Shifting the Paradigm: Enhancing Walkability to Mitigate Air Pollution in Urban India

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Abstract
India has been the world's fastest-growing major economy. At its current growth rate, the country's urban population is projected to soar to an astounding 600 million by 2030 (WUP, 2018). As per the 2011 Census, India had 53 cities with populations exceeding one million. Population growth significantly impacts the number of motor vehicles in many developing countries. As the population grows, individual consumption levels of goods and services also rise. In today's world, transport is a vital service for people, making the size of the transportation sector highly responsive to population changes. The growth rate of motor vehicles has been predominantly concentrated in major cities. Heavy reliance on motorized vehicles has led to externalities such as traffic congestion, road accidents, challenges for active transportation (walking and cycling), air pollution, and noise pollution. India's transport sector accounts for approximately 17% of the country's total energy consumption and contributes 60% of greenhouse gas (GHG) emissions from various activities. The transport sector is also recognized as a significant contributor to air pollution, which negatively affects public health. Urban planners must prioritize Non-Motorized Transport (NMT), such as walking and cycling, in their planning efforts. The paradigm shift from vehicles to NMT can guide the nation toward sustainability. This study examines how enhancing walkability, a key component of NMT, can contribute to reducing air pollution. Key factors influencing walkability and its connection to air pollution include the impact of increased pedestrian activity, which enhances Quality of Life (QoL). Additionally, a paradigm shift toward sustainable transportation modes like buses, metros, and walking has been noted. The findings of these studies highlight the need to create comfortable walking environments, establish protected bicycle lanes, and explore methods to replicate such initiatives on other busy streets across India to enhance Quality of Life (QoL).
Keywords: *Vehicular Growth, NMT, Sustainability, Walkability, Air Pollution*

1. INTRODUCTION

Transport has long been acknowledged for its role in economic development, but its environmental impact is equally well-recognized (Grazi & van den Bergh, 2008). Investments in transportation can drive or support structural changes and play a vital role in reducing urban pollution. However, for developing countries, achieving a disconnect between transportation investments and pollution remains a significant challenge.

Cities play a major role in greenhouse gas (GHG) emission. Globally, 70–80% of GHG emissions are recorded from cities (NIUA, 2021). India ranks third globally in GHG emissions as of 2017. The Indian economy is predicted to be impacted by climate change if emissions continue at current rates, even though per capita emissions are lower than half of the global average (Garg et al., 2017). India's GHG emissions have doubled between 1990 and 2015, and this upward trend is anticipated to persist.

The energy sector, which accounts for the largest share of CO2 emissions, is the primary contributor to the country's overall GHG emissions. With projected urbanization and economic growth, energy demand in India is expected to rise substantially, leading to a corresponding increase in GHG emissions. In Indian cities, the majority of emissions originate from industrial activities, followed by energy consumption in the built environment (28% of total emissions) and the transportation sector (24%).

India's Nationally Determined Contributions (NDCs), developed under the Paris Climate Agreement, recognize cities as critical sub-national stakeholders. These commitments focus on enhancing energy efficiency in the building sector, promoting climate-resilient urban development, reducing emissions in the waste sector, and advancing sustainable transportation systems (Tulasi Anantharamakrishnan, 2021; Bhat, 2022).

Vehicles operating within cities contribute substantially to GHG emissions and play a major role in deteriorating air quality. Promoting Non-motorized Transport (NMT) can improve air quality as vehicular flow will reduce when people shift to NMT. NMT, also known as active transport, encompasses modes of transportation powered by human effort rather than fossil fuels (Saelens et al., 2003).

2. LITERATURE REVIEW

India is currently dealing with two significant public health issues: air pollution and physical inactivity. Walking and cycling in particular are examples of NMT that can save lives, mitigate the consequences of climate change, and reduce air pollution and physical inactivity. About 5 million deaths occur each year as a result of physical inactivity, whereas 74 thousand premature deaths are caused by emissions from motorized transportation (Grazi & van den Bergh, 2008).

