provoke annoyance responses and changes in social behavior"[2]. A variety of studies associate urban noise with various health factors. Increased secretion of cortisol, a stress hormone, can be caused by noise exposure in residential spaces[3]. Long term elevation of cortisol levels has been associated with insulin resistance (commonly resulting in diabetes), stress ulcers, and cardiovascular disease. A meta-analysis of seven noise related cardiovascular disease studies found that adults whose residences were exposed to traffic noise levels above 60 dBA had a noticeable increase in myocardial infarction[4]. A similar meta-analysis of various noise related health studies also found an increase in cardiovascular disease for people exposed to airplane and roadway noise[5]. Another study investigating the effects of noise on children found higher resting systolic blood pressure, higher overnight cortisol excretion, and higher heart rate reactivity to acute stressors[6]. A review of literature over the last three decades by Ising and Kruppa concluded that further investigation needs to be done on the long-term effects of urban noise on humans[7]. In addition to its epidemiological implications, noise is also associated with annoyance which affects one's quality of life. Annoyance due to noise can be a result of interference with activities like sleep, conversations, and listening to music or television. As an example, children exposed to higher noise levels at home coincided with higher noise annoyance ratings as well as deficits in long-term memory, speech perception, and standardized reading scores[8]. Noise annoyance has both acoustic and non-acoustic causes[7]. Acoustic factors include level, frequency, and time dependence while the non-acoustic factors include individual noise sensitivity, relationship to the source of noise, and past noise experience. By studying annoyance, it is possible to quantify acoustic quality and how occupants are responding to the aural environment, or soundscape. Blomberg et al. highlight the changes in the United States soundscape since the 1970s citing more recent noise sources added to the urban soundscape including car alarms, sound systems, leaf blowers, and others[9]. All these noise sources contribute to the urban soundscape, but limited data is available on their specific effects on noise annoyance. The majority of annoyance-based noise research focuses on transportation noise—air, rail, and road noise. The Schultz Curve[10,11] provides a relationship between community noise exposure and annoyance due to transportation noise and shows a considerable increase in annoyance rate for average noise levels above 60-70 dBA. This corresponds with the findings of a more recent study suggests that 80% of residential occupants can be satisfied by the internal noise levels when the exterior levels of the exposed side of the building are below 60 dBA[12].

Proven design techniques

In order to reduce noise annoyance and the negative health effects, it is necessary for designers and developers to consider noise sources originating externally and internally to buildings. The external noise sources are typically environmental transportation noise sources like airplanes, trains, and vehicles. Internal noise sources tend to originate from other occupants and building systems. Through industry experience and academic research, proven design techniques have been established to help mitigate both external and internal noise issues.

High noise annoyance has been repeatedly associated with living spaces oriented toward noisy streets[12,13,14,15,16,17,18]. It is possible to reduce the influence of noise on the inhabitants by locating non-living spaces like hallways, closets, etc. on the noisy side of a building and living spaces like bedrooms and living rooms on the quiet side of a building. A study of 956 adults found that having access to a quiet side of residence reduced disturbances by 30-50%[12]. The building itself can also be used as a noise barrier to help protect the soundscape in of other buildings and nearby outdoor environments. Additionally, moving a building away from a major arterial street has been found to reduce the risk of annoyance by 40%[19]. Designers must also be aware of how the building design and site layout can create problematic sound reflections that can focus the sound or allow the sound to travel around a building.

Innovative tools are available to predict and analyze the threat that noise can have on a project site and proposed building. Modern acoustic modeling software can be used to predict the environmental noise levels across a project site by accounting for various environmental noise sources and local terrain. Identifying the noise level at the exterior of the building allows for further analysis to determine the anticipated noise level within the building due to the environmental noise. Together these analysis methods allow the design team to make strategic decisions about where to locate necessary sound insulation and how to save project costs in non-essential locations. The effectiveness of these methods is dependent upon how early an acoustic consultant is involved in the design process.

Internal noise sources also add to an occupant's perception of the aural environment requiring acoustic analysis of interior partitions. Both floor-ceiling and demising wall constructions should be analyzed for air-borne sound transmission while the floor-ceiling construction should also be analyzed for structure-borne sound. The resulting recommendations depend on the overall use of the spaces, the partition design, and the construction materials employed. While it can be difficult to predict the rate of annoyance for a specific design, it is possible to determine the average change in annoyance due to improved STC and IIC. Research has shown that for every 1 point increase in sound insulation rating (STC or IIC) there is an improvement in acoustic satisfaction of 4%[20]. Therefore, a five-point increase in rating results in a 20% increase in acoustic satisfaction corresponding to a 20% decrease in annoyance. The five-point increase also corresponds to an easily noticeable change in sound level and is considered a significant increase in sound insulation.

Increasing a partition's sound insulation rating alone may not address all potential or existing noise problems. It is important to consider the frequency range of concern. A common example of this frequency dependent issue is low-frequency noise due to footfall—someone walking on the floor overhead. Wood-frame construction is known for footfall noise problems because of the inherent lack of mass and stiffness associated with this method of construction[21]; however, the problem can exist in many construction types. This issue has been compounded in recent years by a transition away from padded carpets to hard floor finishes like hard woods and ceramic tile. Resilient layers are essential in a floor ceiling construction to reduce impact noise. Even with concrete construction, it is important to implement resilient layers under the finished floor in order to reduce the sound energy transfer from one occupied space to another. Another common construction method containing extensive interior noise control issues is the glass curtain wall. The challenge is sound transfer at the connection between the glass façade and the demising walls, floors, and ceilings. The standard connection is often a simple metal mullion with minimal sound insulation properties. The result is sound easily transferring between spaces which is commonly referred to as flanking noise. Both footfall noise and flanking noise represent only two acoustic issues currently facing designers, occupants, and acousticians in urban building design. The sooner acoustic issues are addressed in the design stage the sooner informed decisions can be made by all parties involved.

Conclusion

New urbanism poses many challenges to the building industry including how to address acoustic issues in the urban environment. The acoustics of a project are only one aspect of a design, but it has far-reaching implications from site layout to construction materials and methods. Designers must consider how the inhabitants of the spaces will be affected by noise control issues associated with multi-use and multi-family buildings and the other noise sources associated with the urban environment. The health effects of noise in the urban environment continue to be investigated and span from annoyance to stress-related illnesses. As populations and population densities continue to increase, there is no reason to believe these adverse effects of noise will decrease without a conscious effort to address them. Design techniques to reduce noise annoyance and improve acoustic satisfaction in the urban environment have been implemented in the building industry and proven through research studies. It is necessary for designers and developers to apply those techniques to potential noise issues in the schematic design stage and proactively address the acoustic challenges involved with new urbanism.

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