Environmental Impact Assessment

Project No. 47279-002
May 2018

PAK: Karachi Bus Rapid Transit Project

Part 2

Prepared by the Transport and Mass Transit Department, Government of Sindh, for the Asian Development Bank.

5. Description of the Environment

213. The Environmental Base Map for the Project is shown in Figure 5-1. It shows the principal features of the Project and surrounding environment, including urbanized area, green space, water bodies, and administrative boundaries. Also shown are key institutional buildings and other proposed transport improvement projects. The map shows green space and roads with a zone of influence some 50 m each side of the proposed alignment; however, the zone of influence may be wider or narrower depending on the type of impact being considered.

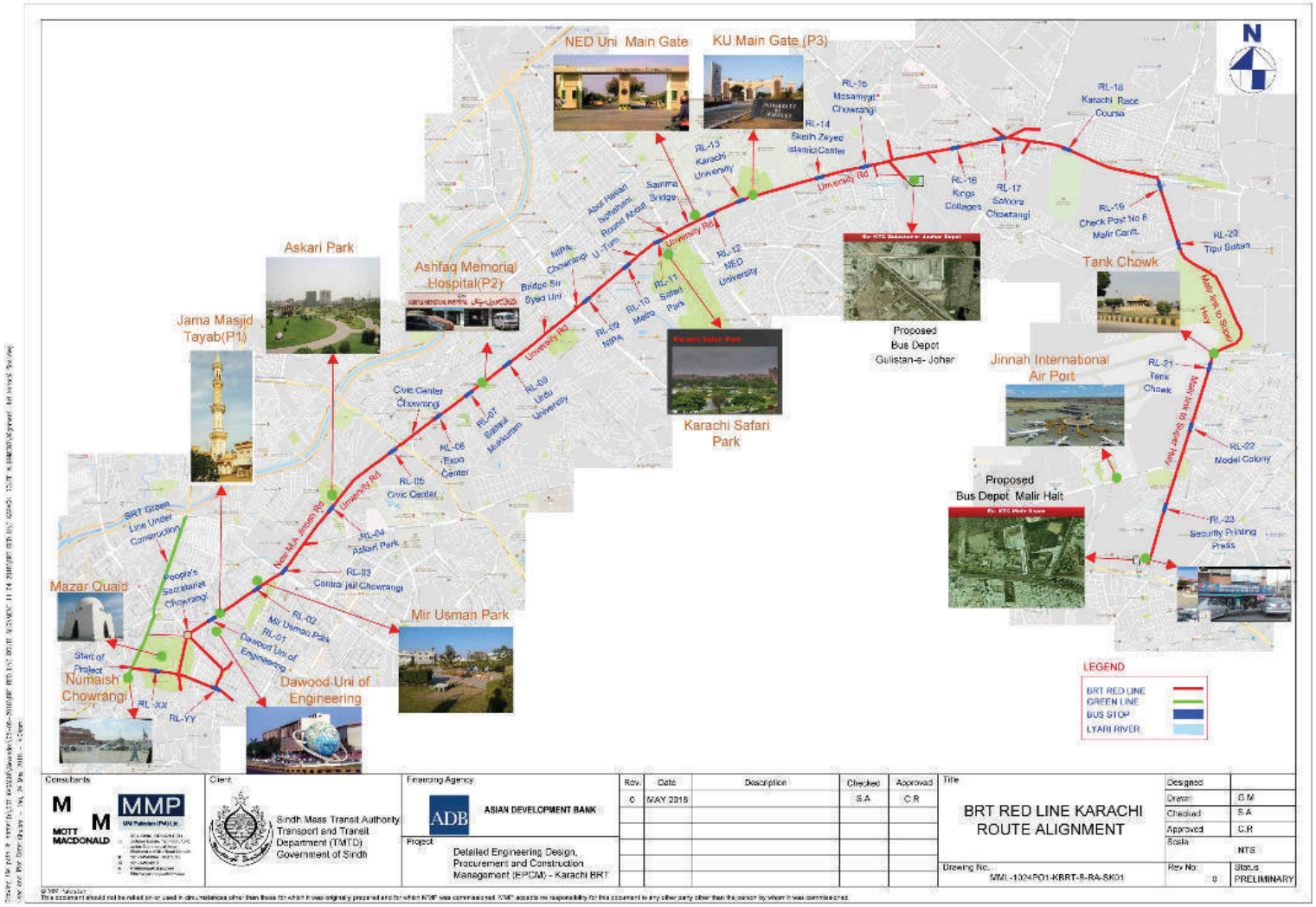


Figure 5-1: Environmental Base Map

5.1 Physical Resources

5.1.1 Meteorology, Air Quality and Climate

Meteorological Parameters

214. Karachi is located just above the tropical zone on the coast of the Arabian Sea at 24.9 N latitude and 67.13 E longitude at about 20 m ASL (airport weather station). It is classified as BWh (arid/desert/hot) under the Köppen system. According to Budyko's criteria, Karachi is characterized by the following parameters:

- Radiation index of Dryness: 7.54
- Budyko Evaporation 211 mm/year
- Budyko Runoff 1 mm/year
- Budyko Evaporation 99.5 %
- Budyko Runoff 0.5 %

215. Best estimate of annual rainfall is 212 mm. Net moisture allowance follows the pattern shown in Figure 5-2 and as can be seen, precipitation is exceeded by evapotranspiration for every month (arid/desert), hence it is only during heavy rains that Karachi experiences runoff. Note that these values as well as other data in this section are long term averages compiled by the FAO and available through its "Climate Estimator"[11]. No particular year is represented in Figure 5-2. On the other hand Figure 5-3 depicts last 9 years maximum and minimum precipitation at Karachi.

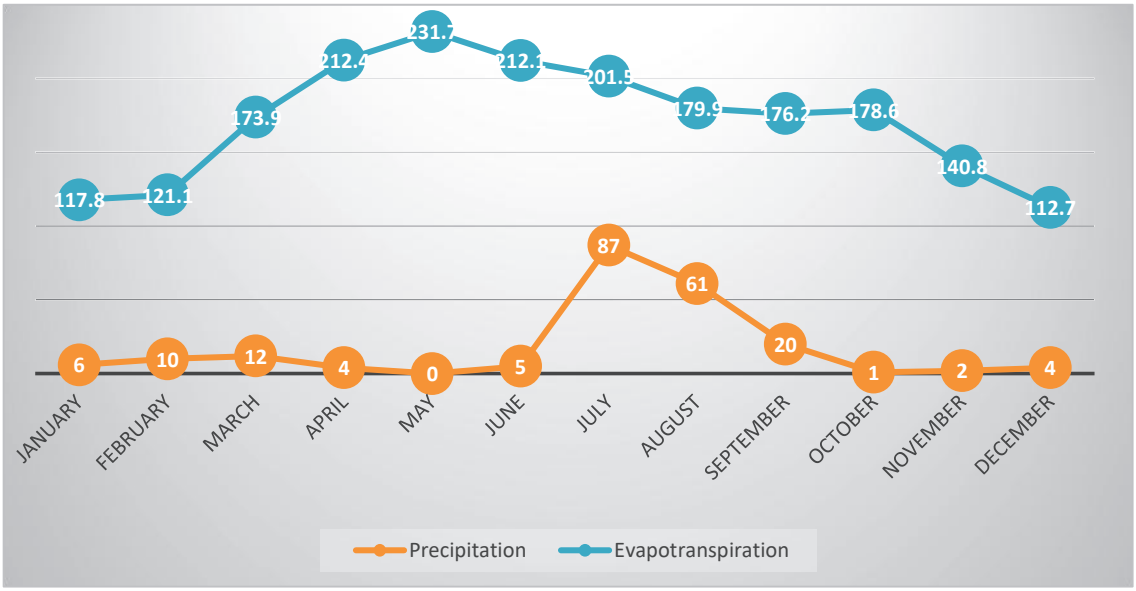


Figure 5-2: Monthly Average Precipitation (mm) and Evapotranspiration (mm) at Karachi Airport

[11] The FAO Climate Estimator is a software program and database that provides estimates of average climatic conditions at locations throughout the world. The program can be used to create climatic maps and extract data in various formats for further processing, available at http://www.fao.org/nr/climpag/pub/en3_051002_en.asp.

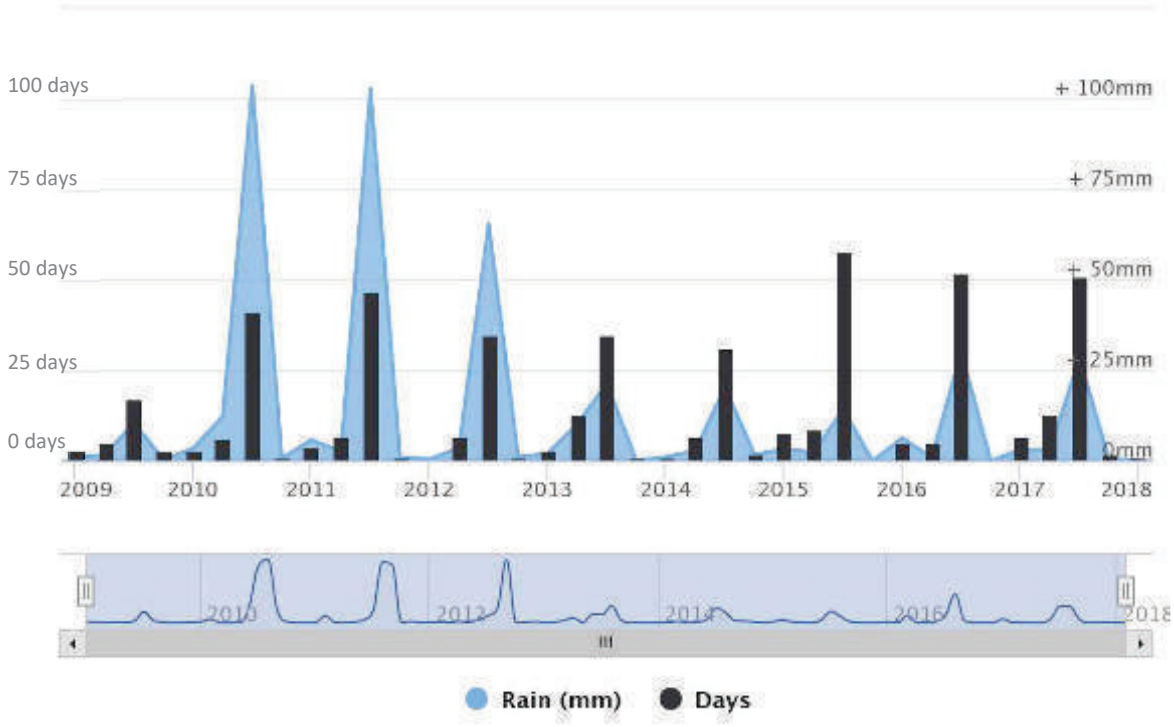


Figure 5-3: Minimum and maximum Precipitation (mm) and Evapotranspiration (mm) at Karachi (2009-2018)

Source: Pakistan Metrological Department

216. Temperature ranges are shown in Figure 5-4. Cool weather can prevail during the night from November through March; however daytime temperatures are generally hot. Temperatures may reach 40 C during May (considered the hottest month), and extreme temperatures of greater than 45 C are not uncommon. No particular year is represented in Figure 5-4. On the other hand Figure 5-5 depicts last 9 years maximum, minimum and average temperature of Karachi.

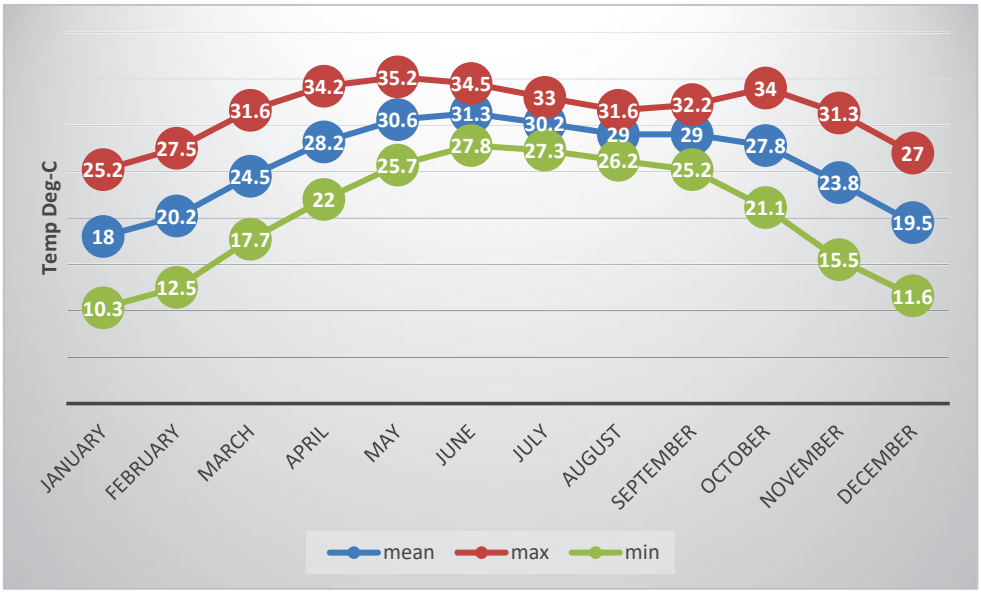


Figure 5-4: Monthly Averages for Mean, Maximum and Minimum Temperatures (Deg-C) at Karachi Airport

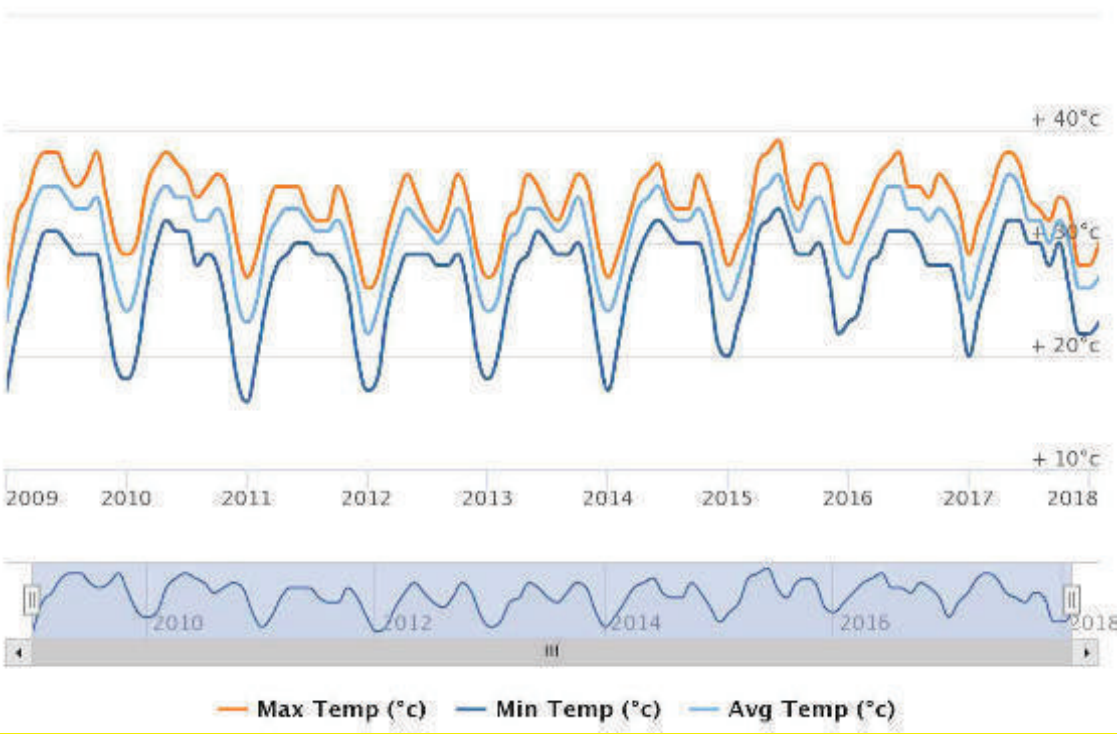


Figure 5-5: minimum, maximum and average temperature of Karachi (2009-2018)

Source: Pakistan Metrological Department

217. Despite arid conditions, humidity is relatively high throughout the year. The average annual relative humidity is 75.9% and average monthly relative humidity ranges from 60% in December to 85% in August (Table 5-1). Figure 5-6 depicts last 9 years average cloud and humidity of Karachi.