The study is about the connection between air quality and walkability. Walkability starts from the decision of any person. To make that decision happen to the users, the information of barriers is necessary to overcome. Walkability offers a wide range of benefits for individuals and society as a whole. It promotes better physical health, enhances air quality, mitigates climate change, improves personal finances, and boosts accessibility and mobility. Walking is a green and clean mode of transportation, characterized by low carbon footprints, minimal energy use, and zero local emissions. Also in India, walking is the most favored mode of transportation among low-income households due to its affordability.

Air Pollution

An air pollutant is any substance that changes the natural characteristics of the atmosphere, whether through chemical, physical, or biological means (Rees & Wackernagel, 2008). Air pollution can take place both indoors and outdoors. Typical sources include motor vehicles, industrial activities, household combustion devices, and forest fires. Particulate matter, carbon monoxide, ozone, nitrogen dioxide, and sulfur dioxide are pollutants of great public health concern. Both indoor and outdoor air pollution are major causes of illness and death, contributing to respiratory issues and other health conditions. WHO data reveals that 99% of the global population breathes air with pollutant levels exceeding WHO guideline limits, with low- and middle-income countries experiencing the highest exposure.

Air quality

The quantity of dangerous compounds (pollutants) present in the air is referred to as air quality. It is discovered by keeping an eye on several pollution indicators. The harmony of human, plant, animal, and natural resource life on Earth depends on maintaining good air quality. The ecosystem and/or human health may be impacted by poor air quality (Winkler et al., 2016). Air quality is intricately connected to the planet's climate and ecosystems. Many sources of air pollution, such as fossil fuel combustion, are also major contributors to greenhouse gas emissions (Grazi & van den Bergh, 2008). Significant environmental health risks are posed by air pollution in developed, developing, and UN LDCs; the type and severity of these risks vary based on variables like population density, regulatory frameworks, industrialization levels, and socioeconomic circumstances. Long-term exposure to air pollution, especially PM 2.5 and NO 2, is linked to higher rates of cardiovascular disorders like ischemic heart disease, heart attacks, and strokes as well as respiratory conditions like lung cancer, asthma, and chronic obstructive pulmonary disease (COPD) in developed nations (Grazi & van den Bergh, 2008). Policies aimed at reducing air pollution present a dual benefit by improving public health through a reduced disease burden and contributing to both immediate and long-term efforts to mitigate climate change.

Air Quality Standards

Air quality standards are designed to safeguard human health and the environment from the adverse impacts of air pollutants. These guidelines are established collaboratively by the government and international agencies such as the WHO, focusing on pollution control and health protection. There are some factors considered while setting legally binding standards: Sensitive receptors, pollutant behavior, natural levels and technical feasibility.

Walkability

Walking, cycling, push scooters, skateboards, skates, hand carts, rickshaws, and wheelchairs are all considered forms of NMT for short commutes up to 7 km. These modes are typically utilized for either transportation or leisure. One NMT strives to give the public a clean, safe, and healthy environment as part of sustainable transportation. These forms of transportation not only have a minimal carbon footprint, but they also lessen air pollution and traffic in cities (Winkler et al., 2016). The earliest scientific papers on walkability emerged in the early 1990s, originating from the field of urban development and focusing on the quality of urban and suburban environments [1] (Cervero & Kockelman, 1997, Southworth & Owens, 1993). It has been demonstrated that specific environmental factors, including population density, mixed land use, and street design, encourage people to engage in walking (Southworth, 1997). Consequently, the idea of a direct connection between the quality of the pedestrian environment and people's inclination to choose walking as their primary mode of transportation is now acknowledged. Over time, the concept of walkability gradually gained recognition in other fields of research. Investigating the relationship between environmental perception, physical activity, and individual body weight marked a significant milestone in walkability studies within public health (Mansoor, Kashifi, Safi, & Rahman, 2022). The partnership between urban planner Lawrence D. Frank and psychology researchers was notable, as they explored the connection between urban design and residents' physical activity (Cerin, Saelens, Sallis, & Frank, 2006), neighbourhood mobility, BMI (body mass index), active modes of transport and air quality (Cerin, Saelens, Sallis, & Frank, 2006), as well as neighbourhood walkability, walking, car use and obesity (Kerr, Frank, Sallis, & Chapman, 2007). Both walking for transportation and walking for recreation have been studied, with some researchers addressing both aspects simultaneously (Yang & Diez-Roux, 2012). Another typical research feature is that most of the papers pertain to walkability of urban areas.

