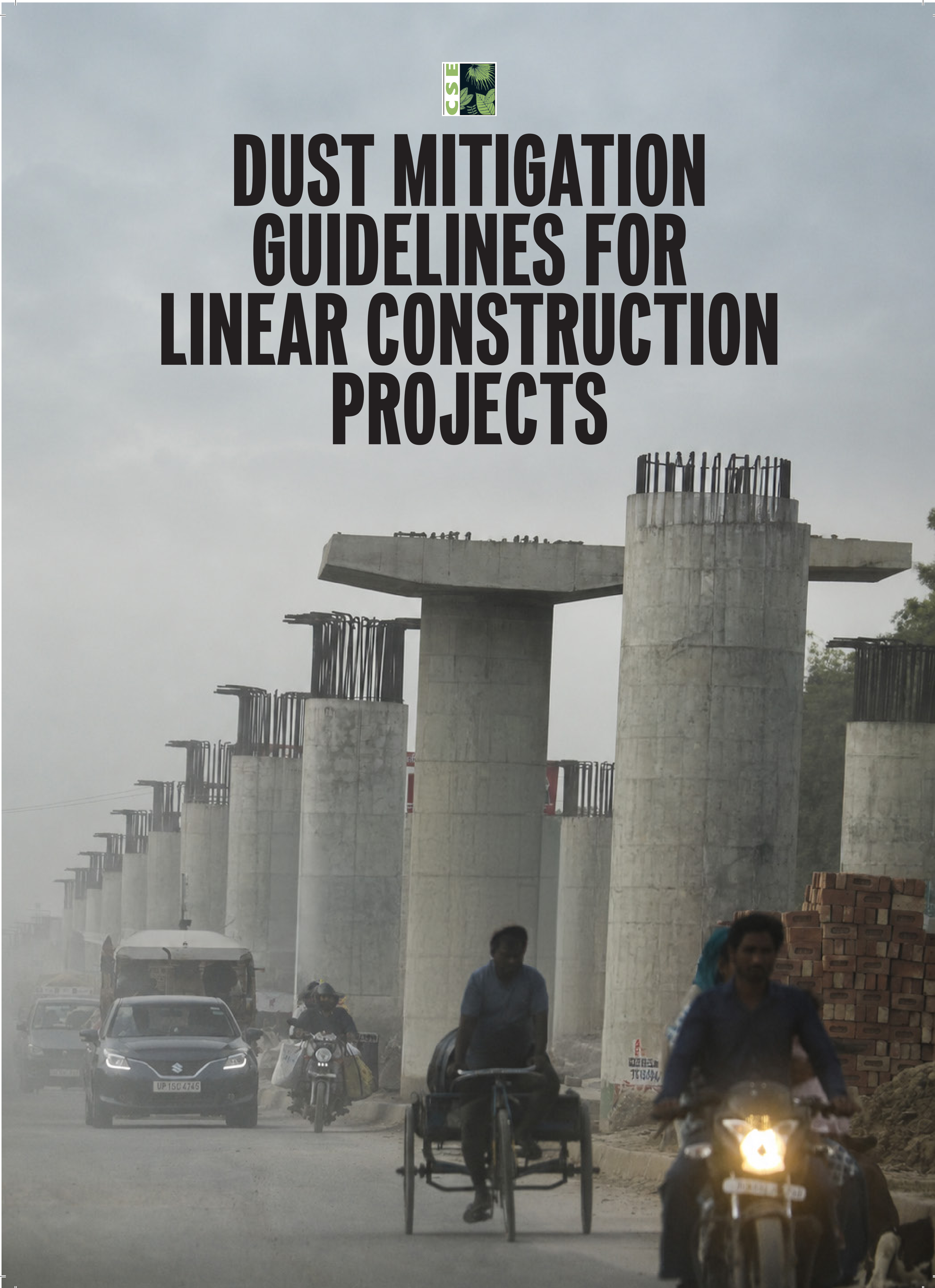
DUST MITIGATION GUIDELINES FOR LINEAR CONSTRUCTION PROJECTS



DUST MITIGATION GUIDELINES FOR LINEAR CONSTRUCTION PROJECTS

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Introduction

India is poised for a massive expansion in built space, with projections indicating that the country's building stock could more than double by 2040.[1] Estimates suggest that real estate could contribute up to 15.5 per cent of total economic output by 2047.[2] This growth extends beyond buildings and is being accompanied by a rapid expansion of linear infrastructure projects such as roads, railways, metro systems, pipelines, canals, and electricity and communication networks.

Between 2014 and 2026, the national highway network expanded from about 91,000 kilometres (km) to more than 1,46,000 km.[3] The railways added 31,000 km of new track, roughly equivalent to Germany's entire rail network between 2014 and 2024.[4] Metro systems have spread from just five cities to 26, with operational length increasing more than fourfold from 248 km in 2014 to nearly 1,100 km by 2025.[5] Alongside this, India has added almost 6,000 km of petroleum pipelines in the last five years alone,[6] is rapidly expanding its electricity transmission network, and is pushing for drainage and sewerage coverage across several cities.

This rapid growth in construction activity is accompanied by fugitive dust emissions, which are associated with every stage of construction and demolition (C&D) activity, from the storage of materials and waste, and loading and unloading operations to transportation and on-site processing and handling.

According to a source apportionment study for Delhi, roads, construction, and soil dust accounted for up to 42 per cent of PM_{10} generation during the summer.[7] Similar evidence from other Indian cities also demonstrates the significant contribution of construction-related dust to ambient air pollution. In Surat, 48 per cent of PM_{10} has been attributed to soil, road, and construction dust based on receptor modelling,[8] while Pune reports 11.49 per cent of PM_{10} originating from construction and road dust.[9]

Health implications

Dust is a major environmental and public health concern, and construction-related dust is a significant contributor to the deterioration of ambient air quality in Indian cities. Over 2 million deaths in 2023 in India were attributable to outdoor air pollution,[10] of which dust is a significant contributor.

Air quality assessments commonly use particulate matter (PM) as a key indicator of pollution levels because these particles are closely linked to adverse health outcomes. PM concentrations are widely monitored to evaluate ambient air quality, assess compliance with standards, and estimate exposure-related health risks. Particulate matter is a mixture of solid particles and liquid droplets suspended in the air and is a major component of dust generated during construction activities. These particles vary in size and composition and are commonly classified based on their aerodynamic diameter. PM_{10} refers to inhalable particles with a diameter of 10 micrometres or less. $PM_{2.5}$, or fine particulate matter, consists of much smaller particles with diameters of 2.5 micrometres or less.

The health implications of particulate matter depend largely on particle size. Larger particles, such as PM_{10}, are generally trapped in the nose or upper respiratory tract and therefore do not penetrate as deeply into the lungs, causing comparatively less damage. In contrast, $PM_{2.5}$ can easily enter the human respiratory system, reaching deep into the lungs and, in some cases, entering the bloodstream. This ability to penetrate deep into the body makes $PM_{2.5}$ particularly harmful, as it is associated with a range of serious health impacts, including respiratory and cardiovascular diseases (see *Table 1: Characteristics of PM_{10} and $PM_{2.5}$ particulate matter*).[11]

Table 1: Characteristics of PM_{10} and $PM_{2.5}$ particulate matter

Type of PM	Behaviour of PM	Effects on the human body
PM_{10} consists of coarse airborne particles with an aerodynamic diameter between 2.5 and 10 micrometres	Due to their relatively larger size, these particles are heavy and settle rapidly out of the atmosphere, typically within a few hours. PM_{10} tends to travel only short distances from its source.[12]	PM_{10} particles are small enough to enter the lungs. These particles typically deposit in the primary bronchi, where they can cause respiratory issues such as aggravated bronchitis, coughing, and reduced lung function.[13]
$PM_{2.5}$, or fine particulate matter, includes particles with a diameter of 2.5 micrometres or less	They have a negligible sedimentation rate, which allows them to remain suspended in the air for several days to many months. $PM_{2.5}$ can travel over long distances, potentially thousands of kilometres. They can easily penetrate indoor environments far beyond the boundary of a construction site.[14]	$PM_{2.5}$ particles' microscopic size allows them to bypass the body's filter mechanisms and penetrate deeply into the terminal bronchioles and alveoli. Once in the alveoli, these particles can cross the lung-capillary interface and enter the bloodstream. This translocation can cause irreparable cardiovascular damage, arterial inflammation, and is a major contributor to lung cancer and premature death.[15]

Source: Multiple sources

According to the State of Global Air report based on the Global Burden of Disease (GBD) 2021 dataset, long-term exposure to $PM_{2.5}$ contributed to roughly 4.14 million deaths worldwide in 2019, representing a substantial portion of air-pollution-related mortality. In 2019, there were 980,000 deaths attributable to $PM_{2.5}$ in India.[16] Among 69 potentially modifiable risk factors, ambient $PM_{2.5}$ exposure ranks sixth overall, following major factors such as high blood pressure, tobacco use, and elevated blood sugar. Notably, it is the highest-ranking risk factor within the environmental and occupational category.[17]

The World Health Organization (WHO), in its Air Quality Guidelines (2021), prescribes a 24-hour mean limit of 15 $\mu g/m^3$ for $PM_{2.5}$ and 45 $\mu g/m^3$ for PM_{10}, based on evidence linking particulate exposure to both short-term and long-term health outcomes.[18] These limits are not threshold values below which no harm occurs; rather, they represent concentrations at which health risks rise sharply. In India, the National Ambient Air Quality Standards (NAAQS), notified under the Air (Prevention and Control of Pollution) Act, 1981, are less stringent, allowing 60 $\mu g/m^3$ (24-hour) for $PM_{2.5}$ and 100 $\mu g/m^3$ (24-hour) for PM_{10}.[19]

Various studies, however, indicate that particulate matter in and around construction and demolition sites often exceeds the standards set by WHO and India's NAAQS. A study examining particulate emissions at five construction sites in Kanpur found consistently severe exceedances of air quality norms across all locations. Concentrations of both $PM_{2.5}$ and PM_{10} were reported to be 18–20 times higher than the National Ambient Air Quality Standards (NAAQS). This is concerning, as it implies that particulate matter in air inhaled by workers and residents in the vicinity, especially $PM_{2.5}$, is much higher than the CPCB limits or the WHO's guideline values.[20]

Increased risks for construction workers

For individuals who are exposed to dust regularly, particularly construction workers, continual inhalation leads to a gradual accumulation of particulate matter in the body, significantly increasing health risks. They are exposed at close range and for extended durations during dust-intensive activities. The effects of such exposure are often not immediate; instead, they can take years to manifest, by which time the damage may be irreversible. As a result, construction workers, along with communities living along active construction corridors, face prolonged and compounded health risks arising from sustained dust exposure.[21]

The risks intensify as ambient particulate matter concentrations continue to rise. $PM_{2.5}$ levels above 90 $\mu g/m^3$ can trigger physiological stress and respiratory complications, while prolonged exposure to concentrations exceeding 120 μg/m^3 has been associated with increased respiratory and cardiovascular illnesses, higher hospital admissions, and symptoms such as breathlessness, wheezing, and chest tightness even among otherwise healthy individuals.[22]

Silica is of particular concern in dust emanating from construction and demolition activities. Silica is a basic constituent of construction materials and is known to bypass the body's natural filtration mechanisms, making exposed populations susceptible to pulmonary infections and long-term respiratory diseases. Cutting, drilling, grinding, demolition, and recycling activities generate high levels of respirable silica dust, which is linked to increased risk of silicosis and lung cancer in construction workers.[23] Silicosis happens after a few years of continuous exposure, is incurable, and can be fatal.[24]

Why this report?

