

Evaluating the Contribution of Urban Pollution to Climate Change and the Effectiveness of Mitigation Strategies in Developing Countries

Shilpi Pandey*

Delhi Skill and Entrepreneurship University, Pusa II Campus, Delhi, India

*Email: pandeyshilpi35@gmail.com

Abstract

In developing countries urbanization and its associated energy consumption and transport growth are leading to increased environmental pollution in an ever growing urban population, and causing elevated concentration of greenhouse gases in the air. This article reviews the contribution to climate changes from urban pollution, and analyzes critically the efficiency of mitigation strategies in developing countries. Using secondary research (from recent peer reviewed literature) and evidence from the IPCC this study covers most significant urban pollution sources, climate and environmental impacts and mitigation actions. Results suggest that these different transport-related, energy, waste and urban development aspects are important contributors to urban emissions and urban climate pressures. Emissions can be reduced while maintaining a healthy and environmentally friendly, and compact city development through sustainable transport, renewable energy, energy efficiency, and waste management. But lack of funding, lack of infrastructure, and governance and implementation obstacles decrease the effectiveness of mitigation. The article underscores the importance of having packages of climate policies and measures for air quality, coupled with better institutions and investment time-scale.

Keywords: Urban pollution; climate change; developing countries; urbanization; greenhouse-gas emissions; mitigation; sustainable urban development.

1. INTRODUCTION

Rapid urbanization and industrialization in developing countries have resulted in increasing emissions from transportation, industries, energy consumption, construction activities, and improper waste management. These urban pollution sources contribute significantly to greenhouse gas emissions and short-lived climate pollutants, while simultaneously deteriorating local air quality and affecting human and ecosystem health. However, the magnitude of their contribution to climate change and the effectiveness of existing mitigation measures remain inadequately understood in many rapidly growing cities.

The review aims to evaluate the contribution of major urban pollution sources to climate change and assess the effectiveness of mitigation strategies in developing countries. The study will examine trends and spatial patterns of key pollutants and greenhouse gases, identify major emission sources, and explore their relationship with urban growth, land-use change, energy consumption, transportation, and waste generation. It will further evaluate mitigation measures such as cleaner transportation, renewable energy adoption, urban greening, improved waste management, energy-efficient infrastructure, and pollution-control policies.

Using a combination of air-quality and emission data, remote sensing and GIS, climate indicators, secondary datasets, policy analysis, and selected city-level case studies, the research will compare pollution-climate interactions across representative urban areas. Particular attention will be given to identifying strategies that simultaneously reduce air pollution and greenhouse gas emissions, thereby generating climate, environmental, and public-health co-benefits.

2. Urban Pollution and Climate Change in Developing Countries

2.1 Urbanization, Pollution and Major Emission Sources

The environmental situation of developing countries is undergoing a transformation in response to urbanization. Growth of cities due to population growth, migration and economy. As cities in developing nations grow, so do growing demands for housing, transport, energy and infrastructure, as demonstrated by Henderson and Turner (2020). When urbanization is high, demands can lead to high levels of greenhouse gases and pollution. Air pollution is an important issue in urban areas because pollutants and GHGs are generated by transport, industry, electricity generation, and construction and waste management in urban areas. In their study, find a clear country trend linking urbanization and air pollution, but note this correlation changes depending on the country and its level of development. This indicates that urban expansion does not place equal environmental pressures all around the world (Wang et al. 2020). Rapid urbanization has had a notable impact on the Global South, where urbanization can happen at the same time as limited infrastructure development and environmental control. According to Zhang et al. (2023), the trend of increased air pollution under the surge in urban growth in the Global South is growing of concern. Likewise, Sooktawee et al. (2024) connect air-quality issues with broader issues of atmospheric and climate changes in LMICs. So, pollution due to urbanization can become a local environment problem as well as a global climate issue.

