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CLEAN AIR ASIA

IBAQ Integrated Programme for Better Air Quality in Asia

A Primer On Critical Issues In Cost-Benefit Analysis For Air Pollution Reduction Strategies In Indian Cities

Economics Of Air Quality Management

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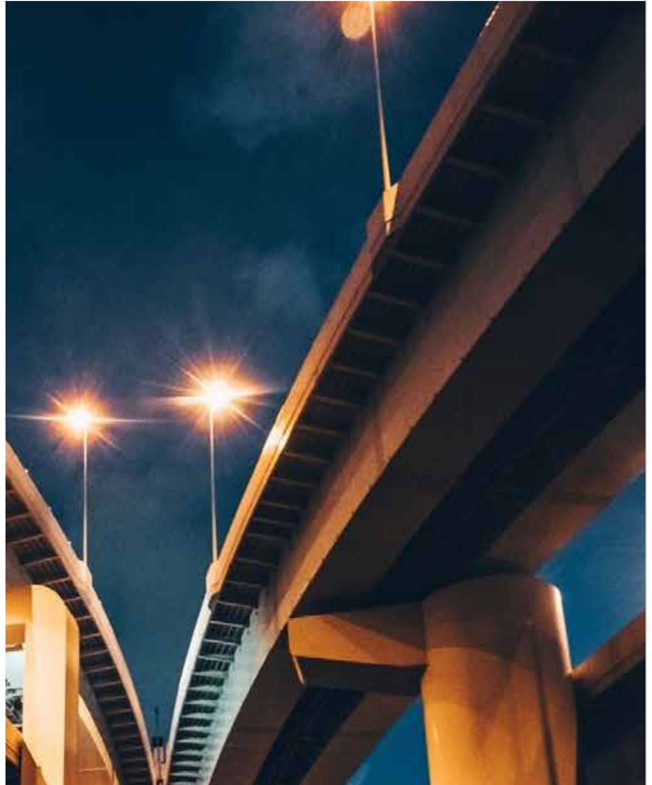

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The discipline of economics arguably should play a central role in meeting the sustainable development challenges. The core question at the heart of sustainable development is how to allocate the finite resources of the planet to meet 'the needs of the present, without compromising the ability of future generations to meet their own needs[1] '

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I. ABOUT THE PRIMER

We are at the doorstep of an unprecedented public health crisis. Development steered by rapid urbanization has caused environmental damages to the extent that one can't help but question fundamentals of how we operate. Unbreathable air quality is one such epitome of the unsustainable system.

Globally, 4.2 million deaths are caused due to ambient air pollution[2]. In India, the situation is particularly severe. 15 of the world's most polluted cities are housed in the country[3], and almost every second child in the country's capital is suffering from irreversible lung damage[4], whilst millions more forced to live a poor quality of life because of air pollution. Thus, making air breathable is a major priority, and we need to act swiftly and incisively. Whilst we have only recently started to deal with the problem, the situation is worsening at an accelerated pace. Time at hand is short, the costs of opportunities are still unclear, and we do not know the magnitude of the tradeoffs.

In such a scenario, it is encouraging that the Government of India has chalked out the comprehensive National Clean Air Programme working in tandem with the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs). As expected, one of the first actions that have been mandated for cities is to develop comprehensive 'Clean Air Action Plans'. The aim of these plans will give efforts a direction and sense of mission, however, many of them lack economic perspective at this stage. Incorporating the economic dimension in these plans will strengthen them by aiding in better planning, prioritizing, budgeting, cost reduction, and even impact evaluation, all of which will help maximize outcomes (cleaner air), given time and resource constraints.

This primer is being launched to complement current efforts to abate air pollution, and to raise attention on four critical issues, whose integration in air quality management plans should lead to better decision making: optimum interventions, cost estimations, cost rationalization and impact assessment.

This primer on the 'Economics of Air Quality Management' is a joint initiative by Clean Air Asia and Envecologic. We hope it will be useful for urban planners, municipal corporations, policy makers, pollution control boards and civic authorities who are concerned with the issue of air pollution.

Prarthana Borah
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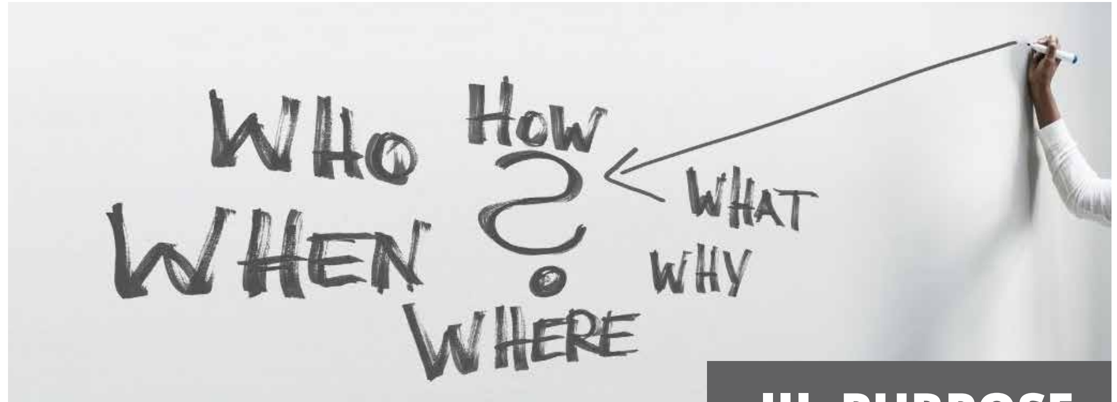
II. OBJECTIVE

Highlighting critical issues on the 'Economics of Air Quality Management' to provide basis for discussion with stakeholders, which should lead to more efficient decision and policy making. This primer can be used to kickstart discussions and debate, in order to improve planning and execution, and paves the way to the identification of interventions, estimation of costs and benefits, evaluation of impact, and prioritization of interventions. This is undertaken in order to support air pollution abatement efforts at national, state and, above all, district/city level.



III. PURPOSE

While 'objective' mainly defines 'what', 'how', and 'who','purpose' imparts greater rationality to the Economics of Air Quality Management. The overarching purpose of this document is to kickstart the debate that will, we hope and in time, lead to the development of a standard framework and to guidelines on 'Economics of Air Quality Management in India'. The debate, and the future manual, will become key tools in the toolkit Clean Air Asia is making available to support urban planners, municipal corporations, policy makers, pollution control boards and various civic authorities who are directly or indirectly concerned with the issue of air pollution in developing effective air pollution reduction strategies for cities in India.

IV. STAKEHOLDERS AND USERS

Who should then be the stakeholders and the primary users of this primer?

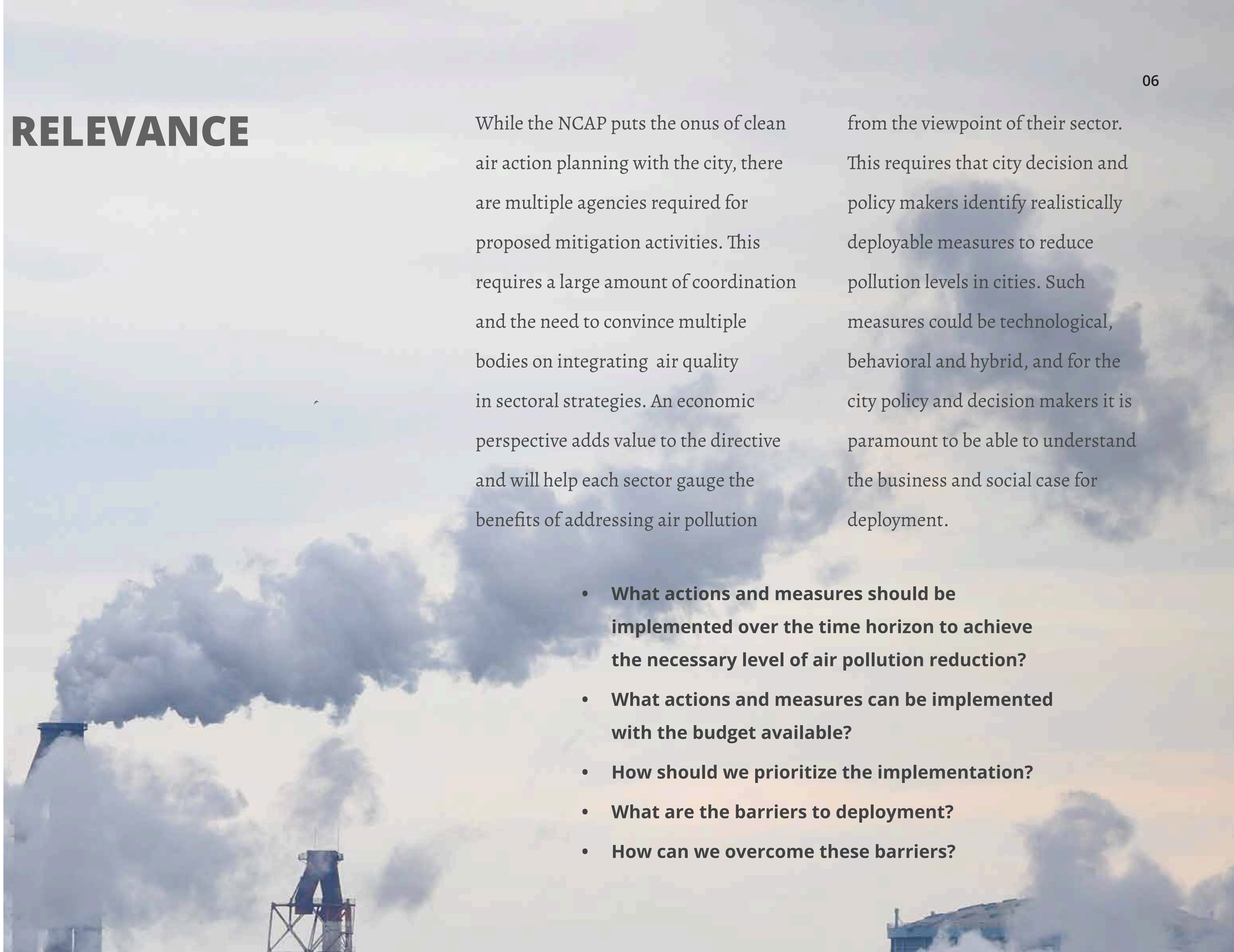
The primer is principally thought as an instrument to trigger the debate on critical issues surrounding the cost benefit analysis.

As such, the stakeholders in this process are :

- Policy makers in cities.
- Decision makers in the public administration who make key decision on actions that may influence air quality.
- Private enterprise leaders whose businesses impact the urban arena, and have an important role to play in reducing air pollution from their operations' .
- Citizens, citizen groups, both formal and informal, whose health and wellbeing are influenced by air quality and have a role to play in pressurizing policy and decision makers as well as implementing behavioral change at individual and household level.
- Charities, NGO and advocacy institutions that have a primary role to play with innovative and transformative ideas, and in monitoring the implementation of air quality plan.

1. CONTEXT & RELEVANCE

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, launched the National Clean Air Programme (NCAP), which proposes strategies to reduce air pollution. In 2019, the NCAP identified 102 (later increased to 122) non-attainment Indian cities on the basis of continuous violation of the National Ambient Air Quality Standards (NAAQS)]. These 122 cities have also been directed to prepare Clean Air Action Plans with approval from the Central Pollution Control Board. Except for a few, current Clean Air Action Plans are wish lists of measures to be adopted and activities to be done to reduce air pollution.



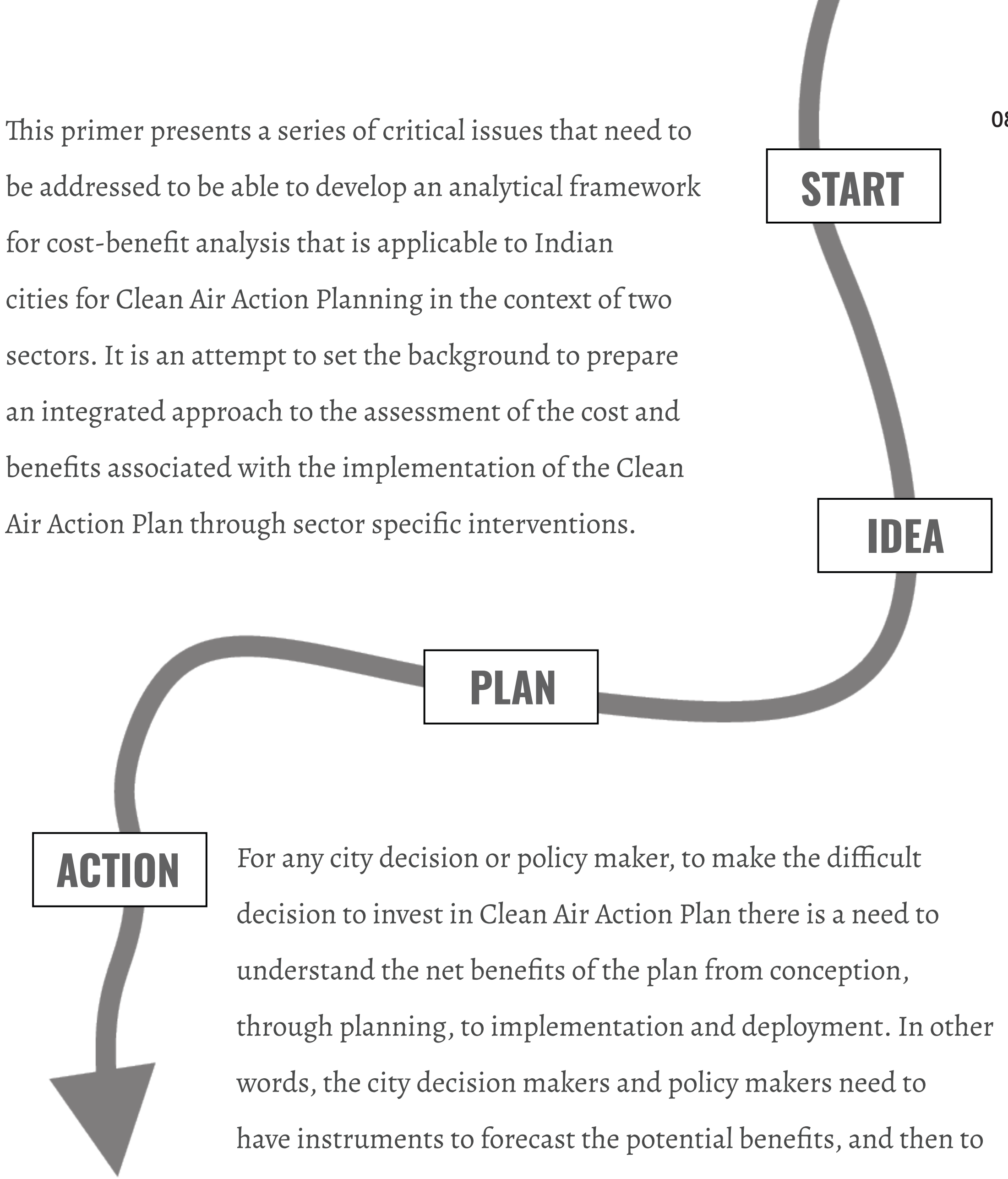
While the NCAP puts the onus of clean air action planning with the city, there are multiple agencies required for proposed mitigation activities. This requires a large amount of coordination and the need to convince multiple bodies on integrating air quality in sectoral strategies. An economic perspective adds value to the directive and will help each sector gauge the benefits of addressing air pollution from the viewpoint of their sector. This requires that city decision and policy makers identify realistically deployable measures to reduce pollution levels in cities. Such measures could be technological, behavioral and hybrid, and for the city policy and decision makers it is paramount to be able to understand the business and social case for deployment.