India has set ambitious targets to speed up the expansion of its linear infrastructure network. The country plans to expand its high-speed road network fivefold by adding nearly 17,000 km of access-controlled highways by 2033, with an estimated investment of US $125 billion.[25] In parallel, the government has set an ambitious target of increasing the pace of highway construction to 60 km per day.[26] Alongside highways, the construction of flyovers and elevated corridors continues to accelerate across urban and intercity transport networks. The Union government, along with several state and city governments, has announced new elevated infrastructure projects to address congestion and improve mobility.[27, 28, 29, 30]

Metro rail expansion remains another major driver of linear infrastructure construction. India has set a target of developing 5,000 km of operational metro routes across 100 cities by 2047.[31] Investments in metro systems have increased nearly fivefold over the past decade,[32] with metro and mass rapid transit systems accounting for approximately one-third of total urban allocations in FY26.[33]

Rail infrastructure is also undergoing substantial expansion through new high-speed and regional rapid transit corridors. The railways received a record allocation of Rs 2,78,000 crore in FY26.[34] Further, the Union Budget 2026–27 announced seven new high-speed rail corridors connecting major city pairs, including Mumbai–Pune, Pune–Hyderabad, Hyderabad–Chennai, Chennai–Bengaluru, Delhi–Varanasi, and Varanasi–Siliguri. Together, these projects signal nearly 4,000 km of additional dedicated high-speed rail services beyond existing projects.[35]

Large-scale expansion is also underway in the power and urban utility sectors. The government has announced plans to invest more than Rs 9 trillion in power transmission infrastructure by 2032.[36] To support growing renewable energy generation, the transmission network is expected to expand to 650,000 circuit kilometres by FY32, including the addition of 114,000 circuit kilometres by 2027.[37] Simultaneously, under AMRUT 2.0, projects worth Rs 66 thousand crore had been approved as of February 2026 for urban water and sewerage infrastructure, including the laying of more than 34,500 km of sewer lines.[38]

As construction of these linear projects increases, so does the risk of dust pollution. This necessitates the need for guidelines that are specifically attuned to the challenges and requirements of linear projects. Existing dust mitigation guidelines are often inadequate and poorly suited to the nature of linear projects.

Current regulatory responses also tend to be reactive rather than preventive. For instance, under the Graded Response Action Plan (GRAP), construction activities in the Delhi–NCR region are periodically banned when air quality deteriorates beyond prescribed thresholds. However, such blanket restrictions lead to significant economic disruptions, project delays, cost escalations, and severe livelihood impacts on daily-wage construction workers. In 2023 and 2024 alone, construction activities in Delhi–NCR were halted for a cumulative period of 78 days under GRAP.[39]

The inherently linear nature of infrastructure projects further complicates regulation and enforcement. Since these projects often traverse multiple administrative jurisdictions, dust mitigation guidelines and implementation responsibilities are fragmented across different authorities, weakening monitoring, coordination, and overall compliance with control measures. These limitations underscore the need for a risk-based and project-specific approach to dust management that can enable infrastructure expansion while safeguarding air quality and public health.

What are linear projects?

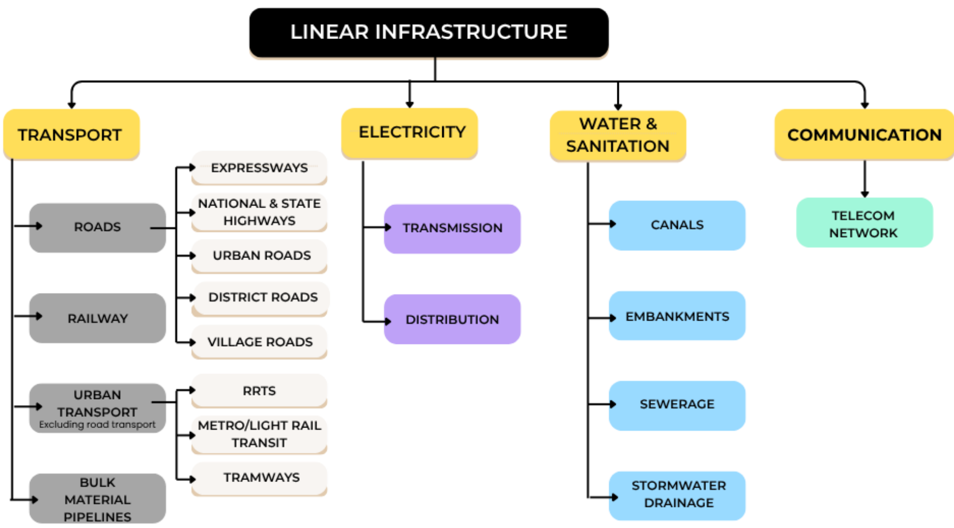
As per the Ministry of Environment, Forest and Climate Change (MoEFCC), "linear projects" refer to projects such as slurry pipelines, oil and gas transportation pipelines, highways, and railway lines that involve the extraction, sourcing, or borrowing of ordinary earth exceeding 20,000 cubic metres.[40] However, this definition is limited in scope because it relies on a rigid volumetric threshold of earthwork rather than the actual length and environmental impacts (like fugitive dust and habitat fragmentation) of the construction alignment.

To address this gap, linear projects can be more comprehensively defined as construction projects with a predominantly linear geometry, where the length substantially exceeds the width, and are typically characterised by a sequence of repetitive activities carried out across the project alignment.[41, 42]

Types of linear projects

India currently lacks a comprehensive categorisation of linear infrastructure projects. MoEFCC's definition offers only an illustrative list consisting of slurry pipelines, oil and gas pipelines, highways, and railway lines, which falls short of capturing the full range of linear project types.[43]

Figure 1: Types of linear infrastructure



Source: CSE

A more comprehensive basis for classification can be drawn from the Ministry of Finance's "Harmonized List of Infrastructure," which establishes a uniform definition of infrastructure to support project prioritisation, financing, and inter-agency coordination.[44] Based on this framework and the defining characteristics of linearity, such as elongated spatial geometry and continuity across alignments, a broader range of linear construction project typologies can be identified and analysed (see *Figure 1: Types of linear infrastructure*).

Transport

Roads

Roads are land-based pathways with a right-of-way intended for public use. Based on construction materials, road pavements are primarily classified into flexible pavements, which use bituminous layers, and rigid pavements, which use concrete slabs. The Indian Roads Congress (IRC) further classifies roads into urban and non-urban roads. Non-urban roads include expressways, national highways, state highways, major district roads, other district roads, and village roads. This classification is based on factors such as road function and traffic volume.[45]

Railways

Railway tracks, including the electrical and signalling systems, tunnels, viaducts, and bridges, form the linear part of the railways—essentially fixed operational assets managed, operated, and constructed by the Indian Railways.

Urban public transport (except road transport)

The Ministry of Housing and Urban Affairs (MoHUA) classifies Urban Public Transport into the following subtypes:[46]

- *Regional Rapid Transit System (RRTS):* It is a high-speed, rail-based commuter network designed to strengthen regional connectivity across urban and peri-urban areas. Operating at speeds of up to 180 km/h, with train frequencies of five to ten minutes and station spacing of five–ten km, it serves larger urban agglomerations by connecting peripheral regions to city centres. It has fewer stops and higher speeds than metro rail, but more frequent halts than long-distance railways.[47]

- *Metro rail:* It is a fully segregated, high-capacity, rail-based mass transit system that can be at-grade, elevated, or underground. Owing to its dedicated right-of-way and advanced system design, metro rail can carry approximately 40,000–80,000 passengers per hour per direction (PPHPD). Metro systems also encompass monorails, which operate on a single track that serves as both support and guideway.

- *Light Rail Transit (LRT):* Typically, an at-grade rail-based system that is partially segregated from regular traffic, it offers moderate capacity and serves as an intermediate mode between metro rail and tram systems.

- *Tramways:* At-grade rail systems that operate without segregation, often sharing road space with mixed traffic. They are generally slower but are well suited for short-distance urban mobility.[48]

Bus-based systems, such as BRTS and conventional bus services, are not assessed as a separate category in the dust risk classification framework, as they typically rely on existing road infrastructure and do not involve the construction of distinct linear assets beyond those already captured under road projects.

Bulk material transportation pipelines

These refer to pipelines used for the transportation of bulk materials, such as oil, natural gas, slurry, water, and iron ore, over long distances.

Energy

Electricity transmission

The transmission system serves as the critical link between electricity generation sources and consumption centres (load centres), enabling the transfer of power across the grid.[49] It forms the high-voltage spine that moves bulk power across states.

Electricity distribution

The electricity distribution system is the infrastructure responsible for providing power from the transmission grid to the end consumers.[50] It steps down the voltage and handles the last mile of delivery to consumers.

