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EVALUATION OF PHYSICAL ENVIRONMENT OF KAKARBHITTA-PATHLAIYA ROAD SEGMENT OF EAST-WEST HIGHWAY OF NEPAL

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ABSTRACT

The Government of Nepal (GoN) is planning to upgrade the two-lane East-West Highway to four-lane standard in phase wise basis, in response to the increased number of vehicles and frequency of travel associated with the increased population growth. In the first phase, the GoN is planning to upgrade the Kakarbhitta-Pathlaiya corridor of the highway. Since the road construction may lead to multi-dimensional environmental degradation, it is crucial to investigate the physical environment of the influence area of the road for the sustainable design of the structures associated with it. Therefore, the overarching goal of this paper is to explore the existing physical environment conditions in the project influence area of the Kakarbhitta-Pathlaiya corridor. Field observation and a walk-through survey were conducted to gather information related to the physical environment. Our analysis indicates that the slope stability along the road alignment is found to be good to the extent that further realignment of any of the subsection is not essential. Because the existing river networks of the project influence area may cause drainage problems associated with water-logging along the highway, the sediment and streamflow capacity of the rivers must be enhanced near the hydraulic structures including bridges and dams, especially during monsoon season. The groundwater is contaminated with the toxic minerals including arsenic in several locations near the road corridor. In addition, dust pollution along the road section is highly noticeable especially during the dry season. Similarly, the noise pollution due to the vehicles running on the highway is significant both for the human and wildlife. However, there are barren lands that can be utilized for quarries, stockpiling, camping, and for other technical purpose during road construction. The study results are expected to provide planners and designers with information related to the valued environmental components in the project area.

Key Words: Physical Environment · Kakarbhitta-Pathlaiya Road · Slope Stability · Dust Pollution · Noise Pollution

Highlights

- The road alignment passes on the loose soils of the fluvial sediments.
- Water and sediment transport capacity of rivers, especially near the bridges, must be improved.
- Valued environmental components were recommended.

1. Background

Road linkages and systems are vibrant to these days' economy and society (Button and Hensher 2001), and road infrastructures are extremely essential for a land-locked country like Nepal, where other transportation means are either unavailable or expensive. While the Government of Nepal (GoN) is undertaking the construction plan of the east-west railway network, there has not been any railway network in Nepal so far. In this context, roads are not only responsible for safe and efficient movement of goods and public throughout the country, but these infrastructures also serve the permanent part of the physical, cultural, and social environment (Robinson 1971; Lay 1992). Nowadays, roads networks are one of the most prominent man-made features on the modern landscape (Sanderson et al. 2002).

East-West Highway of Nepal is the longest road linkage, which was constructed about 50 years ago. It is 1035 km long, which extends from eastern to western border of Nepal and traverses through the southern low lying Terai (southern flat plain) of Nepal. The highway is situated within two geographic regions including Gangetic Plains (Terai Region) and Siwalik Range. Moreover, it crosses three physiographic units including Terai (northern edge of Gangetic Plain), Siwalik Range, and Dun Valleys with a variation of elevations approximately from 200 m up to 700 m from sea level. The region is characterized with rock and soil types mostly of alluvial nature. The highway is single-lane bituminous carriageway width, which has been rehabilitated/upgraded to the double lane during different periods in between 1998-2005.

The existing condition of the East-West Highway is poor. Many bridges, most of which are more than 40 years old, also require rehabilitation or replacement. Due to the significant growth in population, the number of vehicles and frequency of the travel has increased significantly in the recent years. In order to address this situation, the GoN is planning to upgrade the two-lane East-West Highway to four-lane standard in phase wise basis. In the first phase, the GoN is planning to upgrade the Kakarbhitta-Pathlaiya corridor of approximately 366 km.

The Kakarbhitta-Pathlaiya road segment of East-West Highway encompasses 10 districts in the zone of influence (Figure 1). Five districts viz: Bara, Rauthat, Sarlahi, Mahottari, and Dhanusa are located in Central Nepal and five districts: Siraha, Saptari, Sunsari, Morang and Jhapa - are located in Eastern Nepal. The road is situated in the eastern Terai region of Nepal, mostly in the plain area with a fast-growing population, in different ranges of urban centers along the road including small, medium, and large. Even though the area is mostly developed for agriculture, the industrial developments have been actively taking place in the region for the last decades.

