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Environment Impact Assessment of Highway Expansion – A review

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Abstract

Highway expansion improves the quality of existing roads and enhances the connectivity between prime economic centres. The escalating traffic and need to bolster the economic capability of the area leads to the expansion of highways. Moreover, the accession activity disturbs the ecosystem and induces myriad changes in the surrounding panorama. Also, it affects both abiotic and biotic components, directly and indirectly. Thus, to know and predict the impact on the environment and socio-economic conditions of the residents, Environment Impact Assessment of National Highways is imperative. Therefore, this paper reviews the influence of highway expansion on air, water and soil quality and the socio-economic conditions and health status of the natives.

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Keywords

EIA,
Highway expansion,
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Introduction

India have been experiencing a better fiscal growth over the last decade, accompanied by growing hunger for natural resources and rapid proliferation of infrastructure development due to industrialization, urbanization and modernization; which are yard sticks for the degree of heights of development in terms of technology and economy. Road refinement and highway development projects in India have chiefly amplified the quality of existing roads and have strengthened linkage between cardinal economic centres. The spike in India's growth has involved a considerable expansion of infrastructural development projects which provides the vital foundation on which other sectors of the economy can be built. The construction of new highways is the quintessential public sector investment, by which government attempts to encourage monetary growth in rural as well as in urban areas[1]. An effective, smoothly operating transportation infrastructure, as highway network is a prioritized concern for society and is a chief component of transportation system at the National, State and local level, thus, highway projects are generally undertaken to ameliorate the efficient connectivity, financial and social welfare of the personages. From an ecological perspective, development inevitably causes damage to the natural assets of the environment, to a greater or lesser extent.

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The building of highways leads to direct destruction and removal of existing ecosystems, and the reconfiguration of local landforms. Moreover, expansion of roads has diverse ecological effects on the topography which is signified by both abiotic and biotic components of terrestrial and aquatic ecosystems[2,3]. The construction activities acts as an important source of particulate matter into the atmosphere and causes significant impact on the air quality. The activities like land clearing, ground excavation, cut and fill operations and the construction of a particularly facility itself adds a substantial amount of PM into the atmosphere and are also a source of airborne ultrafine particles[4]. These activities have also been identified as a major source of pollutants to natural water bodies such as rivers, lakes and streams[5]. Pollutants emitting from various activities like soil erosion, use of fossil fuels, paint, solvents, cleaners, use of harmful chemicals, construction debris and dirt are added to adjacent water bodies through both direct and indirect discharges which leads to physical, chemical and biological degradation of water quality[6,7]. The roadside soil and residential area have been polluted seriously due to an increasing flow of motor vehicles along highways[8]. Whereas, pollution from heavy metals mainly coming from automobile is considered as a serious environmental issue[9]. Dust and other air pollutants from various construction activities impact greatly the health and quality of life of people living and working close to highways and proximity near major roadways has also been linked to increased risk of respiratory complications, cardiovascular disease, and other adverse health effects[10]. Mortality due to pulmonary diseases and chronic obstruction has also been observed among workers at construction sites[11]. Modification in the land use pattern in the areas that receive greater connectivity due to the highway has lead to changes in the structure of settlement, location of industries, trading and other services, which illuminate refinement in the design of economic activities, income generation, price inflation and employment conditions prevailing in the concerned region. A new land use pattern may in turn wheedle greater accessibility to job markets, health and educational facilities etc; in turn will magnetize funds for the development of feeder roads, power distribution networks, telecommunication facilities and other modes of connectivity. Hence, leads to changes in the echelon of well-being and human development, through their impact on consumption level, educational attainment and health status in the local economies consequent to such road development[12]. In the contemporary scenario India's biggest challenge is how it reconciles the pursuit of fiscal growth with the protection of its ecological integrity, i.e., to make monetary growth and human development sustainable. Thus, it requires the identification, understanding and alleviation of the ecological costs of growth without forsaking their benefits. Therefore, highway development and operations should be planned carefully by safeguarding natural resources, keeping in mind the social and environmental impacts and how to minimal these adverse effects. For such planning development project techniques of Environmental Impact Assessment (EIA) becomes vitally important[13]. It is one of the tools that were employed during the authorisation process to provide decision-makers useful information for taking a logical decision[14]. The main motive of EIA is to provide information to the decision makers and public about the environmental implications of the proposed project activity before decisions are made. Besides providing information, it also suggests measures for preventing or reducing those impacts and mitigation plans. Overall EIA offers a systematic process of examination, analysis and assessment of planned activities with a view of ensuring environmentally sound and sustainable development [15].

