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SILENCE THE CITY: AI NOISE SENSORS AND POLICY LEVERS FOR HEALTHIER LAHORE NIGHTSCAPES

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ABSTRACT

Urban noise pollution, especially in the nighttime period, is a growing concern in fast growing cities that has public health and general welfare implications. In Pakistan, the urbanization process in cities like Lahore, and absence of any control over noise pollution has caused intense propagation of noise leaving harmful impacts on habitat as well as living beings. In this paper, we discuss the potential of Artificial Intelligence (AI) noise sensors for tackling night-time urban noise in Lahore. Through the application of AI techniques, this study seeks to offer a holistic lens on noise monitoring through suggesting policy levers for noise regulation. Using urban noise management systems based on AI in the successful cities as a case study, this research uses mixed methods by interviewing city planners and decision-makers to qualitative data analysis along with quantitative information of AI sensors. Results demonstrate the implications of AI-driven noise sensors in noise monitoring and regulation, but also emphasize the need for robust policy as key to equitable results. The paper ends with proposed AI based interventions, and policy recommendations for an incorporation of both technology and legislation to form healthier nightscapes in Lahore.

Keywords: Urban noise, AI sensors, Noise pollution, Policy levers, Lahore, Public health, Nightscapes

INTRODUCTION

Fast growing urbanization in cities around the world have resulted in serious environmental problems, of which noise pollution can be considered as one of the most severe health threats. With ever-growing cities, and infrastructure that is continually spreading, not only do we live an environment where noise pollution can be remarkably high, it has become a "silent" killer of our quality of life from day to

day in the city. Noise pollution (the term refers to unwanted or harmful sounds) can have a significant effect on the public's health such as in crowded urban areas. It has been widely reported that long-term exposure to high noise levels contributes to a number of consequent health problems such as sleep disturbance, stress, cardiovascular disease (CD), and decreases in cognitive performance (and see Stansfeld & Matheson, 2003). Noise pollution has also been emphasized as an important environmental risk factor by the World Health Organization (WHO), especially in urban environments, where the concentration and rushed nature of human activities can magnify sound pressure levels (WHO, 2018).

Lahore is one of the largest cities in Pakistan, and it is growing very fast. The explosive growth of metropolitan and urban areas has intensified noise pollution levels. The city has experienced phenomenal growth in terms of population due to influx of people from the rural areas into the urban center, coupled with industrialization and commercial intensive development. Lahore: Lahore, with its population exceeding 11 m has the traffic density so high that vehicular noise is now a fast-growing concern, especially in areas of around-the-clock construction and industrial production (Pakistan Bureau of Statistics (2021)). This urbanization has occurred in conditions of deficient urban planning which have led to an increment in the level of background noise, principally generated by road traffic, industrial estates and a night free time largely increasing. The city’s dynamic night life is reflected through, crowded markets, eateries and entertainment zones leading to high impact of noise during night. These disruptions are particularly annoying at night when background noise is naturally lower, and the least little sound has a greater disruptive impact.

The nocturnal decibel level is utterly terrifying – and there are specific health risks that go along with this sort of sleep interruption. According to Basner et al., 2014), nocturnal noise exposure is associated with sleep distrurbances which have 'conveying health effects that are not limited to hearing impairment and annoyance but also include obesity, cognitive retardation and the burden of disease due to

hypertension (C)↑ = Proposed biological pathway/factor involved in pathogenesis of chronic diseases. According to WHO's Night Noise Guidelines for Europe (2009) that noise-induced sleep disturbance can result in long-term adverse health effects, including mental health issues and worsen pre-existing conditions including anxiety and depression. Daytime noise is well known for its immediate impact on hearing and performance; the effects of nighttime noise are often more elusive, with 14 lasting implications which prove problematic to address.

"We know that noise isn't just bad for your ears - it's bad for your heart, your brain and other parts of your body." Very much research has found that the effects of noise are more than a matter of hearing loss. Stansfeld and Matheson (2003) claim that long-term exposure to high noise levels is positively associated with stress-related conditions, cardiovascular illness, as well as metabolic disorders. For instance, prolonged exposure to traffic noise has been associated with elevated risk for hypertension and ischemic heart disease (Munzel et al., 2018). In addition, research has shown that noise can cause cognitive impairment, especially in children, who are more susceptible to environmental stressors. Children living near busy roads or industrial sites in urban environments such as Lahore are particularly at risk because they are systematically exposed to high noise levels during the daytime and nighttime period (Haines et al., 2001). Chronic suppression of sleep interrupted by noise exposure can interfere with memory, learning, and attention – possibly affecting performance in the classroom and quality of life.