- **What actions and measures should be implemented over the time horizon to achieve the necessary level of air pollution reduction?**
- **What actions and measures can be implemented with the budget available?**
- **How should we prioritize the implementation?**
- **What are the barriers to deployment?**
- **How can we overcome these barriers?**

A blueprint, that is a (standard) integrated framework-based approach to the economics and finance of air pollution reduction strategies may be an important instrument the cities can use to answer these questions.

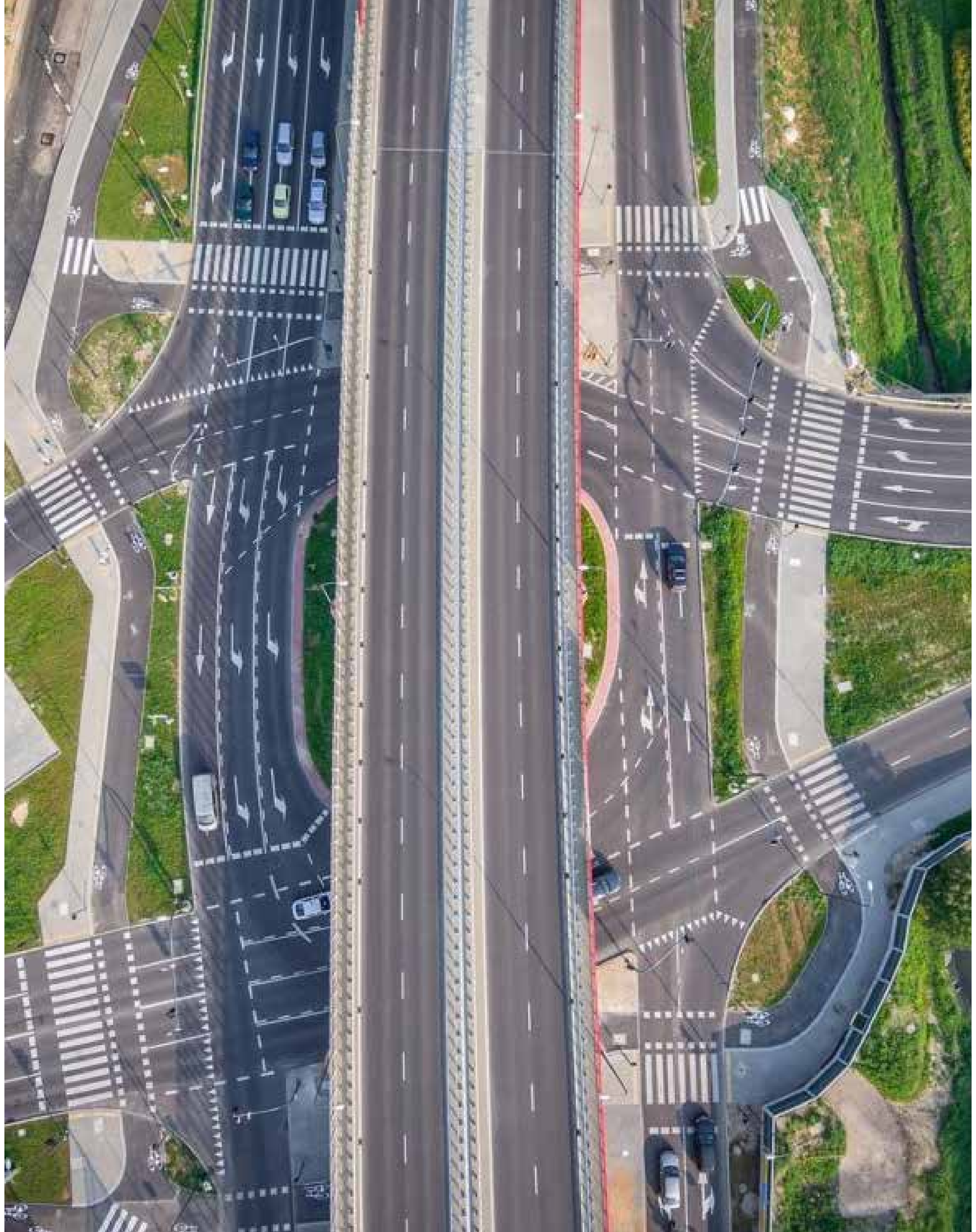
An important aspect of such framework is the cost benefit analysis, or CBA. With CBA, the costs incurred (initial and running) to implement and deploy the actions and measures are compared to the ancillary benefits (and co-benefits) achieved. For example, benefits are reduction in PM2.5 and in PM10 concentrations in the air of the city and the co-benefits can be in the form of lives saved by better air quality or improved Disability-Adjusted Life Year (DALY).

This primer presents a series of critical issues that need to be addressed to be able to develop an analytical framework for cost-benefit analysis that is applicable to Indian cities for Clean Air Action Planning in the context of two sectors. It is an attempt to set the background to prepare an integrated approach to the assessment of the cost and benefits associated with the implementation of the Clean Air Action Plan through sector specific interventions.



For any city decision or policy maker, to make the difficult decision to invest in Clean Air Action Plan there is a need to understand the net benefits of the plan from conception, through planning, to implementation and deployment. In other words, the city decision makers and policy makers need to have instruments to forecast the potential benefits, and then to monitor, report and evaluate the process of implementation in order to compare the effective benefits achieved to such forecast.

The measures in the Clean Air Plan requires interventions on the major sectors of the economy, may drive changes to infrastructure, and include transforming the structure of industries, such as clean use of energy, measures for industrial pollution control, measures for motor vehicle pollution control, education, and capacity building. As we discussed, such measures can be technological, behavioral, or a combination of the two, and the evaluation of the costs and benefits of the three different types of measures may be very different.



To illustrate the critical issues that may emerge when attempting such evaluations, this primer looks as two aspect, to provide a reference for the identification of similar criticalities in other Clean Air actions or measures. Identifying such critical issues is of practical significance for advancing the long-term effective mechanisms of the cost-benefit analysis of India's city level clean air interventions.

The achievement of air quality objectives is a long-term and difficult mission, and air quality improvement becomes increasingly difficult with the strengthening and advancement of air quality control measures. In terms of improving the infrastructure, for example the energy and transportation infrastructure, certain regions remain dependent on developing traditional industries where the structural problems of pollution remain prominent.

In particular, Small and Medium sized Enterprises, which constitute the backbone of the traditional economy, and that are experiencing structural barriers to transitioning to a green model, may fall outside National Clean Air Programe and Clean Air Action Plan, and are in need of specific measures. Thus, any economic framework we develop would need to be sufficiently flexible to adapt to the local socio-economic and environmental conditions, that may be very different between areas, whilst still supporting the efficient design and implementation of the air pollution reduction plans.

For example, adjusting the transport infrastructure is a disruptive task, yet significant opportunities for

improving freight movement are present. While pursuing efforts to advance environmental control and improve air quality improvements there is a need for investigating multiple issues of transportation and find the best local approach.

Finally, any framework would need to include co-benefits and integrate with other existing strategies that are already under implementation, such as climate mitigation strategies, climate adaptation strategies and SDG achievement strategies, to avoid wasting precious and scarce financial resources on reimplementing actions and measures that are already included in other plans, and to avoid the issue of double counting.

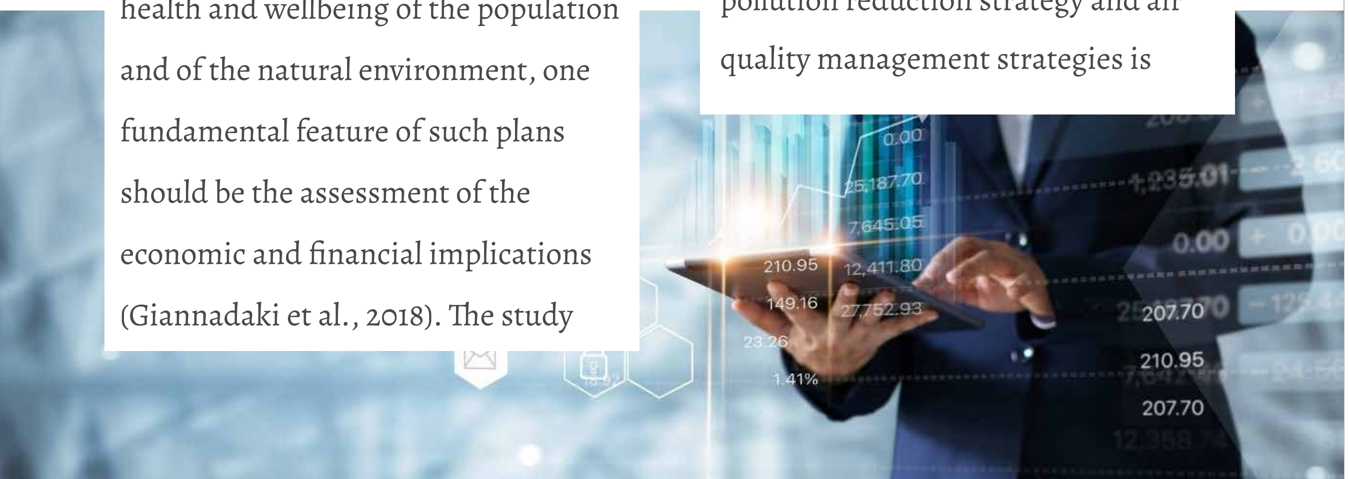
2. BACKGROUND TO THE WORK

Air pollution is increasingly being acknowledged as a major threat to human health causing an estimated 7 million deaths annually: in other words, one in eight deaths globally can be linked back to air pollution. The negative implications of air pollution do not end in increased mortality rates (Landrigan, 2017; Martuzzi, 2019). We know that air pollution affects Disability Adjusted Life Year (DALY), the Year of Life with Disability (YLD) and the Year of Life Lost (YLL), three important indicators of health wellbeing, see e.g. (Gu et al., 2019). We also know that it has major negative impacts on productivity of labor because it causes absence from work, it increases vulnerability to other illnesses (Gupta et al., 2020), and it has been proven to reduce intellectual and physical productivity in the workforce (Kahn and Li, 2020; Zhang et al., 2018).

The overall economic cost of air pollution is extraordinary and impacts

all sectors of the economy (Croitoru and Sarraf, 2017; Desaigues et al., 2011; Pearce, 1996; Quah and Boon, 2003). According to an OECD study, the annual global welfare costs resulting from outdoor air pollution are estimated to reach $18-25 trillion in 2060, up from $3 trillion in 2015 (Landrigan, 2017, OECD,2016). While there cannot be a one-size-fits-all approach, combination of strategies including sound policy framework, incentivizing the adoption of end-of-pipe technologies, creating disincentives through environmental tax, implementing air quality standards etc. will certainly help avoid the worst impacts of air pollution (Pearce, 1996).

Designing air pollution reduction plans and air quality management plans is rapidly becoming a priority for society as a whole and for governments at all scales, from the international to the city scale, see e.g (Foell et al., 1995; Gwilliam et al., 2004; Han, 2010; Li et al., 2004; Schöpp et al., 1998; Shrivastava et al., 2013; Zheng et al., 2016). Whilst the focus of these plans should be the assessment and the introduction of measures to reduce air pollution and manage air quality to improve health and wellbeing of the population and of the natural environment, one fundamental feature of such plans should be the assessment of the economic and financial implications (Giannadaki et al., 2018). The study and assessment of such implications, forms part of the economics of air pollution reduction strategy and air quality management strategies. It includes the study assessment and evaluation of costs, benefits, social (Wong Eva Y et al., 2004) and environmental co-benefits , direct and indirect effects on the economy, as well as financial mechanisms and effects of air pollution reduction and air quality management strategies. Whilst a comprehensive and systemic framework for the economics air pollution reduction strategy and air quality management strategies is



still missing, it has been proven that reducing emissions can benefit society not only from a health and wellbeing perspective, but also from an economic (Gouldson et al., 2011, 2013b) and financial perspective ((Gouldson et al., 2015, 2013a)).
The implications are complex and generate positive systemic effects.

For Example,
On the one hand air pollution reduction contributes directly to human health improvement, on the other it improves food security and food quality and reduces crop damage, which in turn contribute further to human health improvement, generating a positive feedback cycle.

At the same time, clean air contributes to the improvement of the natural environment through improved ecosystem services, such as urban and peri-urban forests (Paoletti et al., 2010), and thus to our ability to mitigate and adapt to climate change, which makes society more resilient and contributes further to health improvement.

However, while the debate on how air quality influences human health has evolved and reached the media and the general public, the study of the economic and the financial dimension is still underdeveloped. In particular, scientific and commercial literature on the economics of air quality management strategies at city level is still relatively scarce, and we do not yet have an accepted standard and integrated, systemic framework that may be used by decision and policy makers.

Yet, whilst reducing air pollution and introducing air quality management practices is an absolute priority, an economic and financial perspective conducted using robust methods and used with intelligence, could help decision makers and policy makers make better and more informed decision and use the scarce economic and financial resources efficiently on the one hand, and increase the acceptance by the private actors and the general public on the other.