Table 5-1: Humidity and Dew Point Temperature for Karachi

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Aver
Relative Humidity (%)	61	70	77	79	83	83	83	85	84	79	67	60	75.9
Average Dew Point Temperature °C (°F)	12.2 (53.9)	15.4 (59.8)	20.2 (68.4)	23.2 (73.8)	26 (78.8)	27.5 (81.5)	26.6 (79.9)	25.7 (78.3)	25 (77.1)	23.5 (74.4)	18.6 (65.6)	13.4 (56.1)	21.5 (70.6)
Interpretation	Comfortable	Comfortable	Humid	Very humid	Severely high	Severely high	Severely high	Muggy	Muggy	Very humid	Humid	Comfortable	Very humid

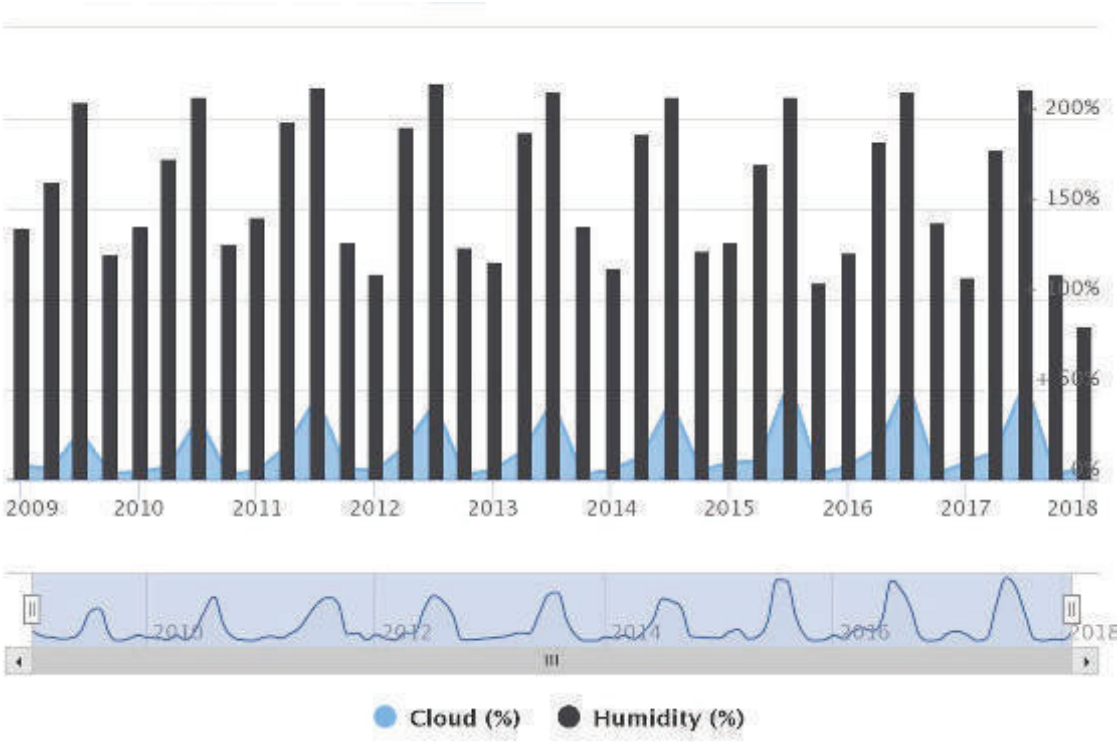


Figure 5-6 Average cloud and Humidity of Karachi (2009-2018)

Source: Pakistan Metrological Department

218. Karachi weather is considered pleasant and is famous for its breeze from the sea. The wind speed has highest velocities during the summer months, when the direction is south-west to west. Last nine years Maximum and average wind speeds are given in Figure 5-7 and the Onshore winds from the Arabian Sea contribute to humid conditions, with winds from the west-southwest and southwest 57 % of the time and are depicted in the wind rose in Figure 5-8.

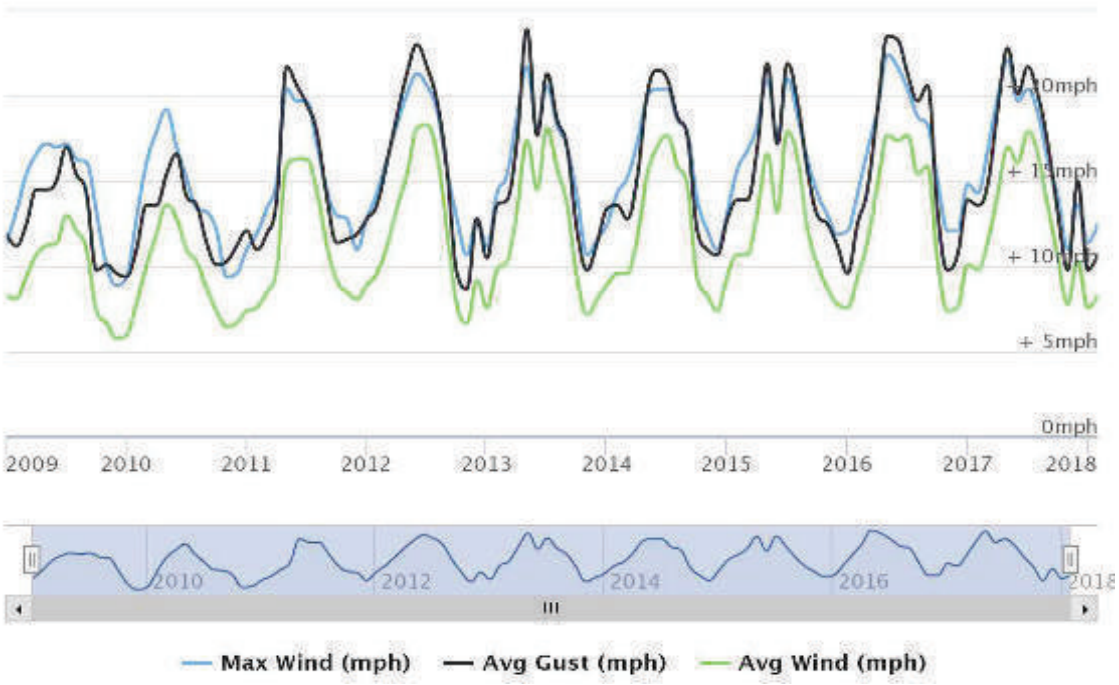


Figure 5-7: maximum and average wind speed of Karachi (2009-2018)

Source: Pakistan Metrological Department

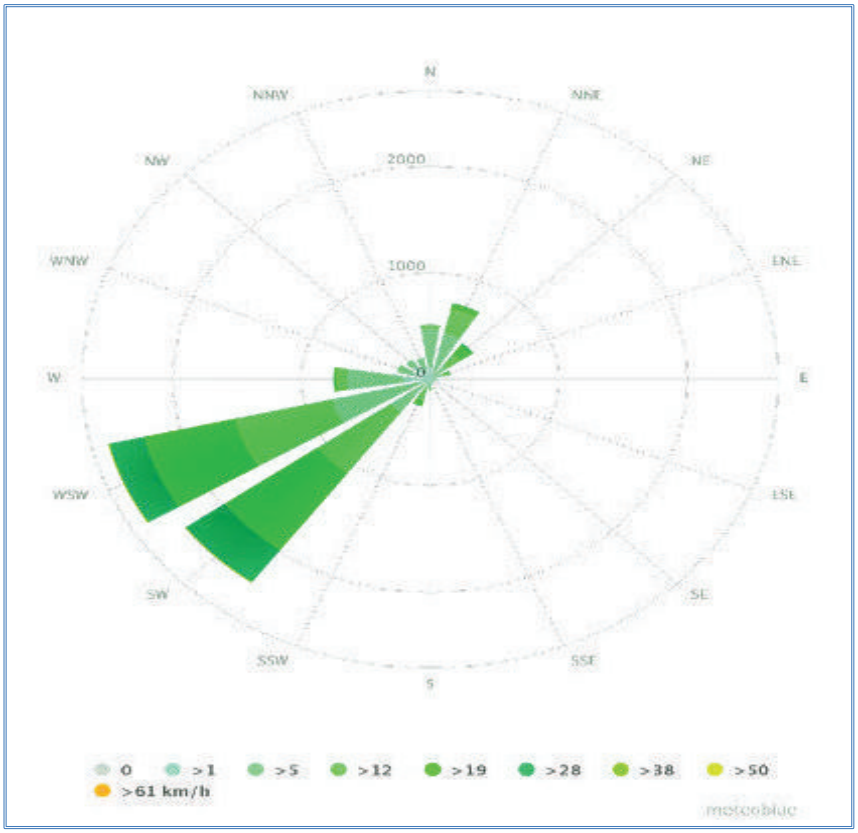


Figure 5-8: Annual Wind Rose for Karachi

Air Quality

219. The main sources of air pollution in Karachi include motor vehicles, uncontrolled waste burning, and industry, including metal working shops, chemical and engineering works, an oil refinery, railroad yards, jute and textile factories, printing and publishing plants, and food processing plants. Re-suspended dust, and small scale unlicensed businesses using 'dirty fuels' for manufacturing and production purposes are also contributors.

220. Air pollutant emissions are directly related to fuel consumption. Pakistan's consumption of petroleum products is growing at 6 per cent annually, of which one-half is consumed by the transport sector. The high content of sulphur in diesel (0.5-1 %) and furnace oil (1-3.5 %) is a major contributor to air pollution. Energy from waste fuels such as waste paper, wood and textile waste contribute a disproportionate load. Industrial emissions are further compounded by the widespread use of small diesel generators in commercial and residential areas in response to the poor reliability of electricity supplies. (Hashmi, et.al 2005)

221. Air pollution from vehicles is severe, with high concentrations gaseous emissions, and fine particulate that cause respiratory problems for an exposed population. The number of diesel trucks and buses has increased. A major share of the emission load from motor vehicles can be attributed to low quality diesel fuel and oil burning two-stroke engines.

222. To offset this trend, Karachi has witnessed an increase in vehicles fueled by compressed natural gas (CNG) in recent years and many formerly diesel fueled vehicles have been converted to run on CNG. However, there has been a greater increase in traffic overall and Karachi has a preponderance of old buses that run on diesel fuel and produce high emissions. Buses and trucks cause significant air pollution and since the main sources of pollutants are traffic, and traffic has increased on the Red Line corridor, it is assumed that air quality has deteriorated as a result.

223. The main air pollutants in Karachi City are nitrogen oxides (NOX) sulphur dioxide (SO2) particulate matter (PM10, PM with diameter of 10 microns or smaller and PM2.5, i.e. PM 2.5 microns or smaller) and carbon monoxide (CO). Motor vehicles are the major source of PM pollution. Most of the PM pollution (>80%) comes from diesel-run vehicles. Sindh Environmental Quality Standards (SEQS) for these parameters in addition to lead (Pb) and ozone (O3) are set by the Government and have been promulgated at provincial level by the Government of Sindh as well as standards for vehicle emissions in line with Euro II. Finally, the Government has promulgated tailpipe emissions standards. All these standards are discussed in Sec. **6.4.1**.

224. Karachi's air quality generally is considered poor, however due to its sea breeze some of the pollution gets blown away. The information from methodologically constrained studies show mixed results as follows:

- A 1990 survey (Ghauri et.al. 1994) monitored CO at 9-10 ppm along the busy urban streets; maximum NO2 concentrations were 0.3-0.5 ppm during the daytime; with an ozone maximum around noon of 40 ppb and 50 ppb, below WHO's interim quality guideline.
- A 2005 study by Hashmi et.al. that shows hourly readings over 24 hours for O3, SO2, CO and NO2 measured at five locations in Karachi. O3 concentrations were well within the WHO guideline of 100 µg/m3 8-hr average; NO2 and SO2 also were well within the WHO guideline of 200 µg/m3 (1-hr average) and 20 µg/m3 (24-hr), respectively.

- The Feasibility Study and Development of a Transport Control Plan of Karachi Metropolis (May 2007) presented data for these parameters of air quality for three locations on M A Jinnah Road between Numaish and Tower. At that time all five parameters (NOx, SO2, PM10, PM2.5 and CO) were found to exceed the SEQS.
- Finally, another report (Kalwar 2014) quotes the World Bank's data with the following maximum values: PM2.5 201 µ/m3; SO2 173 µ/m3; NO2 122 µ/m3; O3 86 µ/m3; CO 2 mg/m3. For reference, WHO's interim target for PM2.5 is 35 µ/m3, whereas its guideline is 10 µ/m3. WHO guideline for O3: 100 µg/m3 8-hour mean. Both NO2 and SO2 are within WHO's guideline for short term average concentration. (200 and 400 µ/m3 respectively). Data by this same author show excessive levels of PM at major intersections, including some along the Red Line, as well as SO2, NOX, O3 and CO, all exceeding WHO limits, based on data taken by SUPARCO in 2004.

225. In summary data indicate Karachi's frequent bouts with poor air quality, but with some respite, and without consistent monitoring that might give a clear picture of the situation. Meteorology, e.g. freshening winds from the southwest from across the Arabian Sea, may have a large part to play in whether levels exceed recommended guidelines (either WHO or the Sindh ambient guidelines) on any specific day.