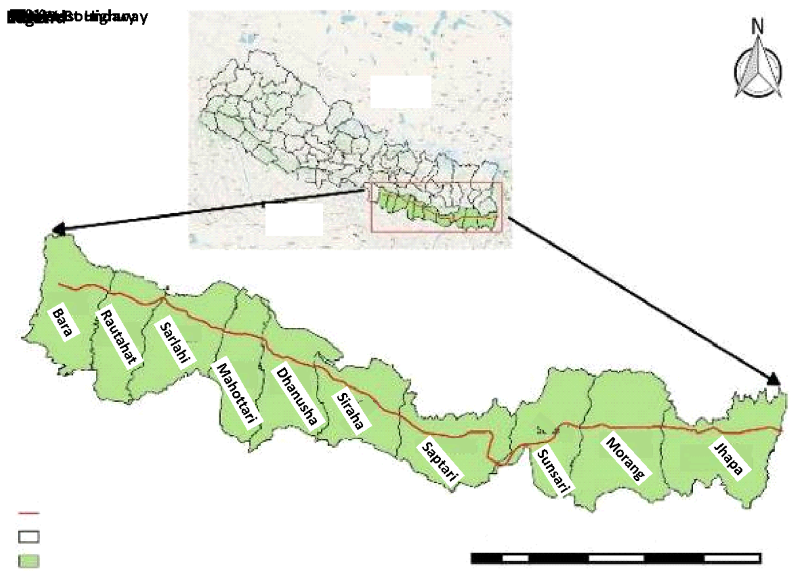

Fig. 1 Map showing districts through Kakarbhitta-Pathlaiya road section of East-West Highway (Regmi 2022)

The physical and environmental characteristics of this region including elevation, relief, slope gradient, features, geomorphology, geology soil type, and landuse, are crucial to influence the sustainability of the road. Therefore, this paper aims to deliberate the existing physical and environmental conditions in the project influence area. Field observation and a walk-through survey were adopted to evaluate the physical environment; and hence the following "valued environmental components" were identified: Topography and geomorphology; Natural drainage and watershed management; Soil; and Atmosphere.

2. Topography and Geomorphology

The proposed road alignment passes through the loose soils of the fluvial sediments of the Indo-Gangetic Plain. The road alignment is located at the south of the Main Frontal Thrust in Nepal. The geological characteristics of the region is drift and indicates that the road alignment lies in residual and old alluvial soil deposits. The project area along the road alignment is stable in terms of slope, and stability of the soil condition seems to be good. Since slope instability and landslides are not expected, the necessity for realigning any of the subsections is not envisaged on account of geological consideration particularly due to the stable soil slope. However, potential problems due to bank erosion along the rivers are anticipated (Figure 2). Riverbeds provide various range of construction materials needed for road construction. So, bank slope conditions may be recommended as "valued environmental components" that can be affected during road upgrades, specifically, during bridge and road construction while collecting the construction materials from the river beds.

Fig. 2 Fragile bank slopes and soil erosion along the river

Not only direct, but indirect and cumulative effects may impact the bank slope stability, including high siltation and possible flooding in the monsoon season. This issue is addressed by the GoN (1982, 1992, 1997), which ensures control of erosion, landslides and sedimentation in road development projects. River bank slope instability and soil erosion will serve as indicators of adverse impacts, associated with road development, which can be monitored during and after road upgrades and bridge construction. It is recommended to extract materials for road construction, at least, 1 km upstream from each bridge site along the highway to prevent the adverse impact of bank erosion.

3. Natural Drainage and Watershed Management

The drainage network in the project area is represented by 23 major rivers, which can be grouped as old pre-Himalayas (Koshi River), young Mahabharat (Kankai, Kamala, Bagmati and Lal Bakiya) and very young Post-Siwalik (other rivers) (Adhikari 2013). All other rivers depend on rainfall for their runoff except the Koshi River, which is snow-fed. Other water-bodies are represented by wetlands, springs, canals, artificial ponds, ditches, etc.