For example, a thorough understanding of the economic benefits and co-benefits could validate stringent air quality regulations as it can demonstrate how air pollution control policies may contribute positively to economic growth, see

e.g (Amann, 2017; Jiang et al., 2020; Kinney and Nori-Sarma, 2011), reinforcing the case for integrating air quality principles into mainstream planning and policymaking. Thus, the inclusion of an economics component can help assist policy makers in developing regulations that support achievement of both good environmental quality as well as better human health standards at less costs. Furthermore, economics can provide a framework to unfold practical aspects of uncertainty, timing and evaluation of costs and benefits which can make air pollution regulation and policy more effective through realistic planning taking into consideration timelines, behaviour and finance. The implementation of such strategies would indeed require the planning, design and implementation of both supply side and demand side technological, behavioural and hybrid measures.

Such measures could have important implications on the social and economic life of the city at all scales, and may require cities to redesign the infrastructure, and to modify the space planning processes and the regeneration and redevelopment processes.

These changes in turn have profound impact on the economy: employment and other hardly won Sustainable Development Goals related target such as poverty reduction, gross value added per person, ability to attract investment, and indictor of social justice such as the Gini index and Human Development Index may be affected. Gender, equity and social justice goals may also be impacted by this radical transformation of the economy, with wealth gaps and health gaps widening further if critical counter measures are not put into effect, see (Clark et al., 2014) as a case in point.

Such counter measures, for example fiscal policies, such as tax rebates and tax credits, incentives and subsidies (López and Palacios, 2014), need to be carefully tuned both from a social and economic perspective in order to achieve the air quality standards and the sustainable development goals.

Yet, decision and policy makers in cities are under pressure to make swift and radical decisions, and the range of options available is daunting. There are hundreds of options and measures to reduce air pollution and improve air quality, but there is often a lack of information on their realistic social and economic performances, and on approaches to prioritize intervention.

This is in turn a major barrier to adoption, and makes it hard to develop, business economic and social cases for investment, which makes it difficult for cities to harvest the indispensable funds.

Decision makers and policy makers often find themselves asking:

- **What are the priority actions?**
- **What is the best choice I can make within the available budget?**
- **How do I convince a funder (whether public or private) to invest in the strategy?**

To answer these questions, policy and decision makers need robust yet friendly frameworks that can support them in making decisions and promoting policies. A robust integrated economic (and financial) framework would help prioritise, distribute resources and convince funders to invest in such plans. Whilst a standard and integrated framework is not yet available, several candidates exist.

Whilst a standard and integrated framework is not yet available, several candidates exists. On the one hand we have well developed and accepted approaches to the economics of low carbon strategies. They range from the ELCC (also known as Mini Stern Review) to the MAC curve-based McKinsey approach. Such approaches have pioneered economic frameworks to support decision making in cities, and they can be extended and integrated to other sources of air pollution, offering a well-tested systematic approach. (Gouldson et al., 2013b, 2013a, 2012a, 2012b).

On the other hand, we have a broad range of well tested Cost Benefit Analysis approaches with a relatively long history of application, trials and failures, which can be put to use to cover the costs benefits analysis, which is one of the most important pillar of the economics of air quality management plans. The most notable of these CBA frameworks are in use and are recognised as robust tools by policy makers and decision makers at different scales, from the UN agencies and programmes, to macroregional policy making bodies such as the European Union, to government agencies.

Finally, several toolkits are currently under development, testing and validation. These toolkits have not gone through the trial, fail and adapt process that allows frameworks to be robust and accepted by the wider community, and are not widely available yet, but show promising ability to integrate co-benefits within the air pollution management plans. Whilst some of these tools have been so far used at different scales and they can be tuned and parametrized to work at the city and metropolitan scale.

In India, the national government's clean air mandate has started to take shape in terms of the 2018 National Clean Air Programme (NCAP). Under the programme 122 non-attainment cities have been identified with high air pollution levels and were first required submit the city level clean air action plans. (Ganguly et al., 2020)

The NCAP sends important and significant signals regarding the economics of air pollution management strategies. First, the inclusion of Ministry of Finance among the promoters of the implementation of the program highlights the importance of the economic and financial aspects. Second, the involvement of Department of Economic Affairs (DEA) in discussion on the funding mechanism for NCAP with reference to air pollution abatement schemes shows that the linkages between economic, finance and implementation are being embedded in the process . Third, there is explicit mention of the need for economic and financial considerations across the whole plan.

Close assessment of the city plans indicates that most of them could be improved through economic and financial considerations. Underdeveloped economic and financial considerations are making decision and policy making less effective, efficient and efficacious, and reduce and constraint the ability to plan budget, control costs exploit the opportunities, benefits and the co-benefits, or assess the social impact the proposed action plan can achieve.

The availability of a standardized systemic and integrated framework for the economics of air pollution reduction and air quality management strategies that can be applied by city decision makers and policy makers should improve the ability to deliver effective strategies at the city scale. This framework in the intention of the authors should be complemented by a socio-economic scenario-based toolkit and by guidelines on the development of financial instruments for the financing of the measures contained in the air pollution reduction and air quality management strategies.

The aim of this document is then to provide a first small step in the development of such framework. For this reason, in the followings we highlight some critical issues in the development of one of the pillars of the framework, the cost benefit analysis, and we open them to discussion and comments to the community of experts, policy makers, decision makers, professionals, practitioners, scholars.

Addressing such critical issues through a participatory process involving the major stakeholders will constitute a robust basis for the development of the standardised integrated approach to the economics of air pollution reduction and air quality management strategies for Indian cities.

3. CRITICAL ISSUES FOR THE DEVELOPMENT OF COST BENEFITS ANALYSIS

Rationale

This Economic Framework has been developed to impart strength to the air quality management in India. As noted in preceding sections, four areas which are crucial in ensuring that efforts to improving air quality deliver results pertain to identifying opportunities, planning/budgeting, cost rationalization and evaluating efforts.

This framework offers a set of guidelines enabling authorities to achieve the ultimate objective of improving air quality from decision making and planning through implementation and evaluation, given limitations such as financial constraint, time constraint etc.

Figure 1 illustrate the *Economic Framework*, with its four main *value streams and economic tool* under each, as stated :

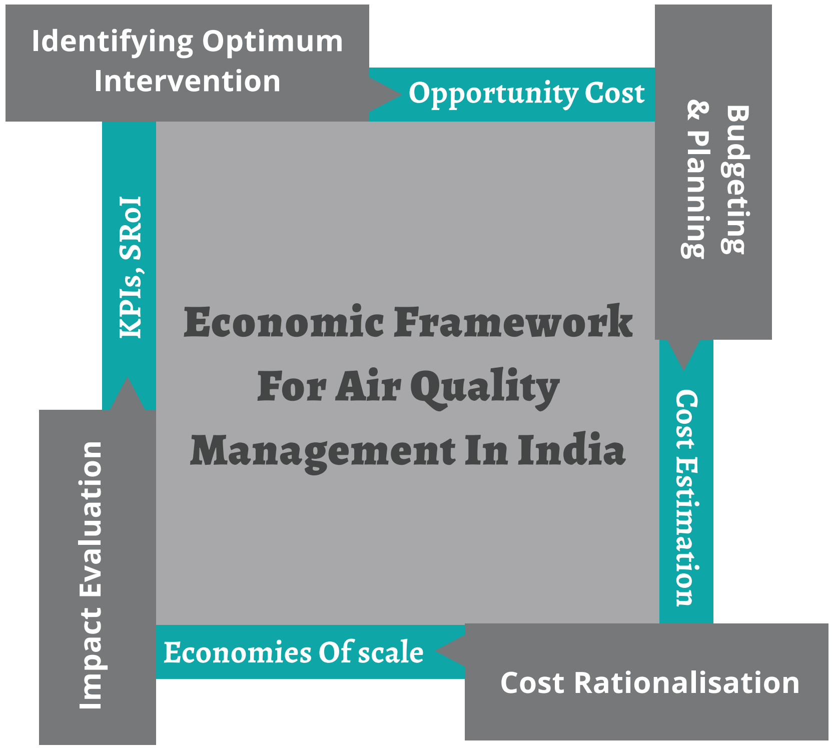


Figure 1: Economic Framework for Air Quality Management

Table 1: Economic Value Streams & Tools

Value Stream	Economic Tool
Identifying Optimum Intervention	• Opportunity Cost • Production Possibility Frontier
Cost Estimation	• Should-cost Estimation • Value Chain Approach
Cost Rationalization	• Economies of Scale
Impact Evaluation	• Key Performance Indicators (KPIs) • Social Return on Investments (SRoI)

While the principle of each of these value streams and tools can be used at any point in a project implementation, even in combination wherever required, they do also particularly play exclusive role in various stages, as indicated in Figure 2.

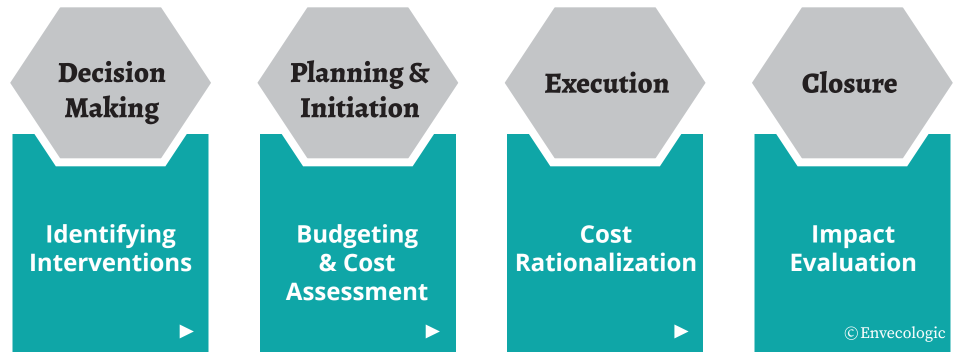


Figure 2: Economic Value Stream mapped to Clean Air Project Stages

By and large, consideration of economic dimensions is crucial right from the stage of defining 'what to do'. The fundamental knowledge of cost principles forms the basis of opportunity cost, cost determination, an even cost rationalization, all of which have emerged from the traditional neo-classical economic wisdom. Greatest plans committing the most promising outcomes are worthless if they aren't practical or executable. The most significant rationale of this framework is that it ensures and focuses on improving actionability of air quality management plans.

3.1 Identifying Optimum Intervention

3.1.1 Why is it important?

At a time when air pollution is leading to public health crisis, implementing just about any solution that promises to reduce pollution is not sufficient. This is because we have limited time and resource to make a difference. Hence, it is prudent to assess the solutions after mapping them against the dominant pollution source and passing them through optimization tests.

3.1.2 Scarcity

Economic principles are fundamentally driven by the consideration that we do not have the ability to satiate all our wants and the need to make choices arise because there is scarcity.

We cannot possibly undertake all measures to combat air pollution at the same time because of scarcity of resources, including money, manpower, skills, and capacity, information, time. Furthermore, governments operate on a finite and often limited budget, which need to be divided amongst a number of items for public welfare.

As example, we can consider thought experiment where the local government has ₹ 100 to spend on welfare measures, such as reducing air pollution or building hospitals. The local government has a range of options going from spending all money on air pollution reduction, and spending none on hospitals, and vice versa. In this scenario, with a finite budget, every additional rupee spent on air pollution abatement means that a rupee less is available for hospitals. Governments do not have enough budget allocated for air quality management hence they have to trade-off the implementation of some air quality measures against the satisfaction of other needs of the citizens. In such a resource and budget constrained situation, prioritizing interventions is essential.

Whilst economics cannot and should not be the main driver of decision making and policy making on critical issues that can affect the health and wellbeing of the citizens such as air quality or climate change mitigation and adaptation, it can offer us some instruments that can support decision makers in their decision-making processes by giving insights on resource allocation and distribution. In the following section we introduce three of such concepts and we look at how to use the corresponding indicators in a very simple case, a thought experiment. Whilst such though experiments are conceptually interesting and can help us understand a concept, they are not realistic, and the decision and the policy makers need to recognize that the process of modelling the economic costs and benefits is a complex systemic task.

3.1.3 Opportunity Cost

On instrument that local government decision makers can use to try to identify the optimum air quality management interventions is the Opportunity Cost.

The Opportunity Cost is the costs you incur because when you make the decision to choose one intervention, you forego the opportunity to make alternative decisions, i.e. you cannot choose alternative interventions, because you have used up your budget: all the costs and the benefits from alternative interventions are lost or foregone.

To calculate the opportunity costs, you need to consider the different feasible alternatives, hence opportunity cost only exists when there are at least two alternatives, and the decision maker has to select one. In such a scenario, selecting one over the other implies that the value of the rejected choice is given up.

This "sacrificed" value is the opportunity cost of the choice made. In other words, it is the loss of potential gain from one alternative, against the chosen one[5].

For example, if the government has just enough budget to either build roadside pavements or buy mechanized road sweepers, then opportunity cost of the former would be the reduction in pollution achieved by the sweeping machines.