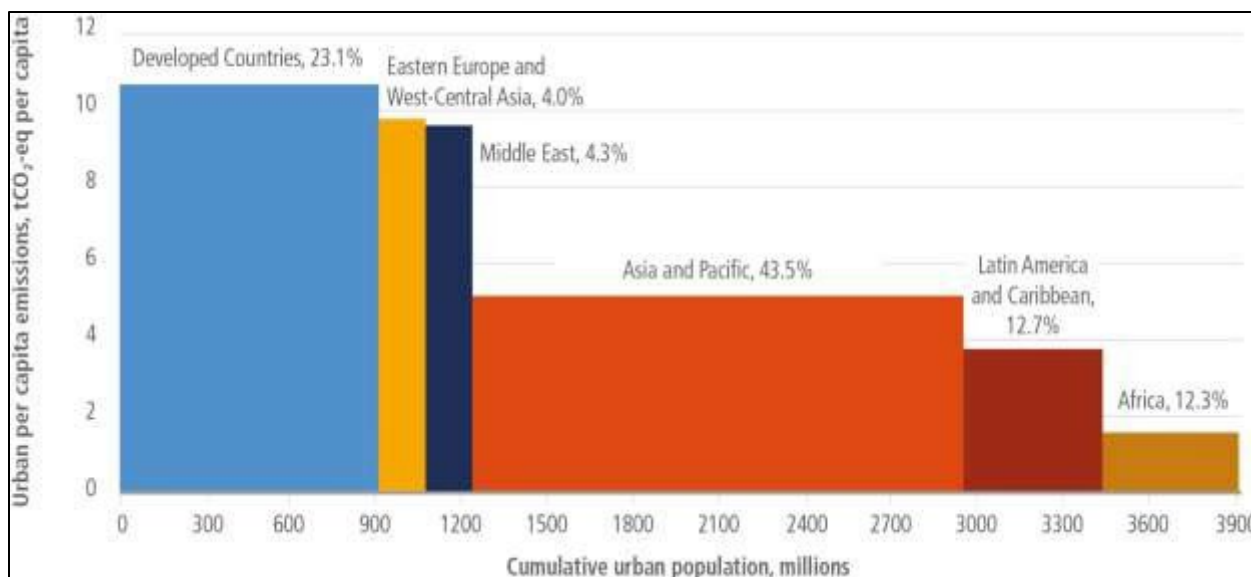


Figure 1: 2015 average urban GHG emissions per capita

(Source: <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>)

Emission reductions represent regional-relationship differences between average urban greenhouse-gas emissions per person (Figure 1). The figure also includes variations in urban population size. This is important because there could be a big urban population in developing countries, but different per capita emissions. Population growth and emission intensity are thus relevant factors for urban climates' responsibility.

2.2 Relationship Between Urban Pollution and Climate Change

Pollution in urban areas is closely linked to climate change because many of the activities which emit harmful pollutant gases emit GHGs as well. The transportation, production of energy, industry and buildings can thus be responsible for bad air quality and for climate change. Luqman, Rayner and Gurney (2023) offer direct evidence that urbanization is linked to carbon dioxide emissions – explaining the significance of increasing urbanization in climate policy. de Oliveira and Bhuiyan (2024) emphasize the significance of cities in context of climate change and highlight the challenges of developing countries in cities with emphasis. When cities employ carbon intensive systems, they can consume a lot more energy and emit a lot more pollutants with rapid urbanization. But, with development in an urban area also comes opportunities for cleaner transport, efficient building, renewables, and improved infrastructure. Further evidence of the interaction of climate and air-quality pressures is provided from India. In highly-urbanized areas, show how climate and air-quality problems can affect one another (Miinalainen et al., 2023). So, when fossil fuel use is curtailed, this is likely to result in both climate mitigation and air quality benefits.