Water quality in the project area was tested from two different locations, Sirsiya River from Parwanipur and tube well water from Simara bazaar. The drinking water quality from the tube well showed that all the physical parameters are within National Drinking Water Quality Standards (NDWQS), the limit as prescribed by GoN. However, the biological parameters of fecal coliform were found exceeding the acceptable standards in the water sample collected from the tube-well at Simara Bazar. Similarly, at Sirsiya River in Parwanipur, the concentration of BOD_5, oil, and grease were found to be 108 mg/l, and 19 mg/l respectively, which is almost two times higher than the limit of the generic standards for both. This can be due to the direct disposal of domestic and industrial liquid and solid waste into the river.

The project road lies in the Siwaliks and Terai regions (Figure 3). The Siwaliks region is known to have limited groundwater availability. However, the Terai region has abundant groundwater resources to supply drinking and other domestic purposes. The seasonal range of depth to the water table in the Terai varies from 0 to 10 m below the ground surface. The quality of groundwater in this area should be monitored closely, as the presence of arsenic and other minerals have been detected in several areas.

Fig. 3 Siwalik range border and Terai Plain

The climate of the region is tropical with hot and wet summer, where maximum temperatures can reach up to 42°C during summer, and minimum temperatures can reach as low as 16°C during winter. Annual rainfall is very high, which is as high as 1500-1800 mm/year, in many areas along the highway. Rainfall is more intensive during monsoon season (June – September) with large spatial variations relevant to orography. Heavy rainfall occurs on some sections of the southern Himalayan slopes. Rainfall is also high along the Siwalik range. Regions close to the Indian border receive about 1500 mm rain in a year, while at the foothills of Siwalik, the annual rainfall reaches 2000 mm. On the northern side of the Siwalik, the rainfall diminishes again. In the lee-ward side of the ranges, rainfall is reduced due to the effects of rain shadow. Even though, most of the areas through which this road passes is safe in terms of flooding and inundation, it has caused extensive suffering to the people in the Terai and northern districts of Bihar (India). In 1993, people have encountered the unprecedented and devastating flooding in the Bagmati River. Poor water management, lack of proper flood forecasting and awareness to the community were the main cause of massive destruction (Bhusal 2002).

The water network is abundant in the project area, and water may cause drainage problems along the highway, especially during wet monsoon seasons, associated with water-logging and heavy rainfall in the region. The areas of possible water-logging should be identified and mitigation measures should be proposed at the planning and design stages. The river capacity for sediment transport and flow, especially in the places of bridges' must be considered taking into account the foreseeable increased precipitation and flooding associated with the global climate change.

The devastating flood, especially in the monsoon season, can inundate the road and infrastructures in future because the rainfall amount is predicted to be increased further in the Terai region due to climate change. Meteorological stations in the Terai region show an increasing level of precipitation in July from 1970 to 2009. The frequency and intensity of rainfalls has also increased including rainfalls causing rise in flash floods and debris flows (Dixit et al. 2008). The escalation in total rainfall intensity facilitated an increase in the number of landslides. In such scenarios, more floods can be expected along the highway and the design of the drainage structures should be made accordingly to prevent seasonal disasters in specific areas of the Lal Bakaiya and Bagmati River basins. The impact of climate change reveals that there could be substantial increase in the number of extreme rainfall events resulting in the frequency and magnitude of extreme river flows.

So, the natural drainage systems should be considered as a "valued environmental components" in the project area. The natural drainage system can be affected directly and indirectly through the quarrying and stockpiling as well as barrier construction activities for natural flow (especially small streams and brooks in the project area), especially during road upgrades, bridge construction and highway operations. Therefore, adequate drainage systems need to be provided to prevent water-logging along the road in the wet season.

The management and protection of natural drainage are regulated by several national laws such as GoN (1982, 1992, 1993(b), 1997) and other documents. The climate change scenarios for possible flooding should be considered at the planning and design stage road upgrades to prevent the destruction of adjacent villages, agricultural areas, and natural habitats. Well planned and proper drainage system can prevent flooding along the road. Road elevation is also an important parameter that should be considered to prevent flooding. In some places, the existing highway lies very close to the other linear structures, such as the new planned Railway and Post road. The Railway is planned to have height in several meters (up to 5-7 m), which will cause the additional impact on reinforcing the water-logging and drainage problem. The coordination among the stakeholders for various projects is essential for the location and design of drainage structures.