226. Air quality data taken during the preparation of the EIA at four locations along the alignment and two depot sites are shown in Figure 5-9 and the air quality data in Table 5-2. The four locations along the alignment were selected because they are representative of typical conditions: Tank Chowrangi in a relatively undeveloped and sparsely populated area, where residential neighborhoods are separated from the main roadway, which has only limited access; Karachi University in an extensible area of University Rd. set back from the roadway and not heavily developed, yet on a path to growth; Ashfaq Hospital a 'sensitive receptor' in a somewhat densely traveled and populous section; and Tayyab Mosque within the most heavily traveled section adjacent to People's Secretariat Chowrangi and the Mausoleum. Given that only a limited number of air quality samples were to be taken and analyzed, these locations seemed most representative of the overall alignment, and of greatest use in the analysis. Gaseous parameters are 24-hour averages compiled from hourly readings taken by SUPARCO using its mobile monitoring van. Particulates and lead are measured based on a high-volume sample taken over a 24-hr period. All values are within the relevant SEQS limits, though particulate parameters are high throughout.

Table 5-2: Ambient Air Quality along Alignment measured on 23-26 Jan 2018 (µg/m^3)

	NO	NO_2	NO_x	CO	SO_2	O_3	$PM_{2.5}$	PM_{10}	SPM	Lead
Tank Chowrangi	6	20	26	1.8	15	14	57	114	361	0.19
Karachi University	27	51	78	2.7	18	22	57	133	391	0.21
Ashfaq Mem. Hosp.	25	42	67	3.3	25	21	65	126	410	0.25
Tayyab Mosque	28	46	74	2.8	30	23	49	128	390	0.28
Gulistan-Depot	7	20	27	1.5	24	13	39	109	254	0.18
Malir Depot	14	38	52	3.0	36	24	62	141	368	0.33
Related SEQS	40	80	--	5	120	130	75	150	500	1.5
Related WHO guide line		200				100	25	50		

227. SEPA has started monitoring ambient air quality as of January 2018 from their Head Quarters located in the Industrial area of Korangi. All criteria pollutants are within SEQs limits except particulate matter as shown in Table 5-3

Table 5-3: Ambient Air Quality monitoring results at SEPA headquarter

Parameters	SEQS	31-Jan	06-Feb	12-Feb	20-Feb	6-Mar	12-Mar	19-Ma	27-Mar	13-Apr	19-Apr	25-Apr	2-May	10-May
NO	40	14.73	12.72	13.26	13.93	7.23	19.55	19.42	19.55	19.02	18.75	19.55	19.02	19.69
NO_2	80	51.75	52.98	50.11	48.46	33.68	52.16	45.59	51.96	46.2	48.46	53.8	52.57	50.11
SO2	120	38.86	119.71	46.57	37.14	26.29	64.29	54.86	71.14	61.71	68.86	63.11	71.14	72.86
CO	5	2.48	1.4	0.49	0.58	0.78	0.58	0.45	0.3	0.5	0.75	0.78	0.61	0.44
O3	130	16.07	20.57	7.71	70.29	8.14	5.12	11.79	16.5	8.57	7.07	12.86	8.36	5.36
PM2.5	75	-	-	-	84	89	81	48	88	91	81	83	94	64
PM10	150	245	264	98	-	-	-	-	-	-	-	-	-	-

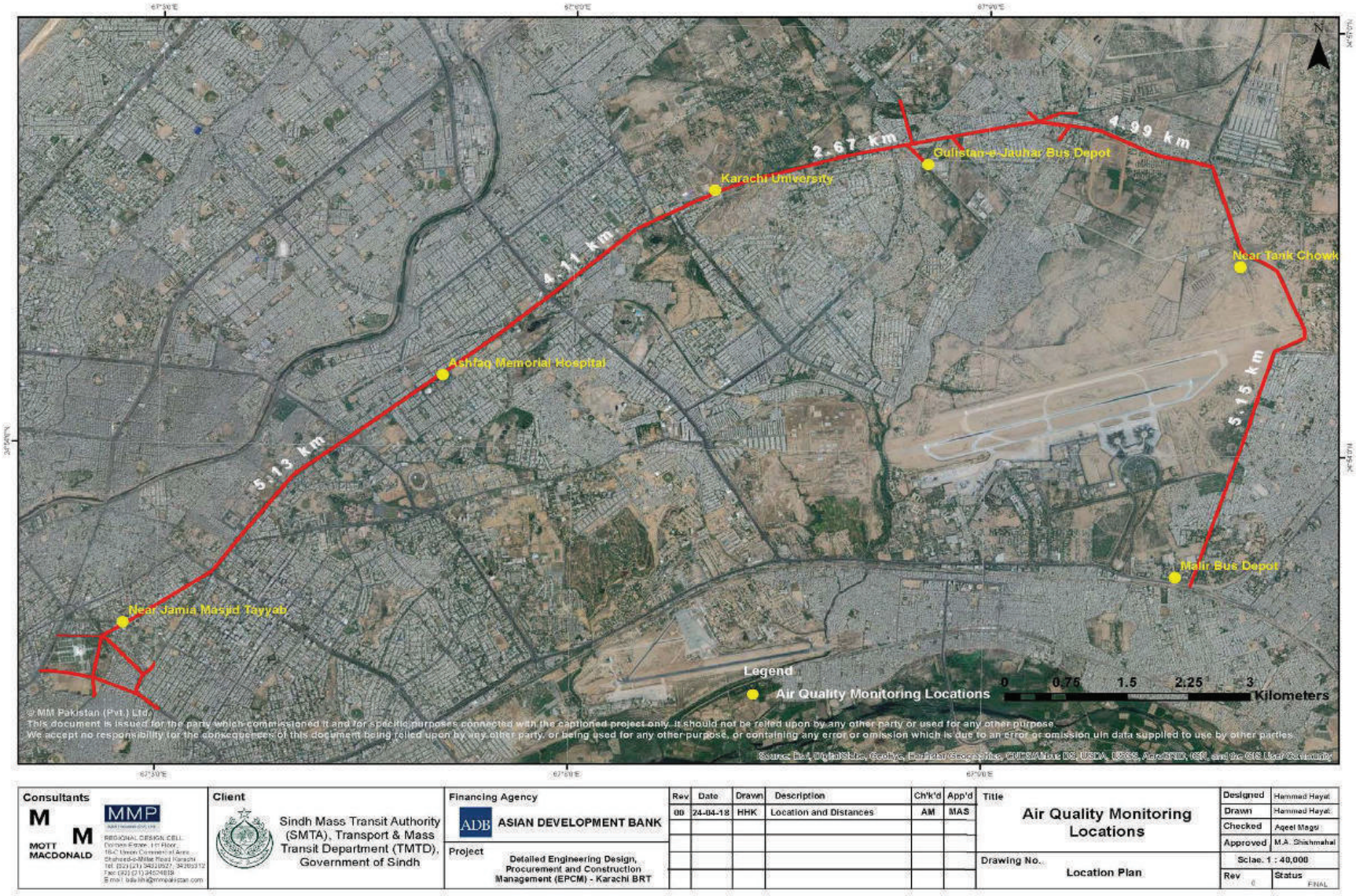


Figure 5-9: Ambient Air Quality with sampling interventions

Noise

228. Traffic is a major contributor of noise pollution in all the big cities of the World. Karachi is noted for its high level of noise from improperly maintained vehicles, weak and ineffective noise pollution regulations and lack of enforcement.

229. Noise levels recorded along the proposed alignment during project preparation in 2015 are shown in Table 5-4. One-hour Leq values ranged from 74 – 81 dBA, which exceed the standards set by the Ministry of Environment shown in Table 5-5. It is against a backdrop of high street-level noise that impact from the KBRT needs to be evaluated.

230. Results of noise monitoring during preparation of the EIA are shown in Table 5-6. These data are the maximum, median and minimum one-hour Leq values recorded over a 24-hour period at the locations. Figure 5-10 shows the 24-hour data, indicating that while overall values are not excessive, there is very little fall-off during the nighttime hours in noise levels at these locations. The difference in the average of daytime (7 AM to 7 PM) and nighttime values across four locations is less than 7 dB (70 vs 63 dBA).

231. Noise readings taken at additional 19 sites along the alignment, providing the necessary data for constructing an impact scenario related to noise described in Sec. **6.5**.

Table 5-4: Noise Levels along Alignment recorded during the PPTA (2015)

Area/Junction	Original Chainage	Leq-hr (dBA)	Leq-10 (dBA)	Lmax (dBA)
University Road				
Safoora Chowk	0+200	78.3	82.1	89.6
Proposed Depot	DEPOT	56.4	58.3	66.8
University Gate	3+900	74.2	76.3	82.7
Federal Urdu Sci. College	7+750	78.6	80.6	89.9
New MA Jinnah Road				
Jail Chowrangi	12+460	75.0	77.8	90.9
Shahrah E Qaideen	SEQ 1+500	74.7	76.5	82.5
Mazar.e.Quaid Gate	14+000	73.5	75.8	79.9
MA Jinnah Road				
Fdepot Lines	16+380	80.6	81.9	97.3
Kaldiqu Dina Hall	18+900	76.8	79.2	84.9
Mereweather Tower	22+500	76	76.5	93.6
Shahrah E Liaquat				
Shahrah E Liaquat	02+250	78.5	81.7	92.8

Table 5-5: Sindh Environmental Quality Standards for Noise

S. No.	Category of Area/ Zone	Effective from 1 July 2010** Limit in dBA (Leq)***		Effective from 1 July 2012 Limit in dBA (Leq)***	
		Day	Night	Day	Night
1.	Residential area	65	50	55	45
2.	Commercial area	70	60	65	55
3.	Industrial area	80	75	75	65
4.	Silence Zone	55	45	50	45

Reproduced from SRO 1062(1)/2010

** Note these regulations were made effective for the State of Sindh on 1 January 2015 (Notification No. EPA/TECH/739/2014)

*** This is assumed to be a one hr Leq.

Table 5-6: Noise Levels recorded on 23-26 Jan 2018 (Leq-1 hr)

	Tank Chowrangi	Karachi University	Ashfaq Hospital	Tayyab Masjid	Gulistan Depot	Malir Depot
Maximum	78.4	72.8	80.6	79.5	64	66
Median	64.1	66.3	68.9	68.35	59	60
Minimum	52.4	52.4	56.2	54.2	44	52

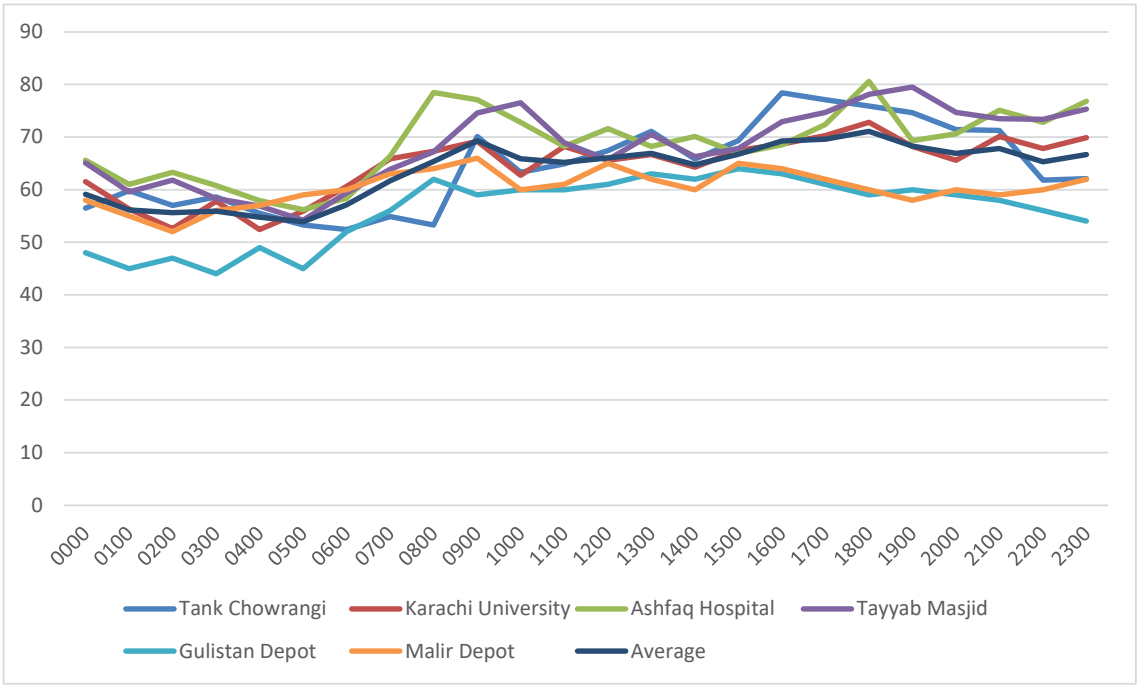


Figure 5-10: Hourly Trend in Noise Levels recorded on 23-26 Jan 2018

Climate Change and Effects

232. Climate change acting hand-in-hand with urban dislocation and growth promises to exert a significant negative impact on Karachi's urban infrastructure systems and services, its built environment and ecosystem services, and therefore on its urban population and economy. As one of the region's coastal mega cities, which includes Manila, Bangkok, Jakarta, Mumbai and Shanghai, Karachi will face increased flooding and damage from unpredictable weather patterns along with other forms of extreme event including drought with attendant risks on water supply, heat waves with attendant effect on fuel consumption and water use, sea level rise that impacts mangrove and other ecosystems, flood water removal, and complicity with tropical cyclones. (Anwar 2012)

233. Another prominent study (Hasan et.al. 2017) maintains that Karachi, being a city of migrants located in the midst of an alien and unwelcoming province, suffers from a disconnect of governance that bodes ill for dealing with the effects of climate change:

> *"Of the estimated 3.35 million 'illegal' immigrants in Pakistan, 75 per cent (or 2.5 million) are settled in more than 100 migrant-concentrated residential areas in Karachi. Living conditions in these settlements are mostly cramped, and services such as clean drinking water, sanitation and solid waste disposal are hard to come by. Research from the region suggests that processes and structures of unplanned rapid urbanisation, environmental change and social exclusion reinforce urban vulnerability for migrants." (p. 6)*

234. The report concludes with recommendations to enhance capacity and political support for institutional reforms, reconstitute the low-cost housing market and support private and public-sector cooperation in health and housing provision, as means for reducing vulnerabilities among the katchi abadi population.

Figure 5-11: Katchi Settlements Flooded and Dry

5.1.2 Geology, Soils and Groundwater

235. The physical features of Karachi and the hinterland in southern Sindh includes plains, hills, rivers, valleys and coasts. The City covers an area of approximately 3,530 km2, comprised largely of flat or rolling plains, with hills on the west and north demarcating the limits of urban expansion.

236. Arabian Sea beaches line the southern coastline of Karachi. Dense mangroves and creeks of the Indus Delta can be found toward the southeast along the coast. Cape Monze, an area marked with projecting sea cliffs and rocky sandstone promontories is located toward the North West. Beaches can also be found in this area including nesting locations for the green turtle, like Hawkes Bay.