However, roads influence the abiotic components of terrain including other array of factors such as, the hydrology, the mechanics of sediment and debris transport, water and air chemistry, microclimate and levels of noise, wind, and light adjacent to roadsides. Thus the extent and intensity of the consequences vary with the position of the road relative to patterns of slope, prevailing winds and surrounding land cover[16]. Therefore, review of scientific literature was conducted on the work done regarding Environmental Impact Assessment of National Highways with the purpose of providing an overview of the environmental impacts of transport infrastructure, and to edifice the information according to environmental assessment terminology.

Review and Discussion About Effects of Highway Expansion on Ecosystem

Air Quality

Air pollution is one of the most often recognized environmental repercussions of roads. Toxic chemicals associated with air borne particulates cause diseases and increased mortality in humans, and indeed, this aspect of transportation has been the focus of intense scrutiny by researchers, regulators and lawmakers for several decades. Air pollution is widely considered to be the dominant environmental result of road related transportation. Air pollutants also enter aquatic systems by adding metals and hydrocarbons to water bodies from atmospheric sources[17]. However, the broader ecological effects of chemical pollution due to road related transportation has been less well-studied, although it is clear that toxins enter and persist in the environment and interact with biota.

The impacts of road widening projects vary with the intensity of construction works involved, various operational stages and the importance attached to the impacted environmental attribute. The widening of NH-5 from existing two lanes to four lanes showed no significant adverse impacts on the environment but however, the temporary impacts on air quality, water quality, soil quality, noise levels, flora and socio-economic condition of the project area were predicted[18]. To study the adverse effects of project over humans, flora and fauna and environment; EIA of Road from Ujjain to Jaora was carried which showed the effect of expansion on various environmental factors as air, water and soil. The air was found to be polluted due to heavy loss of road side trees and increased concentration of Carbon monoxide up to 365,470 μg/ cub m[19]. Even the local air quality deteriorated in road widening scheme in South London during and after the completion of the project[20].

Few studies have considered the air quality impacts of new road construction and its subsequent operation. The available studies are limited for the construction of urban road tunnels and are thus not directly applicable to most urban road schemes[21,22]. There is ample evidence that construction activities are an essential source of particulate matter (PM) with 3.8 per cent of total particulate emissions from open sources in the US in 1976, posing substantial temporary impact on air quality[23]. Emissions of PM during the construction of building or road are associated with land clearing, ground excavation, cut and fill operations and the construction of a particular facility itself. PM emissions from construction are largely in the coarse fraction but they are also a source of airborne ultrafine particles[4]. Increased concentrations of ultrafine particles (UFPs, <0.1 mm) are commonly found near roadways and thus substantial reduction in traffic can improve local and regional air quality in high traffic areas and urban areas[24].

Volatile chemicals associated with roads are introduced to the environment from vehicular emissions which includes carbon monoxide (CO), nitrogen oxides, volatile organic compounds, sulphur dioxide (SO_2), particulates from exhaust and road dust, lead (Pb), methane (CH_4) and toxics including benzene, butadiene and formaldehyde. In addition to these primary emissions, secondary pollutants are formed by chemical reactions in the air, mainly ozone, which is produced by combination of nitrogen oxides with volatile organic compounds in the air. So vehicular pollution dispersion models have been used globally for regulatory purpose of pollution from vehicular emissions. In India various roads and highways project carry out the air dispersion modelling to predict the future air quality and air quality trends to make potent air quality management plan along the proposed corridor. The application of CALINE 4 model for air quality management purpose along the highway corridor is widely used and the performance evaluation of CALINE 4 model was carried out to assess its predicting capabilities on an urban highway corridor in Delhi which indicated an incremental increase in CO and the dispersion of increased CO concentrations to a distance of 150 m on both the sides from the fringe of the mixing zone width[25]. Reduction trend of pollutant concentration of CO and PM_{10} to about 0.5 ppm and 40μg/m^3 respectively, and a sharp drop at distance of 100–150 m was observed around the highway in Tehran, Iran[26].