Most of the bridges and culverts along the Kakarbhitta-Pathlaiya section are old and mostly damaged, which need the urgent replacement or restoration to ensure the movement of vehicles. In 2017 summer, one of the bridges in the Bara District was completely damaged causing delays for vehicle movement. As a result, traffics were diverted into the earthen road through the river bed, which was possible in the dry season but could paralyze traffics in the next wet season in future. The proper management of natural water drainage, affecting the road structures and surrounding environment, is vital in the Terai region, because any interruption in natural drainage structures may not only cause traffic congestion and delay problems, but also may lead to ecological disaster. For example, this might lead to the degradation of Sal forests due to waterlogging and destructive flooding of settlements including the loss in agricultural products resulting in the loss of income, assets and the lives of local inhabitants. Appropriate planning and maintenance of such structures are extremely important during the design and development of the highways.

Siltation is another crucial problem in the Terai region (Figure 4), which can seriously damage the hydraulic structures including bridges and culverts. The impact of siltation near bridges and culverts should be considered for the design of bridges and culverts in order to avoid the accumulation of silt. Siltation may cause improper functioning of culverts resulting in the strengthening of flooding effects.

Fig. 4 Siltation may cause improper work of drainage structures

Therefore, in order to take into account the seriousness of both designated above problems and interactions between selected "valued environment components" (bank slope conditions and natural drainage systems), following aspects should be revised:

- return period, design discharge, high flood level, clearance above high flood level, length of waterway, water current force, etc.;
- design methodology of bank slope protection works (retaining and breast walls) including subsurface drains and catch drains, etc.;
- design of pavement including selection of an appropriate type of base and sub-base materials;
- road surface camber for quick removal of surface water;
- the frequency of periodic maintenance;
- the road and bridge design parameters conducting consultation with the departmental staff, designers, hydrologists, meteorologists, and climate change specialists.

4. Soils

Soils along the Kakarbhitta-Pathlaiya section are mostly of residual or old alluvial deposits, represented by boulder and cobble, sands, and silts. While the topography is mostly stable, it is possible for soil erosion mostly along river banks. So, riverbank protection is required during the construction of bridges and other road infrastructures. Extensive soil erosion and landslides in upper catchments of the large rivers (Koshi, Bagmati, Lal Bakaiya) have produced significant amount of silt. For example, the soil erosion in the Koshi River basin is one of the highest in the world, which is around 19 m^3/ha/year

(Varghese 2007). There could be many reasons including the age of the river, increased gradient through which river flows such as young Himalaya Mountains causing side and bed erosion along the course, frequent landslides and seismic disturbances, and lack of the flat valleys in the mountains. The Koshi River transports sediment through the steep gradients and narrow gorges in the mountains and foothills, where the gradient is, at least, 10 m/km (IIT 2013). On the plains, the gradient falls below 1 m/km to as little as 6 cm/km as the river approaches the Ganges.

Exposure of fine soil particles from the upper catchment area to the flat plains provides conducive conditions for the formation of fertile plains, which is beneficial for the agriculture development. Thus, the Terai region is known for its abundant agricultural production and fertile soil (Figure 5). Fertile soil is extremely important for the growth of agricultural products to improve the local economy and livelihoods of the local communities. Therefore, the soils of the project area are valued by people; and the protection of soils is addressed in the GoN (1982, 1992, 1997). Since more than 50% of the land-cover area along the Kakarbhitta-Pathlaiya section is occupied by agricultural area, fertile soil of this region is extremely beneficial.