237. Rocks ranging in age from Eocene to recent, deposited under shallow marine deltaic conditions are exposed. Karachi is a part of major synclinorium stretching from Ranpathani River in the east to Cape Monze in the west. (Hamid et.al. 2013) Mehar and Mol mountains lie in the north. Within the synclinorium a number of formations are exposed. The Geotechnical report prepared for this project (MML 2018) identifies these as:

- Kirthar Formation (Eocene)
- Gaj Formation (Miocene)
- Dada Formation (Pleistocene)
- Piedmont and Sub-piedmont Deposits
- Nari Formation (Oligocene)
- Mancher Formation (Pliocene)
- Terrace Deposits

238. The geological map of Karachi and surrounding areas is attached as Figure 5-12. Various rock formations have been folded to form anticlinal hills and synclinal valleys, with moderate to gentle dips. The fold axes run approximately north east to south west and there are two main zones. The first zone is to the east and northeast and is characterized by relatively more intense folding and faulting. Rocks ranging in age from Palaeocene to Oligocene are also exposed in this zone. The second zone is located in the center and to the west and southwest and comprises a large area that opens towards the south and consists of horizontal or near horizontal strata that form gentle undulations in the form of synclines and anticlines with low dips of 2 to 6 degrees (rarely up to 10 degrees). These folds have a general southward plunging direction.

239. According to the geological map, most of the project lies in the TMG designation, comprised of shales and limestones of the Gaj formation in the Kirthar Range. Some of the project area is located within floodplain deposits (Qfx). The Gaj Formation is divided into Lower (Mol) and Upper (Sharji) members. The lower member (Mol) is comprised of clay in the lower part and limestone in the upper part. The limestone unit is very hard, thinly-bedded, light brown to cream colored, massive and nodular. It is siliceous in some parts and may be fossiliferous, coralline and chalky where found exposed in a weathered escarpment. It is generally about 68 m thick and decreases in thickness toward the east. The Gaj formation, whether exposed or underground, encompasses most of Karachi and in particular around the project area.

240. Under the MML/MMP engineering design program, a series of test pits and boreholes were installed along the alignment for soil sampling and testing using a set of analyses for determining the engineering properties of the soils and underlying rock:

- Grain Size Analysis
- Natural Moisture Content
- Triaxial Test
- Modified Proctor Compaction Test
- Direct Shear Test
- Chemical Tests
- Atterberg Limits
- Specific Gravity
- Unconsolidated Undrained Test (UU)
- California Bearing Ratio Test (CBR)
- Unconfined Compressive Strength

241. While the data are extensive from these tests, the general condition is that road aggregate material to a depth of 1.5 m is found to overlie compacted silty clay, generally extending an additional depth of 3 m (ranging from 1.5 to 4.8 m), which in turn overlays interbedded sandstone and shale (the previously described Gaj formation). Limestone and mudstones may be present at specific locations, as well as sand and sandy-gravels in the upper layer. Some deeply bedded sands are found at some locations. The results of standard penetration tests place cohesive soils that were encountered in the range of very stiff soils, (SPT>17) and non-

cohesive soils – the majority of soils present -- in the range of dense to very dense (SPT > 30). As per the geotechnical survey report (MML 2018), the soil profile in the project area is generally SC (sandy clay) having SPT values greater than 50 (very dense soil or soft rock) or SD at shallow depth (silty clay with traces of sand) with SPT values of 15-50 (stiff soils).

Seismic activity

242. Karachi is located in a moderate earthquake zone. Pakistan falls into three seismic zones. Zone-III is the most severe and Zone-I the least. The Karachi Building Control Authority has placed Karachi in Zone-II. Based on the actual events, past observations of fault movement and other geological activities, Karachi is situated in a region where moderate earthquakes may occur of magnitude 5.0 to 6.0 equivalent to intensity between VII and VIII on Modified Mercallis Scale (M).

243. On the basis of earthquakes experienced from 1970 to 2005 (see Figure 5-13), four seismically active zones have been identified in and around Karachi. One seismic zone lies to the west of Karachi, shown as the Ornach Nal Fault merging into the regional Chaman Fault. The zone extends southwest into the Arabian Sea and is aligned with the submarine Murray Ridge; to the north it extends towards Uthal-Bela areas. No large earthquake is known historically on the Ornach Nal system.

244. The second seismic zone follows the south-eastern margin of Kirthar Range from the north to the south, swinging ultimately towards the southwest. This zone includes Thano Bula Khan, Lakhra, Jhimpir, Jungshahi, Thatta and areas further south. The third zone passes across the eastern vicinity of Badin in the northeast-southwest direction along the eastern margin of the Indus Delta. The fourth seismic zone straddles the Pakistan-India border. Earthquakes of low to moderate magnitudes — 3.1M to 4.0M and 4.1M to 5.0M — dominate in these zones. (Sarwar and Alizai 2013) Quakes of higher magnitudes (above 5.0M) take place to the southeast in the Rann of Kutch, which is a known high-risk area. Records show that earthquakes of low to moderate magnitudes have occurred in the following zones – Murray Ridge-Sonmiani-Uthal, south-eastern Kirthar, and NESW Badin. Moderate magnitude earthquakes in Jangshahi, Thatta, Jhimpir and Thano Bula Khan Area produce low to moderate intensity shocks in Karachi, as experienced in 1985.

245. The seismic zoning for Karachi was revised after the 2005 earthquake. Probabilistic Seismic Hazard Assessment (PSHA) carried out for revision of seismic provisions of the Building Code of Pakistan shows that Karachi falls in Zone 2B. The Zone 2B has Peak Ground Acceleration (PGA) in the range of 0.16g to 0.24g for a return period of 475 years and is considered to be at 'Moderate' risk of a major earthquake event. It is recommended that project structures be designed for the requirements of Zone 2B. (MML 2018)

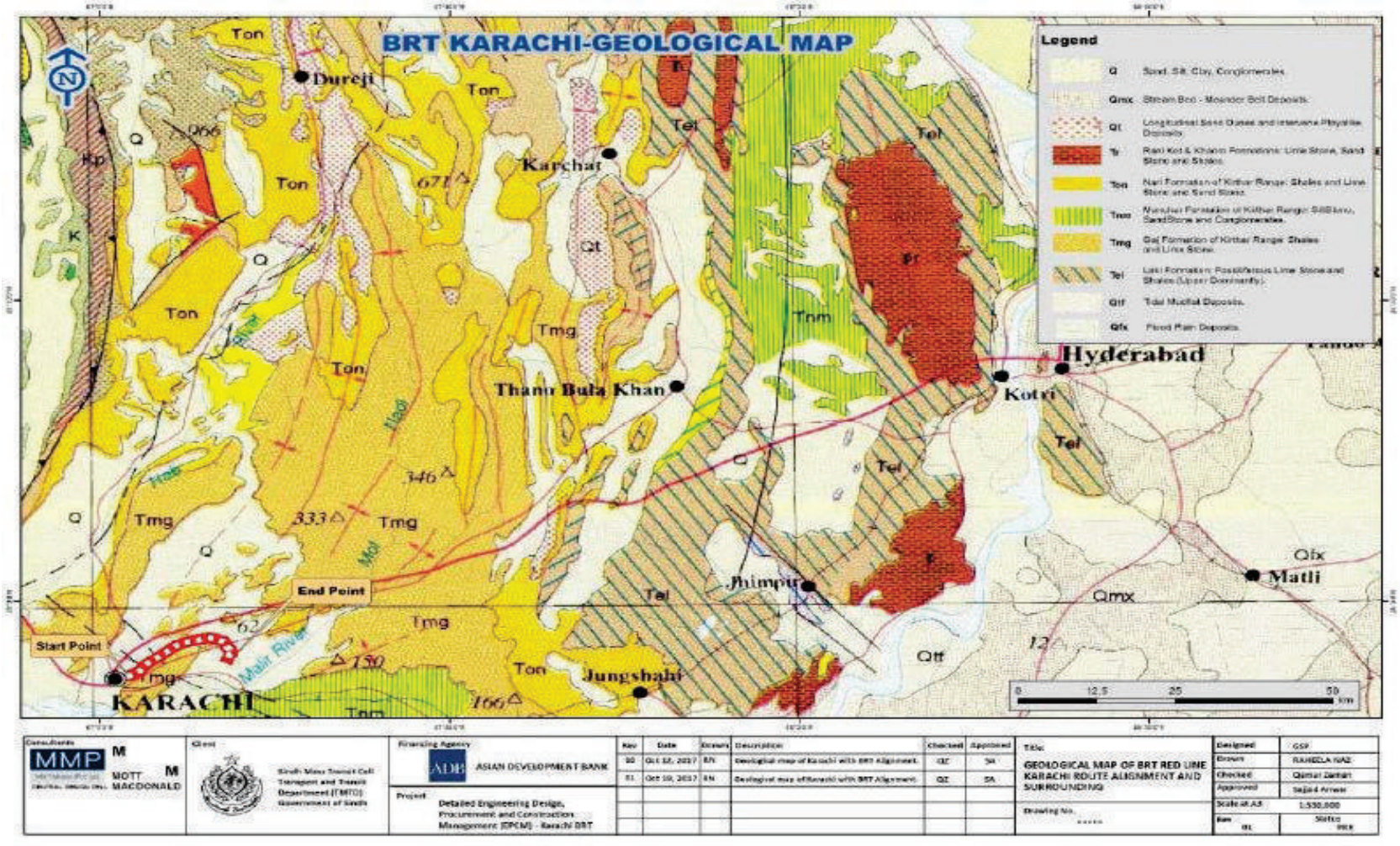


Figure 5-12: Geological Map of Karachi and Surrounding Area

246. Some earthquakes of more than 4M have taken place in the west of Karachi in the Arabian Sea but the earthquakes were not felt in Karachi. The great Bhuj earthquake of 2001, measured 8.0 on the Richter scale and caused enormous damage in Ahmedabad and its surrounding areas but did not cause much damage in Karachi or Hyderabad; even though these two Pakistani cities are situated not far away from the epicenter at Ahmedabad. (Bilham et.al. 2007)

247. Bilham et.al. (2007) traces the historical record with the destruction of the major population center of Bhaminabad around 980 A.D., and other major seismic events, to show the potential for a major earthquake in the Karachi area. Sarwar and Alizai (2013) support the hypothesis of increasing activity among faults and subduction zones near Karachi, and the potential for tsunamis to add to the earthquake threat.

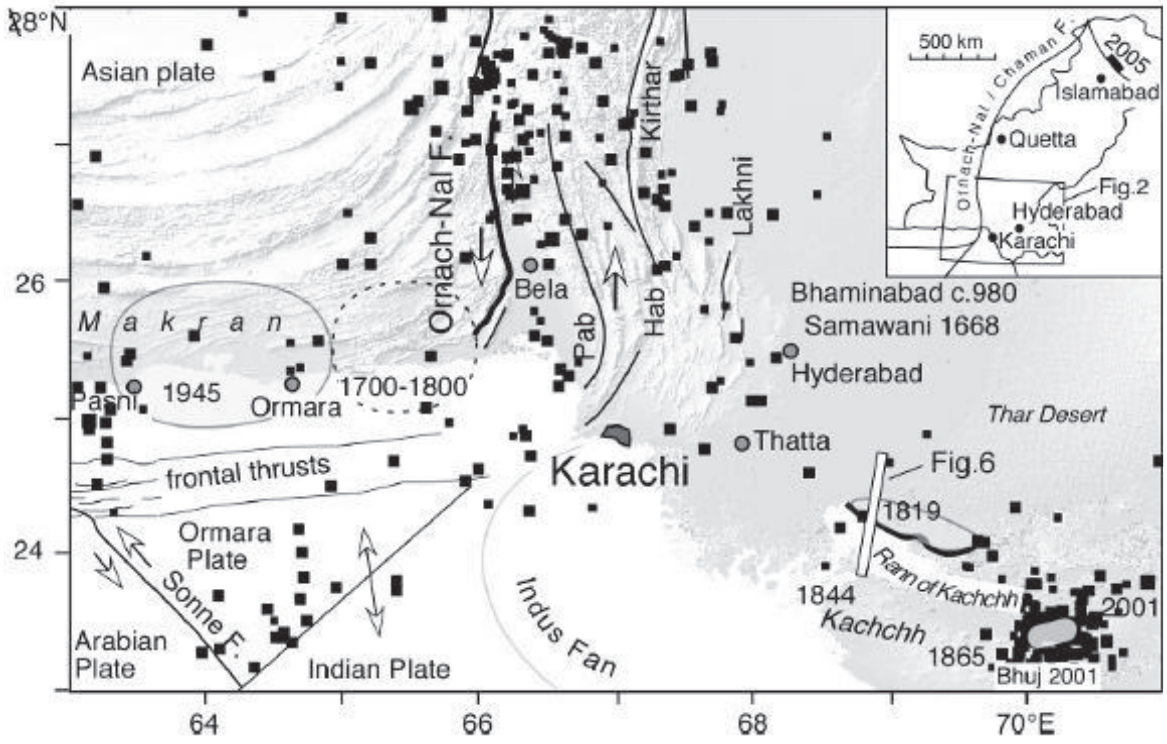


Figure 5-13: Historical Reconstruction of Earthquakes in the Vicinity of Karachi and Southern Pakistan

From Bilham et.al. 2007

248. Seismic risk is set out in the geotechnical report for the project as follows: (MML 2018) The alignment is located in a seismically active zone of moderate intensity (Zone 2) that corresponds to intensity VII of the Modified Mercator scale. "The Probabilistic Seismic Hazard Assessment (PSHA) carried out for revision of the seismic provisions of the Building Code of Pakistan (NESPAK 2007), shows that the site area (Karachi) falls in Zone 2B. The Zone 2B has Peak Ground Acceleration (PGA) in the range of 0.16g to 0.24g for a return period of 475 years and is considered to be at 'Moderate' risk of a major earthquake event. It is therefore recommended that the project structures should be designed to cater for the requirements of Zone 2B."

5.1.3 Hydrology, Water Quality and Sediment

249. Four drainage systems are said to encompass Karachi City, the Lyari, the Malir, the Budnai, and small streams referred to collectively as the coastal basin. These can be seen generally on the following map (Figure 5-14), with the alignment for the BRT Red Line shown in red as a road (second from bottom, center), a drainage divide, or crest along some of the alignment, and wholly within the Malir drainage along the northeastern section. The Malir River Basin and the Lyari River Basin contribute about 80% of the surface runoff from the City.

250. Thus, the natural drainage system of Karachi City includes mainly the tributaries of the Malir and Lyari Rivers, both of which share areas within the Project. While these are perennial streams, instream flow is intermittent, and fresh water inflow depends on rainfall and runoff; both rivers also intercept discharges from sewer lines and outfalls and carry sewage to the sea from all parts of the City. The Budnai Basin and the Coastal Basin are minor basins. The Malir River flows from the east towards the south and centre, and the Lyari River stretches from north of the City to the southwest ending in the Arabian Sea. Karachi Harbour is another hydrographic landmark, and is a sheltered bay to the southwest of the city, protected from storms by Sandspit Beach, Manora Island and Oyster Rocks.