3.1.4 Tradeoff

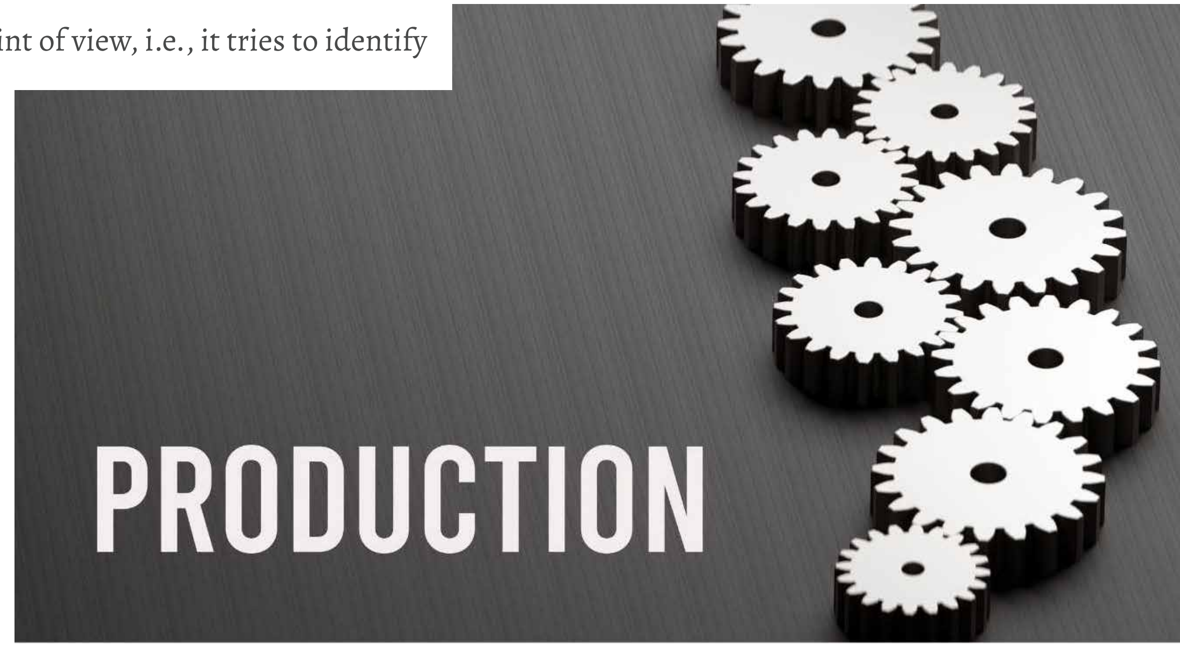
Introducing the concept of opportunity costs also introduces the concept of tradeoff. You have a tradeoff whenever you have a limited budget and you need to choose among different interventions, that can be implemented in toto or in part, and to do so you need to establish how much of each intervention you can implement and how much of each intervention you need to forfeit within the budget you have. This exchange in value between the different interventions is called a *tradeoff*.

The coal capital of India, Dhanbad, Jharkhand, has deployed six water sprinkling vehicles as opposed to just two mechanical sweepers. Water is scarce in the city, while pollution due to particulate matter is high, especially from roadside suspension dust, necessitating its removal rather than recurring settling and re-suspension. Forgoing, three sprinklers could have created provision for additional mechanized sweeper, resulting in much more effective outcome.

3.1.5 Production Possibility Frontier

The Production Possibility Frontier or PPF helps decision making in the case where we have a finite budget and with that budget we can only implement different interventions in part, but not in toto. The PPF tries to identify the best mix of interventions that can be implemented within the limited budget from an economic point of view, i.e., it tries to identify the economic tradeoff between interventions that minimizes the opportunity costs we incur.

Let us illustrate opportunity cost, trade off and Production Possibility Frontier with a very simple though experiment in the next section.



3.1.6 Example Of Opportunity Cost, Tradeoff And Production Possibility Frontier (PPF) - Illustration

Let us further understand the concept of opportunity cost with help of a simplified example, where we only consider direct costs.

A city municipal corporation has a budget of ₹ 1 Cr to spend on installing air purifying smog towers and/or creating green buffer zones, given the following unit costs:

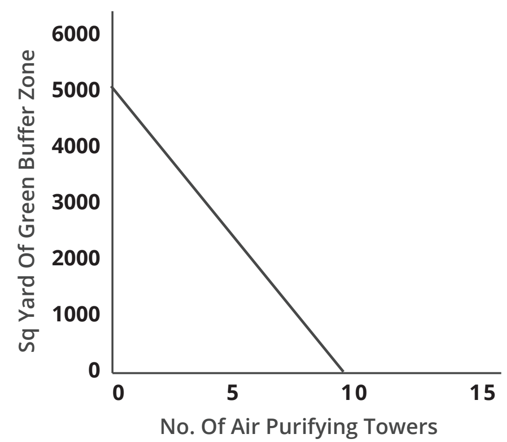
Cost of 1 Air Purifying Tower = ₹ 10,00,000

Cost of 1 square yard of green buffer zone = ₹ 2,000 per Sq yard

The budget constraint allows us to draw only the possibilities listed in Table 2:

Table 2: Opportunity Cost & Production Possibility Frontier

No. of Smog Towers	Sq. Yard of Green Buffer Zone
0	5000
2	4000
4	3000
6	2000
8	1000
10	0



The opportunity cost of one Smog Tower is equivalent to 500 square yards of green buffer zone. Conversely, the opportunity cost of 100 square yards of green buffer zone is equivalent to 0.2 Smog Tower. This means that large green buffer zones, a fundamentally sound approach for pollution clean-up, will have less budget with every increment in allocation for smog towers, a relatively new technology with uncertain outcomes. The graphical representation of Table 3 shows that the scale of deployment of each intervention is inversely proportion to the scale of the other. In other words, there is a trade-off: spending on one solution means that there will be less available to spent on another one, and we need to operate a choice. If spending is not correctly optimised there is a chance that that a more beneficial intervention or technology receives lesser budget. The slope or the curve connecting the x-axis and y-axis is the Production Possibility Frontier (PPF). The PPF gives all possible combinations of two interventions that can be delivered in the given budget. (Frenkel and Razin, 1975)[6].

Table 3: Opportunity Cost for Ranking Options

	B	C	D	E
Opp. Cost of A	2	0.5	3	0.3

PPF, opportunity costs and trade-offs can then be used to help prioritize the implementation of interventions. Let us consider five interventions (A, B, C, D, E and F) where the

opportunity cost of A is expressed in terms of B, C, D & E as provided in Table 3. Using every unit of A implies forgoing 2 units of B, 0.5 units of C, 3 units of D and 0.3 units of E.

The preferred option is the one with lowest opportunity cost, that is, E, followed by C, B and D. Iterating the approach on all interventions can help develop a rank order matrix of the interventions based on opportunity cost and can help prioritize them. PPF can then be used to support decision making while meeting pollution reduction or budget goals. Table 4 extends Table 2 with additional columns on pollution reduction by each intervention.

Table 4: Production Possibility for Clean Air with fixed Budget

Combina-tions	Number of Smog Towers Units (1)	% Pollution reduced by Smog Towers (2)	Sq. Yard of Green Buffer Zone (3)	% Pollution reduced by Green Zones (4)	Total % Pollution Reduction (2+4)
A	0	0	5000	20%	20%
B	2	5%	4000	18%	**23%
C	4	7%	3000	14%	21%
D	6	9%	2000	10%	19%
E	8	10%	1000	6%	16%
F	10	10%	0	0	10%

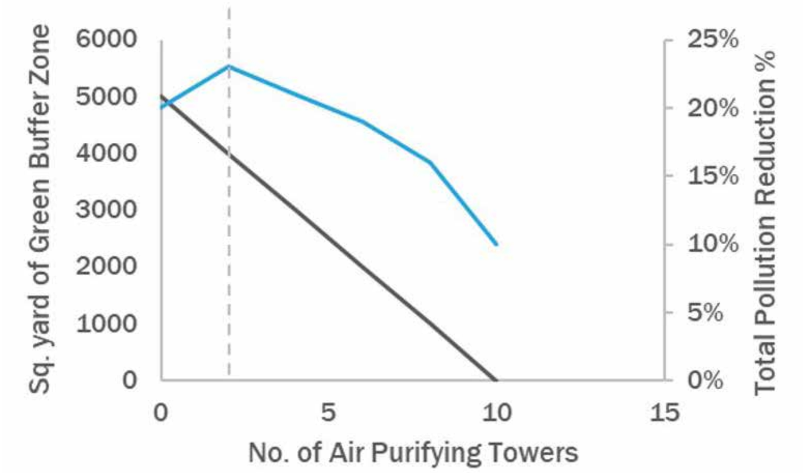


Figure 3: **Point of Optimum Decision**

Whilst all combinations can be implemented within the same budget, combination B with two smog towers and 4000 sq. yards of green buffer zones is the optimum combination of interventions.

Conversely, the PPF approach could be used when a fixed pollution reduction goal is set to help decision makers identify the combination of interventions which cost the least.

One important limitation of the through experiment we have shown is that it relies on a binary option, that on one intervention with one alternative. This case, which is not realistic, is particularly simple, and we must bear in mind that the complexity of the PPF approach increases rapidly with the increase of the number of options included.

3.2 Cost Estimation

3.2.1 Why is this important?

Cost estimation of interventions forms an important pillar of air quality management planning. A prior knowledge how much different solutions may cost is key to identifying which ones are feasible.

In general, budget constraint is a very significant challenge in working towards air quality management in India. It is understandable that the government is dealing with the tough trade-offs at budgetary level and that what trickles down, therefore, to state or cities may seem insufficient to deal with air pollution.

Local authorities often have the pressure to deliver results with severely constrained resources, and in such a scenario, supporting procurement with robust economic tools is essential. Air quality management requires indeed complex interventions, which may entail a ramified value chain with a variety of inputs which may range from planning and engineering expenses, labor costs, civil works, equipment costs etc, and an intensive collaboration with multiple economic actors.

3.2.2 Cost Estimation & 'Should-cost'

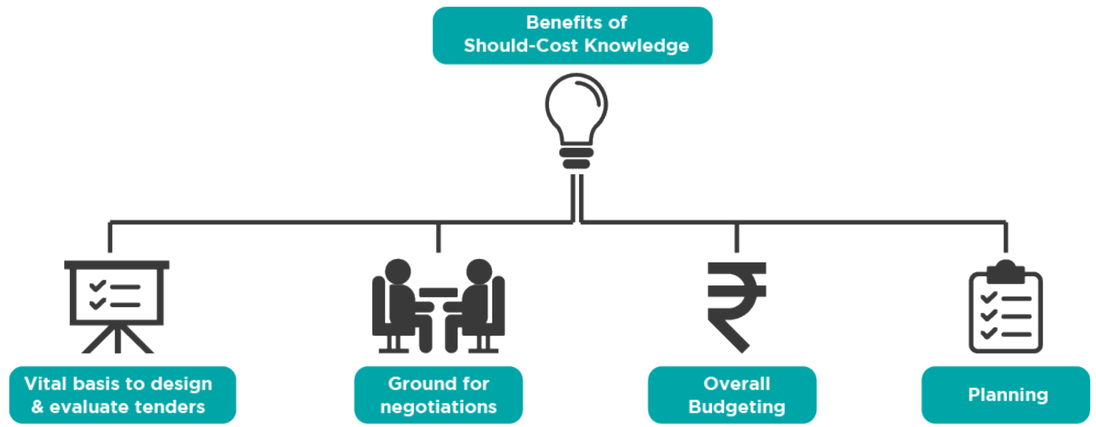
The "should cost" is an ex-ante estimate of how much an intervention should effectively cost in the current market conditions. It is typically undertaken by the buyer, in this case the local government, to evaluate the offer by the supplier (of equipment and services to implement interventions).

This approach essentially requires the buyer to reverse engineer the process to deliver an intervention to determine its true cost. It must be noted that the evaluation of the should cost require the buyer, in this case the local government, to possess a broad range of skills, competences and expertise that are not always available within the organigram of a local government, which may limits its use or may require the local government to outsource the evaluation of the should cost to external consultancies.

The primary goal of the should-cost analysis is then to produce an ex-ante assess of the likely real world cost to the buyer and can support four processes:

- Improve the planning and budgeting process
- Provide reasonable basis to design procurement contracts and for evaluating an implementation proposal
- Decide the likely scale of implementation and the inclusion or exclusion of certain components in the scope
- Robust positioning to drive negotiations to get fair pricing

Figure 4: Benefits of Should Cost Approach



3.2.3 What are the building blocks of the should-cost model?

There are several approaches to the estimation of the should cost. Whilst a full review of all possible approaches to estimate the should costs is outside the scope of the present report, we propose an overview of one of these approaches which is based five major building blocks (Figure 3) to illustrate the concept.

Input factors: The list of inputs required to deliver the intervention, including both tangible, such as resources and materials, and intangible inputs, such as skills, competences, etc.

Cost structure: The costs structure is a break down of the costs of the intervention including the costs of the inputs and of the processes.

Cost Benchmark: The costs benchmarks are the market average, minimum and maximum for the

Figure 5: Building Block of Should-cost

costs in the cost structure, which allow decision makers to understand whether the costs are reasonable and aligned.

Cost Trends: Cost trends allow to estimate how costs will evolve over the period of implementation of the intervention. It must indeed understood that costs do not remain constant, but change with changing market conditions.

Cost Drivers: Cost drivers are factors that effect the evolution in time of the cost of an input or a process. For example, a cost driver could be scarcity on the international market of a commodity that is needed to implement an intervention, or a change in a policy in another country that affects that availability of the same commodity resulting in an increase in price. Sometimes, change in cost drivers reflect in the cost of an input or a process after a certain gestation period. For example, the price of sensor a key cost driver of air quality monitors. Sensors and the underlying technology are mostly sourced from South East Asia and disrupted supply chains due to pandemic has created supply scarcity which is driving an increase in prices.

3.2.4 Cost Estimation: Understanding Value Chain

Value chain analysis can be used effectively for cost estimation, but it does have some important drawbacks. Value chain analysis is the process of identifying and valuating the processes and activities necessary to deliver a product or a service in order to maximise value creation. By extension, value chain analysis could be applied to the delivery of interventions for air pollution reduction.

Value chain analysis relies on capturing a substantial amount of information on these processes and activities (Ensign, 2001). It is important to highlight that for cities on a limited budget, this approach , depending on the level of detail required, may become an expensive process, since it is is time consuming and requires specialists' skills, competences, and expertise. A full value chain analysis down to subprocess level may not be the way forward for cities with a limited budget. One option is to outsource the value chain analysis or to use preexisting similar analysis from literature, but the cost of such actions should be part of the evaluation of the costs and benefits analysis for the air quality management plan.

Let's consider as a case in point an

air pollution abatement action that involves building a waste management plant. In order to evaluate the direct costs using the value chain approach, it is indispensable to understand and map the value chain from garbage collection, segregation to treatment and disposal.