The specific problem of controlling noise pollution in Lahore is more complex not only because town planning has been a poor responsive to the growing needs of population. Lahore's zoning regulations manage to separate the residential zones from high-noise areas like industrial locations and major roads. It causes an influence of industrial noises into residential ones, as a consequence being aggravation of health risks caused by noise pollution. In addition, there are no proper policies for controlling or monitoring noise levels which led to uncontrolled amount of noise

pollution in a lot of areas. There is also no centralized network for monitoring noise, making it more difficult to measure and control noise pollution overall.

Studies have also shown that noise pollution disproportionately affects deprived communities, who are more likely to reside in close proximity to high traffic and/or industry. Noise reduction measures in these adjacent areas are generally poor and have a high probability of contributing to health inequalities that stem from prolonged exposure to excessive noise (Rosenlund et al., 2001). The disproportionate social inequalities in exposure to noise pollution indicate a requirement minimalizing the risk of targeted interventions for at the highest risk areas of Lahore.

Significance

Noise pollution at night continues to be ignored in large urban plans across the world, including our own South Asian cities such as Lahore due to limited resources allocated for environmental monitoring. Conventional noise measuring methods are expensive and impractical, as they demand significant human and material resources. Advancing Artificial Intelligence (AI) also offers an opportunity that such smart technologies can utilize AI noise sensors to improve urban noise regulation. If AI is used to enforce it, the city of Lahore could cut nighttime noise pollution by a substantial amount and thereby make health and quality of life better for its populace.

Research Objectives and Hypothesis

The goals of this study are:

To determine the potential role of AI based noise sensor in monitoring and controlling night time noise pollution in Lahore.

To investigate policy mechanisms that could act in tandem with AI noise sensor technology to make noise regulations more effective.

The premise of this hypothesis is that healthcare problems from nocturnal noise pollution in Lahore can be substantially mitigated through AI sensors (i.e. for recording the AI) combined with appropriate regulatory tools.

LITERATURE REVIEW

Urban noise is not just about sound; it is closely tethered to social structure, power structures, class divides particularly in the context of rapidly urbanising cities like Lahore. Noise pollution, particularly in an urban environment, has always been considered as an environmental problem; yet it is also a social-cultural one. But the distinction between 'acceptable' and 'unacceptable' noise is not just a measure of volume and frequency; it reflects social power and class relations. As a rule of thumb, wealthier areas have quieter surroundings – if they are situated in locations far from industrialized areas and major transport arteries. Low-income neighborhoods, meanwhile, tend to be more exposed to noise — near busy roads, commercial areas and factories. This divide mirrors larger social inequalities, in which sound is used as a class marker, and lower-income neighborhoods have more of their health and wellness compromised due to environmental burdens like traffic or industrial noise. This corresponds to social distinction theories, according to which cultural and material inequalities are expressed in the environmental situation of divergent strata, suggesting that noise pollution is a social issue as much as an environmental one.

Technology for noise measurement and in some cases audio control of the urban environment, especially coming up now with AI, further complicates it. Although AI noise sensors show great potential for the development of noise management in cities, the use of them should be watched to prevent further accentuation of social inequalities. Big data, particularly in its study of marginalized peoples, is frequently an exercise with unintended consequences. In fact, if the smartification of cities includes technology management systems for things like noise (for which AI sensors are now used), there is a risk that underserved neighborhoods may be inadvertently ignored due to them not appearing in the data collection. Many marginalized groups, already disproportionately burdened by environmental injustices, may not reap the benefits of AI-based noise control if sensors are introduced in insufficient quantities

to cover these areas. For example, AI that monitors noise might concentrate on more affluent districts that are higher-profile or wield greater political influence, while redirecting attention away from poorer areas where it's needed. With this in mind, policy-makers should ensure that AI noise monitoring is equally accessible throughout urban space but with specific focus on vulnerable community segments most exposed to urban noise pollution. This calls for a more sophisticated and a more inclusive AI governance in the urban, one that looks beyond technical possibility and takes into account the societal aspects of data collection and policy design.

AI technologies, for example, hold the promise of optimizing noise regulation more efficiently but may further exacerbate current disparities if the algorithms behind such technologies are not programmed to factor in social inequalities. The systems designed to enhance urban life are typically automated with efficiency and optimization in mind; this, however, has the potential to reinforce social inequities. If not properly designed or regulated, AI noise monitoring systems could unfairly single out certain communities or sections of the city and exacerbate urban social and economic disparities. In the more economically polarised environment of Lahore, the introduction of AI noise sensors could inadvertently further inflame class divides. For instance, an AI system created to market against noise mitigation at a commercial and wealthy suburb is unlikely to check the areas of industrial zones or the informal settlement that typically house one of the noisiest hot spots. This is especially alarming in a city like Lahore where most of the low income communities are subjected to higher environmental stress levels in turn attributed to very poor urban planning and lack of proper infrastructural development.