251. Drainage channels collect surface runoff through hundreds of small/large side channels and lined nullahs (drains) that serve as important components of the drainage network. These are generally dry built channels and streambeds that flow into the main rivers described above. Whenever a heavy rain takes place, the huge amount of runoff that course through these channels may cause the rivers to overflow their banks and spread over adjacent floodplains. In any event, the drainage network of the city is severely stressed due to increased runoff from paved surfaces, and encroachment on drainage channels.

252. The Lyari River is an ephemeral stream having a substantial catchment area starting from as far back as the Badra range of hills, some 100 km north of the city. Its catchment covers an area of 700 km2, out of which approximately 150 km2 is in the metropolitan area.

253. The river is the main contributor to an estimated amount of 200 MGD of sewage that enters the Arabian Sea. A large number of industries including leather tanning units, pharmaceuticals, petrochemicals, refineries, chemical, textile, paper and pulp, engineering works and thermal power stations, located along the river, regularly discharge their untreated industrial waste, including the waste flows from the SITE industrial estate in Orangi that flows via the Orangi Nala to the Lyari and thence to the ocean. (Nergis et.al. 2013) A range of contaminants affect the marine ecology along the coastal shelf.

254. Malir River is shorter with a smaller drainage area. It is ephemeral and is constituted from two major tributaries, the Mol and Khadeji, as well as some minor tributaries. Khadeji is a perennial stream that originates at Khadeji falls and gains flow as it travels across the Malir Basin. The Malir and Khadeji River basins include dry hill torrents and flow depends upon precipitation during rains. Once the Malir enters urban space, it receives large amounts of industrial effluent from the Korangi industrial area, and discharges into the sea. Data by the World Bank (2006) report values of 650 and 1,250 mg-COD/L for the Lyari and Malir Rivers, respectively.

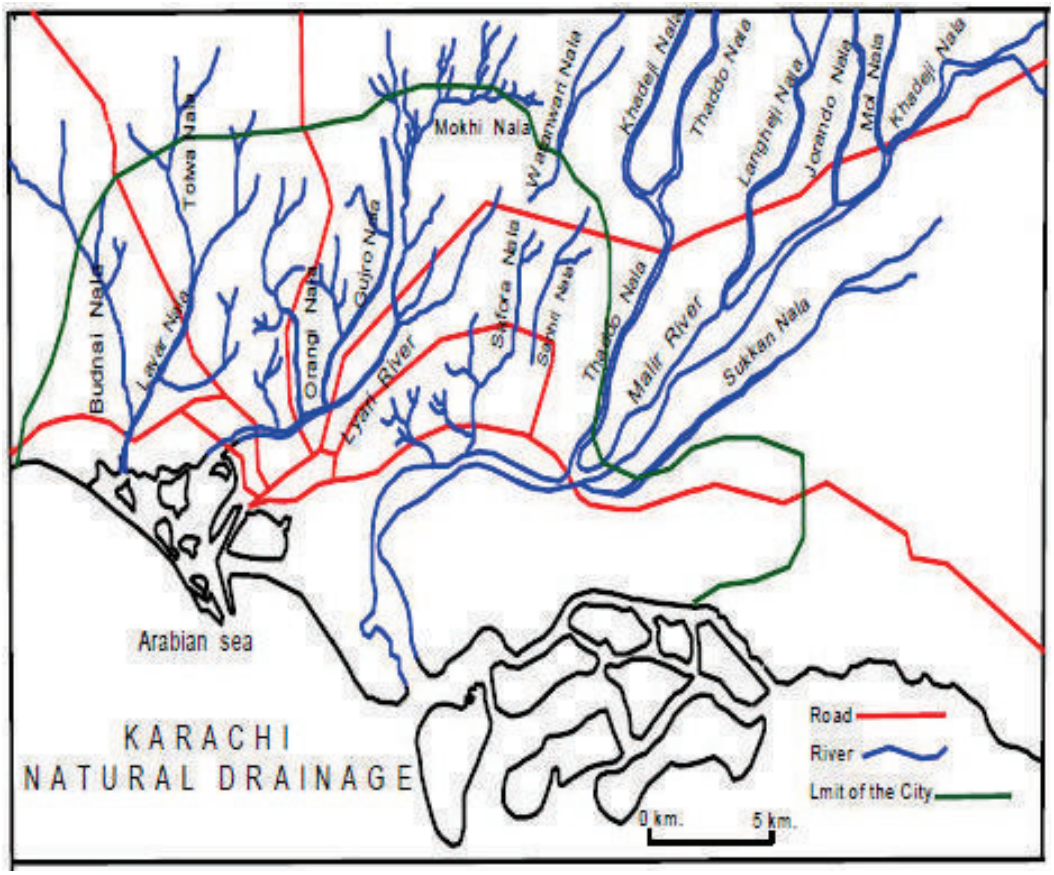


Figure 5-14: Generalized Schematic of Drainage Basins in Karachi Metropolitan Area

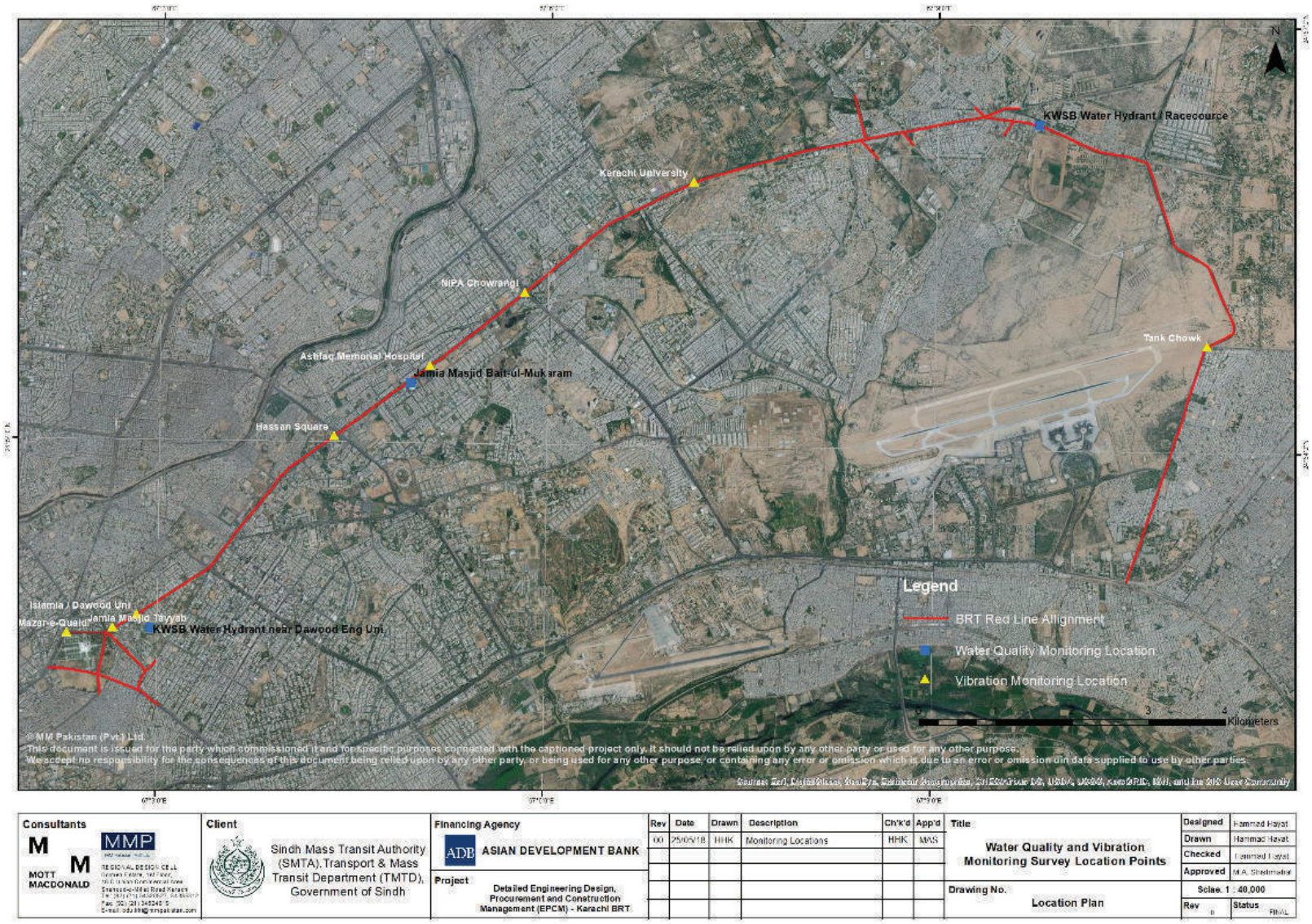
from Akhtar and Dhanani 2012.

Ground Water Quality

255. Karachi obtains its drinking water from the Indus River about 120km to the east and the Hub River in the west. Some limited groundwater is extracted for private use in the Karachi area, but groundwater resources in the Karachi area are limited. The aquifers close to the coastal belt are mostly saline and unusable for domestic purposes. Aquifers near the Hub River are well developed and serve as sources of water for agriculture and domestic use. The aquifers are estimated to lie at depths of 50-100 m.

Water Quality Monitoring

256. Samples were taken from two water taps on the Karachi Water and Sewerage Board supply network, one at the KWSB water hydrant in front of the Racecourse and the other at the KWSB water Hydrant near Dawood Engineering University. In addition, a sample was taken from a deepwell located at the Jamia Masjid Bait-ul-Mukaram (Jamia Mosque). All samples were analyzed for the set of drinking water quality parameters specified in the SEQS (2014). The analytical results are shown in Table 5-7 and their locations are shown in Figure 5-15 theses are indicative of drinking water suitability of water supplied through pipeline and from deep wells in use in the area. Coliform is present in most samples, indicating inadequate chlorination or perhaps cross-contamination. All other parameters are within the range specified by the SEQS.



Consultants: MOTT MACDONALD / MMP	Client: Sindh Mass Transit Authority (SMTA), Transport & Mass Transit Department (TMTD), Government of Sindh	Financing Agency: ADB ASIAN DEVELOPMENT BANK	Rev	Date	Drawn	Description	Ch'k'd	App'd	Title: Water Quality and Vibration Monitoring Survey Location Points	Designed: Hammad Hayat
		Project: Detailed Engineering Design, Procurement and Construction Management (EPCM) - Karachi BRT	00	25/05/18	HHK	Monitoring Locations	HHK	MAS		Drawn: Hammad Hayat
										Checked: Hammad Hayat
										Approved: M.A. Shaikh
									Drawing No.: Location Plan	Scale: 1 : 40,000
										Rev: 0 Status: FINAL

Figure 5-15: Water Quality & Vibration Monitoring location points

Table 5-7: Drinking Water Suitability of Hydrants and a Well in the Project Vicinity

S. No.	Parameters	Unit	*SSDWQS	Tap Water #1	Tap Water #2	Deep well
1	E. Coliform	MPN	ND/100 ml	27	ND	32
2	Fecal Coliform	MPN	ND/100 ml	42	ND	56
3	Total Coliform	MPN	ND/100 ml	69	ND	88
4	pH	-	6.5 – 8.5	8.11	7.92	7.92
5	Color	TCU	≤ 15	2	2	2
6	Taste	-	Acceptable	Acceptable	Acceptable	Acceptable
7	Odor	-	Acceptable	Acceptable	Acceptable	Acceptable
8	Turbidity	NTU	< 5	0.93	1.18	1.08
9	Total Hardness	mg/l	< 500	270	279	713
10	TDS	mg/l	< 1000	423	431	1285
11	Aluminium	mg/l	≤ 0.2	0.041	0.05	0.16
12	Antimony	mg/l	≤ 0.005	ND	ND	ND
13	Arsenic	mg/l	≤ 0.05	ND	ND	0.014
14	Barium	mg/l	0.7	0.13	0.112	0.197
15	Boron	mg/l	0.3	0.098	0.073	0.128
16	Cadmium	mg/l	0.01	ND	ND	ND
17	Chloride	mg/l	< 250	79	81	179
18	Chromium	mg/l	≤ 0.05	0.007	0.006	0.019
19	Copper	mg/l	2	0.012	0.013	0.008
20	Cyanide	mg/l	≤ 0.05	ND	ND	ND
21	Fluoride	mg/l	≤ 1.5	0.11	0.14	0.23
22	Lead	mg/l	≤ 0.05	ND	ND	ND
23	Manganese	mg/l	≤ 0.5	ND	ND	ND
24	Mercury	mg/l	≤ 0.001	ND	ND	ND
25	Nickel	mg/l	≤ 0.02	ND	ND	ND
26	Nitrate	mg/l	≤ 50	2.8	3	8
27	Nitrite	mg/l	≤ 3	ND	ND	ND
28	Selenium	mg/l	0.01	ND	ND	ND
29	Res. Chlorine	mg/l	0.2 - 0.5	0.04	0.05	ND
30	Zinc	mg/l	5	0.064	0.049	0.141

Climate Vulnerability—Flooding

257. Despite dry conditions, flash flooding is common (see Figure 5-16). Pakistan's regional flooding in 2010 left one-fifth of the country's land area submerged. Flooding of Karachi on 1 Sept 2017 left 16 dead. These and other similar events seem not to be addressed in a statistical fashion in the literature, though causative factors are mentioned including blocking of drainage channels through land encroachment by both wealthy and poor inhabitants. Drainage is enough of a critical factor to be overly compensated for in the design of streets for the more affluent parts of the City.

Figure 5-16: Images of Flooding in Karachi

258. Although the climate of Karachi is arid and rainfall is low and highly variable, whenever torrential rain comes and heavy rainfall occurs within a short duration surface runoff intensifies. This is because the rate of water percolation into soil is lower than the amount of rain water falling on the surface. Heavy showers take place in the city either due to the effects of tropical storms usually in June, which rarely affect coastal areas but bring heavy showers for short periods and cause flooding. As the result of a tropical storm (6 June 2010) Karachi received 130 mm rain within a day which caused huge surface runoff. The heavy monsoon rain mostly occurs in July and August and is the main cause of flooding in the city. However, its reoccurrence is estimated to occur at between about 3 to 5-year intervals. Flood affected areas of the city and areas susceptible to flooding include the old city areas such as Kharadar, Mithadar, Bunder Road, Ram-swami and Arambagh.