Dust also provides adsorption surfaces for volatile contaminants that are subsequently deposited either by dry or wet deposition, and causing phytotoxic pollutants to enter plant tissues, hence results in respiratory ailments in animals and humans. The air near roads is grimy, peculiarly near unpaved roads and this road dust impacts vegetation by covering surfaces and affecting photosynthesis, respiration and transpiration, there by resulting in plant injury and decreased productivity[27]. Grime and other air pollution from demolition and construction also impacts greatly the health and quality of life of people working and residing close to the highway. Inferior air quality also affects the health status of the surrounding people and to prove this many studies has been conducted by various researchers. Reduction in the lung function efficiency of the traffic policemen exposed to vehicular pollution on the highway crossings passing through Jagaon city was observed[28]. Similarly workers at the construction site are found to be suffering from pulmonary disease[11]. Studies have also reported an increment of mortality due to chronic obstruction due to air pollution[29]. A large number of epidemiological studies have shown that long- term exposure to the particulates causes adverse health effects specifically exposure to ultra-fine particles in addition to, fine and coarse particulate matter[30,31].

Soil Quality

Roads serve as major link among communities through which food and other important commodities are transported. It is an essential amenity that plays a major role in enhancing social and economic activities. However, road construction has also resulted in heavy environmental pollution especially, on soil[32]. It is clear from various reports that roadside soils may be contaminated from various anthropogenic activities such as industrial processes, energy production, vehicle exhaust, waste disposal as well as coal and fuel combustion[33]. Soil plays an important role in assessing the potential environmental impacts of automobile emissions as soil along roadsides is being contaminated with emissions from various vehicles in the form of metal and several researchers have indicated the need for a better understanding of heavy metal pollution of roadside soils[34]. Heavy metals reported to cause potential hazards are Cd, Cr, Pb, Zn, Fe and Cu[35,36]. Public motor roads affect natural environment to a large extent because automobile act as line sources of heavy metal pollutants[37]. Emissions from heavy duty and commuter vehicles on the roads were reported to contain lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), and Copper (Cu) which are present in fuel as anti-knocking agents and these leads to contamination of air and soils[38,39,40].

Ndiokwere[41] investigated the effect of automotive emissions of Cd, Cu, Cr, Ni, Pb and Zn on soil, vegetation and crops along the highway with high traffic density where decrease in concentrations of the metals with distance was found and higher accumulations of the metals on vegetation and soil samples near to the highway than from sites at a greater distance was also noted. Minute concern has been given to the likelihood of pollution by other heavy metals beside lead which can originate from automobiles, tyre wear and motor oils. Lagerwerff *et al.,*[42] reported that the Cd content of three lubricating oils ranges from 0.20 to 0.26 ppm and that of three diesel oils from 0.07 to 0.10 ppm. The lead content of four tyres of different brands was also found to range from 20 to 90 ppm[43]. Certain components of automotive engines, chasis and piping consist of copper and manganese, while nickel and chromium are usually used in chrome plating[44]. Some of the metals presumably are derived from the wear of metallic automobile parts containing these metals[45]. Vehicle exhausts, as well as several industrial activities emit these heavy metals such that soils, plants and even residents along roads with heavy traffic loads are subjected to increasing levels of contamination with heavy metals[46]. Moreover, release of Pb through vehicular emission, leads to Pb pollution in the atmosphere, soil and crops[47]. The levels of Pb, Cd, Zn and Cu in roadside soils were found to be higher than the soil in the control site. Whereas, pollution assessment methods showed that the sites were extremely polluted. These concentrations, however, were below the critical maximum levels above which toxicity is possible. Nonetheless, the level of contamination could lead to the leaching of these metals to adjacent farmlands and potable water sources, which would eventually find their way into the food chain. Also, constant exposures to the vehicular emissions could lead to the bioaccumulation of these metals in plants and humans until it reaches the critical maximum level of toxicity. The study provided ample information in assessment of the current status of soils adjacent to the highway and brought to the awareness of the residents imminent dangers from roadside activities[48].