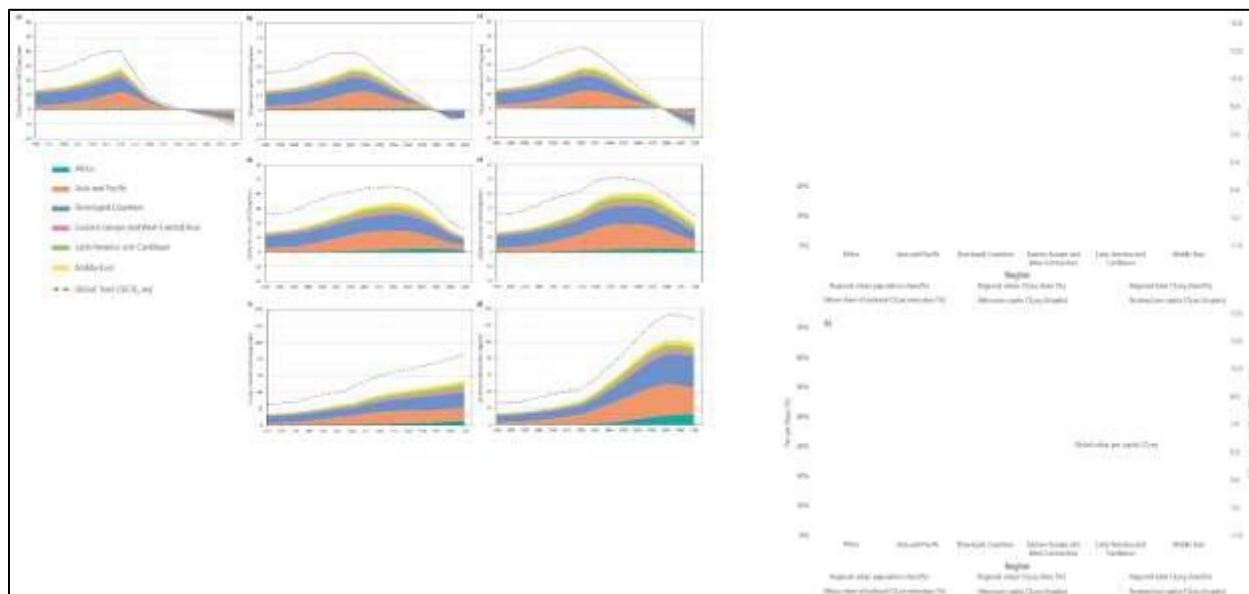


Figure 2: CO₂-eq emissions from global urban areas, 1990–2100

(Source:<https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>)

The projections of future emissions for urban areas are shown in Fig. 2 under the various SSP-RCP scenarios. Lower emission pathways reveal how urban emissions can be reduced through increased mitigation, electrification and resource-efficiency commitments. Higher emission scenarios illustrate the dangers of business-as-usual development with high emission levels, however (Zhang et al. 2023). This emphasizes the need to tackle urban air pollution in addition to climate pressures in the Global South.

3. METHODOLOGY

The method of this study was secondary qualitative research design and examined urban pollution and climate change relationships in developing countries. Uses academic writing and authoritative reporting. IPCC (2022) presents significant evidence of the GHGs emitted by cities, the sources and magnitude of climate risks, and pathways to mitigate such risks. The study also includes 18 peer-reviewed journal articles relating to urbanization, air pollution, transport, energy, waste, governance and climate mitigation. These sources offer international, regional and city level evidence. Clear and specific criteria were used for the selection of literature. Sources were published from 2019 until 2026 and peer-reviewed (where relevant) and directly relevant to Urban Pollution and/or Climate Change or Climate Change Mitigation. Less attention

was devoted to contexts outside the greater part of the industrialized world (in non-English speaking countries, the Global South). The literature was analyzed thematically and comparatively. Major pollution sources were identified along with key themes and compared in determining impacts and effectiveness of climate change mitigation. This method contributes to its research goals to pinpoint similar challenges, distinctions and effective mitigation measures in urban areas from the developing world.

4. Environmental and Climate Impacts of Urban Pollution

4.1 Climatic Impacts

The pollution in cities plays a role in climate change via the emissions from transportation, energy production, industry and other urban activities. Luqman et al. (2023) correlate urbanization with the rise of CO₂ emissions where climate pressure is a function of carbon intensive development. There are also linkages between air quality improvement and climate impacts in India, suggested by evidence. The study by Miinalainen et al. (2023) shows the climate-focussed impacts of measures on air pollution. The results indicate that urban mitigation policies that have a positive effect on emissions of key pollutants can also yield positive impacts in both sectors. vulnerabilities of cities in developing-country contexts regarding the challenges of climate change. Environmental strains might occur due to fast urban development and escalating energy demand (de Oliveira and Bhuiyan ,2024). Hence, the pollution and GHG emission should be tackled together with respect to effective urban climate policy. It should also reflect on the fact that urban areas are facing greater environmental challenges as a result of climate changes. This is an enabling factor for integrated mitigation measures that help achieve emission reductions in order to enhance urban, environmental conditions.