5.2 Biological Resources

5.2.1 Flora

259. The definitive source of information on Karachi's flora is Jafri (1966). In his taxonomy, he included 72 families, 249 genera and 403 species, excluding some of the commonly cultivated and almost naturalized taxa. Work by Hussain et. al. (2010) and others have documented species loss. Their assessment is that, for more than 35 % of the species mentioned in Jafri's Flora of Karachi can now be included in the Red Data book for threatened species, and categorized as extinct, endangered, vulnerable, rare, indeterminate, or threatened. (Hussain et.al. 2010)

260. Hussain et.al. (2010) lists 16 native tree species that are threatened, 11 threatened species of shrub, and 29 species of understory shrub species, also considered threatened. Threatened woody climber species number 11, and herbaceous climbers that are threatened number seven (7); while herbaceous plants (herbs) considered threatened number 59. The authors state that

among trees Tecomella undulata has become locally extinct, along with three other tree species that are endangered, and one (1) in the rare category (Mimosa hamata).

261. Some time back, Karachi University campus provided the best representation of the flora of Karachi. As of 2010, many have been eradicated, so that the main repositories remaining of Karachi's native and indigenous plants are in the protected and enclosed areas of Malir cantonment, Shah Faisal cantonment, Masroor Airport area and Korangi, and PAF base area. (Hussain et.al. 2010)

262. The principal habitats are arid hills and low lying sandy areas found in and between the courses of the Lyari and Malir rivers that run through Karachi City. Hillside vegetation comprises mainly camelthorn (Prosopis spicigera), wild caper (Capparis decidua) and large succulents such as Euphorbia caudicifolia. Sandy areas are typically vegetated with a sparse cover of small trees such as Acacia senegal, Zizyphus nummularia and Prosopis cineraria (mesquite), and shrubs such as Leptadenia pyrotechnica, Colotropis procera, Rhazya stricta, Inula grantioides, Zygophyllum, simplex and Sueda fruticosa. Species on calcareous hills include Vernonia cinerascens, Commiphora wightii, Grewia tenax and Euphorbia caducifolia. Shallow slopes with varied soils at low altitudes are populated by (trees) Zizyphus nummularia, Salvadora oleoides, and Capparis deciduas. Shrubs such as Grewia tenax, Seddera latifolia, and Rhazya stricta are the most commonly found species, together with the grasses Ochthochloa compressa, Cymbopogon jawarancuss and Aristida funiculata.

263. Prosopis cineraria (mesquite), Indigofera oblongifolia, a perennial shrub found in a range of habitats including grassland, bushland and sandy soils, and Euphorbia caducifolia, a succulent that grows profusely on sandy soils, form the most common combination of native vegetation of Karachi City.

264. However, a wide variety of trees has been introduced over the years and the Karachi University Botanical Garden, opened to the public in 2008, exemplifies many of these species, with over 2,000 exotic and indigenous plant species represented. While the Garden is located on 80 ha of land at the campus near the alignment, KUBG is set back sufficiently far so as not to be affected by the project.

265. Destruction of native plants occurs through clearing of brush and 'cleanliness drives', where those instigating these moves are unaware of the plants being eradicated. Habitats have shrunk and species numbers been reduced placing many on the threatened species list. Work undertaken by the Red Line should take care not to further reduce habitats for native tree species.

266. EMC (2015) lists some nine types of tree, 10 shrubs, and two grasses as likely to be present in the area of the Green Line alignment. The tree count conducted for the Green Line identified some 72 tree types. Vegetation of the hill slopes and hillsides comprise mainly camel thorn (Prosopis spicigera), wild caper (Capparis decidua) and large succulents such as Euphorbia caudicifolia." A similar ecological setting is present in undeveloped open space along the Red Line alignment. It is difficult for animals and plants to survive the natural environment around Karachi due to severe arid conditions, land clearance activities and other impacts of urbanization. Natural areas of vegetation are restricted in the urban area to depressions and low-lying areas where moisture can gravitate, condense and be available for part of the year.

267. The vegetation (tree count) survey conducted for the Red Line identified Table 5-8. Description of means for tracking trees removed during construction, and replanting trees, is described in Section **6.12**.

Table 5-8: BRT Red Line, Tree Count Survey: Summary of Distribution of Enumerated Trees among the Median, Right Side and Left Side of the Transport Corridor

Strip	S-1	S-2	S-2 (A-D)	S-3	S-4	S-5	S-6	S-7	S-7 (A-D)	S-8	S-9	S-9 (A-C)	S-10	S-10 (A-B)	Total
Median	541	431	203	1,538	435	868	467	259	255	303	950	630	1,566	**589**	**9,035**
Right Side	302	70	298	42	168	1,263	2,085	-	687	-	254	441	948	**1152**	**7,110**
Left Side	24	9	554	33	309	568	1,402	-	56	-	476	283	1,167	**540**	**5,421**
Total	**867**	**510**	**1055**	**1,613**	**912**	**2,699**	**3,954**	**259**	**398**	**303**	**1,680**	**1354**	**3,681**	**2281**	**21,566**

268. **Explanatory Note**: In addition, **812** and **1,224** trees have been enumerated in Bus Depot-1(Johar) and Bus Depot-2 (Malir Halt) respectively. When these are added to the trees enumerated along the proposed BRT Red Line road route (**21,566**), the total of enumerated tress comes to **23,693**.

5.2.2 Fauna

Avian Fauna

269. Shaukat and Raza (2016) conducted long term observations of avian species at Karachi University and Dow University campuses (1996-2015, K.U. and 2008-2015 D.U.H.S.) Bird species identified over the period are listed in Table 5-9. These locations are close by the Red Line alignment, and so can be said to share ecological space with the alignment. However, since the Red Line will be built in the median of what is a 50 m wide roadway right-of-way, these ecologies share little similarity, and few if any of these species would remain present for long in the space where the BRT is to be constructed. Where campuses have preserved an ecological setting with both native and planted trees and foliage that allow bird life to flourish, such is not the case along the median of the roadway; trees planted in this setting function to buffer the air and noise pollution load from vehicles. Few birds are expected to be found roosting in trees along the roadway median.

Table 5-9: Birds of Karachi and Dow University Campuses (1996—2015)

Scientific Name	Common Name
Streptopelia tranquebarica	Little Brown Dove
Streptopelia senegalensis	Laughing Dove
Columba livia	Blue Rock Pigeon

Scientific Name	Common Name
Corvus splendens	Sindh House Crow
Dendrocitta vagabunda	Rufous Treepie
Passer domesticus	House Sparrow
Passer pyrrhonotus	Sind Sparrow
Alauda arvensis	Eurasian Skylark
Hirundo rustica	Barn Swallow
Motacilla alba	White Wagtail
Motacilla flava	Western Yellow Wagtail
Lanius vittatus	Bay-Backed Shrike
Lanius meridionalis	Southern Grey Shrike
Acridotheres ginginianus	Bank Myna
Acridotheres tristis	Common Myna
Sturnus roseus	Rosy Starling
Pycnonotus cafer	Red Vented Bulbul
Pycnonotus leucogenys	White Cheeked Bulbul
Cinnyris asiaticus	Purple Sunbird
Phylloscopus collybita	Chiffchaff
Estrilda amandava	Red Avadavat
Lonchura punctulate	Scaly-Breasted Munia
Amandava amandava	Red Avadavat
Dicrurus macrocercus	Black Drongo
Phoenicurus ochruros	Black Redstart
Copsychus fulicatus	Indian Robin
Turdoides striata	Jungle Babbler
Coturnix coturnix	White Wagtail
Francolinus pondicerianus	Grey Partridge
Francolinus francolinus	Black Partridge
Upupa epops	Hoopoe
Merops orientotalis	Green Bee-Eater
Coracias benghalensis	Indian Roller
Halcyon smyrenensis	White-Throated Kingfisher
Alcedo atthis	Common Kingfisher
Milvus migrans	Black Kite
Circaetus gallicus	Short-Toed Snake-Eagle
Circus aeruginosus	Western Marsh-Harrier
Accipiter badius	Shikra
Egretta garzetta	Little Egret
Bubulcus ibis	Cattle Egret
Ardeola grayii	Indian Pond Heron
Vanellus indicus	Red-Wattled Lapwing
Psittacula krameria	Rose-Ringed Parakeet
Eudynamys scolopacea	Asian Koel
Tyto alba	Barn Owl
Athene brama	Spotted Owlet
Pterocles exustus	Sandgrouse
Dipnopium benghalensis	Golenbacked Woodpecker

(Shaukat and Raza 2016)

Mammals and Reptiles

270. EMC (2015) listed some 19 mammals, of which six are domesticated bovines, and six species of reptile, known to have been present in Karachi district. See Table 5-10. Only a few would be found in the typical urban space of the built-up City, and even less along the median where construction takes place. Most information in the literature related to fauna currently inhabiting areas near Karachi in Sindh Province focuses on the coastal zone including its mangrove embayment fringe and areas around Buleyji that are rich in marine biodiversity.

Table 5-10: Mammals and Reptiles Historically Present in the Area of Karachi District

Common	Scientific Name	Status
Mammals		
Indian Hedgehog	Paraechinus micropus	Very rare
Asiatic Jackal	Canis aureus	Rare
Chinkara	Gazalla bennetti	Very rare
Indian Fox	Vulpes bengalensis	Rare
Small Indian Mongoose	Herpes javanicus	Common
Indian Pangolin	Manis crassicaudata	Rare
Indian Desert Cat	Felis silvertris ornate	Rare
Indian crested porcupine	Hystrix indica	Rare
Ratel or Honey badger	Mellivora capensis	Vulnerable
Hog Deer	Axis porcinus	Very rare
Cairo Spiny Mouse	Acomys cahirinus	Rare
Grey spiny mouse or Rock mouse	Mus saxicola	Rare
Desert cat	Felis libyca ornate	Rare
Hares, rabbits		Common
Domestic Bovines:		
Domestic Sheep	Ovis aries	
Domestic Cattle	Bos Taurus	
Domestic Goat	Capra hircus	
Indian Water Buffalo	Bubalus arnee	
Arabian Camel	Camelus dromedaries	
Domestic Horse	Equus caballus	
Reptiles		
Spiny tailed lizard	Uromastyx hardiwickii	Common
Krait	Bangarus caerulus	Vulnerable
Indian Python	Python molurus	Very rare/ Endangered
Mugger	Crocodylus palustri	Vulnerable
Gharial	Gavialis gangeticus	Endangered
Marsh crocodile	Crocodulus palustris	Endangered

5.3 Socioeconomic Resources

271. There are many reports and documents available describing the socioeconomic setting of Karachi. The USAID/IMMAP Pakistan Development Perspective report (USAID/IMMAP, undated) provides a comprehensive overview with data and graphics, but without any particular theme. The work by Anwar et.al. (2013) is aimed at characterizing gender themes in the development of the City, and provides much detailed and quantitative data. ADB's Megacity Final Report (ADB 2005) also contains extensive textual and tabular data related to development themes. Infrastructure conditions along roadways are described in the ITDP final report related to Karachi NMT & Parking Improvement Plan & Design (ITDP 20115a). A number of transport planning documents, such as the KTIP reports and others, also contain excellent through somewhat dated summaries of Karachi's urban environment. Results obtained from primary socioeconomic survey and the above mentioned reports have been used to describe the socioeconomic conditions of Karachi in overview, and then, to the extent possible, for the areas nearby the Red Line alignment. The results of public consultations are contained in section 8.3.4. Figure 5-17 below shows some of the public consultations and socioeconomic activites.

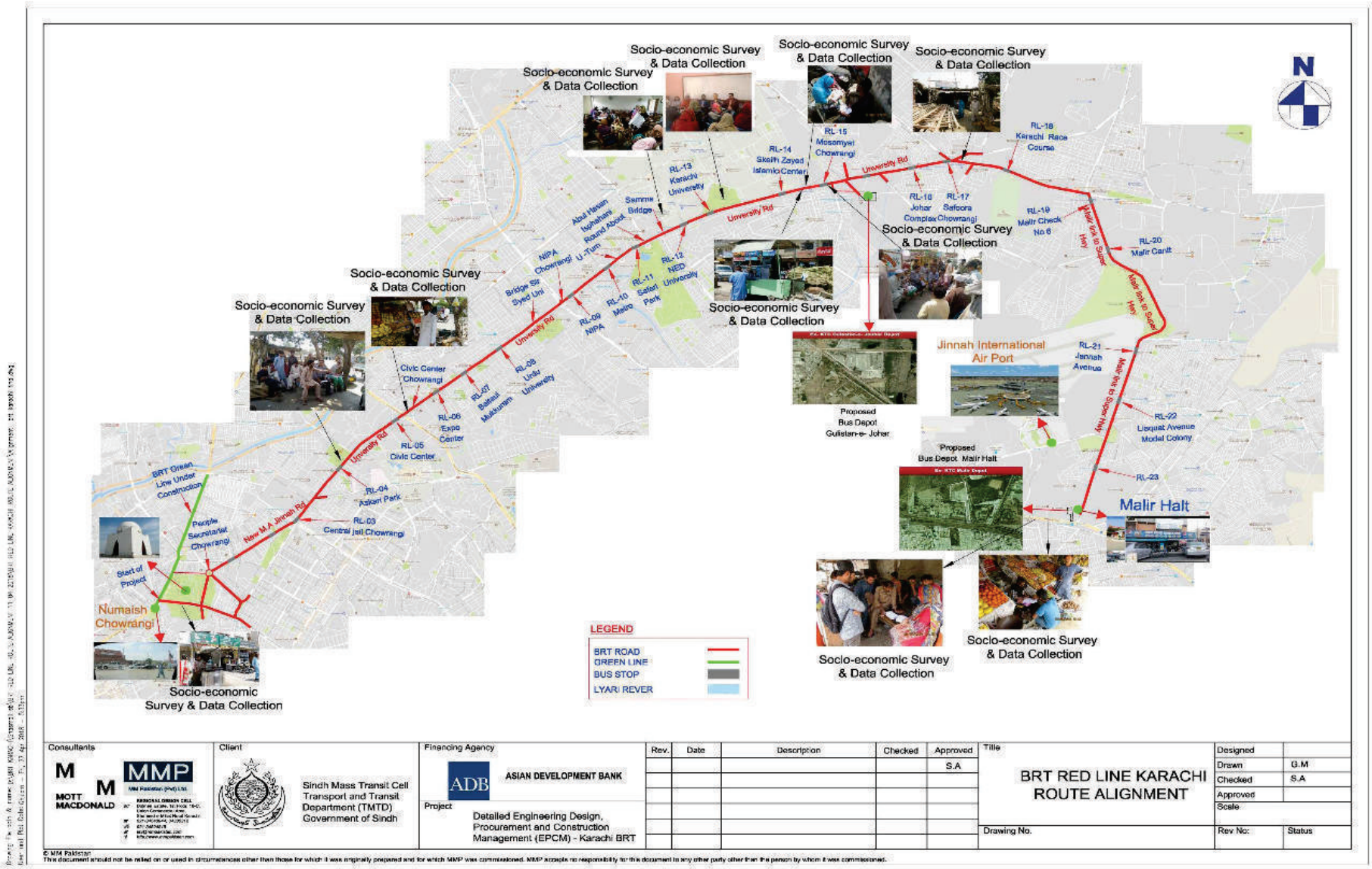


Figure 5-17: Socio-economic Survey and Data Collection

5.3.1 Population

272. Provisional results of the 2017 census show urban Karachi with a population of 14,910,352 capita, an increase of 58% over the 1998 urban population 9,448,808. Karachi's population increase was outstripped over the same period by Lahore (116%), Peshawar (100.4%) and Islamabad (91.8%). Karachi grew at an average annual rate of 2.43%.