In this case, mapping the supply chain to evaluate the direct costs of the implementation, whilst technically feasible, is a costly endeavor which requires a very broad range of competences, skills and expertise, from engineering to socio-economic expertise to consumer behavior expertise. The task of estimating the costs, including the social and

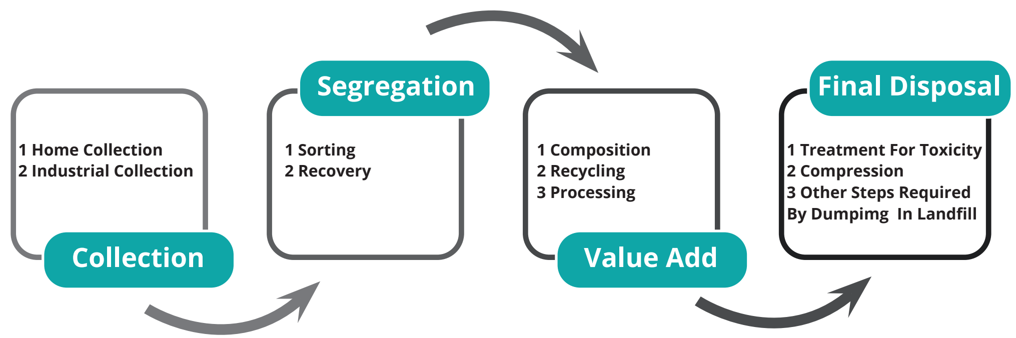


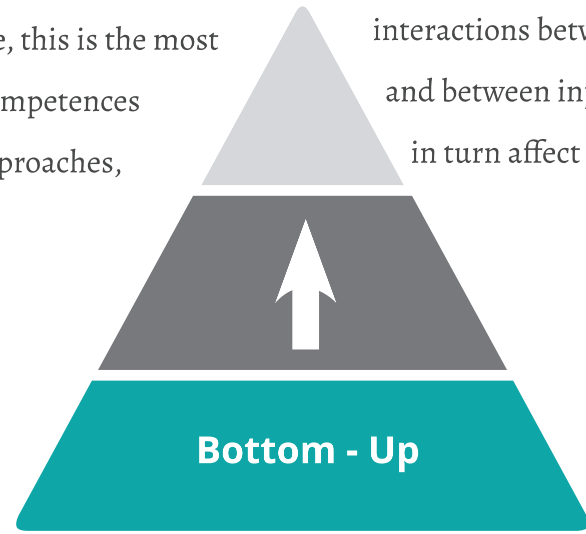
Figure 6: Simple Value Chain for Waste Management

environmental costs, the costs of disruption, and the hidden and missing costs, of implementing a waste management plan tends to be a complex and costly task, which includes considering the costs of participatory and negotiated co-decision and co-planning processes that involve the citizens. This expertise is available on the market at a cost, and it is worth considering the use of pre-existing benchmark maps and examples.

3.2.5 Cost Estimation Using The Value Chain: The Bottom-Up Approach

The Bottom-up approach is the theoretically preferred way to produce a cost estimation based on the value chain analysis.

It relies on estimating progressively aggregated costs after the value chain has been analyzed and all the basic processes and components identified. Albeit very precise, this is the most data, skills and competences intensive of all approaches, and it is very time consuming. Although it is to be kept in mind, that time and effort intensity in cost estimation will largely depend upon what process we are trying to estimate and the complexity of that process. Furthermore, if aggregation is not undertaken with attention, it may miss some of costs due to the interactions between processes, and between inputs, which may in turn affect the costs.



3.2.6 Cost Estimation: Unit Cost Approach

The Unit Cost approach focuses on breaking down the various segments of the project to implement an air pollution reduction measure or action into billable elements.

This is done to develop a comprehensive understanding and blueprint of the total cost of the project, particularly helpful in case of budgeting. Establishing “units” of work ensures that every provision of labor and materials is accounted. Air quality management often becomes a very complex exercise, sometimes including integration of an assembly line of activities and technologies. For example,if an organization wanted to set up towers to monitor air pollution levels, they only need to calculate the cost of one ‘unit’. In this case, should the organization want to set up 10 identical towers across one could start from the calculation made for a single tower, and adjust the costs of the multiple towers using coefficients linked to factors of scale.

This method is particularly useful in the earlier stages of planning and determining order of magnitude of the costs of a project considering budgetary restrictions. Negative externalities like weather changes, delays in projects, economic and political issues, changing technology, and availability of equipment and materials are some of the external influences that may affect the accuracy of cost estimates.

3.2.7 Cost Estimation: Comparative Method

This method is also commonly referred to as ‘cost by analogy’. It relies on using the costs for a system that is similar or related to the system undergoing the cost analysis and makes adjustments for the differences between the two methods. This is approach is not data, resource or time intensive and relies on establishing the differences, for example the ratios, between two different actions or measures, where know the costs of one of the two actions, or we have market based estimates. Once the matching criteria have been met between the actual part, and the part whose cost is going to be estimated, a ratio is developed to find the scale between

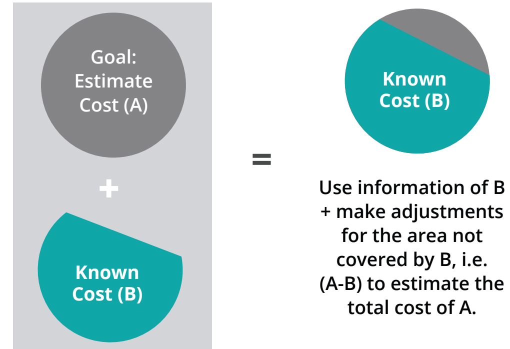


Figure 7: Cost Estimation by Comparative Method

the parts. The total cost is then scaled according to the ratio. Of course, the accuracy of the estimate depends on how accurately we can establish the relation between the costs of the action of which we know the costs, and the action of which we do not. The advantage of this system, beyond the low data, resource and time intensity, is the fact that it does not require broad skills and competences sets, or large infrastructures to produce acceptable estimates.

3.3 Cost Rationalization

3.3.1 Why is this important?

Urban local bodies (ULBs) or municipal corporations often have to work under immense pressure to deliver results while dealing with financial constraints. Lack of pre-defined goals, processes that are not streamlined and unclear planning further add to their woes. One of the major adverse outcomes of all these lacunae is budget overshoot. It is often noted that the actual cost ends up exceeding the budget, leading to either scoping down the project or approving more additional budget. This either upsets the current objective or impacts other projects in the pipeline.

Hence, cost reduction strategies, especially in air quality management in India, is essential. In this context, knowledge of 'should-cost' plays a vital role, as we will discuss subsequently.

There are at least five standard strategies that can help reduce cost while executing interventions to combat air pollution (Figure 8).

Figure 8: Cost Reduction Strategies for Clean Air Action Projects

3.3.2 Economies of Scale

This is a classical economic advantage captured by reducing per unit cost of goods when they are produced or delivered on a large scale. In our case this can be achieved, for example, through procurement programmes on networks of cities.

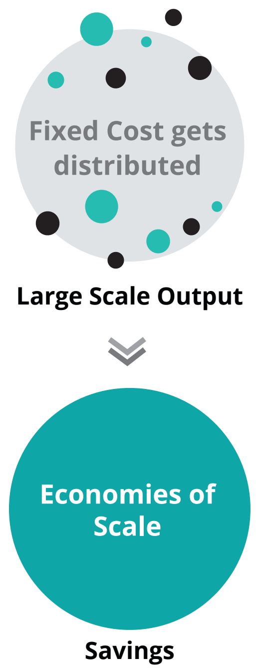


Figure 9: Economies of Scale Driving Cost Reduction

In fact, price negotiation happens on bulk purchase precisely because the provider has created enough margin during bulk production, or bulk procurement, that can be used to give discounts, for example because of the distribution of the costs of production machinery over a larger number of products and clients. Whether it is procurement of air quality monitoring devices or building a large waste management unit, economies of scales benefits can be accrued.

Figure 10 is a Cost Vs Output chart representing 'Economies of Scale' scenario, an old micro-economic concept. The U-curve represents the long run average cost curve (LRAC), which tend to fall as output increase but begins to rise beyond a threshold output level as existing infrastructure or technology becomes insufficient to handle the output load, and demands additional spending on upgradation. It is, therefore, evident that economies of scale benefits can accrued as we move from Q1 to Q2. As the cost curve begins to rise, every incremental work costs more per unit, known as Diseconomies of scale.

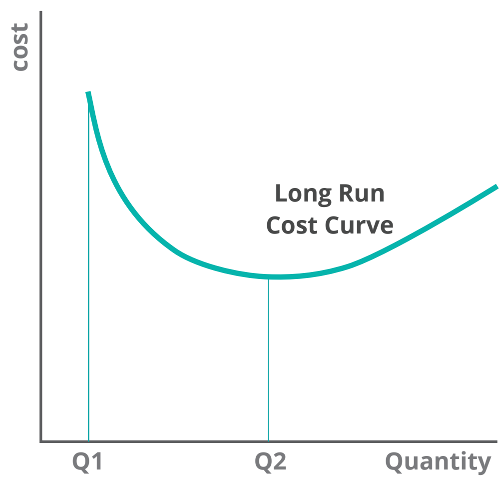


Figure 10: Economies of Scale

The air pollution issue is a scale problem and offers immense opportunity to exploit economies of scale benefits given the material resources required as part of the response, such as building waste management plant, deploying e-rickshws or electric buses, or even procuring sensors for pollution monitoring purpose.

3.3.3 Cost Omission

Careful investigation of interventions from this perspective is essential to rule out alternatives with high opportunity costs in the interest of cost reduction. Sometimes opportunity cost of one intervention is so high that similar outcomes can

be achieved using a combination 2-3 other measures in lesser cost, creating a window for saving. For example, cost of introducing 200 electric buses in a city could exceed $50 million, while greater emission control can be achieved by combining procuring CNG buses (1/4th the price and displaces equal number of 2 & 4 wheelers from the street) and controlling roadside dust suspension by paving[7]. Figure11 illustrates cost saving decisions based on opportunity cost. Note that the bars are not drawn to any scale and are just indicative, meant for purpose of discussion. Total cost structure consists of four components A, B, C and D, sum total of which represent the total cost. Note the following conditions:

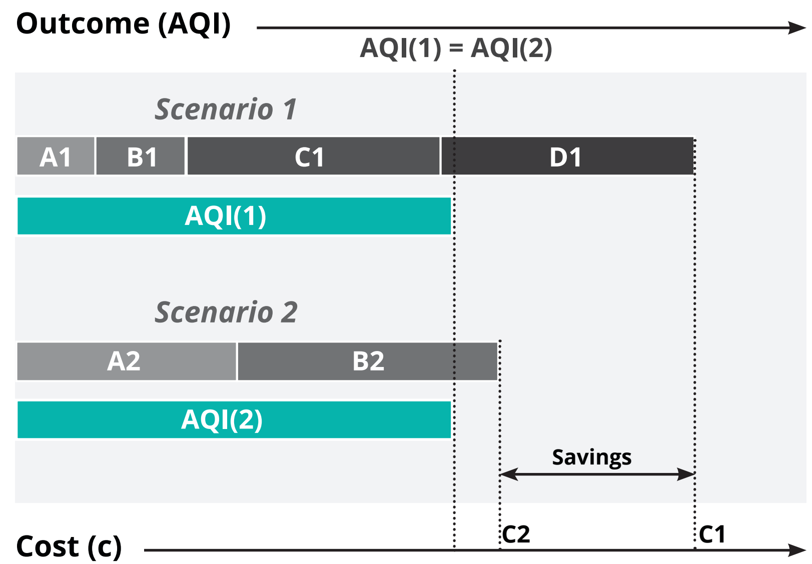


Figure 11: Opportunity Cost based cost Saving

- Opportunity cost of C and D are much larger than A & B
- In scenario 1, A1+B1+C1+D1 lead to air quality level of AQI1
- In scenario 2, items with higher OC are dropped; available budget is split between A & B
- A & B are more efficient components and can achieve the same air quality with lesser cost

Total cost in achieving the same outcome in scenario 2 was lesser, amounting to savings (= C1 – C2). The cost reduction is direct result of dropping the interventions with higher opportunity cost.

3.3.4 Should-cost

As the name implies, it is the cost of undertaking an activity which 'should' prevail in normal circumstances. Knowledge of input costs, rate of inflation, cost composition/cost drivers etc. are useful in determining the should-cost. It can be used a strategic tool to negotiate to drive the prices down if they appear to be higher than the estimated should costs. It can also provide basis to evaluate tender bids with low cost (without under-cutting the quality).

Should-cost is a strategic tool clean air programs could use to evaluate tenders or to even negotiate for non-tender situations, when there is freedom to choose suppliers. The scale at which activities are being

undertaken is unprecedented given how the air pollution crisis has escalated in the last 4-5 years. A variety and unique combination of solutions are on the table for considerations such as installing smog towers, building green zones in cities etc., which have been missing precedence in terms of cost implications. Should-cost, in such a scenario, becomes more crucial in providing a baseline and preventing any possibility of formalizing over-estimated quotations.

Figure 12: Should-cost Knowledge based Savings

3.3.5 Cost Drivers

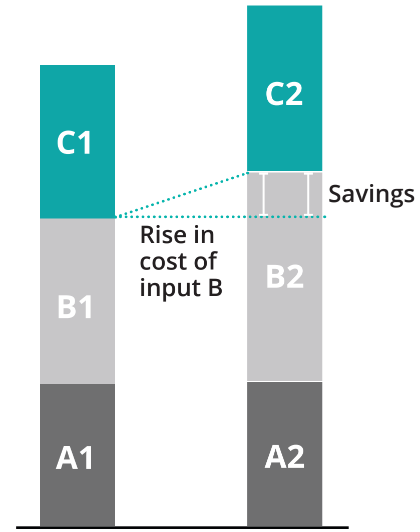


Figure 13: Cost Saving Spend Decision

Information on cost drivers can help in effective planning and budgeting that can help reduce project costs. In one of the cities in India, 30% of the total budget was spent on public awareness on air pollution, leaving little for other key areas such as pollution mitigation (20%). Knowledge of what is the cost driver here can help rationalize overall spend. In this particular case, if manpower is the leading cost driver, then public awareness efforts must look into opportunity to reduce reliance on large headcounts using technology or local partnerships as alternative means to spread awareness.

3.3.6 Inter-departmental Coordination:

Complex and multi-layered nature of the government machinery often leads to lack of coordination between departments, resulting in redundancies. This is also known as the "silo effect". For example, construction debris lying on roadside is a commonplace sight in Indian towns and cities. Figure 14 explains this saving. Four circles represent cost structures of four departments. Exploiting any potential overlap can help save with improved coordination. For example, while waste of any kind must be removed by municipal authorities and Public Works Department is concerned with civil maintenance and repair work, latter has the logistical capacity to clear up debris. A better coordination between the two can lead to many trips and labor cost saved.

