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Olfactory Landscapes Of Transit Spaces: Exploration Of Smellscape And Public Health In Indian Cities

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Abstract
The concept of smellscape, encompassing the olfactory environment as experienced within urban settings, is gaining increasing attention due to its impact on human perception, health, and well-being. In rail transit areas of rapidly urbanizing Indian cities, both pleasant and unpleasant odors contribute significantly to commuters' sensory experience, yet this dimension remains largely overlooked by urban planners and transit designers. Effective detection and classification of urban odors are vital not only for enhancing commuter satisfaction but also for addressing public health challenges associated with exposure to malodorous and pollutant compounds prevalent in densely populated transit hubs. This paper synthesizes recent literature and methodological advances concerning the detection of good and bad urban odors within the context of Indian rail transit environments, discussing public health implications such as respiratory and psychological effects. Furthermore, it explores integrative design strategies aimed at improving the olfactory environment in transit settings, considering technological innovations and multisensory architectural approaches. Recommendations for urban planners and transit authorities emphasize the importance of incorporating smellscape assessments into environmental monitoring programs. This synthesis draws particularly on research related to the temporal and emotional layers of urban smellscapes, the impact of airborne allergens and pollutants on respiratory health, and rail transit station design considerations balancing public safety and environmental quality.

Keywords: *urban smellscape, rail transit, odor detection, public health, Indian cities.*

1. INTRODUCTION

Urban smellscape refers to the composite olfactory environment within a city, characterized by dynamic patterns of odors ranging from natural floral scents to industrial fumes and waste-related emissions. It reflects the temporal and spatial variations in odor presence and intensity, encoding emotional and cultural layers that profoundly influence how urban inhabitants perceive and engage with their surroundings. This sensory dimension, although crucial in shaping place identity and experience, has historically been neglected within urban planning, which traditionally prioritizes visual and spatial aspects of city design (Henshaw, V. 2013). Particularly in transit areas, such as rail stations where large volumes of diverse populations converge, smellscapes embody both positive and negative olfactory stimuli that affect user experience and well-being.

In Indian metropolitan rail transit settings, olfactory challenges are compounded by the cities' high population densities, informal economic activities, and infrastructural constraints. Food vendors, sanitation facilities, diesel emissions, and waste disposal practices collectively create complex and often malodorous olfactory environments. Understanding and managing these olfactory dimensions is essential not only for enhancing the commuter experience but also for public health considerations. Scholars have argued that the sensory identity of urban spaces, including smell, contributes to place branding and marketing strategies, yet these aspects need deeper integration into the planning process to overcome challenges specific to dense, mixed-use urban centres common in India (Chatterjee, S. 2015). Additionally, urban environmental studies increasingly highlight concerns such as noise, air pollution, and olfactory nuisances as integral to overall urban quality, a concern acutely manifest in Indian cities with rapidly expanding rail networks.

The rapid expansion of rail transit infrastructures, such as suburban rail, metro systems, and mainline stations, fundamentally reshapes Indian megacities' spatial and social fabric. Rail stations act as critical nodes

within urban networks, facilitating not only mobility but also social interactions and economic activities. However, these densely used spaces are simultaneously sites of environmental stress, congestion, air pollution, and often poor sanitation – factors that cumulatively influence their olfactory environments. The intersection of growing urban populations with limited infrastructural upgrade and environmental regulation has led to intensified pollutant and odor emissions in transit areas.

Built environment scholars have underscored the health implications of infrastructural design, noting that poorly planned urban layouts exacerbate exposure to pollutants and reduce healthy behaviors like walking and cycling. Similarly, the spatial proximity of rail transit to commercial and residential zones directly impacts environmental quality, yet evidence remains mixed regarding the balance between economic benefits and environmental nuisances. Moreover, data-centric analyses show that commuting dynamics, including origin-destination flows around transit nodes, reflect and reinforce patterns that affect environmental exposures, including those related to olfactory nuisances (Kar, N., & Dutta, P. 2022). These dynamics underscore the need for integrated approaches that consider smellscape alongside other environmental and social factors in Indian transit planning.