Water and sanitation

Canals

Canals are open anthropogenic waterways (excluding channelised rivers) that connect two or more natural or anthropogenic waterbodies of various sizes, structures, and functions, such as transportation (e.g., navigation canals), defence (e.g., moats), and irrigation (including ditches).[51]

Embankments

Embankments are structures constructed parallel to rivers, utilising mostly the earth materials found in the vicinity to confine the flow of water within defined channels and protect adjacent areas from flooding.[52]

Sewerage systems

A sewerage system is a closed system of pipes extending from the waste receptacle to the final disposal point, either on land or into a body of water, under gravitational or free flow.[53]

Stormwater drainage systems

A stormwater drainage system is designed to safely collect and transport stormwater runoff and consists either of a network of open drains connected by junctions or of underground conduits connected by manholes. It includes various components, such as street inlets, gutters, catch basins, engineered detention basins or tanks, pumping stations, and outfall structures.[54]

Communication

Telecommunication cable network

This includes optical fibre, wire, and cable networks that provide broadband and internet connectivity. Telecommunication cables function by transmitting and receiving modulated signals through different media.

Elevated dust and exposure risks in brownfield projects

Infrastructure projects can also be classified as greenfield or brownfield developments. Greenfield projects are built on vacant or previously undeveloped land, such as agricultural fields, forests, or open areas, where construction starts from scratch with limited interference from existing infrastructure. In contrast, brownfield projects involve infrastructure development on land that has already been built upon and used for non-agricultural purposes. As brownfield projects are carried out within existing built-up areas, they involve additional construction activities and operational constraints that can increase both dust generation and the number of people exposed to dust emissions. The higher dust and exposure risks associated with brownfield construction arise from several factors:

- *Demolition and dust generation:* Brownfield projects often require the deconstruction, demolition, or dismantling of existing structures and utilities, generating substantial volumes of different types of dust.

- *Underground utility conflicts:* Foundation and excavation work in brownfield areas is often delayed due to the need to shift existing underground utilities. Utilities—such as water pipelines, sewer lines, electricity cables, telecom networks, and gas lines—are spread across dense urban areas and are managed by multiple agencies, making relocation a complex and time-consuming process. Even with preliminary surveys and trial pits, unexpected utility conflicts frequently emerge during excavation, requiring additional approvals, coordination, and rerouting. The lack of effective inter-agency coordination and delays in obtaining clearances further disrupt construction schedules. These repeated interruptions prolong excavation activities, keep soil exposed for longer durations, and consequently increase dust generation.[55]

- *Higher exposure risks:* Since brownfield projects are typically located within already developed and densely populated areas, a larger number of receptors, including residents, pedestrians, roadside vendors, and nearby commercial establishments, are exposed to dust emissions generated during construction activities.

The need for separate rules for linear projects

Existing dust mitigation guidelines

India has notified guidelines and regulatory provisions to address dust generation from C&D activities. These intend to reduce fugitive dust emissions by prescribing preventive and suppressive measures at construction sites, during material storage, and along transportation pathways.

The Environment (Protection) Amendment Rules, 2018, notified by the Ministry of Environment, Forest and Climate Change on 25 January 2018, lay down mandatory dust mitigation measures for construction and demolition activities. These rules require all building and infrastructure projects that need environmental clearance to include dust mitigation practices into their Environmental Management Plans, without which the project cannot be implemented. The same notification also makes dust mitigation mandatory for all construction and demolition activities, irrespective of environmental clearance requirements. These mandated measures enforce a comprehensive dust mitigation strategy across the entire lifecycle of construction materials, strictly regulating their active handling, storage, and transport to minimise airborne particulate matter and localised air pollution (see *Table 2: Existing dust mitigation guidelines*).

In addition to the Environment (Protection) Amendment Rules, the Central Pollution Control Board (CPCB) issued 'Guidelines on Dust Mitigation Measures in Handling Construction Material and C&D Wastes (2017–2018)'. These guidelines provide operational directions for reducing dust during the handling, storage, and transportation of construction materials and waste (see *Table 2: Existing dust mitigation guidelines*).

Unique challenges associated with linear construction projects

While these guidelines collectively create a comprehensive framework for dust mitigation in conventional construction settings, they are largely designed around static, site-based projects with defined boundaries and limited spatial spread. In such settings, conventional dust management measures, such as site enclosures, wind barriers, water sprinkling, material covering, wheel washing, and access control, can be deployed with relative effectiveness. Linear construction projects, however, differ fundamentally in their spatial characteristics.

Table 2: Existing dust mitigation guidelines

Environment (Protection) Amendment Rules, 2018, by MoEFCC notification on 25th January 2018, serial numbers 106 and 107	106. Mandatory Implementation of dust mitigation measures for construction and demolition activities for projects requiring environmental clearance: • Building and infrastructure projects requiring environmental clearance require dust mitigation practices in their Environmental Management Plans, without which the projects shall not be implemented. • Paving or black topping of roads leading to or at construction site is required. Excavation of soil shall not be done without adequate dust mitigation measures in place. • Loose soil, sand, construction and demolition waste, or any other construction material that causes dust shall not be left uncovered. • Windbreakers of appropriate height, equal to one-third of the height of the building and with a maximum height of 10 metres, should be provided. • Water sprinkling shall be adopted. • Dust mitigation measures shall be displayed prominently for easy public viewing. 107. Mandatory implementation of dust mitigation measures for all construction and demolition activities: • Cutting and grinding of building materials in open areas are not allowed. • Construction material and waste shall be stored only in earmarked areas, and roadside storage is prohibited. • Uncovered vehicles carrying construction material and waste shall not be permitted. • Identification of construction and demolition waste processing and disposal site shall be done, along with notification of the required dust control measures at the sites.
Guidelines on Dust Mitigation Measures in Handling Construction Material and C&D Wastes, 2017–2018, issued by CPCB	• Transport materials that are easily wind-borne need to be covered by a sheet made of jute, tarpaulin, plastic, or any other effective material. • Barricades should be raised along the perimeter, depending on the nature of adjoining regions. • Dust barrier sheets, such as tarpaulin or plastic, should be mounted on scaffolding around construction or demolition buildings, particularly on sides facing residential areas. • Transport routes for carrying construction material and C&D waste should be identified, preferably to avoid residential, schools, institutional, and hospital areas. • Trucks and lorries should not be overloaded to avoid overflow of material (C&D waste or construction material) during transportation. • As transport vehicles generally operate during the night, transport permits should indicate the material or waste being transported, the quantity being transported, and the loading and unloading locations. • As most cities propose to have one C&D waste facility, the locations of all temporary or intermediate C&D waste storage dumpsites should be placed in the public domain for stakeholders by the concerned department. • Unloading activities at temporary or intermediate C&D waste dumpsites should ensure that dust-borne particles are damped, either through water spraying or by aligning waste disposal in a manner that minimises dust dispersal (e.g., through windbreakers). • Unloading activities of construction materials at onsite or off-site locations should ensure that the dispersal of dust-borne particles is minimised, either through the location of the dumpsite, the use of water sprinklers, or covering with sheets made of jute, tarpaulin, plastic, or any other effective material. • Roads surfaces to be well maintained so that transport vehicles are not subjected to jerks that may result in the ejection of C&D wastes or construction material onto roads. • In many cases, transportation routes may cover several kilometres, making wet damping a major challenge. Regular sweeping (or vacuum sweeping) would assist in reducing the re-suspension of dust due to movement of vehicles, particularly in cities.

- Establishing and maintaining permanent dust-control infrastructure is difficult in linear infrastructure projects because construction activities continuously shift along the project corridor. Projects such as highways, metro corridors, railway lines, flyovers, and viaducts extend over several kilometres and traverse multiple urban and peri-urban landscapes, unlike confined construction sites with a fixed footprint.

- A key challenge in linear infrastructure projects is the large spatial extent of dust exposure. Unlike area-based construction, where impacts remain concentrated around a single site, linear projects spread dust exposure continuously across long corridors passing through residential areas, commercial zones, and transport networks. Studies show that $PM_{2.5}$ concentrations can remain above permissible limits even 200–500 metres from a conventional construction site.[56] In linear projects spanning several kilometres, this impact zone is repeatedly reproduced along the entire corridor. As a result, dust exposure is not localised to one site but extends across large urban areas, exposing significantly larger populations for longer durations.

- Linear projects, such as mass transit or metro systems, occur in the vicinity of existing road networks. Construction activities are sometimes carried out adjacent to busy roads, where traffic movement itself becomes a major dust dispersal mechanism. Dust generated at construction sites is often deposited on nearby paved roads and subsequently resuspended by vehicular movement. All traffic, and not just construction-related vehicles, contributes to this resuspension; this secondary source of dust can remain active throughout the construction period.

- While linear projects can often be executed segment by segment, this is not always feasible. For example, in an elevated metro project, individual pier construction may be completed kilometre by kilometre, but the overall construction cannot be completed until the entire section is ready for track laying. As a result, any incomplete segment sitting idle during this waiting period remains a potential dust hazard unless effective counter measures are implemented.

- The problem is compounded by the extensive movement of heavy vehicles associated with linear construction (see image *Heavy vehicles movement in linear project*). Material sourcing, storage, and deposition sites are often located at varying distances from different stretches of the project corridor,

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Heavy vehicles movement in linear project

making it difficult to maintain support facilities close to all active construction zones. A facility that is conveniently located for one stretch may become too distant as the construction front shifts, increasing the distance travelled by construction vehicles. As a result, dumpers, concrete mixers, trailers carrying girders, and prefabricated bridge components frequently travel long distances along public roads. This continuous movement not only generates fresh dust emissions but also repeatedly disturbs settled dust on haul roads and adjacent streets, leading to persistent resuspension.

Taken together, these factors mean that dust from linear construction projects is not merely a localised nuisance but often a regional air quality concern. The scale of exposure and the persistence of fine particulate matter make dust management in linear projects more complex than in conventional construction.

Limitations of existing dust control regulations for linear construction

While existing dust mitigation regulations and guidelines provide a useful framework for controlling emissions from construction activities, they have largely been developed with conventional, area-based construction sites in mind. Considering the various unique characteristics of linear projects, several prescribed mitigation measures are difficult to implement, inadequate in scale, or ineffective in addressing the unique dust generation and exposure patterns associated with linear projects.