273. Karachi's urban population is divided into six districts, two of which also contain rural populations (see Table 5-11). Cantonment areas are not counted and are generally considered not to be part of the city.

Table 5-11: District-wise 2017 Population for Karachi Division

POPULATION - 2017								
Administrative units	Households	Male	Female	Tsxual	Total	Population 1998	Sex ratio 2017	1998-2017 average annual growth rate
KARACHI DIVISION	2,770,074	8,439,659	7,610,365	1,497	16,051,521	9,856,318	110.9	2.6
RURAL	193,871	606,588	534,499	82	1,141,169	407,510	113.49	5.56
URBAN	2,576,203	7,833,071	7,075,866	1,415	14,910,352	9,448,808	110.7	2.43
Districts								
KARACHI CENTRAL	538,983	1,543,950	1,427,349	327	2,971,626	2,277,931	108.17	1.41
KARACHI EAST	509,239	1,528,019	1,379,225	223	2,907,467	1,472,896	110.79	3.64
KARACHI SOUTH	327,518	943,546	848,010	195	1,791,751	1,478,047	111.27	1.02
KARACHI WEST	634,459	2,065,847	1,848,553	357	3,914,757	2,089,509	111.75	3.35
RURAL	44,051	149,220	134,014	13	283,247	73,568	111.35	7.34
URBAN	590,408	1,916,627	1,714,539	344	3,631,510	2,015,941	111.79	3.14
KORANGI	421,618	1,284,015	1,172,737	267	2,457,019	1,561,742	109.49	2.41
MALIR	338,257	1,074,282	934,491	128	2,008,901	976,193	114.96	3.86
RURAL	149,820	457,368	400,485	69	857,922	333,942	114.2	5.08
URBAN	188,437	616,914	534,006	59	1,150,979	642,251	115.53	3.11

274. Data from the USAID/IMMAP report shows population density in some areas reaching as high as 60,000 cap/sq km and the largest demographic between 5 – 9 yrs. (The expansive type population pyramid shown depicts a greater preponderance of young than old in Karachi's population. The youth bulge is due to a situation in which 20 percent or more of a population is in the age group 15 to 24 years. It is the result of a transition from high to low fertility about 15 years earlier. The youth bulge consists of large numbers of adolescents and young adults who were born when fertility was high followed by declining numbers of children born after fertility declined.

275. The expansive type population pyramid shown depicts a greater preponderance of young than old in Karachi's population. The youth bulge is due to a situation in which 20 percent or more of a population is in the age group 15 to 24 years. It is the result of a transition from high to low fertility about 15 years earlier. The youth bulge consists of large numbers of adolescents and young adults who were born when fertility was high followed by declining numbers of children born after fertility declined.

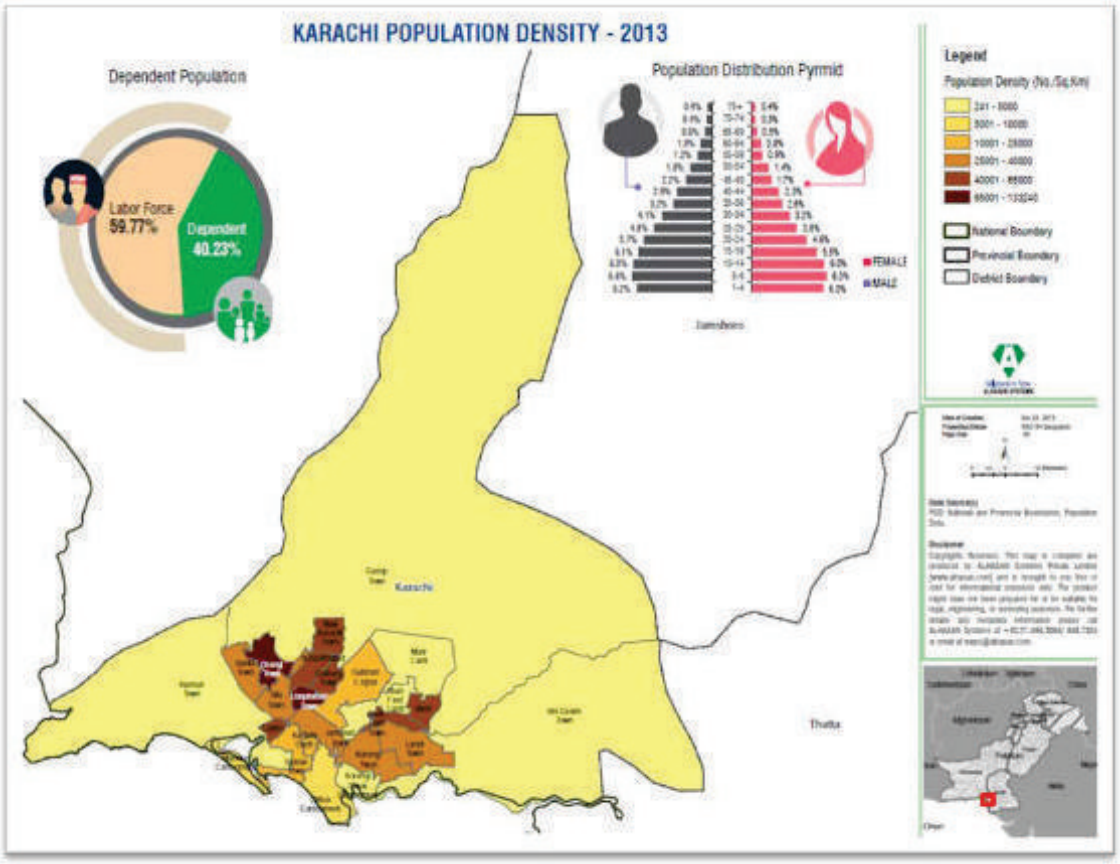


Figure 5-18: Population Distribution by Area, Age and Sex.

From USAID/IMMAP undated.

5.3.2 Land Use

City-wide Aspects

276. From a city-wide perspective, two aspects of land use predominate. One is the presence of the katchi abadi, or squatter developments that dominate in some areas of the City. According to ADB (2005), rapid and uncontrolled growth of the city has resulted in unregulated development and inappropriate land-use changes, with an estimated 50% of the population living in unplanned, poorly serviced and heavily polluted informal settlements. Karachi has been noted for an extreme level of violence over the last ten years, with one of the highest murder rates of any city in the world. The general discourse holds that violence originates in these closely packed informal settlements. While the abadis may be centers for crime and violence, they also constitute the living space of poor and vulnerable people. According to UN research, most of the migrants who end up living in such vulnerable circumstances tend to be women. (Anwar et.al. 2013) The growth of 'Abadis' in Karachi has been extensive, increasing from 212 distinct areas in 1958 to more than 500, as identified by Arif and Hamid (2008).

277. As described in Anwar et.al. (2013) a series of decrees have been passed to regularize and formalize the abadis, which have been more or less successful in achieving some permanence for their inhabitants. The Sindh Katchi Abadis Act (1987) set out criteria for formalizing unplanned settlements, as did the Sindh Gothabad Act (1987) and others. These decrees for land regularization also set out exceptions such as the minimum number of households (40) that

must be present in order to establish eligibility for regularization. Without regularization, those who reside in an unplanned settlement may not receive financial or livelihood support.

278. Unplanned settlements define the city's spatial landscape and remain critical in housing over 60% of its population. Unplanned settlements have grown at twice the rate of planned settlements, fueling Karachi's urban expansion. (Anwar et.al. 2013)

279. Another aspect of land use is characterized by guarded communities for the wealthy. These developments are situated along new infrastructure corridors such as the Super Highway where the city's rapidly expanding middle and upper-middle class population resides. (Anwar et.al. 2013) The upper classes tend to reside in securitized and well-served suburban housing estates, some located in close proximity to the city center, such as the Defense Housing Authority (DHA) area near Clifton Cantonment. High concentrations of wealth can be found in these estates where new areas of commerce and services have emerged.

280. There are of course many other aspects of city-wide land use, such as the old city areas that are mainly built up with five to six storey buildings surrounding MA Jinnah Road. The Central Business District (CBD) is located here and in the direction of the Port. Buildings are older and support mixed use with commercial, shipping offices, and residential space.

281. The Central Business District (CBD) is formed by Saddar Town and neighboring Keamari and Jamshed Towns, and is an area of concentrated commercial and business activities. The main municipal administration buildings are located in the CBD, Keamari and Saddar Town. The next most important area for upscale commercial development is Clifton Cantonment. Otherwise, commercial land use is primarily observed along the main roads. Industrial land use is primarily in the hinterland of the Port of Karachi and Port of Bin Qasim, SITE Town, Korangi Town and Landhi Town.

Localized Aspects

282. The KBRT Project lies along a commercial urban thoroughfare called University Road that runs for about 20 km from Mazar – e – Quaid mausoleum and Peoples Secretariat Chowrangi (intersection) to and beyond the Karachi University area. The alignment is built up on both sides with the dominant land use of mixed commercial and institutional use, plus some off-ground floor residential space. Areas adjacent to the roadway support schools, colleges, hospitals, offices, parks and theme parks, and mosques. Some particular aspects of land use along the alignment are:

- Areas toward the west support commercial uses mixed with residential, with high-rise buildings.
- The area toward the east end of University Road (Safoora Chowk to Safari Park) is dominated by educational institutions on the north side and mixed commercial/residential use (and open space) on the south.
- The area between Safari Park and Sir Syed University has civic, religious and educational institutions along the north side with a mix of recreational, commercial and civic institutions on the south.
- Near National Stadium Road the major land uses on the north side contains open space, a park and the Central Jail. The south side contains civic, commercial and residential land use.

- The Malir Link Rd. contains little development that faces directly onto the road, and while there are a number of housing developments along its length, there is limited direct access.

283. A projection of land use along the project corridor taken from the PPTA IEE document is shown in Figure 5-19. The map does not show land uses along the Malir Cantonment Link Rd, and includes the area from Mazar-e-Quaid to Bolton market along MA Jinnah Rd, which is no longer part of the project. Land use in the vicinity of the project shows to be primarily that of residential occupancy combined with open space. This is misleading in some respects, as ground inspection shows mixed occupancy of buildings adjacent to the roadway for New MA Jinnah Rd. and University Rd. There are also numerous institutions along the thoroughfare that don't appear on the map. Ground inspection indicates that institutional use, commercial space (some of it extensive, such as the Civic Center) and buildings supporting mixed uses (commercial on ground floor and residencies above), or residential units in the second tier of buildings back from the roadway is the rule. Also, there are numerous mosques and educational institutions along New MA Jinnah and University Rds.

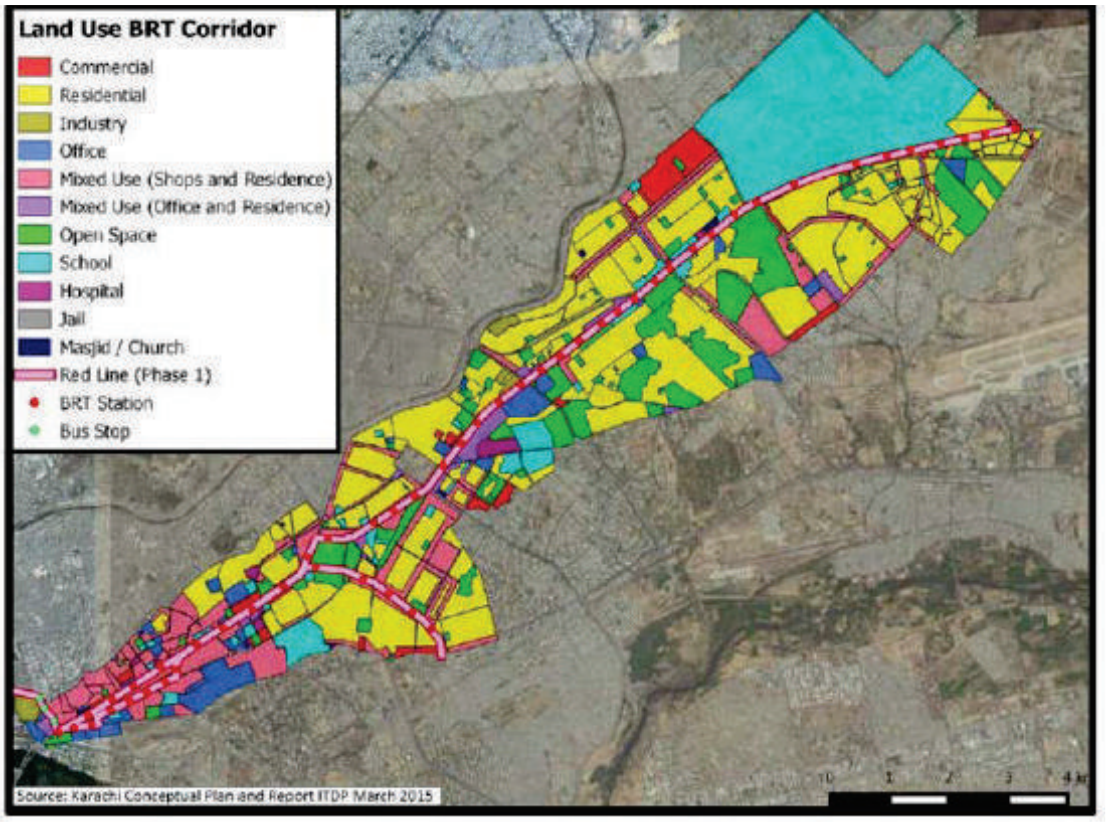


Figure 5-19: Land Use along the Red Line Corridor

5.3.3 Physical Infrastructure

284. Roadway transport infrastructure, motorized and non-motorized, along the alignment is characterized by a broad right-of-way, generally 50 m wide, well developed road surfaces divided by a center median, generally modern and efficient intersections often incorporating grade separations and ramps for merging traffic, but less well-developed pedestrian facilities and generally non-delineated lanes for bicycle travel. Sidewalks are generally in place, but may not be contiguous, or may be broken, in disrepair, or occupied by vendors or parked and sometimes derelict vehicles. Drainage systems provide comprehensive coverage, but may not function well due to clogging, disrepair or lack of adequate inlet capacity. Street lighting is installed along the

median or shoulder of the roadway; electrical and communications cable is generally, but not always, above grade.

285. In some locations (particularly near People's Chowrangi) mixed residential and commercial buildings are built close to the road ROW, which, when coupled with on-street parking, limits the walking space for pedestrians (Figure 5-20). Other areas, especially to the eastern extremity of University Rd along the alignment, are not well developed, such as the area near Safoora Roundabout (Figure 5-21).

