

SUSTAINABLE CONSTRUCTION PRACTICES FOR REDUCING ENVIRONMENTAL IMPACTS IN METRO RAIL DEVELOPMENT

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ABSTRACT

In several of the world's most populous and polluted cities, plans are afoot to build new metro projects or expand existing metro systems. The metro systems when constructed and commissioned will certainly reduce the pollution level and add convenience to the public but such project may grossly aggravate the pollution problem during construction stage especially in respect of noise and air pollution which are generally at their peak in the city just before such projects are taken up for implementation. Further compounding the issue, the metro alignment passes through densely populated areas and high vehicular traffic zones in general; therefore, the construction activity has to be taken up mostly in the vulnerable areas of the city which are the most densely populated and also generally having the highest pollution level. Now-a-days the period of project implementation is getting further compressed resulting in more intense activity of construction and much more increase in pollution level in the shorter period of construction.

In such situation, large population of city which is already suffering from high pollution level may be further exposed to considerably increased pollution level due to the major construction activity. This may lead to very prolonged adverse affect on the public health in general. The paper deals with all the aspects of minimisation of the negative environmental affects in planning and implementation of major metro project in a highly polluted city - especially when the pollution level of certain elements of pollution are already above the acceptable level. The paper also highlights the environmental management system including the planning for route alignment, structures, material used, method of construction, monitoring and other innovative ideas with a special reference to Up Metro which is under implementation in Kanpur having a population of almost 5 million people and being one of the most polluted cities of the UP.

Keywords: Metro rail construction, Urban air pollution, Construction phase environmental impacts, Environmental noise exposure, Sustainable urban infrastructure

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I. INTRODUCTION

The ever increasing population pressure on cities particularly in developing countries is making the existing infrastructure facilities totally inadequate and pushing the pollution level to a new high. The problem of city dwellers is addressed by undertaking large scale infrastructure projects such as construction of metro system to ease the problem of transportation and subsequent reduction in pollution[1]. For most of the parameters like suspended particulate matter (SPM), CO₂, CO, SO₂, NO etc. the existing level of pollution in such cities is already either on higher side or above the acceptable level causing serious concern to health of city dwellers. Major construction activity by its very nature cannot be environmentally friendly and is known to aggravate the existing problems due to pollution especially when such activities are underway in a dense habitation [2].

Any rise in pollution level even for a short period say of one or two years, at places where it is already on a higher side or beyond the prescribed limit is bound to leave adverse effect for a long period to a large cross section of people. A recent study report of "Centre for Occupational and Environmental

Health" in University of California, Los Angeles (UCLA) says "Smog can harm the health of babies .. This should make us pause. Air pollution does not just impact asthmatics and old people but it can also impact people at the beginning of their life and can put them to a disadvantage for the rest of their life". The study to be published in the American Journal of Epidemiology found that "the greatest risk occurred during the second month pregnancy indicate that increase in pollution level even for very short period has serious implications[3]. Apart from human health in general, the effect on some historic buildings, patients in hospitals and children in the school in the area where there is a sudden increase in the pollution level are likely to be much worse. Thus any increase in the level of pollution even during the construction stage of metro system in a populated and polluted locality will cause irreparable and immense damage to the health of the people from womb to old age. Therefore, the major construction activity of metro network in such circumstances requires systematic consideration from assessment of existing and expected pollution during the planning and implementation of

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the project with well defined environmental management system with proper monitoring[4].

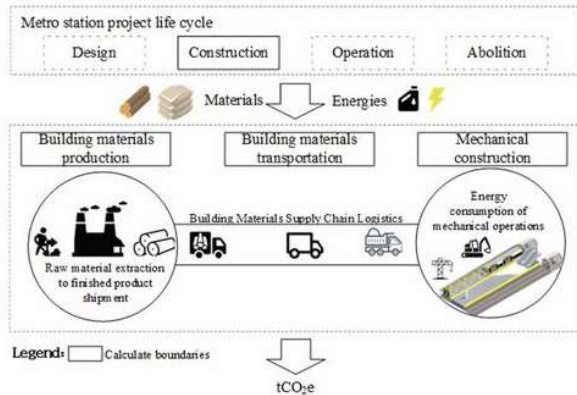


Fig 1: Metro Rail Development Sustainable Construction Framework

A. Research Gap

With the increasing significance of metro rail systems for urban sustainability, little research has been conducted on sustainable construction practices during the construction phase. Most studies focus on operational benefits rather than environmental impacts during the implementation of the project. Therefore, this study addresses the void by analyzing sustainable construction strategies to minimize environmental degradation during metro rail development.