4.2 Environmental and Health Impacts

Pollution in cities is a significant concern for the environment and health. Piracha and Chaudhary (2022) link the pollution in the air to urban heat island and human-health issues. The resulting stresses can contribute to a poor quality of life in cities. Another issue is the fine particulate pollution. Understanding the dispersion of PM_{2.5}, the use of green infrastructural spaces, and the impacts to human health from these areas is summarized by experts Li et al. (2023), who highlight the influence of urban conditions on PM_{2.5} exposure. Green infrastructure can help to mitigate exposure and enhance urban environmental conditions. Risks are particularly relevant in low- and middle-income countries, as the rapid urbanization can boost people's exposure to environmental risks and make communities more vulnerable. Ongoing air quality and environmental issues in these contexts. The degradation of air quality due to urban pollution leads to higher exposure to harmful air pollutants and raises heat and environmental stress in cities (Sooktawee et al., 2024). Under these joint pressures, the health vulnerability may be enhanced especially for vulnerable groups in urban areas who are exposed. The relation can thus be taken as figure 3 given below. Exposure may increase vulnerability to risks for vulnerable populations. All this supports the integrated approaches to climate and environmental policies and public health involving emissions reduction and pollution control along with protecting communities.



Figure 3: Pathway from Urban Pollution to Health Vulnerability
(Source: Self)

5. Mitigation Strategies in Developing Countries

5.1 Sustainable Transport, Clean Energy and Energy Efficiency

The transport and energy planning decisions in developing country cities must balance air pollution and GHG emissions. Public transport is one of the critical choices to consider as it can help to decrease private car use and transport-related emissions. Dharmala et al. (2022) demonstrate that measures to limit the impacts of air pollution in India can simultaneously achieve climate mitigation. Public transportation has to be reliable, affordable and assisted with proper infrastructure, however.

The climate impacts of urban transport electrification will be further reduced depending on the electricity source. In addition to electric mobility, renewable energy is also key. Gierałtowska et al. (2022) relate renewable energy and urbanization and CO₂ emissions and Fang et al. (2022) address the uptake of renewable energy in emerging economies. These studies combined drive towards cleaner energy systems. Energy efficiency is also important as this can lessen energy demand without the restriction of provision needed for operations of essential urban services.

The authors of Luqman et al. (2023) highlighted the importance of this for growing cities and its relationship with emissions. However, where energy demand is growing but investment is constrained by the lack of infrastructure, implementation is challenging. These pressures may grow in proportion to the rate of population growth. As a result, overall solutions involving the use of public transport, electrification, renewable energy and energy efficiency should be planned as a single entity. There is a demand for strategies which are cost-effective, local, and scalable in developing cities which cater to local infrastructure and energy conditions. This can enhance health; minimizing exposure to harmful urban pollutants. Individual projects need to evolve to city-wide change with financial support and long-term planning and coordinated urban governance.

5.2 Waste Management and Green Urban Planning

Another mitigation tool worth considering is waste management due to the effect of rapid urbanization that leads to a rise in municipal wastes. Bad handling, treatment and disposal practices can lead to pollution

and/or aggravate environmental pressures. Pérez et al. (2021) review municipal solid-waste management in cities of developing countries and highlight its significance. Batista et al. (2021) finds barriers and critical factors that have to influence sustainable waste management in developing countries. The results indicate that there is a need for effective systems and institutional strengthening for collection, recycling, treatment and the recovery of resources. More comprehensive climate and environmental benefits can be offered through green urban planning. Li et al. (2023) discuss the role GIs play with regard to exposure to PM_{2.5}. Singh et al. (2021) also highlight the integrated urban climate action opportunities in India. Considering the elements of land use, transport, energy and environmental quality together should be carried out in planning rather than separately.