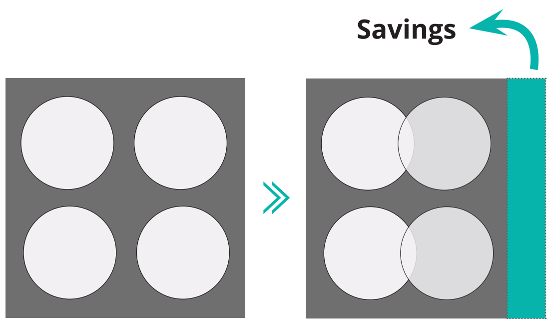


Figure 14: Improved inter-departments Coordination led Savings

3.4 Monitoring, Reporting And Evaluation Of The Impact Of The Outcomes Of Air Pollution Reduction Actions

3.4.1 Why is this important?

This is important to assess areas where efforts must be amped up and where the plan to implement an intervention must be dropped or scaled down if results aren't good despite good effort.

When there is a looming public health crisis and limited resources and time to fix it, then measuring effectiveness of corrective actions is indispensable.

3.4.2 Key Performance Indicator (KPI) for Air Quality Management

A key performance indicator (KPI) is an indicator used to monitor, evaluate, and report on the effectiveness, efficacy and efficiency of efforts directed towards an intended outcome.

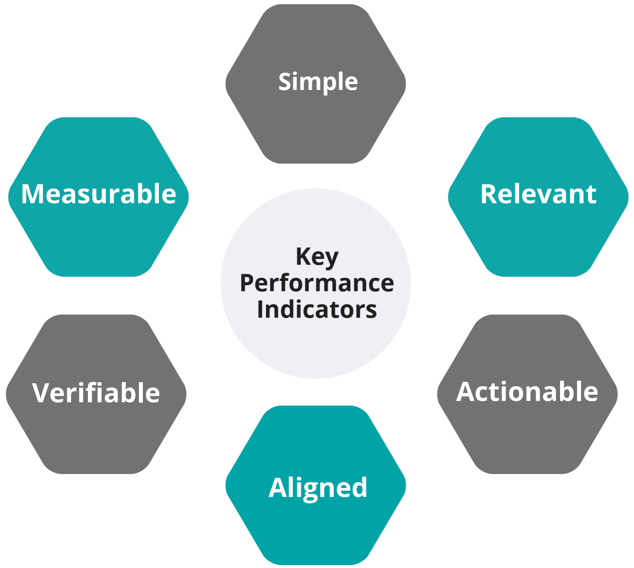


Figure 15: **Attributes of KPIs**

For the scope of our primer, KPIs can be broadly categorized in two groups: quantitative and qualitative[8].
To be useful for decision and policy makers, KPIs used to monitor an action need to be based on a theory of change, which in turns relates them the most important stakeholder groups and have some fundamental attributes.

Many different approaches to the definition of KPIs have been proposed over time, and most of these approaches have converged around a simple set of characteristics.
Figure 15 describes six important attributes of a KPI:

- KPIs must be *simple* to understand and apply, not build additional questions.

- KPIs need to be *relevant* to a specific process, project or objective. This translates into it being specific.
- A minimum qualification test for a KPI is that it must be *measurable*. This is in consonance with the logic of what gets measured gets managed.
- KPIs must be *actionable*, so that any take-away emerging from an improving or worsening performance must translate into action items.
- KPIs must capture information that is *verifiable* to do away with possibility of subjectivities.
- A KPI must be *aligned* with overall objective of the project as well as other KPIs.

One last important attribute is TIMELINESS, that is the KPI should provide decision makers with timely feedback so that response mechanisms can be put in place to correct issues and problems in time to avoid worst outcome.

An example of a KPI to measure the ancillary benefits of air pollution abatement efforts is the Air Quality Index or AQI. To achieve a reduction of the AQI to the levels prescribed by the WHO, it must be broken down into secondary and tertiary indicators (Figure 16).

The primary KPI is in this case the AQI. The secondary indicators are the measures of the levels of the pollutants which constitute the AQI, such as PM 2.5, PM 10, SOx, NOx etc. Tertiary KPIs refer to the measures of the performance of those activities which impact the secondary indicators, such as number of vehicles on road, number of monitoring stations, area of green cover, number electric and diesel buses etc.

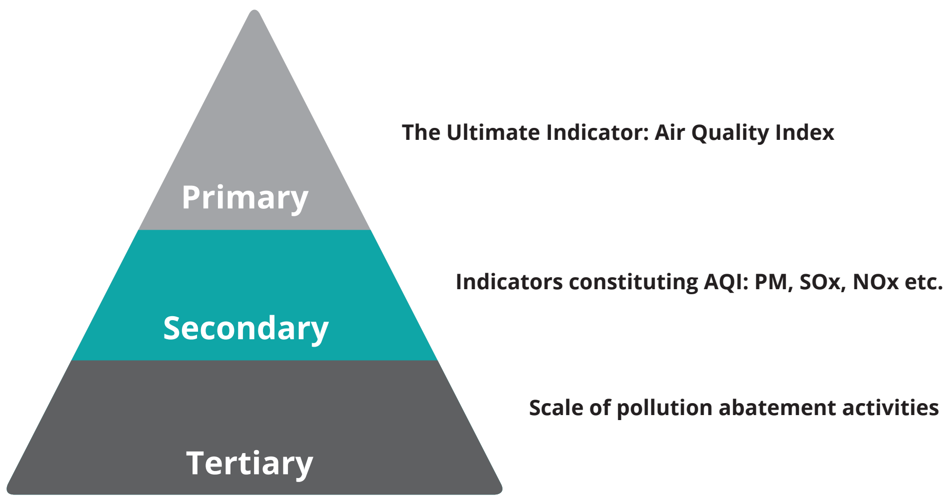


Figure 16: 3-tier KPI Approach for Air Quality Management

3.4.3 The Social Return On Investment

Whilst indicators such as the AQI can also be used as reasonably good proxies for measuring cost-benefits, in most situations we need to identify socio-economic indicators that allow us to develop the social, economic and business case for investment in air pollution reduction interventions.

One example of such performance indicators is the Social Return on Investments (SRoI). The SRoI is one of the most successful attempts to date to account for the social and environmental added value generated by an intervention and that cannot be accounted through traditional financial indicator.

The SRoI assigns a monetary value to inputs and outcomes and uses that assignation to calculate a ratio. For example, if the ratio is 100:1, it means that every dollar allocated generates social value worth $100.

A general formula to calculate SRoI is:

SRoI = Net Present Value of Impact/ Investment Value[9]

Let us understand associated key terms:

- Value of Impact: It is the value in monetary terms of the positive outcomes or benfits resulting from an investment. In our context, it refers to the benefits of reduced air pollution as a result of investment in air quality management.
- Net present value: It is the present value of the sum accrued at a time

- in future because of an investment made today. In the current context, benefits of pollution reduction enjoyed over the next 10 years, for example, must be expressed in terms of today's value to foster SROI calculation[10].
- Investment Value: It simply refers to the amount spent expecting to earn an interest at a time in future. In our context, the air quality improvement spending represents investment.

The following example will illustrate the concept of SRoI more concretely.

Let's note the following observation:

Amount spent in Air quality Management in the city = $1000,000

- **Reduction in DALY (Disability Adjusted Life Years[11]) due to improvement in air quality = 1000 years**
- **Present Value of a Quality Adjusted Life Year (perfectly healthy life) = $50,000[12]**
- **Total value of impact = $50 million**

Therefore, SRoI = $50 million/ $1 million = 50

This implies every dollar spent in curbing air pollution can yield benefit worth $50 in terms of human lives

Using monetary proxies for social, economic and environmental value, to calculate SRoI, has following advantages:

- Feasible to integrate performance management systems with financial management systems.
- Helps reprioritizing and reassessing goals, thereby aiding the planning and decision-making process
- Aids communication with stakeholders

Despite all the advantages, it has a few limitations. All the benefits received from the investment cannot be monetized and thus maybe hard to quantify for the purpose of calculating SROI. Altogether, the process itself is very tedious and time consuming.

3.4.4 Surveys

This is a tried and tested technique to gauge top level sense of how the air pollution interventions faired.

It involves building a questionnaire based on what aspects of performance are required to be captured, collecting responses from targeted stakeholders. The literature on surveys is extremely broad and well developed, and the reader may look at the appendix below to find documentation that can help design the correct survey for their use.

One of the advantages of surveys is that they can be conducted in several forms: face-to-face interview; online survey using email or social media platforms; telephonic surveys; or focused group discussion among many others.

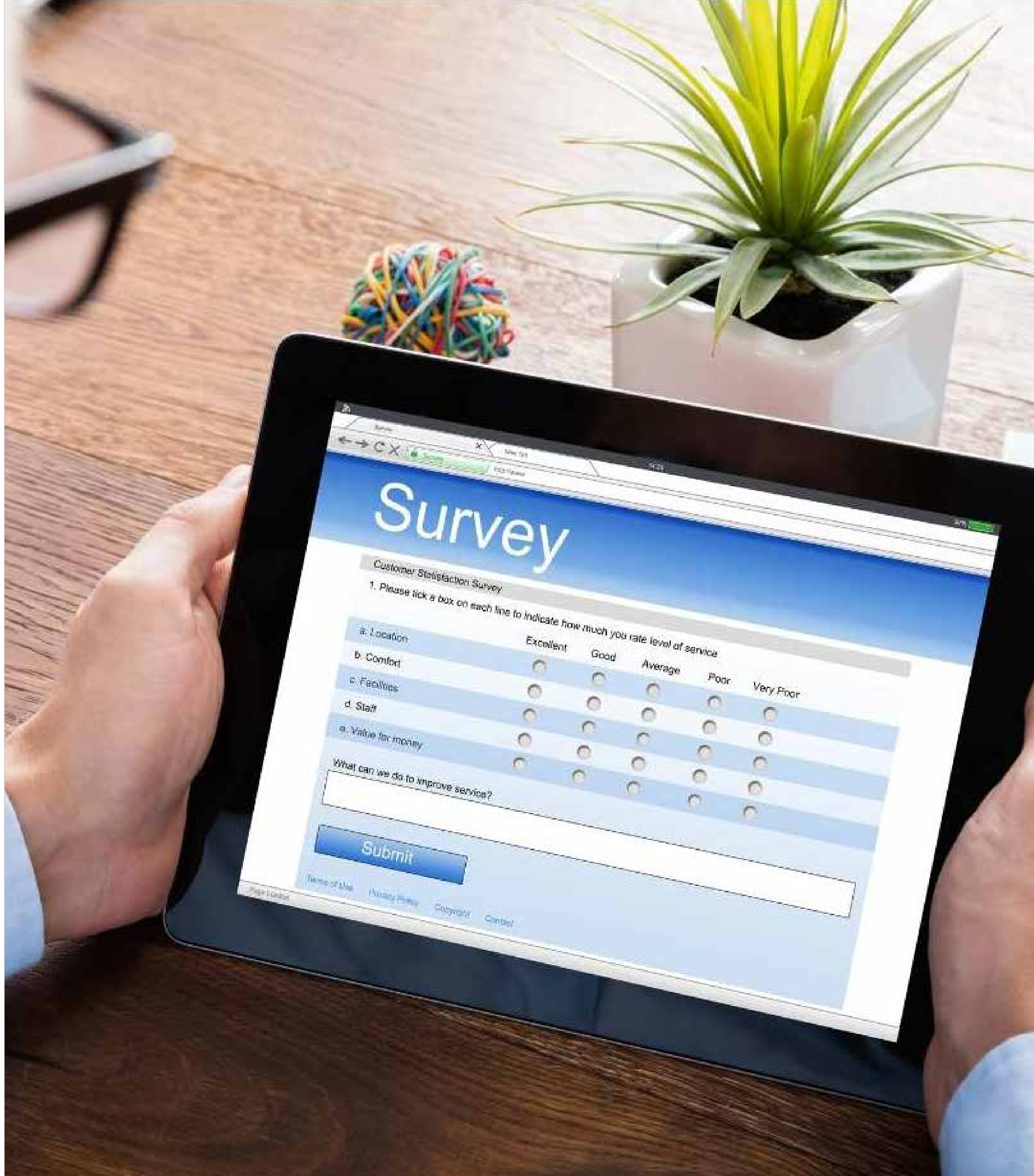
Each one of these different forms carries specific disadvantages that need to be contextualized.

Key points to keep in mind while undertaking this exercise[13]:

- Questionnaire must be designed in a short, direct and objective manner
- Only fully filled questionnaire must be considered.
- Every survey response must record defining characteristics of the respondents, so as to correlate results with the stakeholders in question.
- Sample selection must be done carefully so that it is representative of the population or category in question.

Both questionnaire and sample selection process must be developed such that biases are minimized.

Data must be recorded in an organized format, preferably a structured database of responses so that complete analysis can be carried out[14].



THIS SECTION LOOKS AT THE CRITICAL ISSUES IN THE CONTEXT OF TWO SECTORS: POLLUTION FROM TRANSPORTATION SECTOR AND DUST (ROADSIDE & CONSTRUCTION SUSPENSION)

4. TRANSPORTATION SECTOR

4.1 Overview

India's transportation sector is a vast network that caters to the needs of over a billion people. The steadily growing economy has witnessed an exponential increase in demand for transport infrastructure and services in the last two decades, resulting in an ever expanding and extensive network of rail, road and air transport system. In fact, travel by roads is perhaps the most dominant means of travel which caters to 85% the country's passenger traffic and 60% of its freight[15]. (World Bank, 2011) Various studies have found that transportation sector can contribute up to 30% to the air pollution problem[16]. A study found that as much as two-thirds of deaths which are attributed to air pollution are caused due to exhaust emissions from diesel vehicles[17].