Naser *et al.,*[49] found the heavy metal content with respect to the distances from the road in the order: Ni>Pb>Cd and the order of heavy metal contents was 0m >50 m>100 m>1000 m. The greater concentrations of Ni and Pb in soils near the highway resulted in long-term contamination of heavy metals from transport in the roadside environment. Abechi *et al.,*[50] also reported the decreasing order of the metal along the roadside soils: Fe > Zn > Mn > Pb > Cd > Cu. Similarly the concentrations of Pb, Zn, Cu and Cr at 5-1000 m distances in the roadside soils along Xi'an-Baoji Highway were analyzed for their spatial distribution and contamination levels which showed the moderate level of pollution. Moreover, the hierarchical cluster analysis suggested that Pb and Zn might have originated from the identical anthropogenic and natural sources, while Cu and Cr might have the same original source in the roadside soils along Highway. The results indicated that the heavy metal concentrations of Pb, Zn, Cu and Cr in roadside soil matrix increased initially and then decreased with the increase in distance from the highway edge[51]. Assessment of soil metals (Pb, Cd, Cr, Zn, Mu, Cu, Fe, and Ni) from selected sites along a major road in Ogbomoso, was compared with control site, the selected sites were found to be polluted which indicated deterioration of site quality mainly due to automobile emissions[52].

Excess of metal pollutants deposited on soils gets transformed and transported to vegetation and from plants they passed on to animals and human being[39] and thus, affects the food quality and safety[53]. Food chain contamination is a cardinal pathway for the entry of these toxic pollutants into the human body[54]. The metal pollution in soil at Motorway (M-3) in Nigeria was found to be in permissive limits but slowly passed to the food chain causing menace for all living beings. Researches may also have their application as bio-indicators to detect the presence of atmospheric pollutants on plants for identification and prediction of environmental pollutants[55].

Water Quality

The roadway infrastructure causes measurable impacts on the morphology of stream and river channels which in turn disturbs the biota. Motorways escalates the energy of stream systems, causing channel erosion and scouring on one hand; and on the other hand, cut banks of lanes near streams which cause sedimentation. It has been noted that both highway and road construction projects and operational roads impose a remarkable threat on the water quality. Based on data from long-term observation of the reservoir in Taiwan, verifies the difference in water quality before and after the highway construction. The large-scale land development project harmed the water quality of the reservoir and caused prolonged degradation in its quality[56]. Impact of highway construction projects on natural water bodies in Sri Lanka showed that both highway and link road construction activities foist a notable threat on the quality of water. The pH of water was identified as a chief factor to monitor the water quality of different water bodies adjacent to the construction sites[57]. Severe river pollution has occurred in some cases during road construction[58], also it has been observed that discharges arising from road construction can be serious enough to warrant implementation of control measures[59]. Similarly, loss of top soil near the construction site was observed mainly due to the acquisition of agricultural land and to construction dumps which also increased the levels of SPM in water[19].

The maintenance activities associated with the roadways and the chemical spills along roads are an important source of chemical pollutants along roadsides[60]. Some chemicals affects only the areas nearest to the road itself, while other chemicals are transported via water to greater distances from the road[61]. Toxic contaminants from roads enter the water bodies imperatively via storm water runoff. The contaminants in run-off differ greatly in size and magnitude, and include various hydrated ions and suspended matter. The particles as sand, silt and clay on road and roadbed mostly adsorb heavy metals and organic compounds and a complex and wide array of contaminants associated with vehicles are introduced to the landscape via roadway runoff. Among them are hydrocarbons, asbestos, leads (Pb), cadmium (Cd), and copper (Cu). Moreover chemicals related with the road itself or its maintenance including pesticides, insecticides and deicing salts as magnesium chloride combine with runoff and make their way into stream water drainage system[17,62].