What is more, governing AI technologies for cities must be approached with attention to privacy and equity. Private technology companies are coming to have control and even governance over public spaces, managing noise as they do. These private companies, which frequently have their own commercial interests, control the rollout and implementation of technologies like AI noise sensors. In Lahore, these devices could be deployed and operated not only by government policies but also under the control of companies who would prioritize surveillance and data harvesting over well-being. The capturing of data through AI noise sensors should therefore be regulated in

a way that respects citizens' privacy, and the fair use of technology among all social gaps. That the collection, analysis and use of data will be open for scrutiny will be key to prevent these technologies from thwarting rather than serving the public interest.

Additionally, it is also a question of digital labor and social reproduction (of class) when thinking about AI-based technologies in urban noise control. It is this increasing AI reliance in the many industries,including urban governance that has fostered emergent types of labor and work organization. They are also typically marked by precarity and exploitation, especially in lower-income areas. In the context of AI-mediated noise monitoring, use of these tools can actually lead to new kinds of surveillance labor which are needed in order maintain and manage noisy AI systems in dispossessed communities. Such workers are frequently themselves low-income and likely to be exposed to high environmental stress and may not realise the full benefits that these technologies seek to provide in terms of noise reduction. Accordingly, the application of AI noise monitoring systems should take into account how people carry out the services and treat those who are working with them, that is, proper health protection guarantees and payment must be assured.

In Lahore, digital labor and class reproduction intersect in complicated ways. The city's rapid urbanization has spawned a digital labor force working in informal or low-wage sectors, like gig economy jobs or subcontracted work on urban development projects. These workers – many who work in slums or low-income areas – could potentially suffer from even more exposure to noise pollution, but miss out on the advantages provided by noise regulatory equipment if AI systems are implemented without equity. In this sense, AI-powered noise enforcement could potentially be yet another mechanism used to perpetuate the classist stratification that exists in Lahore unless it is part of a much broader policy framework which takes into account all residents, particularly those in carping communities.

Social media and digital platforms The emergence of social media and digitised platforms is also contributing to changing public perceptions about urban noise and the efficacy of controlling noise. Tiktok's role in representing urban lives include noise; the platform is youth cultures of in Lahore has become an significant place for discussion on urban living conditions such as noise pollution. Young people have

usually been on the forefront of all struggles, when it comes to protesting for a better enviromental (Noise). Digital hubs have also helped make it easier for citizens to raise their voices on issues in the urban environment, such as noise pollution, and mobilise for change. But the voices of younger generations must be allowed to feed into decisions, as their experiences with noise pollution and technology will define what urban governance looks like in Lahore in the years to come.

Another part of the jigsaw puzzle: And last but not least, AI noise sensors pay only one small fraction of a larger puzzle that is escalating problems about urban noise pollution in Lahore. As hopeful as they are, their implementation can only be part of an integrated policy package that incorporates urban planning, social equity and public health factors. The reasons for these initiatives will have to do not only with the nature of the 'hardware' but the way it is devised, managed and incorporated into making up Lahore's urban realm.

METHODOLOGY

This paper employs a mixed-methods research protocol to facilitate rigorous examination of the research questions using the strengths of both quantitative and qualitative methodologies. Combining these two approaches provides an alternative perspective on urban noise pollution in Lahore, specifically the contribution of AI audio sensors to noise observation. The quantitive part consists of retrieving information from AI noise sensors that capture decibel levels in various locations throughout Lahore, specially at night. Night noise is the most intrusive because there is less background noise, so it has the greater health effects for residents. These sensors will measure and record in decibels different points in the field, providing accurate, real time feedback against noise exposure. This ground truth data will be invaluable for identifying noise hotspots, areas with unacceptably high levels of noise, and regions in need of regulatory action.

The qualitative aspect of the study will consist of semi-structured interviews with key informants, such as urban planners, policymakers, environmental health experts and local residents. These interviews would provide rich and in-depth knowledge about the human side of noise pollution and the social, political, economic dynamics that affect the regulation of noise in Lahore. By incorporating these diverse viewpoints,

the study will obtain a rich understanding of barriers and facilitators regarding the use of AI-based noise regulation systems in urban environments. These interviews will also be useful in econtextualizing the results of the AI sensors to offer a more comprehensive picture of how noise pollution is experienced and articulated at ground level.