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Tall wind barriers require space for foundations, but linear projects are often space-constrained

- Installing tall dust barriers is often impractical in linear infrastructure projects. Many guidelines recommend barriers of up to 10 metres in height to control dust emissions. However, such barriers require wide and stable foundations for structural support. Linear construction corridors are typically narrow and space-constrained, leaving insufficient room for the installation and maintenance of barriers of this scale (see image *Tall wind barriers require space for foundations, but linear projects are often space-constrained*).

- Implementing measures, such as wheel-washing infrastructure, demand substantial space for both installation and ongoing operation. However, linear projects are characterised by multiple, frequently changing entry and exit points along narrow corridors, making it difficult to install wheel-washing facilities at every access location without severely disrupting the surrounding area (see image *Entry-exit points for construction vehicles for metro construction*).

- Many prescribed mitigation measures are designed as fixed structures and are based on the area coverage of the control measure. For instance, the Commission for Air Quality Management (CAQM)—the body responsible for coordinating emergency and policy-level air quality actions across Delhi and all NCR states—requires at least one anti-smog gun for a project area between

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Entry-exit points for construction vehicles for metro construction

5,000 and 10,000 square metres, two for 10,001–15,000 square metres, three for 15,001–20,000 square metres, and four for any area above 20,000 square metres. While this formula works for compact, area-based sites, it fails to account for linear projects, where the same total area is stretched over several kilometres, rendering the prescribed number of guns inadequate for controlling dust along an extended corridor.[58]

- Administrative fragmentation presents a major challenge as well. Linear projects often cross municipal boundaries, district limits, and even state borders, placing them under the oversight of multiple regulatory jurisdictions. Each of these authorities has its own enforcement capacity, compliance mechanisms, and dust-control guidelines. The result is a highly fragmented enforcement landscape, where the inconsistent application of rules across different segments of the same project undermines overall effectiveness and accountability.

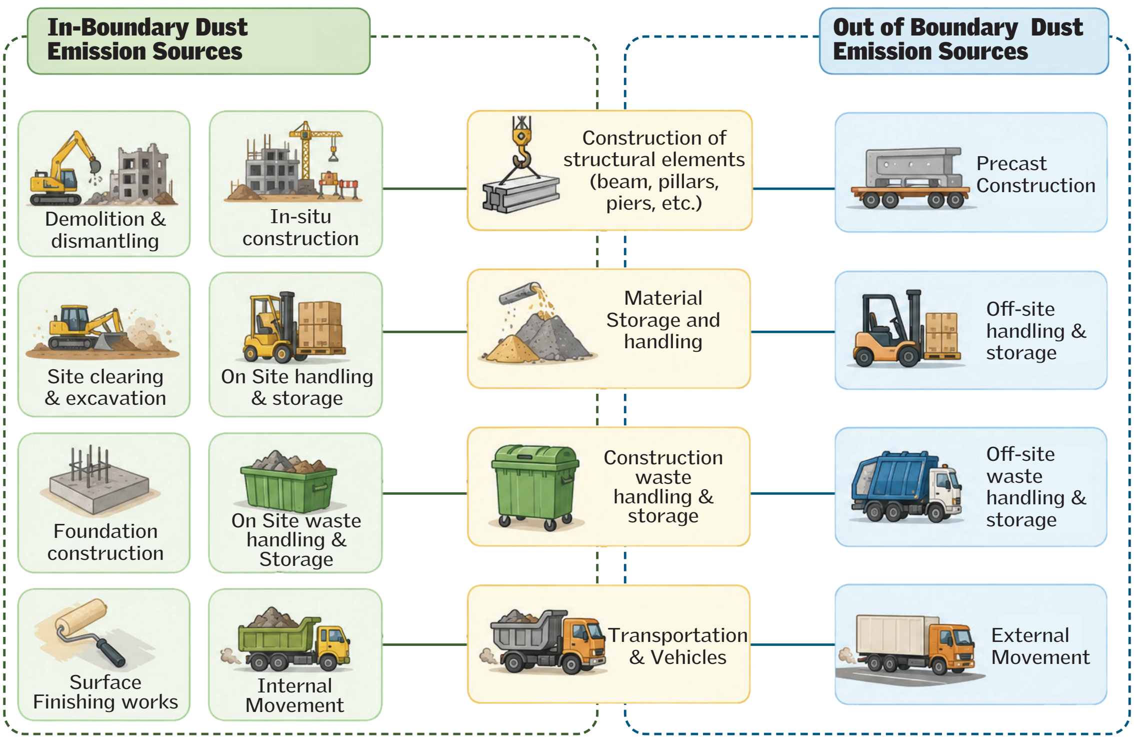
These limitations highlight the need to rethink dust management for linear infrastructure projects. Simply extending regulations developed for area-based construction sites is unlikely to deliver effective outcomes. Instead, dust-control requirements must be redesigned to reflect the scale, mobility, and dispersed nature of linear construction activities.

Dust generating activities

Effective dust management in linear infrastructure projects requires a clear understanding of the activities that generate and disperse dust. Unlike area-based construction sites, linear projects involve multiple moving work fronts spread across long corridors. As a result, dust is generated continuously from a range of activities, including demolition, excavation, material handling, transportation, and construction operations, often affecting both the construction zone and the surrounding areas.

For linear infrastructure projects, dust emission sources can be geographically classified into in-boundary and out-of-boundary emission sources (see *Figure 2: Categorisation diagram of dust emission sources*). In-boundary sources include activities taking place within the active construction corridor, such as demolition, excavation and earthwork, material storage, and the movement of construction machinery. Out-of-boundary sources include emissions from the transportation of construction materials and debris, as well as from off-site material handling.

Figure 2: Categorisation diagram of dust emission sources

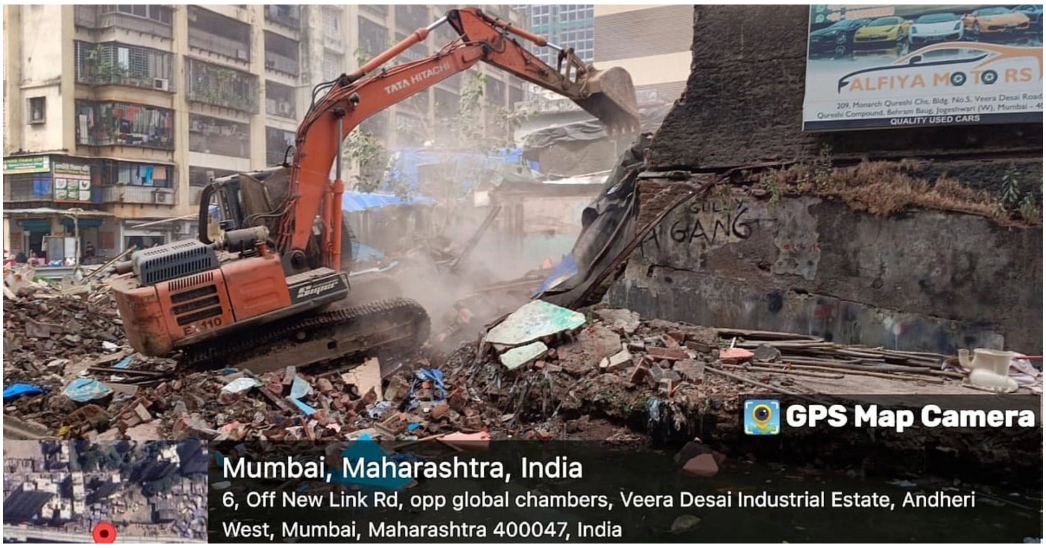


Source: CSE

In-boundary emission sources

Demolition and dismantling

Demolition and dismantling of existing structures are among the most dust-intensive construction activities. Activities such as structural demolition, pavement breaking, concrete cutting, drilling, and milling generate substantial fugitive dust emissions (see image *Demolition for metro construction in Mumbai*). A study of high-rise building demolition in Chicago found that PM_{10} concentrations increased by up to 59 per cent above pre-demolition levels over 24-hour average measurements, while, during active demolition, six-hour average PM_{10} concentrations were four to nine times higher than those recorded at the same time in upwind areas, indicating substantial dust generation.[59] Additionally, one study found that concrete pavement sawing and drilling, and asphalt and concrete milling, can generate respirable crystalline silica dust concentrations up to 280 times the US National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/l, posing severe health risks to workers and nearby populations.[60]



FREE PRESS JOURNAL[61]

Demolition for metro construction in Mumbai

Excavation

Earthwork activities are a major source of fugitive dust emissions due to soil disturbance and the exposure of uncovered land surfaces during site clearing, excavation, trenching, grading, and related operations (see image *Excavation on the construction site*). Earthwork is among the highest dust-generating construction activities because of soil and aggregate stocking, loading, unloading,

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Excavation on the construction site

and transportation across large open areas. These activities generate finer dust particles that disperse over longer distances, especially in linear infrastructure projects, where excavation occurs continuously across multiple moving fronts.

Studies have found that excavation alone can cause a ~35 per cent increase in $PM_{2.5}$ concentrations, while earthwork leads to a ~44 per cent increase compared to non-polluting construction activities.[62]

Foundation construction

Earthwork and excavation are often followed by foundation laying and involve activities such as piling, concrete pouring, etc (see image *Foundation laying at metro rail project*). They contribute to fine particulate emissions through handling of cement, dry sweeping of surfaces, and mechanical disturbance during piling operations. As per a study in China, a majority of the construction PM emissions originated from the earthwork and foundation construction stages.[63]

IMAGE CREDIT: THE HINDU[64]

Foundation laying at metro rail project

PEXELS[65], SUGEET GROVER

Dust during cutting and tiles laying

Surface finishing works

Surface finishing works, like cutting, grinding, and drilling of concrete, stone, tiles, and pavement slabs, generate fine particulate matter, including silica-rich dust (see image *Dust during cutting and tiles laying*). These activities are repeated frequently along linear alignments for utilities, expansion joints, track fittings, and finishing works. Research shows that more than 90 per cent of particulate matter generated during the cutting of cement and concrete is $PM_{2.5}$, making these emissions particularly hazardous for health.[66] A study conducted in Kanpur, India, found that the highest PM_{10} and $PM_{2.5}$ emissions were generated from cutting and laying of tiles, which is a major finishing activity during metro and railway station construction.[67]

Sources with both in-boundary and out-of-boundary emission components

Construction of structural elements

The construction of structural elements—such as piers, pillars, beams and girders—may be undertaken using either in-situ or precast methods. In in-situ construction, components like vertical pillars are cast on-site, concentrating dust from material handling and concrete mixing along the project corridor. In contrast, components such as viaduct segments and full-span girders are precast in off-site casting yards, shifting most dust-generating activities away from the construction site and substantially reducing dust emissions within urban areas.