Fig. 5 Fertile soils in the Terai region provide favorable conditions for agriculture

Thus, soils in the project area may be recommended as a “valued environmental components” that can be affected directly due to the disposal of excavated excess materials associated with road construction and upgrades. The disposal of soil materials will have further impact on soil erosion including the contamination of soils along the roads with adverse effects on the productive top-soil. The Road upgrading will produce a large volume of excess fill materials and require the construction of labor camps and suitable places for stockpiling. Therefore, disposal of excess fill at low impact sites should be undertaken to minimize the damage to environmental and social features. Excess fill should not be dumped over the edge or near drainage lines, above houses, or in any other places where it is likely to cause damage to natural or social features. There is also a threat of losing a significant amount of fertile top-soil in the project area.

As per the norms provided by GESU (2017), the designated disposal sites should be carefully selected and recommended to prevent adverse impacts on soils. Such sites should be away from cultivated land, settlements, water sources, public places, schools, and health centers, forests, fragile ecosystems and landslide-prone areas, etc. Soil protection also should be recommended in the Initial and site-specific Environmental Management Plans through identification of appropriate designated sites for disposal as per the standards given in GESU (2017). Barren land occupies significant area, covering around 4% in all data sets. This is more likely attributed to the presence of open land with sand, gravel, and boulders in river valleys. The presence of barren land in the road corridor indicates that there are opportunities to find places for quarrying, stockpiling, camping, and for other technical purpose during road construction. It is also recommended for the protection of productive top-soil in order to prevent the loss of this fertile layer and keep it for land reclamation after construction.

5. Atmosphere

At present, air quality on the roads is very low due to various reasons including high traffic flow, poor road conditions, destructed soil, car combustion, and lack of mitigation measures. Pollution in road development projects is one of the evident, which directly impacts affecting water and soil. The dust pollution along the Kakarbhitta-Pathlaiya section is visible in the dry seasons. The information on air pollution from the project site is very scanty. Other pollutants also can be considered as indicators taking into account their importance for public health and coverage by a regulatory framework. Arsenic contamination in drinking water is reportedly high. It was estimated that 3.5 million people in the region are directly exposed to arsenic levels between 10 and 50 µg/l (Pokhrel et al. 2009).

Noise pollution is the major annoyance particularly for the people living in roadside settlements close to the highway. It is observed that the noise produced by the vehicle plying on the highway is mostly exceeding 70 dBA, disturbing people as well as wildlife in many cases. There are many adverse effects of road construction/upgrades and operations on air quality. Some of them are dust, gas emission and air pollution from vehicles, etc. Dust emission is most prominent in the dry season, when the effect of pollution is visible on the distance of 1 km and more in open places.

The study conducted by NHRC (2004) shows that Total Suspended Particulate (TSP) and Particulate matter of size less than 10 microns (PM_{10}) levels in the ambient air at Birgunj exceeded several times of the national standard. Average PM_{10} level in Bhanuchowk, Ranighat, and Adarshanagar were found 380 $\mu g/m^3$, 358 $\mu g/m^3$, and 220 $\mu g/m^3$, respectively. However, Birgunj was found to be least polluted among three cities Kathmandu, Pokhara, and Birgunj, with all kinds of gaseous pollutants (NHRC 2004). Observed levels of nitrogen dioxide (NO_2), sulpher dioxide (SO_2), and carbon monoxide (CO) in all locations of this city were found very low than the recommended safe level. Noise associated with Raxaul-Amlekhgunj petroleum pipeline construction was short term in the project area but could not be fully mitigated (NOC 2017). Therefore, residual noise impacts during construction were recognized.

For baseline information, noise level monitoring was conducted at two different locations within the project area. One station was located at Simara (in front of Hotel Samyak) and another one was located at

Amlekhjung (inside NOC staff quarter area). They both used a sound level meter (CENTER 320) and a calibrator (CENTER 326) taking 6 hours data. The monitoring data are illustrated in Table 1, which suggests that the measured minimum and maximum range of noise at two stations ranged from 98.3-52.0 dBA.

Ambient environmental conditions in the project area are candidate "valued environmental components" that can be highly affected by road development. Potential effects of the road development on atmosphere quality and climate can be measured through indicators such as air quality and greenhouse gas (GHG) emission. Since GHG emission is not easy to measure and monitor, air pollution as per legislation and regulatory requirements, is a good indicator and represent one of the priorities for consideration in road development policies in Nepal. Air and noise pollution can cause many health problems for local communities including environmental deterioration.