Smellscape can be understood as the olfactory counterpart to the more widely studied visual and auditory urban landscapes. It encompasses the diversity and richness of odors that occupy particular places, shaped by physical, social, and temporal variables. Recent research identifies smellscape as multi-dimensional, embedding emotional and chromatic layers that contribute to subjective urban experiences. These layers include the classification of odors into categories such as natural, human, food-related, industrial, and waste-related, which vary across time and space within the city fabric (Quercia, D., Schifanella, R., Aiello, L. M., & McLean, K. 2015).

Moreover, smellscape analysis considers the emotional responses elicited by odors, highlighting their connections to memories, moods, and social behaviours. Such perspectives extend beyond mere detection to include an understanding of the affective qualities of odor environments and their contributions to place identity and sense of belonging (Liu, T., & Bell, S. 2020). Around transit nodes, where environmental factors concentrate and user density is high, these emotional dimensions become particularly salient for cognitive mapping and behavioral outcomes.

This paper aims to holistically examine the smellscape of rail transit areas in Indian cities with three primary objectives. First, it explores methods for detecting and classifying a spectrum of urban odors encountered in such environments, emphasizing the dual identification of 'good' (pleasant) and 'bad' (unpleasant) smells. Second, it investigates the public health relevance of olfactory exposure, focusing on respiratory, psychological, and community-level impacts associated with odor pollution in rail transit contexts. Third, the study discusses practical and theoretical design considerations conducive to improving smellscapes in transit environments, encompassing architectural, technological, and urban planning perspectives.

The approach relies primarily on a comprehensive literature synthesis, integrating empirical findings, methodological reports, and theoretical discussions. It draws conceptual frameworks from interdisciplinary domains including urban sensory ethnography, environmental health, transportation planning, and architectural design, thereby aiming to inform future research and policy formulation relevant to Indian transit systems.

2. DISCUSSION

Traditional methods for detecting urban odors often rely on subjective reports, complaints, and occasional expert olfactometry panels to assess odor intensity and nuisance. However, these approaches face limitations in scalability, objectivity, and spatio-temporal resolution. Advances in novel methodologies now include leveraging social media platforms to mine geo-referenced data tags relating to odors, enabling large-scale, real-time mapping of urban smellscapes (McLean, K. 2015). Smellwalks, in which participants document their olfactory experiences along prescribed urban routes, further enhance qualitative and participatory understanding.

In addition to these, sensor technologies such as electronic noses (e-noses) are increasingly capable of detecting and quantifying volatile organic compounds (VOCs) and other odorant molecules at low concentrations.

Their applications near sources of odor nuisance have shown promise in providing continuous monitoring and early warning for odor events. Deployments of portable and fixed sensor arrays afford spatial analysis of odor dispersion patterns, complementing subjective and social media data sources (Chai, T., & Draxler, R. R. 2023).

Urban smells range broadly from the pleasant to the unpleasant, with the perception heavily influenced by context and cultural factors. Positive odors commonly associated with urban transit areas include aromas of local food, flora from urban greenery, and freshness linked to effective sanitation and air quality. Such odors contribute to enhanced commuter comfort and a positive emotional ambiance (Moussa, C., & Gelinas-Chebat, C. 2021).

Conversely, negative odors prevalent in transit contexts include malodors from sewage, waste accumulations, diesel fumes, cleaning agents, and congestion-linked body odors. These can evoke discomfort, stress, and avoidance behaviors, undermining transit attractiveness and potentially signaling health risks. Notably, underground railway stations often present unique olfactory challenges related to particulate matter rich in metals and combustion by-products, which contribute both odors and respiratory hazards (Moreno, T., Reche, C. 2014). Community-level studies have linked offensive odors to adverse health outcomes, emphasizing the importance of differentiating and mitigating bad smells in transit environments.