Transportation (general transportation, internal and external)

Transportation-related dust emissions arise from the movement of construction vehicles, machinery, and other motorised equipment both within and outside the project boundary. These emissions occur through vehicle movement on unpaved haul roads, access roads, staging and parking areas, the resuspension of deposited dust from paved surfaces, and the transport of uncovered materials containing fine particles. Given the extensive movement of heavy vehicles associated with linear infrastructure projects, transportation is often one of the most persistent and widespread sources of fugitive dust generation. The various types of dust emissions from vehicles have been mentioned in the figure below (see *Figure 3: Emissions related to transportation in and out of the site*).

A significant share of dust emissions arises from the movement of construction vehicles along temporary and unpaved roads within construction sites.[68] Dumpers, trailers, concrete mixers, cranes, and trucks repeatedly travel along unpaved or partially paved haul roads, resuspending dust that has settled on road surfaces (see image *Vehicular movement within an active construction site*).

Research suggests that PM_{10} concentrations are strongly positively correlated with the number of vehicle trips, indicating that haulage and construction vehicle movement are among the most important sources of fugitive dust emissions at construction sites.[69] Vehicle movements associated with material handling have also been observed to increase $PM_{2.5}$ concentrations by ~122 per cent compared to no-work conditions, making them a critical contributor to dust pollution on construction corridors.[70]

Figure 3: Emissions related to transportation in and out of the site

Source: CSE

HARIKRISHNAN CU

Vehicular movement within an active construction site

Material and C&D waste handling and storage

Fugitive dust emissions are also generated from the stacking, loading, unloading, and the transfer of bulk materials, including soil, sand, aggregates, and construction debris. In linear projects, these activities occur repeatedly across multiple locations, such as active construction areas, concreting yards, batching plants, and temporary depots. Dust is generated when materials are dropped from height, transferred between machinery, or moved internally (see image *Material handling and uncovered material storage as a source of dust*).

Temporary storage of construction materials along the right-of-way or within the site is a source of dust. Stockpiles of soil, sand, and aggregates are often stored in open areas close to active construction zones or road edges (see image *Material handling and uncovered material storage as a source of dust*). C&D waste stored

SUGEET GROVER, NIDA MARYAM

Material handling and uncovered material storage as a source of dust on-site can also become a significant source of fugitive dust. When debris such as broken concrete, mortar, bricks and fine construction residues is left exposed, it undergoes natural weathering and fragmentation, generating loose particulate matter that can easily become airborne. Wind action plays a key role in lifting and spreading this dust, especially from uncovered or loosely managed stockpiles. Linear construction involves dispersed and frequently relocated storage points, making continuous monitoring and enclosure challenging. Wind-blown dust from storage areas contributes to both localized pollution and secondary resuspension when particles settle on adjacent roads and are later disturbed by traffic.

These activities represent the most common sources of fugitive dust emissions across linear infrastructure projects. However, they are not exhaustive. Each type of linear project has its own construction methodology, involving specialized activities that may generate additional dust emissions. Moreover, the overall dust risk associated with a project depends not only on the quantity of dust generated but also on factors such as construction duration, project location, traffic conditions, meteorological factors, and proximity to sensitive receptors. Consequently, different categories of linear infrastructure projects can exhibit markedly different dust risk profiles.

Dust risk assessment matrix

Effective dust management in linear infrastructure projects requires going beyond listing dust-intensive activities. Not all linear projects create the same dust burden. Some generate large quantities of dust but affect relatively few people because they are located away from dense settlements, while others expose thousands of people daily because construction occurs within crowded environments. The difference lies not only in the amount of dust generated, but also in where and for how long people are exposed. The risk assessment matrix provides a structured way to evaluate linear projects based on three key dimensions—**dust generation** (the amount of dust produced by activities like excavation, demolition, and material handling), **long-term exposure** (the risk to nearby communities and workers over weeks or months), and **short-term exposure** (acute, high-intensity dust exposure caused by traffic congestion and vehicle entrainment). By scoring each project type across these dimensions, the matrix helps planners, regulators, and contractors identify high-risk projects, prioritise monitoring and mitigation measures, and design dust control strategies tailored to the specific challenges of linear construction.

Factors determining dust generation

- **Demolition or existing facilities debris:** This factor accounts for the amount of debris generated from demolishing and dismantling existing structures, pavements, foundations, or other built assets, specifically for brownfield (redevelopment or upgrade) projects. Demolition produces irregular, often fine particulate matter (including silica, concrete dust, and other residues) that can be highly respirable. Brownfield linear projects, therefore, carry a higher dust-generation baseline than greenfield sites, where this factor is negligible.

- **Excavated volume:** This refers to the total volume of earth, rock, or other material removed from the ground during construction (e.g., for cuttings, trenches, or foundations). Larger excavated volumes generally produce greater quantities of loose, fine material that can become airborne. However, the dust potential of excavation also depends on the specific topography of the area and the type of soil being excavated.

- **Backfilling ratio:** It is the proportion of excavated material that is reused as backfill on-site versus disposed of off-site. A high backfilling ratio means that most excavated material remains stockpiled on-site for extended periods, increasing the duration of dust exposure. Conversely, a low ratio leads to quicker removal of excavated material, reducing on-site storage and associated dust generation. Projects with high backfilling ratios, therefore, present greater dust risk from temporary stockpiles.

- **Effective dust-emitting area:** It is the total surface area of bare ground surfaces that is directly exposed to wind and mechanical disturbance during construction. Wind erosion and vehicle or traffic entrainment of dust correlate strongly with the extent of exposed surfaces. Linear projects often create long continuous exposed corridors.

- **Quantity of dry materials handled:** This is the mass or volume of dry, granular, or powdery materials (e.g., sand, cement, crushed aggregate, lime) moved, stored, or applied on-site. Dry materials have low cohesion and high fugitive dust potential, especially during loading, unloading, mixing, and wind exposure. Projects that handle significant quantities of cement or pulverised fuel ash inherently generate more dust unless strict suppression measures are in place.

- **Material transport trip frequency:** It refers to the total volume of vehicle movements (typically haul trucks, delivery lorries, or dumpers) associated with importing construction materials and exporting waste or excess spoil. Each trip generates dust through tyre entrainment on unpaved roads and spillage from loads. More trips mean more frequent dust pulses along access routes and on-site haul roads.

- **Duration of construction:** This refers to the total time required for the construction of the linear project. Longer construction periods generate dust for more months or years and also increase the probability of adverse weather conditions (drought, high winds) that exacerbate dust generation.

- **Wind-driven dispersion potential:** Wind is the primary agent that lifts and transports dust from exposed surfaces. While dispersion potential is highly sitespecific, some general principles can be applied. For example, elevated structures often experience higher wind speeds at greater heights, which increases dust entrainment and downwind transport. Underground sections, in contrast, encounter very low to negligible wind. In dense urban areas, tall buildings and narrow street canyons obstruct and slow down airflow, creating an "urban stilling" effect. This phenomenon reduces near-ground wind speeds and turbulence, limiting the ability of wind to lift and transport dust particles from construction activities.

Factors determining long-term exposure

Long-term exposure refers to repeated or continuous inhalation of dust over weeks, months, or years during the construction phase. This differs from short-term exposure in that health impacts accumulate over time. The assessment scores each project type based on three primary factors—the extent of public exposure in surrounding areas, the exposure risk to on-site construction workers and the duration of exposure.

- **Public receptor proximity and density:** This factor describes the density of populations in the immediate influence zone of the stretch and the type of land use adjacent to the construction corridor. Projects passing through urban residential, commercial, or mixed-use areas expose far more people to dust over extended periods than those in rural areas (see image *A linear project passing through a dense residential habitation*). Higher population density means more individuals at risk of chronic respiratory irritation and cumulative health effects, while sensitive land uses (schools, hospitals, aged care) amplify consequences. Linear projects in dense urban corridors, therefore, score higher than those in sparsely populated or remote alignments.

SUGEET GROVER

A linear project passing through a dense residential habitation

- **On-site exposure of construction workers:** This factor measures the prolonged dust inhalation risk faced by workers directly employed on the construction site, taking into account both the amount of dust generated and the ventilation conditions of their workspace. In open-air conditions, natural wind dispersion reduces persistent concentrations, though workers near dry handling or earthmoving still require controls. However, in poorly ventilated or enclosed environments such as tunnels, dust accumulates with little natural dilution, leading to sustained elevated exposure over shifts and months. Projects with significant underground or confined-space construction score substantially higher than those entirely in open corridors.

- **Per-kilometre chainage construction duration:** This factor measures how many days, weeks, or months each kilometre of alignment remains an active dust source. A higher per-kilometre duration means any fixed receptor experiences persistent dust emissions as the construction front slowly advances. Even moderate daily generation increases cumulative exposure, raises the probability of multiple dry or high-wind events, and extends the period during which control measures must remain effective. Projects with rapid progression (e.g., electrical wire installation) score lower, while those with slow or utility-dense methods (e.g., tunnel excavation) score higher.

Factors determining short-term exposure

Short-term exposure addresses acute, high-intensity dust and particulate matter events that occur over minutes to hours, often with peak concentrations far exceeding long-term averages. This is the critical factor that distinguishes linear construction projects from areabased sites. As construction moves progressively along a corridor, shortlived but intense dust episodes repeatedly affect passing vehicles and nearby commuters.

- **Congestion potential:** This factor measures the extent to which construction activities disrupt normal traffic flow, leading to vehicle queuing, idling, and stop-start conditions. From an air quality perspective, congestion is particularly harmful because idling diesel and petrol engines emit elevated concentrations of ultrafine particles and $PM_{2.5}$ (see image *Congestion due to metro construction*). Projects that require road closures, narrow singlelane working, or frequent traffic holds therefore score higher for short-term exposure.