B. Objectives of the Study

- To evaluate the environmental impacts of metro rail construction
- To research sustainable building practices
- To assess pollution abatement measures
- To suggest eco friendly construction techniques

II. RESEARCH METHODOLOGY

This study uses a descriptive and analytical research design to evaluate the sustainable construction practices in metro rail development. The study is based on secondary data collected from metro project reports, environmental impact assessment (EIA) reports, government publications, and peer-reviewed journal articles[5].

Data Collection: Data have been collected from documented case studies of metro projects in UP metro rail project and concentrated on environmental indicators like air pollution, noise levels and construction practices.

Data Analysis:

- Comparison (before and during construction)
- Trend analysis (changes in pollution)
- Impact assessment (effectiveness of sustainability practices)

Evaluation Framework: Environmental impacts are assessed based on:

- Air Quality (SPM, CO₂, NO_x)
- Decibel levels (dB)
- Emission reduction and efficiency of resources

Such a method is crucial for understanding the role sustainable construction has in minimizing the environmental footprint of metro rail construction.

III. DATA ANALYSIS AND INTERPRETATION

A. Air Pollution Analysis

The development of metro systems leads to a significant increase in air pollution due to dust, equipment and movement.

Table 1: Air Pollution Comparison

Parameter	Before Construction	During Construction	Standard Limit	Impact
SPM	High	Very High	Moderate	Severe increase
CO ₂	Moderate	High	Acceptable	Increase in emissions
NO _x	Moderate	High	Acceptable	Traffic-related rise

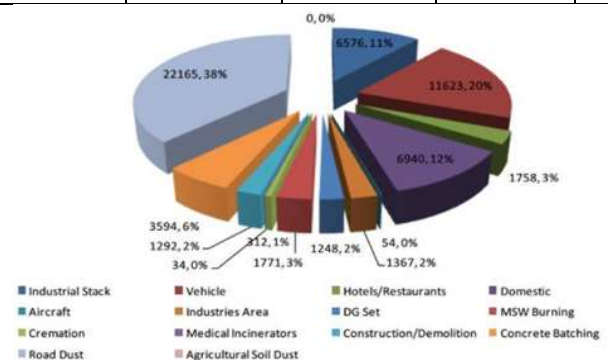


Fig 2: Sources of contribution of air pollution in cities

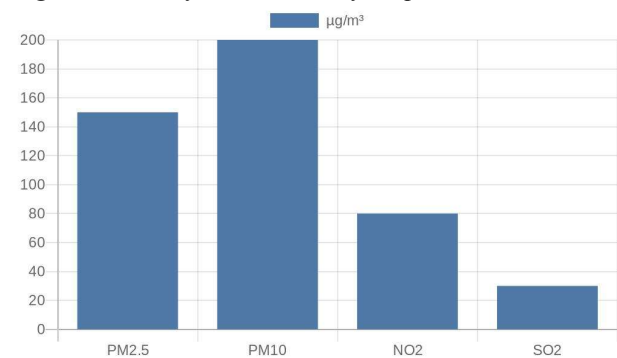


Fig 3: Comparative concentration levels of major air pollutants Higher particulate matter (PM₁₀ and PM_{2.5}) levels compared to gaseous pollutants indicating significant impact of construction and vehicular emissions.

Interpretation: The data shows sudden increase in the SPM levels and hence it is the most critical pollutant. Construction activities like excavation and transport of materials are the main contributors.

B. Noise Pollution Analysis

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noise pollution rises with heavy machinery, drilling and transportation.

Table 2: Noise Level Comparison

Area Type	Normal Level (dB)	During Construction (dB)	Standard Limit	Impact
Residential	55	75–85	55	High disturbance
Commercial	65	80–90	65	Moderate–High
Silent Zones	50	70–80	50	Severe impact



Fig 4: Comparison of noise levels from different sources indicated that construction activities and heavy traffic generate higher decibel levels, contributing significantly to urban noise pollution.