Table 1 Noise Quality Data (Average 6 hours)

Location	Time	Observed Value (dBA)					
		L_{min}	L_{max}	L_{eq}	L_{90}	L_{50}	L_{10}
Simara - in front of Hotel Samyak	08:30-09:30	64.7	95.2	78.0	69.2	74.4	80.0
	10:40-11:40	68.6	98.3	81.2	72.2	75.0	83.4
	13:00-14:00	60.5	88.7	76.9	74.5	77.6	81.4
	18:00-19:00	54.1	97.9	66.1	59.6	65.2	73.5
	20:00-21:00	52.0	86.4	58.4	60.1	63.5	68.5
	21:00-22:00	48.9	83.6	56.2	62.4	66.3	69.7
Amlekhjung - inside NOC staff quarter area	11:10-12:10	58.4	88.4	67.9	62.7	66.2	72.0
	13:00-14:05	55.4	91.2	68.7	60.0	67.8	71.5
	15:10-16:10	61.2	88.4	70.9	64.7	66.7	73.5
	18:30-19:30	52.4	81.4	65.4	60.1	65.8	70.9
	21:15-22:10	47.3	68.8	50.9	52.3	55.8	60.1
	23:00-00:00	48.8	76.5	52.5	51.8	54.6	61.1

Source: NOC (2017)

GoN (1982, 1992, 1993(a), 1997) promotes necessary mechanisms to prevent air, liquid, and solid pollution. Nepal vehicle pollution standard and National standard on air quality ensure the implementation of mitigation measures in road development projects. For noise control, the GoN (1997) is the recommended documents for reference.

While it is impossible to avoid the impact of roads on air quality, mitigation technics to minimize adverse effects on the environment and human health are well known. Mitigation measures include minimizing effects through different actions such as air quality control, water springing during construction in the excavation sites, replanting of trees, management roadsides, emission, and dust control. In this region, the effect of air pollution is invisible at a location where there is dense forest on distance 150-200 m from the road, because broad-leaved trees serve as a natural shield, filtrating air and preventing dust exposure. Therefore, as one of the preventive measures, plantation of trees can be recommended to stop the spread of dust and consume carbon dioxide. Local native trees are the best alternatives to mitigate adverse dust emission effects. Solid and chemical pollution is another issue, especially during the construction stage. Quarries and borrow areas can be recommended for proper management of waste, chemicals, and other hazardous materials during construction. World Bank (1997) recommends restoration and landscaping quarries and borrow areas after road construction for different natural, economic or recreational uses. The impact of noise can be significant especially during construction or road improvement stages, when operations of heavy machinery create disturbance for people and wildlife. While it is impossible to avoid noise during road construction and operations, it is possible to minimize the effect of noise through special barriers, which are usually expensive. In the forest areas, the noise can be significantly minimized using natural barriers like green walls of trees along the road.

6. Conclusions

The Kakarbhitta-Pathlaiya road segment of East-West Highway lies in the Terai region. The road alignment passes on the loose soils of the fluvial sediments of the Indo-Gangetic Plains. The slope is stable along the road alignment, and further realignment of any of the subsections is not essential. The existing river networks may cause drainage problems associated with water-logging along the highway, especially during monsoon season. The areas of possible water-logging should be identified, and mitigation measures should be proposed at the planning and design stages of the road section. Siltation is also a serious problem in the project area. Therefore, the capacity of rivers in future must be improved for water and sediment transport, especially near the bridges in order to cope with the increased precipitation and runoff due to climate change. The road segment of the East-West Highway should be protected in addition to the protection of the entire area of the Terai from flooding and inundation problems. Even though Terai region of the project influence area has abundant groundwater resources for water supply and other domestic purposes, the quality of groundwater should be monitored closely as the presence of arsenic and other minerals have been detected in several areas. The rivers bank slope conditions and soils in the project area may be recommended as “valued environmental components” that can be affected during bridge construction and collection of the materials for road construction. The dust pollution along the road section is most prominent in the dry season. The noise produced by the running vehicle on the highway is disturbing people and wildlife as well. The existing barren lands in the road segment provide opportunities for quarries, stockpiling, camps, and other technical sites during road construction.

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