- **Vehicular traffic entrainment:** This factor considers the number of vehicles passing immediately adjacent to the construction zone, recognising that high traffic volume has a dual effect on dust emissions. On one hand, vehicle-

HARIKRISHNAN CU

Congestion due to metro construction

induced turbulence disperses fugitive dust over a wider area, potentially affecting receptors farther from the source. On the other hand, turbulence also resuspends dust that has already settled on the roadway, generating repeated pulses of particulate matter with each passing vehicle.

The net effect is that high-traffic corridors adjacent to linear construction not only experience wider dust dispersion but also create ongoing reentrainment of deposited material, prolonging short-term exposure for commuters, pedestrians, and nearby occupants (see image *Dust resuspension and dispersion due to traffic).* Consequently, projects located on or alongside busy urban arterials or major intersections score significantly higher for this factor than those in low-traffic or rural settings.

HINDUSTAN TIMES[71], NIDA MARYAM

Dust resuspension and dispersion due to traffic

The scoring framework applies general assumptions based on typical project type characteristics. However, actual dust risk at any specific location is influenced by a range of site-specific factors not captured in this scoring. These include meteorological variables (local wind speed distributions, precipitation frequency, humidity, atmospheric inversions), topographical features (terrain roughness, corridor orientation relative to prevailing wind), geological conditions (soil erodibility, moisture regime, silica content), and detailed receptor characteristics (setback distances, background air quality, temporal use patterns). Consequently, the scores provided here serve as an initial screening tool. They must be supplemented by comprehensive Environmental Impact Assessments (EIAs) and corridor-specific dust assessments, which incorporate local monitoring, dispersion modelling, and construction management plans to accurately quantify and mitigate dust risks for any proposed linear project.

Results

Table 3: Risk assessment of linear construction projects

Types			Dust generation	Long-term exposure	Short-term exposure	Overall risk
Roads	Flexible/Rigid	Expressways	High	Low	Low	Medium
		Highways	High	High	Medium	High
		Urban roads	High	Very High	Very High	Very High
		District roads	Medium	High	High	High
		Village roads	Medium	Low	Low	Low
Roads - Elevated	Open structure flyover		High	Very High	Very High	Very High
	Reinforced earth wall flyover		Very High	Very High	Very High	Very High
Railways/ Metro	At-grade	GF	High	Medium	Medium	Medium
		BF	Very High	High	Medium	High
Metro/ RRTS	Underground	TBM/NATM -GF	High	Low	Medium	Medium
		TBM/NATM -BF	High	Medium	Medium	Medium
	Elevated	GF	Very High	Very High	Very High	Very High
		BF	Very High	Very High	Very High	Very High
Tramways	At-grade	BF	High	Very High	Very High	Very High
Bulk material pipelines BF		GF	Medium	Low	Low	Low
		High	Medium	High	High	
Canals BF		GF	High	Medium	Low	Medium
		Very High	Medium	Low	High	

Types			Dust generation	Long-term exposure	Short-term exposure	Overall risk
Embankments BF		GF	High	Medium	Low	Medium
		Very High	High	Medium	High	
Sewerage/Stormwater drainage BF		GF	Low	Low	Low	Low
		Medium	High	Very High	High	
Electricity transmission		GF	Medium	Low	Low	Low
Electricity distribution BF		GF	Low	Low	Low	Low
		Low	Medium	High	Medium	
Telecom cables	Aerial		Low	Low	Low	Low
	Underground	Trenching	Medium	Low	High	Medium
		HDD	Low	Low	Low	Low

GF - Greenfield BF - Brownfield Very High High Medium Low

Source: CSE

Roads

At-grade roads generate high levels of dust due to continuous linear excavation, large exposed surface areas, extensive handling of dry aggregates and subbase materials, and frequent haulage trips. Flexible pavements require roughly 50 per cent more material than rigid pavements and have lower durability, though they can be built faster and use less concrete, resulting in no major overall difference in dust generation between the two types.[72, 73] However, long-term and short-term exposure risks vary significantly by road class.

Expressways have high dust generation from extensive material and soil handling, but are typically located in rural or peri-urban areas with low population density. As a result, both long-term and short-term exposure remain low, resulting in an overall medium risk. Highways also generate high dust but pass through a mix of rural, semi-urban, and urban settings, leading to high long-term exposure, moderate short-term exposure, and an overall high risk. Urban roads combine high dust generation with the highest population density, sensitive receptors such as schools and hospitals, severe congestion, and close traffic proximity, which elevates both long-term and short-term exposure to very high levels and makes the overall risk very high (see image *Road construction*). District roads produce moderate dust but still have substantial public interaction, resulting in high exposure on both time scales and an overall high risk. Village roads also have

Road construction

moderate dust generation, but low traffic volumes and low public exposure result in low long-term and short-term exposure and an overall low risk.

Flyover roads

Elevated roads generate high to very high levels of dust due to deep piling, elevated concrete handling and, in the case of reinforced earth wall flyovers, massive earthfill volumes, which create extended dust sources at height, where wind dispersion potential is greater. Long-term exposure is very high, since these structures almost always traverse dense urban corridors, with dust affecting public spaces for extended durations. Short-term exposure is also very high due to severe congestion underneath and high traffic volume proximity, with vehicles passing directly below active works, and continuous resuspension of settled road dust. Consequently, both flyover types receive an overall very high risk.

At-grade railways and metro systems

At-grade railways score high for dust generation from ballast laying, track bed formation, and large excavated volumes in cuttings and embankments, with brownfield projects adding demolition debris. Long-term exposure is moderate because while rail corridors run mainly through rural stretches, they also run through urban and suburban areas with continuous public access at level crossings and adjacent pathways. Short-term exposure is similarly moderate due to congestion only at level crossings. The overall risk is therefore moderate for greenfield and high for brownfield at-grade rail.

Metro systems: Underground vs Elevated

Metro projects exhibit a stark contrast between underground and elevated alignments. Underground metro generates high dust levels from large, excavated volumes, but this dust is largely confined below grade, resulting in low to moderate long-term public exposure and only medium short-term exposure from localised portal areas, ventilation shafts, and station boxes. Congestion is minimal except at discrete access points or station areas, giving an overall risk of medium. In contrast, elevated metro generates very high dust levels from concrete handling, pier drilling and beam casting, with concrete requirements exceeding those of underground metro. Elevated metro systems combine higher dispersion due to greater wind speeds at height with very high long-term exposure, as dense urban corridors are directly underneath the viaduct for the entire project length, and very high short-term exposure caused by severe traffic congestion, extreme vehicle proximity, and continuous dust resuspension on surface streets. Consequently, the elevated metro are classified as very high-risk projects, demonstrating that exposure and high traffic adjacency can dramatically increase overall risk despite similar dust generation volumes.

Tramways

Tramways, typically brownfield projects in city centres, generate high dust from breaking existing pavement, excavating for track foundations, and handling dry concrete. Long-term exposure is very high due to maximum population density and sensitive receptors (e.g., shops, offices, and residences). Short-term exposure is very high as well—lane closures create extreme congestion, frequent stops and idling increase $PM_{2.5}$ emissions, and high traffic volume proximity leads to continuous dust resuspension. This results in a very high overall risk.

Pipelines

Bulk material pipelines generate only medium level of dust in greenfield settings because their narrow trenches limit the exposed area per kilometre. However, the backfilling ratio is high, resulting in significant on-site stockpile storage. For greenfield pipelines, long-term exposure is low, since they traverse mostly rural or undeveloped land with few permanent receptors, and workers in open trenches benefit from good ventilation. Short-term exposure is also low due to limited traffic disruption and infrequent road crossings in greenfield corridors. Consequently, the overall risk for greenfield pipelines is low (see image *Laying of pipelines*). In contrast, brownfield pipelines have high dust generation because excavation occurs near existing roads, utilities, and built structures, where space constraints increase material handling intensity. Long-term exposure is medium, as brownfield pipelines pass through urban segments with higher public presence


FLICKR[74]

Laying of pipelines

and workers remain in ventilated trenches. Short-term exposure is high, driven by frequent traffic disruption at road crossings, proximity of active traffic along access tracks, and resuspension of dust from nearby vehicles, especially for pipelines installed within congested urban corridors. This results in an overall high risk for brownfield bulk material pipelines.

Canals

Greenfield canals score high for dust generation because they involve long linear earth cuts and large exposed surfaces, but long-term exposure is only medium, since it typically passes through agricultural or semi-rural land with few receptors. Short-term exposure is low since there is low traffic adjacency except at road crossings, giving an overall medium risk. Brownfield canals have very high dust generation, raising the overall risk to a high level.

Embankments

Embankments generate high levels of dust from the import, spreading, and compaction of large fill volumes over long linear distances, combined with extensive erodible exposed surfaces. For greenfield embankments, dust generation is high, but long-term exposure is medium because these projects are typically located in semi-urban or rural settings where public receptors are set back from the construction zone, reducing sustained exposure. Short-term exposure is low due to limited traffic adjacency, resulting in an overall medium risk. For brownfield


NIDA MARYAM

Excavation for stormwater drainage at a road junction

embankments, dust generation is very high, and long-term exposure is high because these projects occur within or near existing developed areas where residential and commercial receptors are continuously present. Short-term exposure is moderate due to limited traffic interaction, leading to an overall high risk.

Sewerage and stormwater drainage

Sewerage and stormwater drainage works generate only low dust generation in greenfield settings because excavation is typically narrow and shallow, with limited handling of dry aggregates and pre-cast pipes, and the linear footprint is relatively small per kilometre. Long-term exposure is low for greenfield projects as receptors are low. Short-term exposure is also low due to limited traffic proximity. For brownfield sewerage and stormwater drainage, dust generation is medium due to frequent cutting of existing pavements and handling of excavated material near buildings and roads. Long-term exposure is high, as these projects occur within densely built urban areas where schools, hospitals, markets, and residences are immediately adjacent to open trenches for weeks or months, and multiple utility conflicts prolong the exposed period. Short-term exposure is very high as well, driven by continuous traffic congestion, pedestrian movement, and road crossings that generate repeated dust resuspension, resulting in an overall high risk (see image *Excavation for stormwater drainage at a road junction*).