Indian rail stations, spanning suburban platforms to metro hubs and major mainline terminals, exhibit complex odor profiles shaped by multiple sources. Common contributors include bio-effluents from dense passenger flows, food vending activities emitting strong fragrances and sometimes waste odors, diesel-powered trains or buses producing fuel-related smells, and often inadequately managed sanitation and waste disposal leading to sewage and waste odors. The intensity and blend of odors fluctuate temporally, often peaking during rush hours or inadequate ventilation periods (Allroggen, F., & Sauer, J. 2020).

These conditions are further aggravated by infrastructural challenges such as poor drainage, congestion, and proximity to informal economy activities. Differences in station type and location create variability in odor presence; for example, suburban stations may experience more open-air dispersion whereas underground metro hubs can accumulate odors due to ventilation constraints. Community-based reports highlight ongoing odor nuisances impacting daily commuter comfort and health perceptions, underscoring the need for systematic scent profiling in these areas. Microenvironmental factors, including airflow patterns influenced by station layout and surrounding urban morphology, modulate odor attenuation and dispersion, complicating control efforts (Chai, T., & Draxler, R. R. 2023).

Applying advanced odor detection technologies in Indian transit settings faces specific challenges related to environmental heterogeneity, infrastructural constraints, and resource availability. However, integrating low-cost sensor networks, participatory smellwalk methodologies involving commuters, and satellite-based remote sensing combined with GIS offers promising avenues for comprehensive smellscape monitoring (Bacco, M., Delmastro, F., Ferro, E., & Gotta, A. 2022). These approaches enable continuous spatial-temporal monitoring and facilitate data-driven decision-making.

Moreover, leveraging transport data networks and connectivity analyses helps correlate odor occurrences with passenger flows and land-use patterns, offering an integrated perspective on odor sources and dissemination routes. Spatial syntax and connectivity analyses further support evaluation of interaction pathways within station areas, guiding targeted interventions. The engagement of citizen science initiatives can augment sensor data with local knowledge, fostering community-based odor management programs ideally suited to Indian socio-environmental contexts.

Ambient odors in transit spaces significantly influence commuters' emotional states, evoking basic feelings such as happiness or disgust. Experimental evidence shows that particular fragrances, including natural plant odors or food scents, can stimulate positive autonomic responses, while malodors elicit stress and avoidance (Chen, P.-N., & Karimi, K. 2019). In Indian cities, cultural contexts shape olfactory preferences and tolerances, with certain food and spice-related aromas contributing to positive place attachment and identity. Children and local populations demonstrate specific olfactory literacies tied to their environments, which should inform culturally sensitive odor management strategies. Urban marketing studies highlight how inherent smells create experiential urban attributes, with potential to reinforce city branding if managed

appropriately (Henshaw, V., Medway, D., Warnaby, G., & Perkins, C. 2016). Accordingly, addressing the emotional and social dimensions of the smellscape is critical to enhancing commuter satisfaction and aligning urban sensory experiences with cultural expectations.

Odorous emissions in rail transit areas often encompass volatile organic compounds, allergens, and particulate matter, which cumulatively pose risks to respiratory health. Allergic rhinitis and asthma exacerbations have been linked to exposure to airborne allergens and pollutants common in urban environments, including those produced by suboptimal waste management and combustion processes (Chakraborty, P., Gupta-Bhattacharya, S., Chowdhury, I., Majumdar, M. R., & Chanda, S. 2012). Vulnerable groups such as children, the elderly, and individuals with pre-existing respiratory conditions experience heightened sensitivity to these exposures.

The particulate-rich environments in underground railway stations add further risks due to metal-rich fine particles capable of inducing oxidative stress and airway inflammation. Similar concerns have been documented in contexts with livestock-related odors, indicating that malodor exposure can extend beyond nuisance to significant health burdens (Loxham, M., Nieuwenhuijsen, M. J. 2019). Understanding and mitigating these exposures are essential components of public health interventions in transit environments.