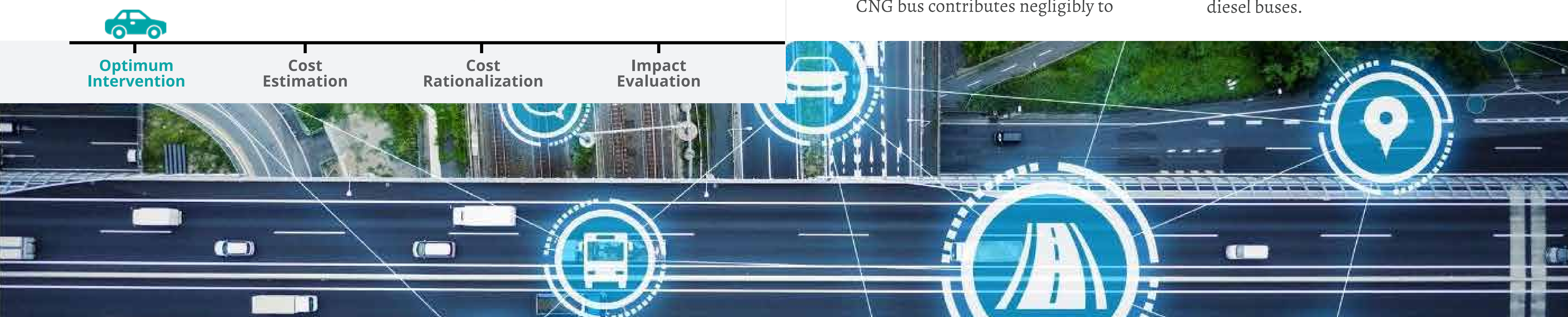
4.2 Applying the critical issue analysis for Air Quality Management in Transportation Sector.

4.2.1 Optimum Intervention

While it is mainly the exhaust fumes from vehicles,transportation sector is characterized by multi-layered challenges which exacerbate the emissions.

For example, number of vehicles on road are ever increasing but poor traffic management causes jams and contribute to greater pollution. Deficient public transport, commercial diesel vehicles' passageway through cities, high average daily journey requirement etc. are some of the other challenges. Within limited budget and time, which aspect must be targeted to bring out maximum result is matter of investigation.

It is evident from the discussion in this primer that identifying optimum interventions become much easier once the opportunity cost and trade-offs associated with air pollution mitigation plans are highlighted.



To illustrate the opportunity cost argument with a very simple thought experiment, one can consider a simplified case: the decision of whether one should invest in electric buses or in CNG. To do so, we will construct a simple example, where we substitute 12-meter long CNG buses with electric buses of identical performance. The cost of a 12-meter long CNG bus is about $75,000 whereas that of an identical electric bus is $300,000[18]. Assuming that a CNG bus contributes negligibly to the air pollution and works equally well in displacing four wheelers from the road, it would not be wrong to infer that electric buses have a high opportunity cost.

In the Indian context too, the price variation between the electric bus and the CNG/diesel bus cannot be ignored.

Let's work through a scenario where New Town Transport Department has a budget of ₹ 10 crores to figure out whether to spend on electric buses or diesel buses.

- Cost of an electric bus = ₹ 1 crore
- Cost of a diesel bus = ₹ 25 lakhs
- Pollution reduced by electric bus is approximately 1.5 times as much as diesel bus
- Pollution reduced by diesel bus (by displacing 4 wheelers) = x
- It is given that the marginal reduction of pollution diminishes as number of buses increases beyond a point because not everyone is willing to give up cars and more congestion due to over-crowding of buses

Table 5: Electric & Diesel Buses: Opportunity cost & Trade-off

Combinations	Electric Buses (Ev)	Pollution Reduction By Evs	Diesel Buses (Dvs)	Pollution Reduction By Dvs	Total Pollution Reduction
A	10	15x	0	0x	15x
B	8	12x	8	8x	20x
C	6	9x	16	16x	25x
D	4	6x	24	24x	30x
E	2	3x	32	28x	*31x
F	0	00	40	29x	29x

Result: All combinations can be afforded from A through F, however E is the optimum because it reduces the pollution more than any other, which is an economic efficiency (increase in output at the same cost is equivalent economic gain from reduced cost for the same outcome).

4.2.2 Cost Estimation

There can be many cost estimation technique, the foundation of which mostly lie in understanding the value chain and estimating the should cost. in the following example we want to free e- rikshaw service to improve last mile connectivity between residentialo area and nearest metro station in the city of new town.

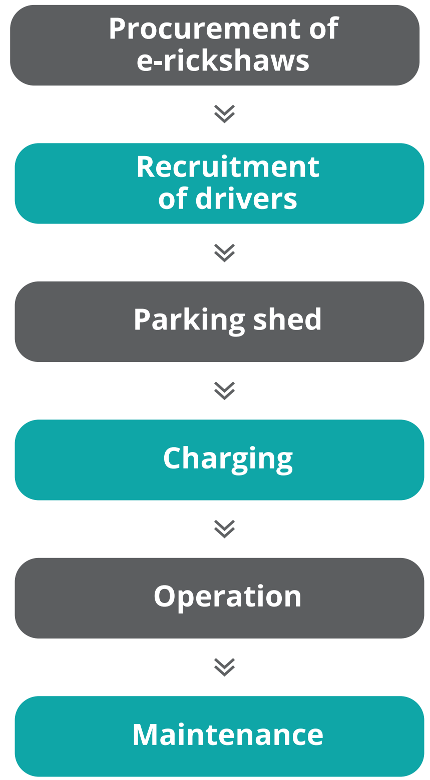


Figure 17: Value Chain of e-rickshaw service

Accordingly, taking cue from the value chain, we enlist following questions that could help us with the bottom-up approach of cost estimation, as carried out in Table 6.

Total number of e-rickshaws required = 20*25 = 500

Total cost of e-rickshaws = ₹ 2 lakhs*500 = ₹ 10 crores

Total salary expenditure for a year = ₹ 10,000*12*500 = ₹ 6 crores

Question	Answer
What is the Cost of procuring 1 e-rickshaw?	₹ 5 lakhs
What is cost of hiring a driver?	₹ 10,000 per month
What is the cost of parking shed for 20 e-rickshaws?	₹ 1 lakh
What is cost of charging an e-rickshaw?	₹ 100 per day
What is annual O&M costs?	₹ 10,000
How many metro stations must be covered?	25
What is the average no. of rickshaws required per sta-tion?	20

Table 6: Cost components for bottom up cost estimation for e-rickshaw service

Total annual O&M cost

= ₹ 10,000*500 = ₹ 50 lakh

Cost of shed = ₹ 1 lakh*25

= ₹ 25 lakh

Cost of charging =

₹ 100*365*500 = ₹ 1.82 crores

Total approximate cost of the project = Rs 18.57 crores

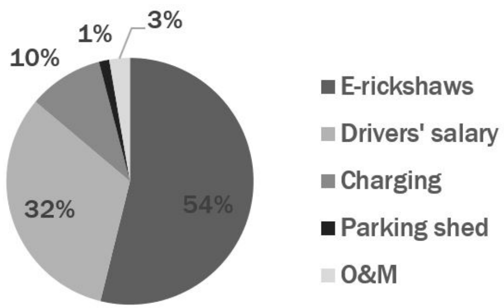
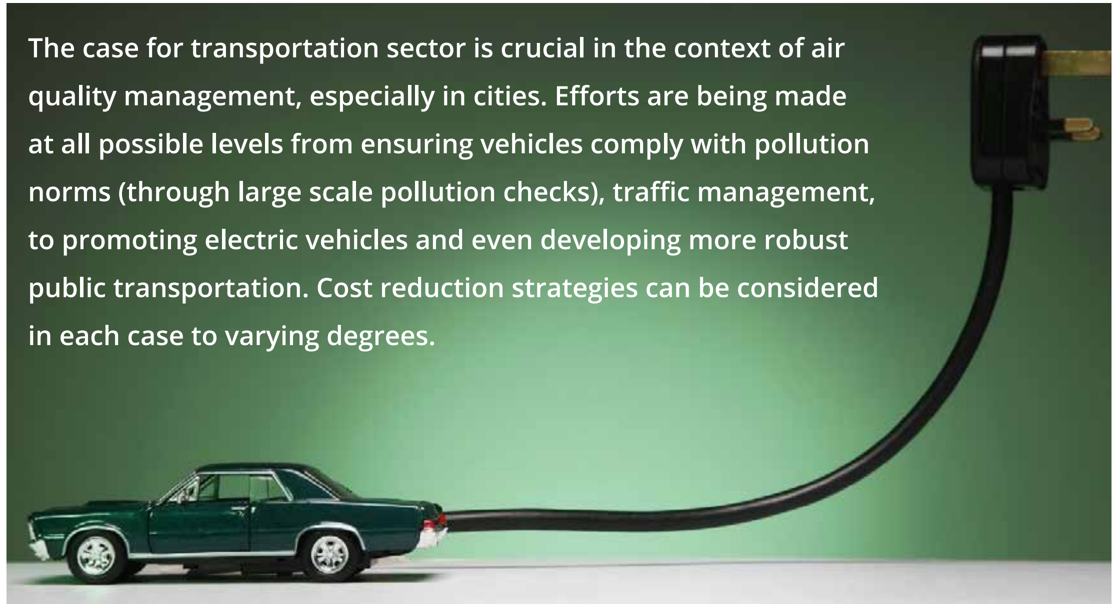


Figure 18: Cost Structure of free e-rickshaw service

Of course, the example above is oversimplified for the sake of the argument, and in a real-world application we would need to keep into account a series of important socio-economic variables: for example, instead of the simple total cost of the project, we would need to use the Net Present Value of the project.

4.2.3 Cost Rationalisation



The case for transportation sector is crucial in the context of air quality management, especially in cities. Efforts are being made at all possible levels from ensuring vehicles comply with pollution norms (through large scale pollution checks), traffic management, to promoting electric vehicles and even developing more robust public transportation. Cost reduction strategies can be considered in each case to varying degrees.

Let us look at the prospects of a key cost reduction strategy – economies of scale, widely applicable as adoption is on a rise for technologies such as electric vehicle, especially battery packs. Cost of Li-ion battery packs fell by 85% in the last decade and will further fall by 35% by 2024 to below $100 per kWh[19]. This is largely driven by economies of scale, besides improved technologies[20].

The economies of scale cost reduction benefits are also passed on to consumers, and larger the procurement volume, higher is the consumer welfare[21]. This implies that EV battery packs, which is a significant EV cost component, offers immense opportunities for consumers to benefits from bulk orders, something which concerned government authorities can leverage. Other strategy may involve investigating opportunity cost approach to prioritize interventions with least cost. This means exploring alternatives entailing greater pollution reduction potential with minimum cost, such as better traffic management, stricter pollution checks etc.

4.2.4 Impact Evaluation

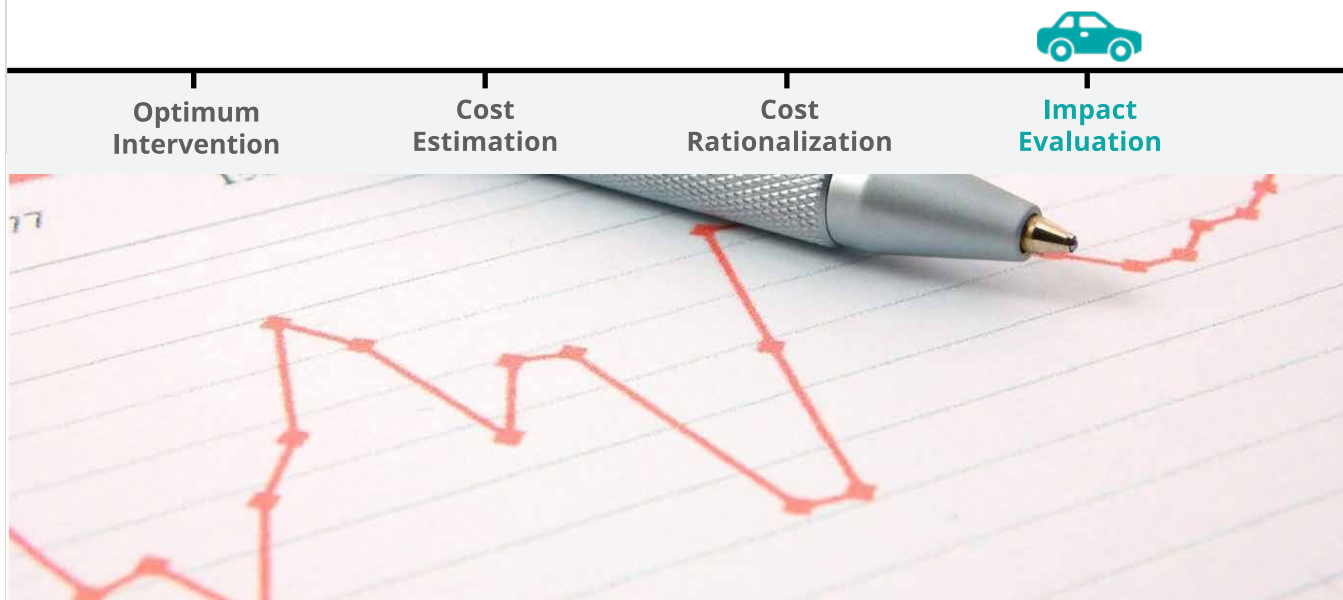
Let us hypothetically consider the following positive impact of turning an area characterized by a crowded market area, adjoining densely populated residential area, into a car free zone.

- Local vehicular emission cut down significantly resulting in fewer people experiencing breathing related ailments.
- Let us assume that cost of implementing this move was $20,000, and 5,000 saved people $10 on their doctor visit, on average, for that year.

Quantifying the benefits, we get:

- **Investment = $20,000**
- **Impact value = $50,000**
- **SRoI = Impact Value/ Investment = $50,000/ $20,000 = 2.5**

Every dollar invested resulted in benefits worth $2.5



5. DUST FROM ROADSIDE SUSPENSION AND CONSTRUCTION & DEMOLITION ACTIVITIES

The growth of Indian economy is heavily dependent on growth in infrastructure. The scale of construction & demolition (C&D) activities is evident from the fact that India generates about 150 million tonnes of C&D waste every year. These activities lead to high levels of dust suspension and are significant contributors to the rising air pollution levels across the country. In Delhi, for example, this factor alone makes up up to 40% of ambient air pollution, according to TERI-ARAI source apportionment study on the city[23].

Controlling the dust produced by roads and worksites is an important but largely neglected part of clearing India's air. Poor and outdated C&D practices across worksites and limited enforcement of by state urban department[24], make construction and demolition the third largest contributor of coarse pollutants[25]. In a study conducted in 2015, 19 building sites in Delhi were examined and in around all of them, the air quality of the site exceeded the safe limits by at least three times the safety limit[26].

Much discussion in the country has been on how proper construction and maintenance of the roads would allow less dust to be suspended in the air. This along with lining pavements with shrubs to absorb dust material and better construction and demolition activities need to be implemented.