SWARA Technique

The SWARA technique offers policymakers a tool to select the optimal decision by considering diverse scenarios and incorporating criteria aligned with their goals and objectives (Ghoushchi, Rahman, Raeisi, Osgooei, & Ghoushji, 2020). Specialists are integral to the execution of any major project. The SWARA technique is also highly effective for decision-making and policy formulation at the highest levels, particularly in addressing critical issues (Narayanan, 2018). SWARA is a Multi-Criteria Decision Making (MCDM) method used to address uncertainties in evaluating the linguistic expressions of criteria and alternatives (Erdogan & Tosun, 2021). The primary advantage of the SWARA technique in decisionmaking is that it eliminates the need for complex assessments to resolve decision problems. It facilitates the prioritization of criteria by determining their weightages in alignment with an organization's strategies or plans.

Basic steps of SWARA technique

The fundamental principles of SWARA and the process for determining the relative weights of criteria can be outlined through the following steps (Zolfani & Saparauskas, 2013).

Step One:

Criteria need to be organized based on their level of importance. In this stage, experts rank the defined criteria based on their importance, placing the most significant criteria first, the least significant last, and those of intermediate importance in between.

Step Two:

Determine the scientific criteria (Sj) by assessing their relative significance based on average values. Starting with the second-ranked criterion, evaluate how much more important each criterion (Cj) is compared to the next criterion (Cj+1).

$$Sj \leftrightarrow j+1 = \sum_{k=1}^{r} Cj \leftrightarrow j+1 / r \quad (1)$$

Step Three:

Calculate coefficient (Kj) as follows:

$$Kj = \begin{cases} 1 & j=1 \\ Sj+1 & j>1 \end{cases} \quad (2)$$

Step Four:

Determine recalculated weight qj as follows:

$$qj = \begin{cases} 1 & j=1 \\ qj - 1/Kj & j>1 \end{cases} \quad (3)$$

Step Five:

Calculate the weight values of the criteria with the sum that is equal to one:

$$Wj = qj / \sum_{k=1}^{m} qj \quad (4)$$

Where Wj represents the relative weight value of the criteria.

3. Objective

The objective is to prioritize walkability attributes to improve air quality in Surat using SWARA MCDM technique.

4. Study area

India, the largest democracy and one of the fastest-growing economies, is undergoing rapid urbanization. With a population of more than 1.4 billion, of which nearly 35% resides in urban areas, cities are facing increasing travel demand, rising private vehicle ownership, and pressure on existing infrastructure (Grazi & van den Bergh, 2008). This urban growth has intensified environmental concerns, particularly air pollution, which has become one of the most critical challenges to sustainable development.

Air quality in Indian cities consistently ranks among the worst globally. According to the World Air Quality Report (2023), 14 of the world's 20 most polluted cities are in India, with annual PM2.5 levels in cities such as Delhi, Lucknow, and Patna exceeding the WHO guideline of 5 µg/m³ by more than ten times (IQAir, 2023). The transport sector is a significant contributor to this problem, responsible for 20–30% of urban PM2.5 emissions and a large share of nitrogen oxides (NOx) and carbon monoxide (CO) (Mansoor et al., 2022; Garg et al., 2017). These pollutants have severe health impacts, with long-term exposure linked to increased mortality and morbidity (Hales, 2021). In India, outdoor air pollution is estimated to cause 1.67 million premature deaths annually (WHO, 2022).