Electricity transmission

Transmission lines generate moderate dust because only discrete tower footings are excavated, and there is no continuous trench or large exposed surface. Long-term exposure is low, as alignments are typically in remote or agricultural areas away from public receptors. Short-term exposure is negligible with no traffic congestion or proximity effects. Thus, the overall risk is low.

Electricity distribution

Electricity distribution via overhead poles generates low dust generation in both greenfield and brownfield settings, as the only activities are pole hole excavation and limited handling of aggregates for pole footing, with minimal earthworks and short duration per location. For greenfield projects, long-term exposure is low because work occurs in undeveloped or rural areas with few permanent receptors. Short-term exposure is also low due to the absence of nearby traffic and pedestrians, resulting in an overall low risk. For brownfield projects, long-term exposure is medium, as work takes place in urban or suburban corridors where residences, shops, and offices are present within proximity, and multiple pole locations along a street prolong cumulative exposure. Short-term exposure is high because each pole raising causes traffic disruption, with construction vehicles and workers operating adjacent to active roads, leading to significant dust resuspension. Consequently, the overall risk for brownfield electricity distribution is medium.

Telecom cables

Aerial telecom cables, whether in greenfield or brownfield settings, involve very little ground disturbance and minimal traffic impact. As a result, dust generation, long-term exposure, and short-term exposure are all low, resulting in an overall low risk. Underground trenching for telecom generates medium dust due to the narrow trench, has low long-term exposure because receptors are not adjacent to open trenches for extended periods, but produces high short-term exposure from repeated street openings and associated congestion, leading to an overall medium risk. Horizontal directional drilling (HDD) for telecom is a trenchless method of cable laying in which a tunnel is drilled, and a utility is pulled through the drilled underground tunnel. It generates low dust since drilling limits dust to launch and receive pits, and it has both low long-term exposure and low short-term exposure, yielding an overall low risk.

Dust mitigation guidelines for linear projects

To develop a comprehensive set of guidelines addressing the distinct challenges of dust mitigation in linear construction projects, CSE reviewed Environmental Impact Assessment (EIA) reports of several linear infrastructure projects, such as the Mumbai-Ahmedabad High Speed Railway Project, Varanasi-Kolkata Expressway, Haryana Orbital Rail Corridor Project, Delhi–Meerut Regional Rapid Transit System Project, Delhi Metro Phase Project, and Mumbai Metro. In addition, relevant national and international literature on dust mitigation practices and inputs from expert consultations were incorporated into the development of these guidelines.

Dust control measures and guidelines tailored for linear infrastructure largely focus on adapting stationary control mechanisms into mobile solutions wherever feasible, for example, mounting anti-smog guns on vehicles to enable dust suppression along moving work fronts. However, the most critical strategy for linear projects lies in managing short-term exposure by separating construction activities from traffic through staggered time and space use. This approach minimises the overlap between workers, nearby communities, and moving vehicles, thereby reducing acute dust inhalation risks.

Pre-construction steps

- During the Detailed Project Report (DPR) stage, a Dust Suppression Plan and Spill Response Plan shall be prepared, clearly outlining dust prevention, control, and monitoring measures for all phases of construction.

- A structured inspection and compliance mechanism shall be implemented, including regular visual inspections to ensure that fugitive dust emissions do not remain visible beyond the property boundary for prolonged periods; inspection logs, photographic records, site condition descriptions, and records of corrective actions taken shall be systematically documented and maintained.

- A comprehensive dust monitoring system must be established. This should include the installation of fixed, sensor-based online air quality monitoring devices at regular intervals along the project corridor, with particular attention to high-exposure corridors in high-risk projects. All detailed monitoring data must be recorded and properly maintained for subsequent review and inspection.

- The DPR must establish a clear demarcation of the enforcement jurisdiction of different agencies across the entire project stretch and unified monitoring protocols shall be created for long linear corridors crossing multiple administrative zones.

- All personnel shall undergo mandatory training on the correct implementation of prescribed dust control measures.

Congestion and short-term exposure management

- Construction agencies should prepare and implement corridor-specific traffic management plans, including diversion routes, lane management, and alternate circulation arrangements, before commencement of work.

- Construction activities and vehicular movements should be staggered by time through staggered construction schedules and designated operating hours to minimise congestion, reduce vehicle idling, thus reducing $PM_{2.5}$, and limiting short-term dust exposure in high-traffic areas.

Demolition or brownfield development

- Building interiors shall be stripped before demolition.

- Blasting shall be minimised to the extent practicable.

- Structures shall be sprayed with water or screened before and during demolition.

- Restrict active demolition to ≤100 m^2 of plot area concurrently.

- In case of asphalt milling, spray water on exposed surfaces during dry periods especially near schools, hospitals, rural communities, agricultural areas, etc.

Perimeter control

- Continuous windbreaks shall be installed along the project perimeter to limit wind ingress and reduce dust dispersion across and beyond the site boundary. The wind breakers shall be securely fixed to the ground and maintained at a minimum height of 2 metres in the linear construction zones.

NIDA MARYAM, DMRC[75]

Dust at the base of wind breakers to be cleaned

- Keep site fencing, barriers, etc., clean using wet methods.

- Accumulated dust at the base of wind breakers shall be regularly cleaned to prevent resuspension (see image *Dust at the base of wind breakers to be cleaned*).

- Vegetative strips shall be planted or retained where space permits to act as secondary filters. Vegetation health must be maintained by regular cleaning of leaves.

Material and resource sourcing

- The contractor shall promote the possibility of procuring cement through bulkers instead of conventional cement bags.[76]

- For water sprinkling or wetting, emphasis should be given on the use of STP-treated water or RO reject water.

Excavation activities

- Prepare a muck disposal plan and have the contractor identify approved disposal sites for the final dumping of muck. To minimise disruption in busy city areas, a designated route shall be planned for muck transportation. Routes with less traffic and fewer residential areas shall be preferred.

- Establish strict timelines and standard operating procedures for the timely removal and disposal of excavated material and construction debris to prevent prolonged dust exposure. It shall not be allowed to accumulate on-site beyond the immediate operational requirement.

- Detailed records of muck collection, transportation, storage, and disposal related to environmental compliance, permits, and safety protocols shall be maintained.

- Strip topsoil close to excavation timing to minimise dust and runoff risks.

- Sub-soil and topsoil shall be kept separately.

- Remove slurry off-site before it dries to prevent dried residues from becoming secondary dust.

- While excavating an area, dedicated movable mist spray machines and sprinklers shall be used to prevent dust emission. During mucking, muck piles shall be kept constantly damp by sprinkling with water. The use of high-pressure water jets for this purpose shall not be permitted.[77]

- To reduce the amount of dust, only wet drilling shall be allowed.

- Excavation zones shall be enclosed using green sheets, wind barriers, or dust curtains around the perimeter.

- Disturbed areas in construction and demolition sites that remain unutilised for seven days or more should be stabilised using chemical agents or dust suppressants.

- Reuse of excavated soil at other sites shall be undertaken in consultation with relevant authorities. Excavated soil shall be explored for reutilisation for backfilling purposes.

- Designated sites must be identified for excavated material storage and dumping. Locate such facilities away from dense residential areas, schools, and hospitals. Ensure all storage and dumping areas are stabilised and regularly covered or sprayed.

- Agencies should develop accurate and updated pre-construction utility maps and ensure coordination across departments to prevent repeated excavation, project delays, and associated dust generation.

- Stabilise disposal sites within one month of completion.

- Measures to rehabilitate the borrow sites shall include contouring of the slopes within each site and replanting sites with native species.

Material and C&D waste handling

- Wherever feasible, loading and unloading operations shall be conducted within a three-sided enclosure. Where enclosure is not practical, temporary tarpaulin covers or three-sided screens shall be installed around the transfer area, and water sprays shall be operated at the point of transfer.

- Maximise off-site manufacturing of components, such as precast concrete elements, modular structures, and preassembled utilities to reduce on-site cutting, mixing, and fabrication activities. Wherever feasible, material processing activities should be shifted away from dense urban areas.

- Materials shall be kept adequately damp during handling to prevent dust generation and dispersion.

- Dust barrier nets and sheets shall be used wherever feasible (see image *Dust barrier sheets used in metro construction*).

- Unloading shall be carried out on the wind-protected side to minimise dust dispersion.

NIDA MARYAM, KOCHI METRO[78]

Dust barrier sheets used in metro construction

SUGEET GROVER

Anti-smog gun mounted on vehicle

- Drop heights during loading and unloading shall be limited to ≤ 1.5 m to reduce dust generation. Where higher drops are unavoidable, continuous water spraying shall be applied at the transfer point during operations.[79]

- Mobile vehicle-mounted and static fine-mist/fog units shall be deployed to suppress residual or persistent dust plumes during high-emission activities such as heavy machinery operation and material unloading (see image *Anti-smog gun mounted on vehicle*). Units shall be positioned upwind of the plume and at elevated locations for effective dispersion control.

- High dust-generating material handling activities shall be undertaken within properly enclosed spaces to minimise fugitive dust emissions. These enclosed areas shall be fitted with dust collection systems to control emissions at source.

- No soil screening shall be carried out at the site project. Subbase material shall be used immediately after off-loading.

- Cutting and grinding of materials shall be carried out in enclosed areas, and a wet jet shall be used during the process.

- Provide proper dust collector for hand tools. Bag attachment collects dust generated during work activities (see image *Dust collector bags for hand tools*).[80]

LAND TRANSPORT AUTHORITY (LTA), SINGAPORE[81]

Dust collector bags for hand tools

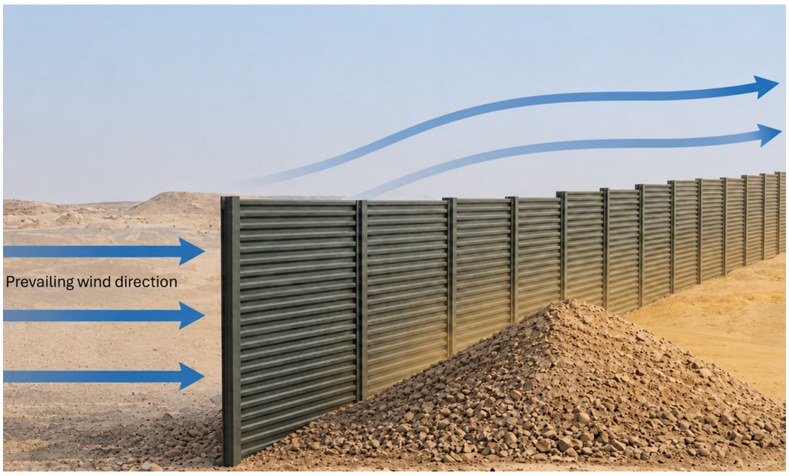
NIDA MARYAM, AI

Uncovered vs Properly covered stockpiles at a metro construction site

Material and C&D waste storage

- All stockpiles shall be fully covered using sheets, securely anchored on all sides to prevent displacement by wind, with no exposed gaps (see image *Uncovered vs Properly covered stockpiles at a metro construction site*). Coverings shall be regularly inspected and promptly repaired or replaced.