Equipment/activity	Sound pressure level at 10m (dB)	Equipment/activity	Sound pressure level at 10m (dB)
Asphalt paver	60-68	Generator	55-71
Bobcat S185	61	Hiab	82
Chainsaw	96	Loader	74
Chainsaw - electric	77	Milling machine	75
Cherry picker	69-79	Piling	79-80
Circular saw	81	Power pack	74
Concrete pour/pump	70-75	Reversing alarm	73-75
Crane	49-82	Rockbreaker	79-91
Drilling	66-92	Scissor jack	66
Drum roller	62-79	Streetsweeper	67-83
Dynapac PC/32	61	Wall saw	81-84
Excavator	70-81	Water blasting	75-94
Franner	74	Wire saw	71-75

Fig 5: Construction equipment noise levels at 10m, showing high emissions from chainsaws, rock breakers and piling machines.

Interpretation: Noise levels are 15–25 dB above permissible limits and can have serious health impacts, including stress, hearing loss and sleep disturbance.

C. Impact Reduction through Sustainable Practices

Sustainable construction techniques reduce environmental impacts.

Table 3: Sustainable Practices to Mitigate Impact

Sustainable Practice	Pollution Reduction (%)	Benefit
Precast construction	20–30%	Less dust & noise
Electric machinery	15–25%	Reduced emissions
Battery vehicles	10–20%	Lower fuel pollution
Trenchless	25–40%	Minimal surface

technology	disturbance
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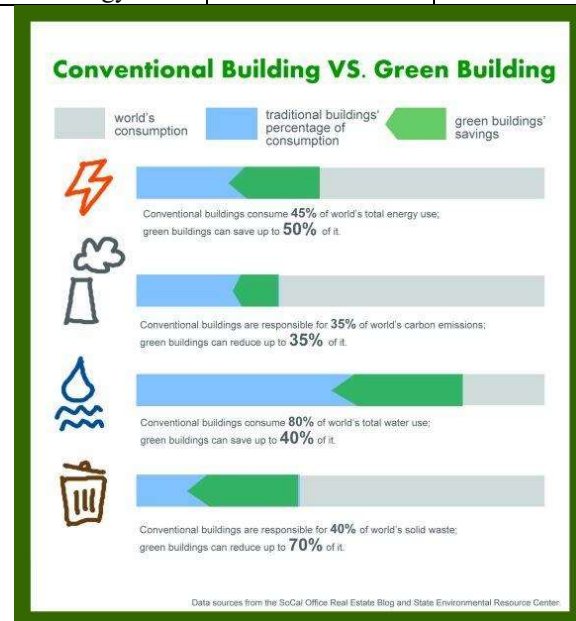


Fig 6: Green Building vs Conventional Impact

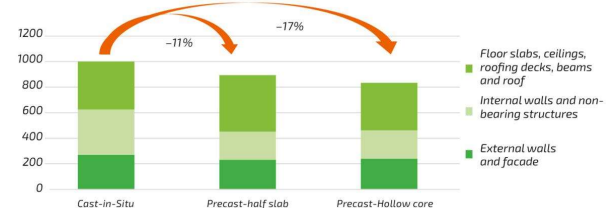


Fig 7: Comparison of Emission Reduction: Cast-in-Situ vs Precast Construction Methods

Interpretation: Among all the practices, trenchless technology and precast construction are the ones with the highest reduction of environmental impact and thus are essential for sustainable metro development.

IV. ASSESSMENT OF EXISTING LEVEL OF POLLUTION

In order to have an organized environmental control, it is necessary to assess the present environmental conditions, population density, socio-economic aspects, traffic pattern etc. within the areas proposed for the metro, so that polluted areas are not further loaded and habitable pollutants are spread over less polluted areas. It would be useful to have a “contour” of pollution level of the city [6] Figure I shows the “contour” of SPM for kanpur. Planned metro alignment is also depicted. Such details can be further combined with population density and increase of pollution during the planned construction. This will enable the metro planning to have a general view of the problem of pollution and also the requirements of the project [7].

Table 4: Air Pollution Comparison

Parameter	Existing Level	Standard Limit	Impact During Construction
SPM	High	Moderate	Very High

CO2	Moderate	Acceptable	Increased
NOx	High	Acceptable	Increased

A. Air pollution in UP and national standards

Uttar Pradesh (UP) is one of India’s most air-polluted states, with major cities like Ghaziabad, Noida, Kanpur, Lucknow, Agra and Varanasi regularly facing poor air quality. There are multiple reasons why the state is highly polluted. The ever-increasing numbers of cars, buses and trucks are greatly affecting air pollution by their emissions. Industries based on coal and thermal power plants emit harmful gases and particulate matter into the atmosphere. Besides, dust from large-scale construction works and biomass burning and crop residue burning in some seasons further deteriorate the air quality. Also a source of large quantities of smoke and pollutants is the state which uses a large number of traditional brick kilns. Road dust and open burning of waste add to the pollution problem. Air quality is a serious concern for the environment and public health in Uttar Pradesh. [8].