Within this context, walkability emerges as a strategic tool for both sustainable mobility and air quality improvement. Indian cities are characterized by a high share of short-distance trips, many of which are currently made by motorized two-wheelers or autos that emit disproportionately high levels of pollutants (Cervero & Kockelman, 1997; Yang & Diez-Roux, 2012). Improving pedestrian infrastructure, ensuring safety, and reclaiming encroached walking spaces can shift a significant portion of these trips toward nonmotorized transport (NMT), directly reducing vehicle kilometers traveled and associated emissions (Saelens et al., 2003; Mansoor et al., 2022).

The relevance of this linkage is further reinforced by existing policy frameworks. The National Urban Transport Policy (2006), the Smart Cities Mission, and the National Clean Air Programme (NCAP, 2019) all emphasize the promotion of NMT to achieve sustainable urban development and cleaner air (Tulasi Anantharamakrishnan, 2021; Bhat, 2022). By integrating walkability enhancements with air quality strategies, India has the opportunity to address both environmental and public health challenges in tandem.

Therefore, India presents a critical study area for examining the relationship between walkability and air quality. Its urban diversity, severity of air pollution, and ongoing policy interventions provide a robust context to evaluate how structured methods such as SWARA can guide the prioritization of walkability attributes to achieve co-benefits in terms of sustainable mobility and improved urban air quality.

5. METHODOLOGY

To carry out the research, questionnaire was prepared based on rigorous literature review. The questionnaire was designed to get the idea which attributes are more important for the walkability. For that, the data was collected from 15 experts from different background like academicians, consultants, Govt. officials and so on.

6. Data collection

Data collection has been done using expert survey. 15 experts from the field of academics, consultants, Govt. officials, NGO persons has been selected for the survey so the different aspects from different groups can be obtained. For the survey, SWARA (Stepwise Weight Assessment Ratio Analysis) is used. The primary three (03) attributes are selected which are Planning. Engineering and Psychology. The secondary attributes is shown in the Table 1. **Table 1** Secondary attributes of Study

Planning		Engineering		Psychology	
P1	Built Environment	E1	Width of footpath, pathway, sidewalk	PS1	Buying daily HH
P2	Obstructions	E2	Rest Area	PS2	Purpose as a recreational activity
P3	Connectivity to Public Transport	E3	Cleanliness of footpath, pathway, sidewalk	PS3	Safety from crime
P4	Distance to Health care facility	E4	Clear Walking zone	PS4	Convenience
P5	Distance to commercial facility	E5	Pedestrian Crossing	PS5	Decision to walk as per Street furniture
		E6	Maintenance of footpath, pathway, sidewalk	PS6	Decision to walk as per Street pattern
		E7	Safety from Traffic	PS7	Decision to walk as per public space accessibility
		E8	Guard rails	PS8	Decision to walk as per recreational facilities

7. RESULTS & DISCUSSION

After completion of expert's survey, the analysis is done using SWARA technique. The final weightage of each parameter is calculated. The weightage for Planning attributes is shown in Table 2. **Table 2** Ranking of Planning Attributes

No	Parameter	Weightage	Rank
P1	Built Environment	307.8962599	5
P2	Obstructions	372.5624357	2
P3	Connectivity to Public Transport	332.5826125	4
P4	Distance to Health care facility	637.1559026	1
P5	Distance to commercial facility	345.7808689	3

The planning parameter 04, i.e. Distance to Health care facility get the highest weightage 637.75, followed by 372.56 of obstructions. It is observed that the health care facility need to be taken care while planning. The weightage for Engineering parameter is shown in Table 3.