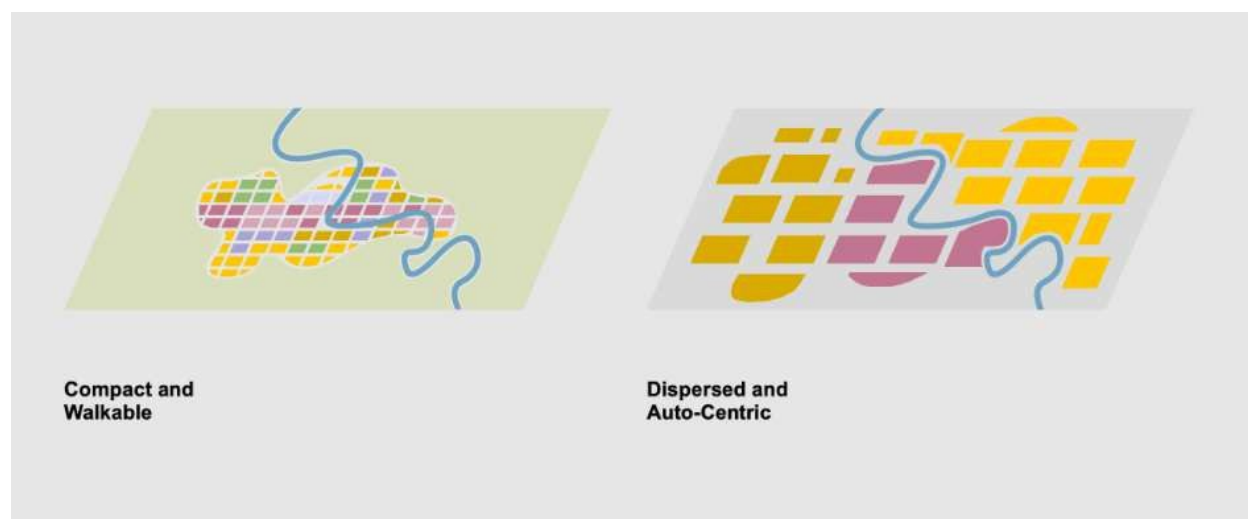


Figure 4: Urban form and implications for GHG emissions

(Source: <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>)

Sustainable, walkable communities put people, jobs and services within each other's reach. This can mitigate trips, encourage walking/bicycling and public transport. Dispersed and auto-centric areas are areas which isolate land use and extend travel distance and potentially contribute to higher transportation demand, energy use and emissions. The IPCC (2022) therefore confirms that the urban form can affect the choice of the mode, and determine different amounts of emissions. Compact development can contribute to reducing unnecessary travels, shift travels to travel modes with lower carbon footprints and enhance the efficiency of travelling. Therefore, the implementation of green planning should be considered in harmony with public transport, the availability of which are important, and with green infrastructure and a waste system that is accessible by the public.

6. Critical Evaluation of Mitigation Effectiveness

6.1 Effectiveness and Co-benefits

Commonality in urban mitigation efforts is a function of what combination of strategies is used and how they are adapted to local circumstances. Key climate and air-quality benefits can be provided through Transport measures. Dharmala et al. (2022) demonstrate the solutions provided by transport strategies towards tackling air pollution and climate change. The advantages rely on the top quality of public transportation, infrastructure, and the change to less high-emission travel. So, it isn't just about the technology being new to get a measurable assessment of transport improvement. What is more important is real changes in emissions and air quality. Renewable energy can also help the mitigation paradigm by decreasing the reliance on carbon intensive energy in the system. Gierałowska et al. (2022) link it to reduction of CO₂ emissions and demonstrate the role of renewable energy in the development of cities. However, if coupled with energy efficiency and electrification this is better achieved through renewable energy. Li et al. (2023) also

demonstrate the potential of these GI infrastructure solutions in combating PM_{2.5} exposure. This means that for every climate benefit there is a co-benefit for air quality and public health when mitigating. When climate mitigation and adaptation strategies are linked together, Sharifi (2021) shows that a range of co-benefits may arise. Similarly, point to potential for integrated urban climate action in India (Singh et al., 2021). These indicate that cities should resist one-off policies, and aim for holistic measures that are integrated.