The nature of interaction of roads with aquatic systems depends on their location relative to the drainage network and the slope. Seven streams receiving drainage from M1 Motorway in England were studied and effects on species diversity and in species composition of macro invertebrate assemblages were reported, but found no changes on either diversity or abundance of epileptic algae. The most damaging agent in aquatic habitats has been said to be siltation and increasing nutrient loads, rather than by chemicals[63]. A particularly detailed study on the effects of motorway run-off on freshwater ecosystems has also been undertaken by Maltby *et al.,*[64]. Roads acts both as a source and sink for water run-off from road surface and for accumulation of water on roads. Roads can act as barriers to water flowing downhill, but can also rush the removal of water. Road networks interact with stream networks, increasing the stream drainage density, the overall peak flow in the stream drainage, and the incidence of debris flows in the drainage basin[65]. Roads extend the drainage network of the stream network when drainage swales along roads directly connecting to stream networks[16]. Faster moving water enters the stream channels increasing the energy of the stream system, eroding channel banks, scouring the channel and increasing the likelihood of flooding downstream[66]. The effects of roads and pollutants in water run-off from roads to aquatic ecosystems have attracted much attention, as these consequences may be both immediate and long-lasting. Water run-off may alter hydrology, increase sediment load, increase nutrients and also result in accumulation of many kinds of pollutants. Proliferation in sediment load and changes in stream flows resulting from logging activities, have caused concern due to removal of vegetation and exposure of soil in a watershed, mass movement of earth leads to overbank deposition in watersheds and also results in changes to the morphology of streams, depositing in channels and creating shallower pools. The shallowness of the pools, combined with increased turbidity of the water and less vegetated banks, raises the temperature of the water in the streams. In the North Fork basin of the Navarro watershed, 100 % of the sediment eroded from cut banks along a highway in close proximity to the main stream channel and was delivered to the channel network[67]. Therefore, Multitudinous management practices (BMPs) aimed at mitigating chemical contaminants at the roadside, and are geared towards reducing the influx of particles into the surrounding landscape.The efficacy of mitigation for chemical toxicity associated with roadway runoff depends on the extent to which contaminants associate themselves with particles that are removed by BMPs and the potency of the BMPs[60]. The effect of sediment heavy metal content on benthic organisms was evaluated for nine study ponds in south and central Florida. Benthic organisms in the bottom sediments with heavy metal content showed less species diversity than typical freshwater lakes and copper appeared to be the most detrimental metal to benthic organisms[68].

Socio-economic Impacts

Development of transport facility like road infrastructure, play a vital role in the socio-economic and cultural development of any region through dynamic externalities that such development often generates. It can be a cardinal element of both direct and indirect interventions for poverty reduction and improvement of socio-economic conditions of rural population which has been persistently marginalized from the benefits of aggregate economic growth. The literature linking transportation to economic variables is rich in scope and scale analysts. Researchers have sought to link transportation improvements with economic growth and development and have shown significant and positive correlations between highway transportation infrastructure and economic activity[69]. However, there has been little assessment of the socio-economic impact of an infrastructural project like construction or widening of a highway. It is however, now being realised that the socio-economic impact analysis with a thrust on distributional issues like poverty reduction, should be made to see how important is the role of a transport infrastructural project in bringing about the distributional justice[70,71]. The developing economies like that of rural India, a large public investment project on road infrastructure development, apart from its broader general equilibrium, effects the national economy and may help in ameliorating rural poverty and improving the socio-economic well-being of the people living in its proximity[12]. Studies assert that transportation infrastructure is important in generating local economic development[72]. The reduction in physical isolation through widespread transport network is quintessential to raise a chief portion of populace above threshold of poverty. The residents in Toli and Bhawani towns of Dailekh district have been exposed to new and dynamic flow of opportunities that enhanced their livelihood due to better access to education, medical facilities and markets through roads[73]. Positive change in environmental situation of the households and institutions located along the Thika highway in Kenya have been observed, especially in reference to increased investment opportunities and greater markets, but influenced mainly vegetation and wildlife, negatively[74]. A unique link between transportation and economic development has been shown by many researchers. New manufacturing locations are systematically influenced by the provision of highway infrastructure. The development of new motorways affects the spatial allocation of new manufacturing establishments but some evidence also indicates that negative effects may occur in terms of displacement. Increase in four-lane highways, interstate access, and two-lane highway density have also been found to stimulate new manufacturing firm employment and environment gains[75]. Some authors find that highways have differential impact across industries. Thus, certain industries will grow as a result of reduced transportation costs, while others contract as economic activity relocates. As with manufacturing, highways affect the spatial allocation of general economic activity[1].