5.1 Applying Economic Framework for Air Quality Management with Respect to Dust from Roadside Suspension and Construction & Demolition Activities (Qualitative approach)

5.1.1 Optimum Intervention

Addressing dust suspension challenges can find a wide array of potential interventions. But the question remains whether it is wise to test and try them all. Given preceding discussions, it is evident that we must put all the possible solutions through the opportunity cost and trade-off test and then prioritize.

Let us look at an example from Delhi where opportunity cost approach can certainly help in prioritizing better for larger impact. According to a third-party audit done in Delhi in 2019, there were 59 mechanized cleaning machines then, procured at over $90,000 each, were plying on the streets at just 33% capacity utilization then[27]. The opportunity cost of this activity has been suspended dust reduction by undertaking about 3.5 million square feet of road-side paving.

This is just to highlight that some of these pollution abatement activities

can be potentially expensive affair with questionable outcomes. A robust opportunity cost exercise can help authorities take a more informed decision. The beauty of this approach including production possibility frontier (PPF) exercise, can help in coming up with an optimum combination of both instead of either selecting or rejecting an alternative.

5.1.2 Cost Estimation

In the context of this action, we could, for example, use a should cost approach described in the previous sections. If we attempt to do so, some critical issues emerge.

In the context of dust management, there are either labor intensive or machine intensive activities. There is one cost aspect about each which are often missed (and should not be missed in should-cost analysis).

- ***Labor-intensive interventions:*** Most ground level workers involved in road cleaning (manual sweeping), in construction or demolition activities and roadside pavemings are unskilled and inefficient[28]. Root cause lies in the fact that they aren't trained, and unsurprisingly there is almost never a training and upskilling budget for the lowest tier of workers. This one element can have immense benefits with least cost.

- ***Machine intensive interventions:*** It is highly recommended that should-cost analysis must include cost of acquisition (capex) as well as O&M cost (op-ex). O&M budget by almost all of the municipal corporations of Delhi were not finalized until after the procurement of first batch of sweeping machines were done.

5.1.3 Cost Rationalisation

Urban Local Bodies and other civic authorities often face budget crunch. There have even been instances when these authorities haven't paid salaries to their staff for several months due to fund shortages. Municipal staff of the capital have, on some occasions, gone on strike demanding salary dues be cleared, leaving major parts of the city un-swept[29]. Many private construction projects also work under budget constraints and do not give dust capture its due attention, a pattern that is further encouraged by poor enforcement of air pollution control norms.

The situation has reached a critical point and cost rationalization efforts at every level is needed. Cost and performance audit must be undertaken to identify sub-optimal utilization of funds and opportunities of cost saving. Opportunity cost approach, for example, can be used to focus on high priority activities, as discussed earlier. Similarly, careful assessment must be done to leverage any economies of scale opportunity for cost reduction.

5.1.4 Impact Evaluation

While biomass/stubble burning may carry smoke over large trans-boundary distances, construction and roadside dusts often have largest local impacts. As noted earlier, compliance and regulatory enforcement has been weak in this context. An effective intervention in this regard is possible only with appropriate monitoring.

Using the concept of 3-tier monitoring explained in the primer already, greater focus must be laid on tertiary indicators to assess the scale of abatement activities. These include area of paving done, keeping the construction materials covered, creating dust (and sound barrier) around the construction site etc. A focused monitoring will lead to streamlined pollution abatement efforts, and will positively influence the primary KPI, that is, region's air quality.

6. LIMITATIONS

1. The primary idea behind development of this primer is to kickstart a discussion with the stakeholders on critical issues that may pave the way to the incorporation of costs benefit analysis and of key economic and financial principles, into air quality management plans for cities in India.
2. The examples and illustration focus on simplified thought experiments and are for the purpose of elucidating principles and applications and do not claim to resemble real case scenario.
3. The target audience of this manual is expected to be familiar with the air pollution management plans, their context and the corresponding measures, such as technologies, behavioral changes measures and means and approaches that can be used to reduce air pollution.
4. Two examples of sector specific interventions are developed to help understanding the critical issues in context. The first case study focuses on reduction of pollution due to emissions from the transportation sector, the second case study on reducing particulate dust from roadside suspension, construction and demolition activities.

7. WAY FORWARD

The overarching aim of Clean Air Asia attempt at developing a standardized approach and a manual on the economics of air quality management plan and air pollution reduction plans is to support city level decision makers and policy makers in India and in Asia more in general in their effort to reduce air pollution and increase air quality in cities.

One important pillar of this approach is costs benefits analysis, and this primer is an attempt at identifying some of the critical issues surrounding the development of a cost benefits analysis in order to open a discussion with all the stakeholders.

Our intent is to kickstart a participatory process that will allow us and our partners to develop a full version of the manual in collaboration with city decision makers and policy makers in 2021.

We hope that such a manual, born from the combined technical expertise of our scientific partners, our stakeholders and Clean Air Asia, will help policy and decision makers in Indian cities to design and accelerate the adoption counter measures to the increasing level of pollution.

The approach and the manual rests on four important components: the methodological framework, i.e. the model or blueprint, the toolkit, the ecosystem of stakeholders and the training to build capacity.

Robust and rigorous methodological approaches for the evaluation of the true business and social case for investment in air pollution reduction and air quality management strategies are the first component of the approach. These methodologies will be scenario based, to allow decision and policy makers to simulate different possible future visions, and simulate the costs, benefits, and co-benefits in the different scenarios. *From the point of view of costs*, it will include methods for the evaluation of the total costs of ownership, hidden and missing costs, costs of disruption, social and environmental costs and well as behavioural change costs. We are working on including standard effects such as price elasticity and rebound. *From the point of view benefits*, we will include both ancillary benefits, and co-benefits at short, mid and long term: in particular, from the social perspective, we propose to focus on health and wellbeing co-benefits, employment co-benefits, Gross value added per capita co-benefits and cultural / recreational co-benefits. *From the environmental perspective*, we plan to include ancillary benefits on air pollution, and co-benefit on environmental degradation, climate change and ecosystem services provisions.

Within this component, our frameworks of reference are going to be the UN Sustainable Development Goals and the Paris Agreement.

The second component is toolkit that implements the blueprint, and that will be available online so that city decision makers and policy makers can use to run simulations on the one hand and learn from other cities on the other. In particular the toolkit will allow to simulate the effects of local scale fiscal and incentivization policies, such as taxes and tax rebates, tax credits, subsidies, incentives and grants. To develop the toolkit, we will need to develop basis of data. So far the focus of cities and research has been on air pollution level and air quality data, whilst the collection of economic social and environmental data have not been sufficiently covered: we will need to address this gap in the near future if we are to develop meaningful models.

The third component is the development of specific training resources on the methodological framework and on the toolkit. The training resources will be tailored to the city policy makers and decision makers, private enterprise leaders and citizen groups, and we will make them available both online and offline.

Last but not the least, the ecosystems of stakeholders need to be developed at city level, in such as way that the major groups of stakeholders in air pollution reduction strategies and air quality management strategies are involved in the development from conception. The stakeholders are indeed in many cases the process owners, and carriers of innovative solutions, and their inclusion and engagement in the conception development and finally implementation of the plans if mandatory for the plans

to be effective. Instruments and mechanisms for engagement vary, and are often contextual, but the realization and the development of permanent round tables, such as could be promoted through city agencies for citizen inclusion or living labs centered around the issue of air pollution may represent an optimal solution working in parallel with analogue experiences developed in both Europe and Asia.

Whilst the major stakeholder groups may change depending on the social, cultural environmental and economic context of the specific city, five groups should be certainly present in all experiences: policy makers at the various scale that are involved in air quality decision makers; decision makers in public administration bodies; private enterprise leaders, including from small and medium enterprises and from the most innovative sectors and from the informal economy; citizen and citizen groups (including informal groups) and charities and NGOs.

The immediate priority of the manual, toolkit and training is to support the air pollution mitigation efforts of 122 non-attainment cities that have been identified by the Government of India.

The air pollution reduction plans of many of the non-attainment cities are indeed missing an economic and financial component, while the plan itself is missing in some cases. We hope that making such important tools available to the decision makers and policy makers in these cities will improve their opportunities of constructing resource-efficient, as well economically and financially efficient, air pollution reduction plans. To accelerate the process of development of the manual, we have now opened the primer document for comments and discussion, and we hope city decision makers, policy makers for local authorities, scholars and practitioners will read it and comment it.

This primer if a first step toward the development of a comprehensive integrated approach to the economics and finance of air quality management

strategies, and it can provide a basis to support the development fresh plans and make the existing ones more actionable.

Finally, the availability of broad range of case studies from India and other countries, covering a wide variety of actions, measures and interventions may serve as a model to promote the adoption of more effective solutions.

Annexures

I. LIST OF FIGURES

II. LIST OF TABLES

III. REFERENCES

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V. SAMPLE SURVEY (Impact Assessment)

Questionnaire

1. In context of Air Pollution, which of the following do you agree with?

- It is an emergency
- It is over-hyped
- It is a problem in October-December only

2. Which of the following ailments have you suffered from in the last 1 year?

- Frequent coughing & wheezing/dry throat
- Itchy eyes
- Lung Infection/ Inflammation
- Asthma/Bronchitis/Emphysema/Eosinophilia
- Nasal tract infection
- Headache/Nausea
- Increased fatigue
- Constant worry of potential health impact
- None of the above

3. Do you believe one or more symptoms mentioned above were caused due to air pollution?

- Yes
- No
- Can't say

4. Do you have children less than 10 years of age?

- Yes
- No

4(a). If your answer to the above is 'yes', then which of the following apply to you?

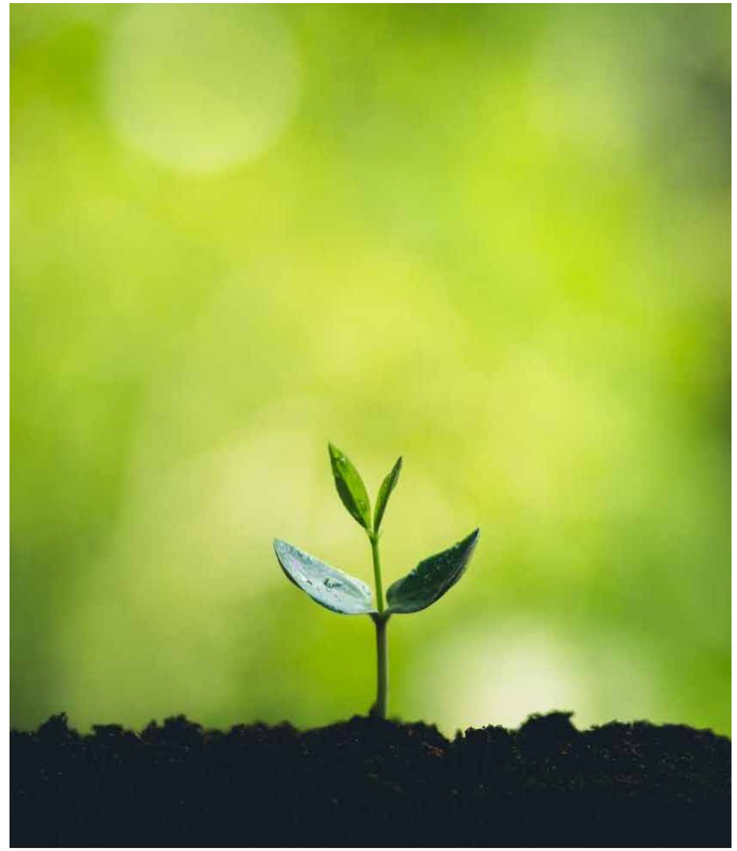
- Cough/throat congestion for long period
- Wheezing or other breathing problems
- Frequent antibiotic courses
- Frequent visits to doctors
- Restricted outdoor activities
- New borns suffering from breathing problem/eye irritation/cough/fever/skin rashes
- Other

5. Which of the following government initiatives on air pollution are you aware of?

- Garbage/Waste/Leaves burning attracts penalty up to Rs 5000
- Banning of construction activities during severe pollution days
- Graded Response Action Plan (GRAP) to be applicable during severe pollution days
- Diesel cars older than 10 years and petrol cars older than 15 years are now banned in Delhi region
- Coal, kerosene, furnace oil and pet coke banned
- None of the above

6. What is the willingness with which you can comply with the following:

- Use public transport
- Comply with odd-even policy (when applicable)
- Use car pools/shared cabs
- Use bi-cycle and walk where I can
- Neither indulge nor allow open construction in my neighborhood
- Plant shrubs/grass where there is loose soil/sand
- Switch off engine of my car at red lights
- Install solar rooftop
- Not use diesel cars
- Plant and maintain trees



Clean Air Asia

Clean Air Asia (CAA) is an international non-governmental organization that leads the regional mission for better air quality and healthier, more livable cities in Asia. We aim to reduce air pollution and greenhouse gas emissions in 1000+ cities in Asia through policies and programs that cover air quality, transport and industrial emissions and energy use.

CAA works with ministries (energy, environment, health and transport), cities in Asia, private sector and development agencies to provide leadership and technical knowledge in the following areas: Air Quality and Climate Change, Low Emissions Urban Development, Clean Fuels and Vehicles and Green Freight and Logistics. Its approach is hinged on science-based, actionable guidance combined with an ethos of partnerships and collaboration as key drivers for meaningful and lasting impact.

Envecologic

Envecologic is a new age sustainability think tank and capacity building firm which works towards understanding and proposing solutions to the challenges of global warming, climate change and fast depleting natural resources. To achieve this, it relies on Thought Leadership, Research & Advisory and Workshop & Training capabilities.

In a short span of time, it has built the reputation of delivering in-depth and applicable intelligence in spheres of energy and sustainability.

What sets us apart is the combination of our research approach, subject matter expertise, and effective application of principles of environmental economics. Domain expertise, coupled with highly skilled consultants, an extensive network of subject matter experts, and proprietary KARE framework (Knowledge, Analytics, Research & Economics) make Envecologic unique and value driven.

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Prarthana Borah is the India director of Clean Air Asia, an international organization working towards better air quality in Asian cities. She leads the India program for informing policy and capacity building on air quality management in Indian cities. An Economist by training, Prarthana has over two decades of experience as a conservation educator, sustainability strategist and environmental policy specialist.

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