Figure 4: Stockpile height to be lower than wind breaker



Source: AI-generated image.

- Height of the stockpile should be maintained below the adjacent wind barrier (see *Figure 4: Stockpile height to be lower than wind breaker*). Gradually sloped piles must be favoured over steep-sided profiles to reduce wind erosion.

- Protect bare slopes with close turfing, concrete grouting, erosion control blankets or canvas sheets.

- Surface dampness must be maintained on all exposed soil and stockpiles during working hours as well as during stoppage.

- Water should be reapplied every three to four hours and whenever the surface becomes dry or dusty. Check this visually at least once per shift and after heavy vehicle use.

- Stockpiles shall be positioned within two to three metres of the wind barrier to maximise its protective effect within the linear construction zone.

- Stockpiles >20 m^3 should be enclosed on three sides with walls extending above the stockpile and projecting beyond the front.[82] Materials and C&D waste shall be stored on impermeable surfaces and shall be barricaded and demarcated with proper signage.

Entry-exit point controls

- At all designated heavy-vehicle entry/exit points, appropriate track-out control measures such as wheel washers, wheel shaker racks, gravel bed systems, or manual cleaning to be adopted.

SUGEET GROVER

Wheel washing facility at Delhi metro site

- At places where wheel washing stations have been installed (see image *Wheel washing facility at Delhi metro site*), wash-water runoff shall be routed to a silt or sedimentation tank for treatment, and under no circumstances shall contaminated water be allowed to discharge onto public roads.

- Where wheel shaker racks are provided, they shall be designed to accommodate the widest and heaviest construction vehicles expected on site. The rack shall be of sufficient length, and a minimum clearance shall be maintained beneath the rack to collect dislodged material.

- Where gravel beds are installed, the aggregate size of stones and gravel shall be large enough to minimise carry-out by vehicle tyres. Sharp-edged stones shall be avoided to prevent tyre damage, and the bed shall be wide and long enough to accommodate the largest vehicles entering and exiting the site.

- Each vehicle shall be subject to mandatory visual inspection to ensure there is no visible carry-out of mud or debris. In cases where residues remain on the vehicle, manual cleaning shall be undertaken before the vehicle enters or exits the site.

Material and C&D waste transport

- Tower cranes should be used, wherever feasible, to minimise on-site movement of heavy vehicles and reduce dust emissions associated with material transportation within the construction corridor.

- All transport operations shall be designed and managed to prevent spillage. All load-carrying vehicles shall be required to be covered and loaded with sufficient freeboard; tarpaulins or other covering media must extend at least 300 mm over the side/tailboards and be securely fastened (see *Figure 5: Properly covered material transport)*. Potential dust-causing material shall not be loaded to a level higher than the side and tail boards.

- Site speed limit of ≤ 10 km/h shall be enforced for all vehicles on-site. Traffic calming measures shall also be used to control speeds physically.

- Behavioural measures may be used for drivers, such as induction briefing, visible local-language speed signage, and signed speed commitment forms for drivers.

Road dust control

- Roads shall be hard-paved for all high-frequency haul routes; these paved surfaces shall be kept free of loose particles by frequent sweeping. If unpaved haul routes are used, apply water-sprinkling at regular intervals (increase frequency during hot or windy days or after heavy traffic) and consider the use of ground protection mats, which provide a stable, protected surface over otherwise loose or unpaved ground (see image *Water sprinkling on roads in and around the construction*).

Figure 5: Properly covered material transport

Source: AI-generated image.

SUGEET GROVER

Water sprinkling on roads in and around the construction zone

- Maintain a daily spill-cleaning regime. Remove visible spillage from haul roads and transfer areas at least once per shift and immediately after any overflow or spill event.

- Use mechanical or vacuum sweepers on paved areas daily. Sweeping operations shall be conducted in a manner that prevents dust and fine particles from being redeposited onto active traffic lanes. Sweeping methods shall ensure effective collection of such particles for off-site disposal. Dry sweeping of large areas to be avoided (see image *(a) Manual sweeping leads to dust, while (b) mechanical sweepers prevent dust*).

- In the event of spillage, immediate sweep-cleaning shall be undertaken and completed before the resumption of traffic to minimise dust resuspension.

- Reuse surfacing materials when haul route alignments change.

Emergency response

- If monitoring shows elevated dust levels, suspend the particular activity, increase watering or fogging, and deploy additional suppression until levels fall.

HARIKRISHNAN CU, SUGEET GROVER

(a) Manual sweeping leads to dust, while (b) mechanical sweepers prevent dust

- To enable rapid response, maintain contingency supplies on-site, including spare tarpaulins, portable fog guns, and additional pumps and hoses, with trained personnel available to deploy these measures within 30 minutes of notification.

Limiting occupational dust exposure

- Sufficient ventilation must be provided in underground projects to prevent any dangerous or harmful accumulation of dusts, fumes, mists, vapours, or gases, and enable workers to carry out work without risk of exposure.

- Appropriate personal protective equipment (PPE) should be provided to protect workers from dust exposure.

Recommendations from construction industry experts

To explore innovative solutions that have not yet been widely adopted, CSE conducted a survey involving industry experts, construction company officials, and academicians associated with architecture, planning, and construction fields. Participants were shown photographs of linear construction projects and invited to propose practical solutions based on the site conditions presented. A few interesting responses generated through this exercise are summarised below.

- Construction projects may face delays or stoppages due to factors such as GRAP implementation. During such periods, sections of the corridor where materials or C&D waste have been stored should be temporarily covered from above with protective sheeting to minimise wind-driven dust dispersion (see image *Cover sections of non-active construction sites*).

- The exposed surface area of stockpiles shall be minimised wherever technically feasible to reduce wind erosion potential (see image *(a) Reducing surface area of stockpiles*).

AI-GENERATED IMAGE

Cover sections of non-active construction sites

AI-GENERATED IMAGE

(a) Reducing surface area of stockpiles, and (b) Enclosing it with windbreakers reduces dust

- Construction should be undertaken in a phased, section-by-section manner, ensuring that one segment is substantially completed and stabilised before initiating work on the next, to limit the overall exposed area at any given time.

- In addition to standard wind breakers, stockpiles may also be screened on sides perpendicular to the corridor. This ensures they remain shielded, even when wind flows parallel to the corridor (see image *(b) Enclosing it with windbreakers reduces dust*).

Way forward

Given the scale of infrastructure expansion in India, dust mitigation must shift from a generic compliance-based approach to a risk-based regulatory framework. High-risk projects, such as elevated metros, urban roads, flyovers, tramways, and brownfield utility projects in dense urban areas should be prioritised for stricter mitigation and monitoring measures. These projects should require enhanced dust management plans, continuous air quality monitoring, mandatory disclosure of mitigation measures, and more frequent inspections. Risk-based prioritisation can help regulators focus resources on projects with the greatest public health impacts.

Current dust mitigation systems are largely designed for stationary construction sites with fixed boundaries. However, linear infrastructure projects involve continuously shifting construction fronts, making many conventional measures ineffective. Dust control strategies must therefore move from stationary to mobile systems. Mobile misting units, movable dust screens, portable monitoring stations, modular wheel-washing systems, and corridor-based mechanised sweeping operations should be deployed to match the dynamic nature of linear construction activities.

Managing traffic congestion must become a key component of dust mitigation in linear projects, especially in urban areas where short-term exposure risks are severe. Construction activities should be planned through staggered spatial and temporal scheduling to avoid simultaneous disruption across multiple stretches. Measures such as night-time transportation of materials, phased lane closures, dedicated haul routes, and limiting excavation during peak traffic hours can significantly reduce congestion-induced particulate exposure. Reducing congestion is critical because vehicular movement contributes not only through exhaust emissions but also through the resuspension of settled road dust.

A uniform dust mitigation framework is unlikely to be effective across all forms of linear infrastructure because construction practices vary significantly by project type. Elevated metro systems, underground tunnelling projects, highways, sewerage networks, transmission lines, and pipelines generate dust through different mechanisms and under different exposure conditions. Therefore, project-specific guidelines should be developed that account for the construction methodology, spatial constraints, traffic interaction, and exposure characteristics associated with each category of linear infrastructure.

Finally, environmental and public health costs associated with dust pollution must be systematically incorporated into infrastructure planning and decision-making. Project evaluation frameworks currently prioritise financial costs, construction timelines, and engineering feasibility, while largely overlooking the external costs of dust exposure and air pollution. Integrating the environmental cost of particulate emissions into cost–benefit assessments can help identify construction approaches and infrastructure typologies that minimise long-term social, environmental, and public health impacts.

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Dust management has traditionally focused on area-based construction sites, but linear infrastructure projects such as roads, metro rail, and utility corridors present far more complex challenges. Unlike fixed-boundary sites, these projects unfold along long, continuously moving work fronts that vary significantly in height and depth of construction, from deep excavations to elevated structures. Construction activities are often carried out in close proximity to residential and commercial areas, placing dust sources directly within people's living and working environments. In addition, traffic congestion caused by construction increases both the dispersion of dust and the duration of public exposure. These factors together demand mitigation strategies tailored specifically to the linear nature of such projects, rather than conventional area-based approaches.

This report serves as a comprehensive guidance document for managing dust emissions from linear construction projects. It identifies dust-generating activities across different stages of construction, categorises the dust risk associated with different project types based on their dust generation potential and levels of exposure, and provides a comprehensive set of guidelines for integrating effective dust mitigation measures into the planning, execution, and monitoring of these projects.

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