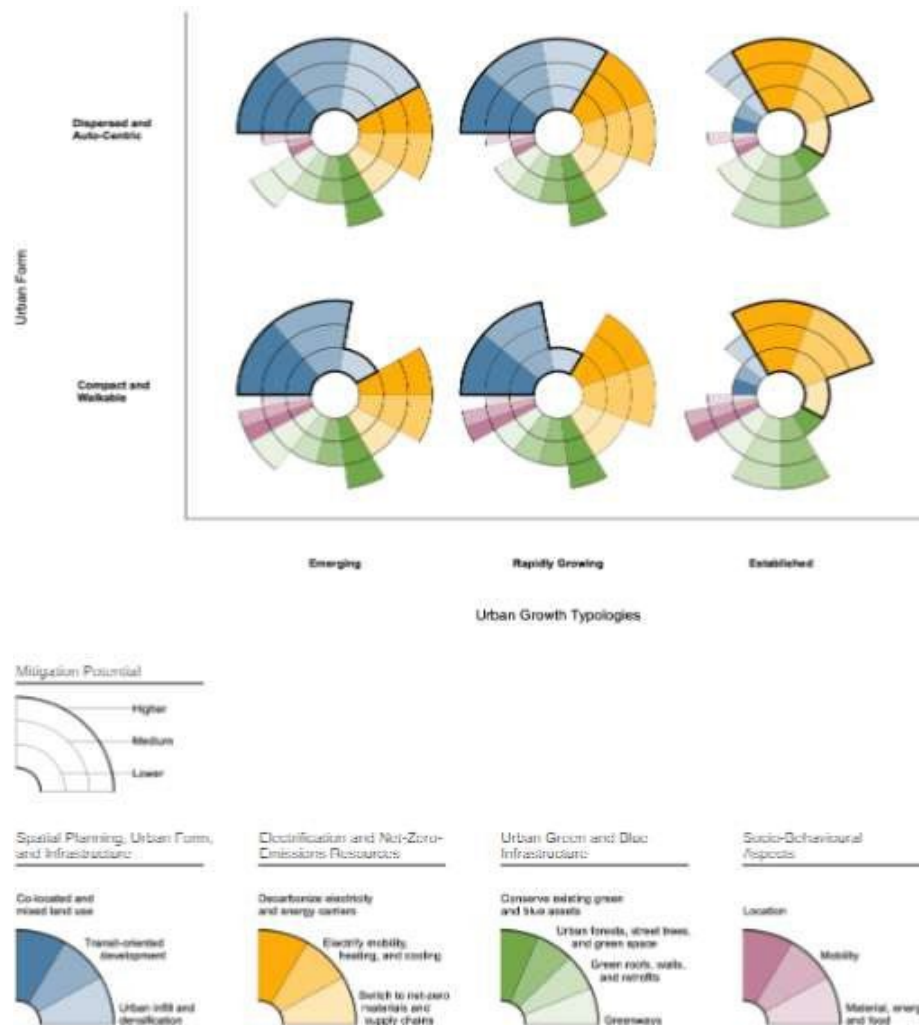


Figure 5: Priorities and potentials for packages of urban mitigation strategies
(Source: <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>)

The figure does support this evaluation by indicating that it is achievable by urban growth, but moreover, it is achievable by urban form. Therefore, there is no existence of any universal remedy. Public transport, spatial planning and green infrastructure, or behavioural measures, may be appropriate for Compact cities while electrification might be needed in other cities. The success will rely on the abilities implemented and the local context.

6.2 Governance, Finance and Implementation Challenges

The effectiveness of mitigation is dependent on technical solutions as well. A city can have access to clean technology but fail to produce results because of lack of governance, weak finance and poor infrastructure or weak implementation. The researchers, Addis et al. (2022) argue the role and significance of urban climate governance in shaping the implementation of climate action. Good institutions are thus required to help coordinate policies, track performance and enforce environmental criteria. Finance is yet another principal impediment. This brings up certain limitations on climate finance. Rapid population growth and increasing needs for infrastructure pose a challenge to developing-country cities due to their inadequate financial resources (Chowdhury and Jomo, 2022). It makes it challenging to invest on a large scale in renewable energy, public transport, waste systems and green infrastructure. This could therefore further exacerbate the difference between actual mitigation and the desired effect, especially if there is financial constraint.