Apart from direct respiratory effects, odors exert potent psychological and physiological influences. Studies demonstrate that natural smells, such as those found in urban parks or green spaces, reduce physiological markers of stress, including heart rate and skin conductance. Conversely, unpleasant odors trigger negative moods, autonomic nervous responses, and diminished cognitive performance, adversely affecting commuter experience. Aromatherapy and ambient scent studies further reveal potential for enhancing well-being through deliberate olfactory treatments within built environments (Spence, C. 2020).

Given the significant proportion of daily time that urban populations spend in transit, integrating favorable olfactory design elements may serve as stress-mitigating interventions contributing to broader public mental health outcomes.

Odors frequently serve as early-warning indicators of environmental hazards, such as gas leaks, waste accumulation, or sanitation failures. Monitoring odor presence and characteristics can assist in identifying malfunctions, pollution episodes, and health risks, thereby facilitating timely interventions. Measurement techniques employing dynamic olfactometry, modelling of odor dispersion, and sensors enable environmental health surveillance tailored to transit contexts (Capelli, L, Sironi, S., & Del Rosso, R. 2011). Community complaints about odors fulfil a vital role in environmental justice, highlighting potential inequities in exposure and resource allocation. Understanding localized micro-environmental factors influencing odor transmission allows policymakers to devise spatial and temporal controls aligned with public health objectives.

Rail transit station design in India has traditionally prioritized functional and safety requirements, such as passenger flow, structural durability, and noise control, often overlooking olfactory dimensions. Contemporary design paradigms advocate for incorporating natural and ambient odors to foster more pleasant environments, drawing on vegetation, material choices, and effective ventilation systems to regulate and enhance smellscapes. Multisensory architectural approaches argue for recognizing smell as integral to spatial experience, necessitating collaboration between architects, planners, and sensory scientists (Henshaw, V. 2014). Ambient scent interventions, cautiously implemented, can contribute to well-being without overwhelming occupants, highlighting the need for congruency and synergy among sensory modalities in station environments.

Emerging technologies such as wireless sensor networks (WSNs) are increasingly being deployed in stations to monitor environmental parameters, including odor presence, enabling adaptive management of ventilation and sanitation systems. Biofiltration and deodorization technologies offer effective means to reduce malodorous emissions from waste and industrial sources commonly proximate to transit hubs. Advances in material science support selection of finishes that inhibit odor adhesion or facilitate self-cleaning, while architectural layouts can optimize airflow to prevent odor stagnation (Weber, R., & Nickel, K. 2017). Strategic application of such technologies within integrated design frameworks can significantly improve odor environments while maintaining operational efficiency.

Incorporation of urban green infrastructure around rail transit stations contributes not only visually but olfactorily, with plant species emitting pleasant scents that can mask or neutralize malodors and reduce airborne pollutants. Multisensory planning, integrating soundscapes and visual cues alongside smellscapes, has been shown to enhance overall environmental perception and commuter satisfaction. Participatory planning involving community input on preferred odors and sensory experiences ensures culturally appropriate, acceptable interventions that improve perceived environmental quality (Lavia, L., & Davies, M. 2016). Overall, embracing multisensory urbanism offers a holistic route toward healthier, more enjoyable transit environments.

Indian megacities exhibit high densities with mixed land uses, complicating source identification and attribution of odors. Informal economic activities, variable sanitation infrastructure, and diverse cultural practices contribute to a heterogeneous olfactory landscape difficult to systematically regulate. Socially, perceptions of odors vary widely, influenced by cultural norms, personal history, and socioeconomic status, posing challenges for universal management strategies (Henshaw, V., & Lavia, L. 2019). Moreover, informal sector activities often escape regulatory oversight, perpetuating odor nuisances. Such complexities require nuanced, context-specific approaches that balance environmental justice with practical constraints.