B. Noise pollution

Noise in addition to its other adverse affect has been found to disturb learning process, psychological development, social activity and verbal communication and deteriorate job performance and safety in work place [9]. The ambient noise levels in UP at some representative locations, primarily along the metro alignment, for each category of area are presented in Table 2 and then compared with the ambient noise standards. This clearly indicates that the noise level is even 20d B(A) higher than the national norms[10].

C. Project Implementation

Agencies should carry out an assessment with major sources for other relevant pollution parameters and population density not only along the locations where environment is likely to be affected because of construction but on the alternative routes for movement of materials. The above information can be a major input for further planning, design, execution and monitoring of metro rail system [11]

V. PLANNING ASPECTS

The general horizontal alignment and the vertical alignment i.e. underground, elevated or at grade of the proposed metro network is more or less decided on the basis of traffic requirements, availability of land, economic consideration, future growth etc. However, there are still several ancillary systems which if planned keeping in view the impact on environment will result in considerable reduction in pollution levels. The above point will be illustrated further with a few examples below[12].

For every 2 km of underground metro construction, during its intense period of physical activity of say 2 years, will add to the pollution level which will be equivalent to plying 500 bus trips per day for only transporting men, material and machine. Therefore, in tunnel construction, the location of shaft to bring out the excavated material (mucking) and supply of construction material should not be decided merely on economy and convenience in construction but also on the impact on existing pollution level at the exit point as well as

all along the route of movement. The route for movement of material etc. should be selected so as to avoid polluted and congested areas even if it means some detour and additional cost [13].

Similarly the location of off the site activities like concrete batching plant, casting yard, spoil dump etc. should be planned keeping in view the existing level of pollution along the route and in the location where they are proposed to be set up. The above said 'contour' of pollution level of city will be of great help in such planning so that pollution levels are contained. Car depot is spread on several hectares of land generally need large filling as the car depot. If overall project planning permits, it is preferable to locate the car depot near the river so that land may be filled by hydraulic fill which is most environmentally friendly method for filling. Generally, the level of air pollution along the river is low, therefore, the addition of pollution during the operation of the depot will have lesser adverse effect than locating the depot in already polluted areas[14].

In high population density cities, the infrastructure facilities and civic amenities are generally inadequate, specially in developing countries. Therefore, there might be some major construction projects under execution by different agencies along with metro rail construction. They are mostly concentrated in the densely populated and polluted part of the city where metro rail system is already in an advance stage of implementation [15]. Though the environmental impact of individual major projects are assessed and the necessary mitigation is planned but an overall comprehensive planning taking all construction activity together is generally lacking which results in unplanned increase in pollution level in an already polluted area . Metro construction is in general the biggest construction project in the city. In absence of overall planning of construction activity from environmental considerations at city level it is the responsibility of the metro planners to take into account all construction activities of the area in their assessment of environmental impact and plan remedial measures accordingly [16].

VI. METHOD OF CONSTRUCTION AND TYPE OF MATERIALS USED

Wherever pollution level has already exceeded the permissible level or is on higher side, every construction activity needs very close scrutiny so that there is no further environmental degradation. The planning of the construction method and the type of materials used is very vital in containing the adverse environmental impact which is clear from a few following examples.

Maximising use of 'precast' concrete structural members will be a big relief to any adverse environmental impact. In an elevated metro construction, by using latest techniques and high capacity cranes, all the members of super structure even the columns and pier head can be precast, thus reducing the adverse environmental impact specially SPM and noise pollution by 20% to 30%[17].

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Use of high strength concrete to optimum level will reduce the transportation and erection cost substantially and also mitigate the pollution. Similarly, proper use of ‘prestressing’ in concrete structure invariably leads to economy, as there is reduction in volume from 20% to 40% in most of the cases, which in turn has a positive impact on environment during construction. The technique reduces weight and volume of structure thus reducing pollution in transport, assembly, manufacture, etc.