It has been observed that institutional capacity has great influence over the method of waste-management and its associated outcomes. Batista et al. (2021) list down the barriers to sustainable waste management in the developing countries. Other than that, intractable problems of coordination and insufficient resources and implementation can sap the effectiveness of otherwise feasible policies. A broader urban case-study issue has also been brought up: the context of urban climate challenges in developing countries, as mentioned by de Oliveira and Bhuiyan (2024); and the practical implementation in urban climate action and its relevance to cities in India (Singh et al. (2021)). The results of these studies indicate that policy effectiveness in mitigating values extends beyond just policy design. This pathway for implementation is then read as:

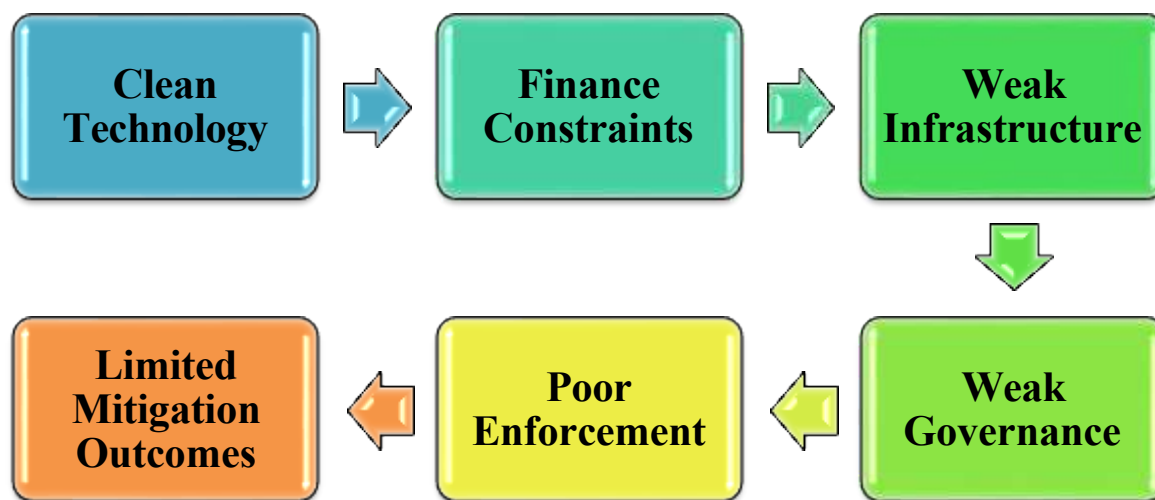


Figure 6: Mitigation Implementation Pathway

(Source: Self)

Figure 6 illustrates the need for integrated governance, robust financial support and institutional capacity and effective monitoring in developing countries. There is no simple question of whether or not there is a technology available for mitigation. It is whether cities can afford the means to effectively put them in place and see significant declines in pollution and emissions.

7. DISCUSSION AND FUTURE DIRECTIONS

Policy Implications

Urban pollution poses a climate and urban development problem in developing countries – and cities need integrated responses, as shown by de Oliveira and Bhuiyan (2024). Thus, policies need to be linked with air-quality management and climate mitigation. Dharmala et al. (2022) found cleaner transport can deliver emissions and air-quality benefits as well. Like that, renewable energy and efficient infrastructure and sustainable urban planning should be prioritised.

Future Research

Implementing bodies, however, is what determines the effectiveness of mitigation. Effective urban climate governance is pointed out by Addis et al. (2022) and another key challenge for developing countries is climate finance (Chowdhury and Jomo 2022). Further research is required to solidify the city level evidence on emissions and to provide a comparison of the emissions mitigation outcomes in developing countries. However, Luqman et al. (2023) and Sooktawee et al. (2024) note the need for better evidence also on the interaction between urban emissions and air-quality. However further research should also include long-term effectiveness, equity impacts, integrated climate and air quality modelling.

8. CONCLUSION

Pollution puts a significant contribution to climate change in urban areas, with regards to transport, energy consumption, industry and waste. The results of this article demonstrate that mitigation actions can lead to a significant reduction in GHG emissions as well as local pollution, which are environmental and health co-benefits. Nevertheless, they are not effective in developing countries due to lack of funding, infrastructure issues, governance problems, and inconsistencies of application. Efficient public transport, renewable energies, waste and compact city development thus need coordinated policy measures. The data also indicates that mitigation methods are not standard and are more effective in communities with different urban development and/or development conditions. Combining technological solutions with more robust institutions, climate finance and inclusive planning is therefore necessary for developing countries. In general, the proper coordination of the policies of climate and air quality is the best tool for reducing urban pollution and ensuring sustainable and resilient urban development.