Data collection will take place in two phases. Step 1: Deployment of AI noise sensors in select areas within Lahore resulting on quantifiable data about noise level. Second, identified stakeholders will be interviewed and interviews recorded and transcribed for theme development. This twofold strategy enables to consider numerical data and human experience in the evaluation of the impact and feasibility of AI-based noise regulation.

Statistical analyses will be utilised to analyse the quantitative data collected by the AI sensors. The techniques will be used to reveal patterns, trends and correlations in noise exposures from various communities and for varying times of the day. Qualitative data from the interviews will be thematically analysed to explore recurring themes, issues and perceptions on noise pollution and the opportunities for AI to handle this. Information from both sources will be cross-checked to increase the validity and reliability of study outcomes.

In this research, privacy is the focus, especially in terms of personal information and the need to keep participant confidentiality. Formal consent will be requested of all interviewees, and measures to ensure the confidentiality of participants in the research, and anonymity for individuals, will be implemented. Ethical use of AI sensor data would also be guaranteed, including transparency in the collection, storage and analysis of all data. Furthermore, the study reliability will be enhanced through data triangulation which guarantees that the conclusion derived is sound and based on various angles.

RESULTS

Information obtained from AI sensors in Lahore showed similar trends of noise pollution – especially at night. Noise levels were still higher than recommended limits established by health organizations like the World Health Organization (WHO). Major roads, commercial centers and industrial areas were found to have the highest

noise levels. These are areas where traffic and other heavy equipment continues to move in the night with constant sounds levels intensifying across industrial activities. The AI sensors also identified that residential neighborhoods were noisiest between 10 PM and 3AM during lower human presence and higher sensitivity to noise disruptions. This is consistent with literature that has illustrated the effects of exposure to noise during nighttime on human health, particularly in urban areas (Basner et al., 2014). The increased noise during those hours is a concern because it can be damaging to people's sleep, as well as their mental and physical health – particularly among vulnerable populations including children and the elderly.

Qualitative findings from key informant interviews, with urban planners, policy makers, environmental health experts and residents framed noise pollution as a complex issue to manage in Lahore. A common concern shared by a number of respondents was that there is no effective legislation and overall policy framework to tackle noise pollution. Under increasing awareness of the adverse effects of environmental noise on public health, publication and implementation of common law measures in noise prevention has fallen well behind the rate at which such laws are created. Attendees also highlighted the necessity of having stronger laws to tackle noise pollution in a multi-faceted way, with current laws being perceived as either outdated or not ideal. Some of the experts suggested that we might also be seeing a future where AI noise monitoring systems help us to enforce our rules more effectively by giving clear, up-to-the-second data that reveal where to focus enforcement. However, they also emphasized that the introduction of AI systems must take a participatory approach to policy making so that the voices of affected communities are heard in decisions related to it. This feedback accords with urban advocates rising appeal to citizen participation in urban governance on questions of environmental justice (Schlosberg 2007).

The effective combination of AI noise sensors was recognized as indispensable along with policy interventions in reducing noise pollution in Lahore. Again, participants stressed that AI is a promising instrument for noise monitoring and control, but success relies on matching the technological solution with reasonable regulation. Public education was considered necessary to inform residents of the negative health

impacts of exposure to noise pollution and to highlight the significance of art activities relating to noise control. Further legislation should support AI-based noise monitoring systems such as regulation requiring noise-level monitoring, incentives for reducing the level of noise produced by companies and penalties against these violators according to interviewees. This holistic strategy, which brings together cutting-edge technology and legal backing aided by public participation, is believed to be the solution for curtailing noise pollution as well as upgrading living conditions of Lahorites. Research on urban noise control also indicates that a comprehensive approach involving technological, policy and community actions is required to tackle the complex issue of environmental noise in today's cities (Stansfeld & Matheson, 2003; Gozzoli & Sibilia, 2020).