The use of the ‘cut and cover’ method of construction for underground metro, the diaphragm wall design as a permanent structural member and not only a temporary structural member, would reduce the volume of excavation transporting of spoil and quantity of concreting. With the availability of better quality of water proofing chemicals, rubber/metal water stoppers along with advanced techniques of construction; the structure so designed will prove environment friendly as well as economical also. Even the environmental damage caused by the construction of temporary diaphragm walls can be largely mitigated by the use of steel sheet piles installed by modern ‘vibrohammers’ powered by ‘noisless’ and ‘green’ power packs in locations where suitable soil strata are encountered [18].

As the transportation of ‘spoils’ to dumping area and movement of precast or ready mix concrete is a major transportation activity to be carried out for a considerably long duration, use of ‘battery operated’ truck is an excellent environment friendly option which planners must look into while finalising transportation scheme as it will alone reduce burden of pollution as generated from plying of thousands of trucks per day for construction of underground metro.

Preference should be given to similarly electrically operated crane hoists wherever possible. As in many developing countries, there is a shortage of electricity in cities, and to complete the construction activity, one has to depend on diesel generators. Therefore, the need for maximising the use of electrical energy in place of fossil energy right from the planning stage needs special mentioning. In such environmentally sensitive locations, the old diesel run machineries should not be allowed to be used and the same should better be a contract condition for construction itself.

Use of durable materials and structures would eliminate the need for frequent repair and replacement thus again reducing the burden on environmental resources.

On a green road like Mall Road, Kanpur, cutting of long rows of fully grown green tall trees along the under ground alignment could be avoided by judiciously reducing the width of digging for construction in a ‘cut-cover’ stretch by replacing outside extension of bottom slabs of the box by providing piles below the box to counter buoyancy. Such innovative method of construction keeping the site condition in view will always give opportunity of reducing avoidable increase in pollution. Versatile and powerful machines for “trenchless” laying of pipes and cables are also helping a lot in containing the pollution in sensitive locations of the city. In such environment sensitive locations, longer length of temporary

‘liners’ should be used in construction of pile foundation to avoid use of Bentonite from environment point of view and minor economic consideration should not come in the way of such decisions. Some of the latest pile driving machineries are equipped with full length temporary liners in pile foundation construction which has been deployed in UP Metro Rail Project specially in sensitive areas.

Table 5: Sustainable Building Practices

Practice	Impact Reduction
Precast Construction	20–30% pollution reduction
Battery-operated vehicles	Reduced emissions
Electric machinery	Noise & air reduction
Trenchless technology	Less disturbance



Figure 8: Sustainable Construction Techniques in Metro Projects

VII. PUBLIC INTERACTION AND ACCOUNTABILITY

Such big construction work suddenly breaking out in the middle of the city is more looked at as a long-term inconvenience. The public and press are to be properly informed of all such construction activities that have any impact on the public [19]. This could be guaranteed by following steps. The press should always be advised of the general scheme of the work affecting the public. The information on the construction activity should be disseminated and discussed not only for the works being done by implementation agency but also by the other agencies in the area which are connected with the project through the regular community interaction programme. A more personal approach is required for those whose living conditions are directly affected by construction activity such as minor vibration in their building, movement of large number of trucks, temporary blocking of their pathway, etc. Such persons should be directly met by Engineers and their representative and Public Relation Personnel and be informed about the steps being taken to ensure safety and environment.

VIII. INTERNATIONAL STANDARD CERTIFICATION (ISO 14001)

When major construction activity is done in densely populated areas, high assurances to the public on environmental issues are needed. The above mentioned steps will certainly help in mitigating the adverse affect on environment but to have “Systematic” and “Continued Improvement” in the

environment management, ISO 14001 Certificate for the construction activities will have a great relevance and benefit to the project as well as to the densely populated and highly polluted city.

IX. CONCLUSION

When a big construction activity like metro rail is planned, the pollution level of a highly populated and polluted city is usually already at its peak. Such a large construction activity compressed in a short period for completion will increase the pollution level further. Recent studies show that an increase in pollution level even for short duration in already polluted areas of city has extremely adverse effect on the health of foetus in womb to old person. All aspects of planning and construction of metro project shall adequately consider the environmental aspects to suit the special circumstances prevailing in highly polluted and populated cities. Health hazards can be minimised by proper planning and execution and adverse effect on highly polluted and populated zones of city can be minimised. Such planning, properly carried out, will also build up public opinion in favour of more public cooperation and good will.

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