REFERENCES

1. Addis, T.L., Birhanu, B.S. and Italemahu, T.Z., 2022. Effectiveness of urban climate change governance in Addis Ababa City, Ethiopia. *Urban Science*, 6(3), p.64.
2. Batista, M., Caiado, R.G.G., Quelhas, O.L.G., Lima, G.B.A., Leal Filho, W. and Yparraguirre, I.T.R., 2021. A framework for sustainable and integrated municipal solid waste management: Barriers and critical factors to developing countries. *Journal of Cleaner Production*, 312, p.127516.
3. Chowdhury, A. and Jomo, K.S., 2022. The climate finance conundrum. *Development*, 65(1), pp.29-41.
4. de Oliveira, J.A.P. and Bhuiyan, S., 2024. Cities and climate change in developing countries. *Urban Climate*, 58, p.102169.
5. Dharmala, N., Kholod, N., Chaturvedi, V., Ghosh, P.P., Mathur, R., Bali, S., Behera, A., Chamola, S., Clarke, L., Evans, M. and Horowitz, R., 2022. Win-win transportation strategies for India: Linking air pollution and climate mitigation. *Energy and Climate Change*, 3, p.100072.
6. Fang, J., Gozgor, G., Mahalik, M.K., Mallick, H. and Padhan, H., 2022. Does urbanisation induce renewable energy consumption in emerging economies? The role of education in energy switching policies. *Energy Economics*, 111, p.106081.
7. Gierałtowska, U., Asyngier, R., Nakonieczny, J. and Salahodjaev, R., 2022. Renewable energy, urbanization, and CO2 emissions: a global test. *Energies*, 15(9), p.3390.
8. Henderson, J.V. and Turner, M.A., 2020. Urbanization in the developing world: Too early or too slow?. *Journal of Economic Perspectives*, 34(3), pp.150-173.
9. Li, L., Zheng, M., Zhang, J., Li, C., Ren, Y., Jin, X. and Chen, J., 2023. Effects of green infrastructure on the dispersion of PM2.5 and human exposure on urban roads. *Environmental Research*, 223, p.115493.
10. Luqman, M., Rayner, P.J. and Gurney, K.R., 2023. On the impact of urbanisation on CO2 emissions. *NPJ Urban Sustainability*, 3(1), p.6.

11. Miinalainen, T., Kokkola, H., Lipponen, A., Hyvärinen, A.P., Soni, V.K., Lehtinen, K.E. and Kühn, T., 2023. Assessing the climate and air quality effects of future aerosol mitigation in India using a global climate model combined with statistical downscaling. *Atmospheric Chemistry and Physics*, 23(6), pp.3471-3491.
12. Pérez, L.E., Ziegler-Rodríguez, K., Pérez, A.T.E., Vázquez, Ó.C. and Vázquez-Rowe, I., 2021. Closing the gap in the municipal solid waste management between metropolitan and regional cities from developing countries: A life cycle assessment approach. *Waste Management*, 124, pp.314-324.
13. Piracha, A. and Chaudhary, M.T., 2022. Urban air pollution, urban heat island and human health: a review of the literature. *Sustainability*, 14(15), p.9234.
14. Sharifi, A., 2021. Co-benefits and synergies between urban climate change mitigation and adaptation measures: A literature review. *Science of the total environment*, 750, p.141642.
15. Singh, C., Madhavan, M., Arvind, J. and Bazaz, A., 2021. Climate change adaptation in Indian cities: A review of existing actions and spaces for triple wins. *Urban Climate*, 36, p.100783.
16. Sooktawee, S., Kanabkaew, T., Lalitaporn, P., Khan, M.F., Permadi, D.A. and Limsakul, A., 2024. Crucial air quality, atmospheric environment, and climate change in low-and middle-income countries. *Frontiers in Environmental Science*, 12, p.1412771.
17. Wang, S., Gao, S., Li, S. and Feng, K., 2020. Strategizing the relation between urbanization and air pollution: Empirical evidence from global countries. *Journal of Cleaner Production*, 243, p.118615.
18. Zhang, D., Martin, R. V., Bindle, L., Li, C., Eastham, S. D., van Donkelaar, A., & Gallardo, L. (2023). Advances in simulating the global spatial heterogeneity of air quality and source sector contributions: insights into the Global South. *Environmental Science & Technology*, 57(17), 6955.