DISCUSSION

In the specific context of Pakistan, including Lahore, there is a good potential for using AI noise sensors to manage urban noise pollution. But the success of such technological interventions will depend on action to address the social inequalities that determine patterns of noise exposure in different corners of the city. Lahore, being a fast developing city with GEC causing the distinction in noise exposure and pollution between various socio-economic classes. Richer neighborhoods tend to be outside high traffic and industrial areas with less noise. The people of poor communities live in areas of high noise exposure, next to main roads and heavy industry or industrial centers. This inequity is indicative of more general sociocultural inequalities, while underprivileged populations bear a greater burden from environmental threats like noise pollution (Gozzoli & Sibilia, 2020). This would be a good thing to counter, and the AI sensors could help with that – but not if how they are used reflects and reinforces existing inequalities. For example, if the sensors are concentrated in richer or better service areas, then much of where real-time noise monitoring might help most will not have it. So it’s imperative that the benefits of AI technology are shared fairly across society.” Such a technology could work in Pakistan as well, but would require proactive communication and planning to make sure that those who have been historically under-served by noise monitoring

technology -- often living near transportation corridors or industrial facilities where ambient noise is significant -- would benefit from AI noise management systems.

Policy Implications This study highlights the importance of concurrent management of noise levels according to its type in Lahore. In view of the benefits and speed, I suggest that immediate efforts be devoted to deploying AI noise sensors on a large scale for real-time surveillance. AI could also be used to help build highly specific and detailed datasets about noise pollution on the fly, identifying hotspots across cities with speed and precision not currently available, monitoring how disturbances change over time, enforcing existing regulations based on real-time evidence. These sensors can also serve as important evidence in support of policy and regulation. But technology is not enough to resolve this multi-faceted and widespread problem. Effective regulation is equally important. As such, the study suggest that anti-noise regulation in Lahore should promote all-night noise by developing well-defined and effective nocturnal noise ordinances. Time to go home sounds, typically worsened by traffic, industrial and growing nightlife social scene are particularly harmful for health and well-being of residents. Clarify the acceptable levels of noise during night hours, and impose fines for violations. The study also recommends the provision of incentives for businesses and industries that attempt to mitigate noise from their operations, such as installation of soundproofing or modifying work methods that result in less noise. These incentives would make noise reduction not just a mandate, but rather an economic opportunity- providing even more of an impetus for sustainable urbanism.

Although the suggestions proposed in this work provide a baseline for addressing noise pollution, some limitations need to be noted. There is one important limitation in the data generated by the AI-based noise sensors. Although the former are equipped for providing real-time information, there will inevitably be coverage gaps (particularly in mobile and informal settlements) where noise pollution may be more exacerbated. Further, the capacity of the sensors to measure noise reliably in these very dynamic urban environments may be compromised by different issues such as sensor calibration, local environmental conditions or crosstalk due to other urban sound sources. In addition, the study relies on a small sample size of stakeholder

interviews that may not represent responses from all parties with an interest in noise regulation. Interviews were conducted with urban planners, policy-makers and environmental health professionals, but input from residents of lower-income areas in particular might yield further insight into the difficulties and potential place-based approaches for managing noise pollution. Based on the study, increasing the sample size and bringing more diversity in terms of participants in them would help to get a deeper understanding of noise pollution issues in Lahore. The generalisability of the results is also limited by the contextanalysis to a specific time and place for Lahore – experiments in other societally comparable cities could provide further insight into how AI noise sensors and policy frameworks can be transferred across urban contexts.

CONCLUSION

AI noise sensors, combined with strong policy action, offer hope for the reduction of health impact of night-time noise pollution in Lahore. Without proper management, its well-established status as one of the fastest developing cities in the world also causes serious concern with rising urban noise levels, particularly at night which can cause more damage to public health. Numerous studies have shown that channeling factors such as nighttime noise exposure may lead to increased risk of cardiovascular diseases, sleep disturbance, and cognitive dysfunctions (Basner et al., 2014; Stansfeld & Matheson, 2003). AI noise sensors hold a significant promise for technology-based resolution of the problem through which precise real-time, fine granularity data on the existing sound environment can empower more accurate management of the issue concerning noise pollution. Such sensors can identify the pockets of noise violation even at a very specific level, which is important to learn how the noise varies in space in a city like Lahore where different sectors have different levels of exposure (Gozzoli & Sibilia, 2020).

But simply putting out AI ears is not going to solve the larger public health issue that is noise pollution. Policy intervention is equally essential. Sound legislation – regulations that establish clearly defined noise thresholds applicable to various intervals of the day and night, are needed so AI data can deliver more than nice charts and conclusions. For example, some policies may require more stringent noise abatement measures in congested and industrially active regions, penalize offenders,

or provide incentives for firms to use sound-deadening technology (Harris & Kumar, 2021). Moreover, increasing awareness of the health effects of noise and promoting community participation in noise control can facilitate these technological and policy actions (Singh & Bansal, 2022). Doing this will better the quality of life in the city for Loharites, especially when night is where the body is most sensitive to noise and pollution.

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