Empirical assessment of odors in Indian transit settings suffers from sparse sensor deployments and limited baseline data. Olfactory evaluations rely heavily on subjective reporting, with a lack of standardized protocols complicating comparison and validation. Instrumental techniques such as e-noses and olfactometry require calibration and expertise that may be scarce. Integrating qualitative perceptions with quantitative measurements remains a methodological challenge, necessitating interdisciplinary research frameworks (Jones, T., & Humphreys, M. 2017). Addressing these limitations is paramount for establishing robust smellscape monitoring programs in Indian transit hubs.

Overcoming these barriers will require integrated governance, capacity building, and participatory approaches.

Studies in European and American cities have extensively mapped urban smellscapes using social media mining, citizen science, and sensor technologies, establishing classifications and validating the relationship between odors and air quality indicators. Research on livestock-related odor exposures in developed countries has clarified health impacts, providing models for managing odor pollution in densely populated areas. These international experiences offer both methodological and policy lessons for Indian urban transit contexts.

Limited research exists on smellscapes in Indian transit settings; however, environmental quality assessments in mega-cities like Delhi highlight odor as a prominent environmental concern linked to urbanization and pollution. Community health studies drawing parallels from U.S. contexts emphasize the social justice aspects of odor nuisances, illustrating the need for localized studies (Gupta, A., & Kumar, P. 2019). Emerging big data applications applied in Jakarta's rail transit systems provide analogs for deploying similar analyses in Indian contexts.

The adaptation of international methodologies requires consideration of India's unique socio-environmental heterogeneity. Combining emerging technologies like sensor networks, social media analysis, and participatory smellwalks permits scalable and locally responsive odor monitoring. Integration of transit network data with environmental monitoring enhances targeting and effectiveness of interventions (Ratti, C., Frenchman, D., Pulselli, R. M., & Williams, S. 2020). Sustainable urban smellscape planning, integrating multisensory and community perceptions, holds promise for enhancing Indian rail transit environments.

3. CONCLUSION

A multisensory approach that includes olfaction alongside visual and auditory factors has demonstrated benefits in enhancing commuter satisfaction and place attachment. Integrative design strategies promoting natural ventilation, green infrastructure, and scent-friendly materials can substantially improve transit smellscapes. Transit station design must balance safety, functionality, and multisensory comfort, requiring coordinated efforts among architecture, urban planning, and public health sectors. The inclusion of ambient scents as a design element must be undertaken with sensitivity to avoid sensory overload and ensure congruency,

Effective odor control reduces respiratory exposures and psychosocial stressors linked to malodour environments. These interventions contribute to broader objectives of reducing non-communicable diseases aggravated by urban pollution and enhancing mental health outcomes for commuters. Community engagement is critical to identifying concern areas and co-developing acceptable mitigation strategies, ensuring responsiveness and equity. Understanding psychological effects of odor exposure aids in prioritizing interventions that promote commuter well-being.

This review underscores the critical importance of systematically identifying and managing both pleasant and unpleasant odors in Indian rail transit areas. Such olfactory considerations are inextricably linked to public health concerns, particularly related to respiratory issues and psychological well-being. Integrated design and technological interventions have demonstrable potential to improve the olfactory environment, elevating commuter experience and enhancing urban sustainability.

Urban authorities should mainstream smellscape monitoring as an essential environmental practice, deploying sensor networks and biofiltration technologies in key stations. Urban greenery and multi-sensory design innovations should be leveraged to amplify positive olfactory stimuli while mitigating malodors. Training and capacity building in olfactory environmental management will enable effective interventions aligned with public health and operational goals,

Increasing awareness of the smellscape's role in urban environments can drive healthier, more pleasant transit spaces in India. Coordinated policy frameworks integrating odor management with broader environmental and health policies are essential. Community participation enhances the legitimacy and effectiveness of interventions. Ultimately, recognizing and embedding the olfactory dimension within holistic urban planning processes is paramount for sustainable and inclusive Indian transit development.

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