Table 3 Ranking of Engineering Attributes

No	Parameter	Weightage	Rank
E1	Width of footpath, pathway, sidewalk	677.0136627	1
E2	Rest Area	168.3263266	5
E3	Cleanliness of footpath, pathway, sidewalk	163.7758864	6
E4	Clear Walking zone	279.8542172	3
E5	Pedestrian Crossing	48.51896534	8

E6	Maintenance of footpath, pathway, sidewalk	379.1625457	2
E7	Safety from Traffic	195.2310423	4
E8	Guard rails	81.1691379	7

For Engineering attributes, width of footpath, pathway, sidewalk is the most important parameter. Also, the pedestrian crossing is not prioritized as getting weightage only 48.52 and rank 8 (last) among all the selected attributes.

Table 4 Ranking of Psychology Attributes

No	Parameter	Weightage	Rank
PS1	Buying daily HH	45.35223615	6
PS2	Purpose as a recreational activity	427.0428417	2
PS3	Safety from crime	267.7320996	4
PS4	Convenience	70.01406423	5
PS5	Decision to walk as per Street furniture	668.9232543	1
PS6	Decision to walk as per Street pattern	33.32451275	8
PS7	Decision to walk as per public space accessibility	34.58347728	7
PS1	Buying daily HH	401.960797	3

Whenever a person walks, first the decision to walk come into picture. Here we have observed that in psychological attributes, decision to walk as per street furniture get the highest weightage among all selected attributes, i.e. 668.923 followed by the Purpose of walking as a recreational activity with weightage 427.042. the lowest weightage was observed in the parameter decision to walk as per street pattern with weightage 33.324.

8. CONCLUSION

Walkability is one of the most vital components of Non-Motorized Transport (NMT) and plays a decisive role in achieving sustainable urban mobility. By promoting NMT, cities can effectively move towards cleaner air and healthier living environments. The present study highlights how regulating the critical attributes of walkability can significantly enhance pedestrian infrastructure and experience at different spatial levels be it a neighbourhood, city, region, or even country. Using the SWARA technique, the importance of each parameter has been systematically evaluated, providing a structured basis for identifying priority interventions. The results underline that targeted improvements such as better sidewalks, safe crossings, shaded walkways, traffic calming measures, and improved accessibility can collectively enhance walkability.

An increase in walkability directly discourages excessive dependence on motorized modes of travel, leading to reduced fuel consumption, lower vehicular emissions, and consequently, an improvement in urban air quality. According to the World Air Quality Report 2023, 14 of the world's 20 most polluted cities are in India, with fine particulate matter (PM2.5) levels in several Indian metros exceeding the WHO annual guideline (5 $\mu g/m^3$) by more than 10 times. The transport sector alone contributes nearly 20–30% of PM2.5 emissions in urban areas, highlighting the urgent need to shift towards sustainable modes. Enhancing walkability offers a practical and cost-effective solution to this challenge, as reducing short motorized trips can significantly cut daily vehicular emissions.

Beyond environmental benefits, higher walkability also contributes to public health through increased physical activity, improved road safety, and enhanced social cohesion by creating more vibrant and inclusive public spaces. These benefits align with broader global sustainability goals, including climate resilience and equitable urban development.

Therefore, strengthening walkability should not merely be seen as an urban design intervention but as an integrated strategy for environmental protection, public health improvement, and sustainable transport planning. Policymakers and city authorities must prioritize pedestrian-oriented planning by integrating walkability parameters into transport policies, air quality action plans, and climate strategies. Furthermore, future research could explore combining behavioural insights, smart mobility tools, and real-time data to refine walkability indices and monitor progress dynamically.

In conclusion, by systematically addressing walkability attributes, urban areas can shift towards lowcarbon, people-centric mobility patterns. This transition will not only mitigate air pollution helping India reduce PM2.5 levels closer to global health standards, but also foster healthier, safer, and more sustainable cities for future generations.

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