Growder *et al.,*[76] stated that a large public sector investment project like road infrastructure development improves socio-economic well-being of the citizens in close proximity to the highway, with greater transport mobility, connectivity with surrounding areas, increased access to the various economic opportunities and amenities of life. The literature on transportation role in rural economic development leads to interesting findings. Though, differences do exist between the implicit-explicit, positive-negative impacts and effects of highways on rural areas. Evidences suggest that road infrastructure has an influence on rural economic development. Highways are either a primary or secondary economic mover. In contrast with other productivity and cost factors or alone, roads tend to serve as producers or inhibitors for rural economic development. However, there are several major shortcomings. Empirical research fails to sufficiently account for the degree of highway accessibility that is necessary to generate rural economic development. The North Carolina's highway infrastructure does not significantly influence rural economic development on a county level, but in areas with a dispersed and dense highway system. The high volume of roadways virtually eliminates resource price differentials because the cost of access to firms is zero. As such, good highway access is not particularly valuable to business and does not influence location decisions. If these assumptions hold, further infrastructure will no longer be a significant economic growth generator. Thus, in some instances increasing highway capacity can actually displace employment and economic activity rather than generating new activities. Still, the literature is not conclusive[77].

The long-term effects of transportation infrastructure are not well understood but include land-use changes, changes in landscape patterns, and the alteration of ecosystem services. Construction of Highway 6 on Puli Township and subsequent urbanization under various land-use policies resulted, in varying degrees of isolation and fragmentation in the overall panoramic pattern and ecosystem services in Puli Township. Indirect effects include the spatial restructuring of certain landscapes, which can drastically influence habitat dynamics. Land-use simulation results indicate that agricultural and environmental conservation policies have significant effects on projected land-use patterns in the southern part of Puli's downtown area and in areas along major roads. Thus, environmental policies will mediate both the direct and indirect impacts of Highway 6 on landscape patterns[78].

Landscape Change and Habitat Fragmentation

It is considered by many authors that, fragmentation of habitats by roads may be the imperative ecological effects of road expansion. Though studies on ecosystem fragmentation are increasing day by day but there are still very few reports which `inspect the effects of fragmentation by roads. Thus, there is a wider space for research on effects of roads, habitat loss and how to overcome those effects[79]. Many direct ecological effects on adjacent aquatic and terrestrial ecosystems has been observed during development of a road network structure but they also have far reaching, cumulative effects on landscapes which have been less well-studied[80]. The loss of habitat, reduced habitat quality by fragmentation and the loss of connectivity through the transformation of existing land covers to roads and road-induced land use and land cover change are some major effects to landscapes due to road network[81,82]. In rural areas, mainly in developing countries, the presence of roads has been strongly correlated with processes of land cover change by facilitating deforestation[83].Habitat fragmentation is believed to have the greatest long-term impact on nature and the effect of road construction varies and depends on the type of road, the stage of economic development in the region[84]. In the Amazon regional climate change, and the amount of forest fragmentation and deforestation, directly related to the construction of roads[85]. The basic principles of land use, transportation, network theory and ecology, comprises of ecological road network theory and provides a framework to interpret the ecological effects of road networks. Thus further, analysis of the effects of a road network on ecosystem suggests that they extend over large areas of the landscape, saturates a landscape and creates isolated patches of habitat[61]. In a study in the Rocky Mountains, Reed *et al.,*[86] assessed the extent of forest fragmentation caused by roads and by deforestation. They found that motorways did contribute more to forest fragmentation than depletion of the forests. Trees may prevent land slips on to roads[87]. In a study of woodlands in Ohio, Kupfer[88] looked at patterns and determinants of edge vegetation and concluded that microclimate influences edge succession. Williams[89] working on forest edges in tropical wet forests of Panama found changes in microclimate penetrating 15 m into the forests and these microclimatic changes can affect areas at great distances from the roads and changing the vegetation composition[90]. The microclimatic changes produced by even narrow roads affect the leaf litter and vegetation composition, soil macro invertebrates, interior-dwelling forest birds, herpetiles, mammals and overall species richness[91].

Conclusion

Roads infrastructure affects both biotic and the abiotic components of ecosystem by changing the dynamics of populations of plants and animals, altering flows of materials in the landscape, introducing exotic elements, and changing levels of available resources, such as water, light and nutrients. Thus, the above discussion infers the view that comprehensive impact of highway expansion has not been carried out elsewhere. This necessitate to carry out impact of highway expansion on air quality, soil quality, water quality, human health and socio-economic condition of populace residing nearby the highway.

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Conflict of Interest

There is no conflict of interest for this manuscript.

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