Figure 5-20: Buildings with No Setback from ROW

Figure 5-21: Area near Safoora Roundabout

286. Electrical power is supplied throughout the Project area from the grid. The low voltage distribution network runs on poles adjacent to the alignment. Poles and lines are inside the ROW and some may need to be relocated before work commences.

287. Karachi Water & Sewerage Board (KWSB) is the sole public water service provider, supplying water for around 90% of the population through pipelines or by tank truck. The remaining 10% of the population depends on groundwater. KWSB pumps water from the Dumlottee Well Field, located on the banks of Malir River about 30 km to the northeast of the city, which is mostly depleted. The Indus River now serves as the main source of water for Karachi. About 550 MGD is taken at the Kotri Barrage through the Kalri Baghar feeder to temporary storage at Kinjhar Lake. Another major source of water for Karachi is Hub Dam. About 100 MGD of water is supplied to Karachi from the dam. The Hub Dam forms a multi-purpose reservoir along the Hub River approximately 50 km to the north-west of Karachi.

288. Telecommunications are provided by Pakistan Telecommunications Ltd. (PTCL) and other private companies. Pakistan Telecommunication Authority (PTA) regulates the establishment, operation and maintenance of telecommunication systems and the provision of telecommunication services across the Country. Telecommunications cables run parallel to and sometimes across the KBRT Project alignment and will need to be protected during the works. Some poles and lines may need to be relocated before the KBRT works start in order to ensure continuity of the system.

5.3.4 Schools and Universities

289. A number of schools, trade schools and universities are found along the alignment, many of national importance. Karachi University, more properly known as the University of Karachi, is a public research university, and is one of the oldest universities in Pakistan, being established as

a federal university in 1951 under the leadership of Oxford trained Dr. ABA Haleem. The NED University of Engineering and Technology also is a public research university and one of the oldest institutions of higher learning in Pakistan. The university is named for its benefactor, donor and philanthropist Nadirshaw Eduljee Dinshaw. Sir Syed University of Engineering and Technology, also located along University Rd., is a private research university. Aligarh Muslim University, located nearby, is a public university. It was originally established by Sir Syed Ahmad Khan as Mohammedan Anglo-Oriental College in 1875. The Muhammadan Anglo-Oriental College became Aligarh Muslim University in 1920. The Federal Urdu University of Arts, Science and Technology, is a public research university located near the National Institute of Public Administration (NIPA) in the residential area of Gulshan on University Rd. NIPA itself undertakes training, research and management consultancy through organizing training courses for middle-level officers of Government and autonomous bodies, on behalf of the Government, and independently. The Dawood University of Engineering and Technology is a public university established in 1962. Its initial financial endowment and foundation stone was laid by the former President of Pakistan Ayub Khan. The University was established by Dawood Foundation under the supervision of Seth Ahmed Dawood in 1964.

290. Other lesser known trade schools, private colleges and secondary schools are located in the area. City-wide origin-destination surveys conducted by the ODBM consultant show that most public transportation trips originate near Defence Chowk, Sachal Goth, University of Karachi and in Saddar Town, while most destinations of public transportation trips are to Dawood Chorangi, Sachal Goth, University of Karachi, Jamshed Town and Saddar Town. The volume of origins and destinations observed along the Red Line Alignment shows the importance of this area for Karachi. Also important is the middle part of the Red Line Alignment, near NIPA, where the survey identified a great number of destinations. (EE 2017)

5.3.5 Public Transportation Facilities

291. Railways use more than 100 km of track length for commuter services within the Karachi metropolitan area. Some important stations connecting this system are located near the KBRT project. These stops are on the Karachi Circular Railway (KCR).

292. The KCR began its operation in 1964 using trains pulled by diesel locomotives to make some 12 round trips a day around the City. The system deteriorated and transport volume declined annually, adversely affecting profitability. The system ceased to operate in December 1999. The Karachi Transportation Improvement Project (KTIP) identified the KCR as an important element in Karachi's future public transport system. KCR operations were resumed on one section of the main line, and a study was done to evaluate repairing the existing 30 km of the circular section and 14 km on the main line, with a provision to extend services to Karachi International Airport. Full-scale restoration has not been implemented due to lack of funds, and rejuvenation of the KCR system is still in proposal stage.

293. Air travel is dominated by Pakistan International Airlines, a state-owned airline headquartered at Jinnah International Airport. PIA operates scheduled services to 23 domestic destinations and 30 international destinations in 27 countries across Asia, Europe and North America. Its main bases are Karachi, Lahore and Islamabad/Rawalpindi, with secondary bases at Peshawar, Faisalabad, Quetta, Sialkot and Multan. The airport location is relatively near the eastern end of the KBRT Red Line corridor.

294. Transport within the Project area is dominated by private vehicles and buses. Traffic surveys by the ODBM consultant provide a detailed look into transport usage along the Red Line Route. The report (EE 2017a) outlines the types of traffic surveys conducted, methodology adopted to execute each type of survey and the outcome of these surveys. The report confirms that public transport has reduced during the last decade due to insufficient investment, resulting in a shift of demand from public transport towards other modes of transport, including motorcycles/private vehicles and informal Chingchi Rickshaws, despite increased in petroleum prices. Referring to JICA's 2005 study, the report states that Karachi's public transport makes up only 4.5% of the total vehicle fleet but serves about 42% of passenger demand, without dedicated lanes or other feasible traffic management intervention. Whereas private vehicles make up 36% of the total vehicular traffic but carry only 21% of passengers.

295. While survey data are extensive and will be analyzed by the ODBM consultant, it is important for the EIA to characterize in a simple fashion the current mix of vehicles along the Red Line route and how that mix will be altered by the functioning of the Red Line BRT. In order to depict the traffic mix, a selected location from the "Classified Mid-Block Results Summary" presented in EE 2017a (Appendix A of the ODBM Interim Report, Table 3-2), as well as the total values from that table are presented herein (Table 5-12). Note that the results for the selected location (Site 35, University Rd. near Ashfaq Memorial Hospital) and those for the entire record of some 44+ sites are generally similar, indicating that the site is representative of the whole, and of other sites. Figure 5-22 and Figure 5-23 show similarity between these data records. The greatest proportion of vehicles is motorcycles, followed by cars and 3-wheelers, which together make up 96 and 93% of the total vehicle count at Monitoring Site 35 and overall, respectively.

Table 5-12: Summary Data from ODBM Classified Mid-Block Survey (Site 35 and Total)

	Car	Taxi	3-whlr	M/cycle	Coach	
Site 35	38,010	767	15,341	51,803	385	
Total	804,278	25,673	323,983	1,392,924	28,738	
Site 35	35%	1%	14%	47%	0%	
Total	30%	1%	12%	51%	1%	
	Mini Bus	Large Bus	Light Frt	Truck	Trailer	Total
Site 35	1,499	177	523	1,407	73	109,985
Total	39,960	17,792	29,480	44,412	11,086	2,718,326
Site 35	1%	0%	0%	1%	0%	100%
Total	1%	1%	1%	2%	0%	100%

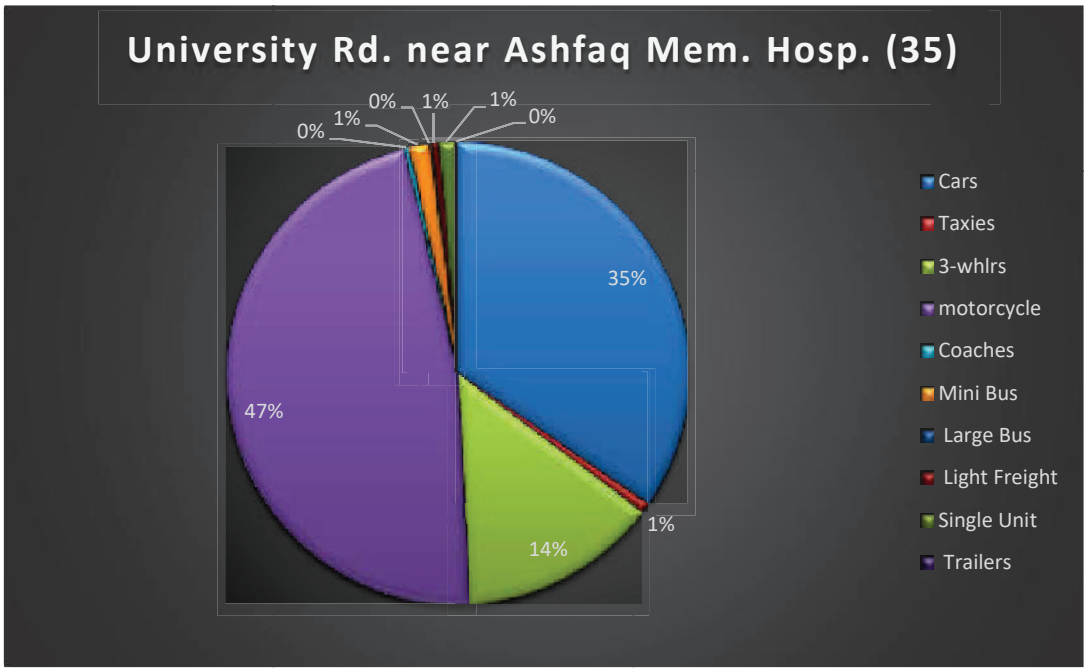


Figure 5-22: Proportion of Vehicle Types (Site 35)

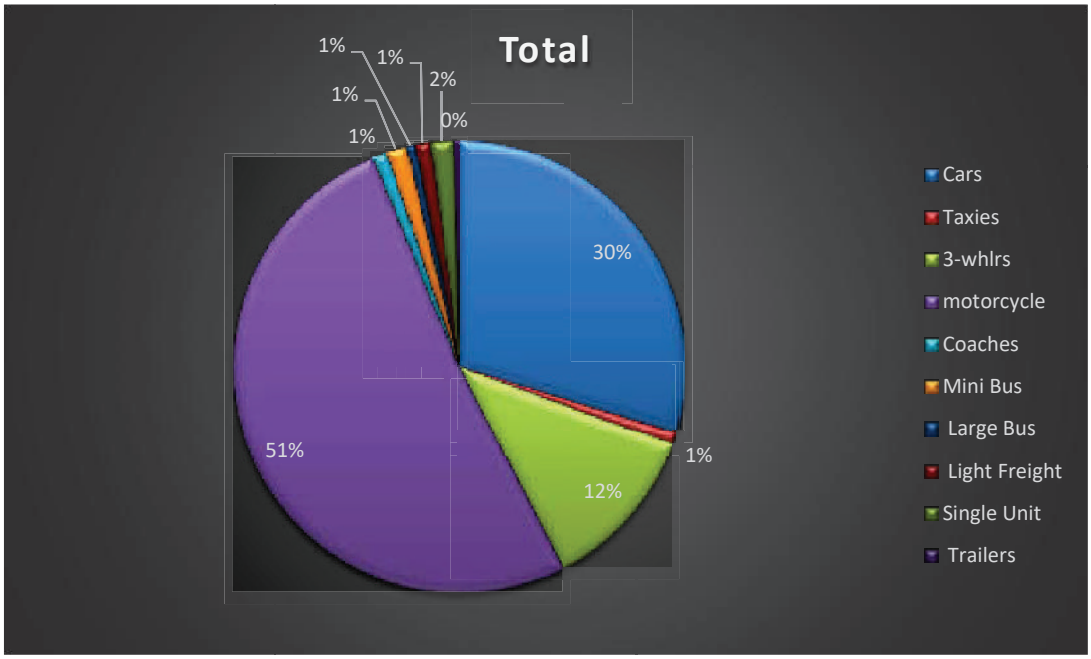


Figure 5-23: Proportion of Vehicle Types (All Sites)

5.3.6 Employment and Livelihoods

296. Karachi's burgeoning population is in part attributed to good employment opportunities in trade and industry. Karachi is said to have an "overtly industrial character" in contrast to its "agricultural hinterland", a development trend likely to further the polarization between urban Karachi and rural areas, and inevitably widen the gap between the city and its hinterland. (ADB 2005) Other sources also point out the extreme difference in income among different social groups and also between provinces.

297. Unemployment remained around 5 % post- 1993-1999, but increased sharply to over 8 % in 2002. Following that, the rate fell during 2003-07 and reached a low point of around 5 % in 2008-09. It rose again to 5.6 % in 2009. Overall there has been a decline in unemployment since 2003-4.

298. Economic growth contributes to real wage increase, employment and poverty alleviation. Forces of supply and demand in the labor market jointly determine wage rates and numbers of people employed. Labor demand is linked to remittances from overseas Pakistanis as well as to the structure of the economy, as represented by land ownership and control over financial assets.

299. Also, there is a demographic transition taking place in Pakistan, and youth employment opportunities take center stage, since new arrivals to the work force must be absorbed productively. While the labor force is growing every year, opportunities for employment are declining. Even so, youth unemployment in Pakistan is below the global average.

300. Trends in age-specific unemployment rates differ considerably for males and females in the labor force. Male unemployment has increased in the last two decades whereas female unemployment has decreased. The gap between the projected female working age population and the projected labor force is likely to increase sharply over time. While a reduction in this gap is desirable, and unemployment among females has historically been higher than among males, the gender gap has narrowed considerably over time.

301. Many unemployed males are students enrolled in colleges, universities, and professional and technical education institutes. The rates of employment in electricity, gas and water, construction, manufacturing, trade (including restaurants and hotels) in urban Sindh are much higher than in the nation. Urban Sindh's participation in finance is almost double the national rate. According to one estimate, 90 % are migrants from different backgrounds and the population is estimated to be growing at about 5 % per year, mainly as a result of internal rural-urban migration, including an estimated 50,000 migrant workers coming to the city every month from different parts of Pakistan. (USAID/IMMAP undated)

302. Employment is in a variety of sectors. Several industrial zones including Landhi, Korangi, FB Area, North Karachi, Dhabeji and Port Qasim were built during the 1990s. Korangi Creek Industrial Park (KCIP) commenced operations from 2013, contributing around Rs 40 billion annually to the national GDP and providing approximately 30,000 direct and 180,000 indirect jobs.

303. Karachi has a large industrial base located in these industrial zones on the fringes of the main city. Karachi has over 15,000 industries in the organized sector while there are more than 50,000 units in the informal sector that are not under the purview of the Labor Department. About 70 % of total industry of Pakistan is located in Karachi and in the Bin Qasim Industrial Area, mostly in the Sindh Industrial Trading Estate (SITE), Landhi Industrial Trading Estate (LITE), Korangi Industrial Area, and West Wharf Industrial Area. In addition, Karachi has a vibrant cottage industry and there is a rapidly flourishing Free Zone with an annual growth rate of nearly 6.5%. Karachi has an Expo Centre, which hosts many regional and international exhibitions. Karachi is home to major industrial associations.

304. Karachi is a major seaport and contains the country's two major ports, the Port of Karachi and Port Mohammad Bin Qasim. The city also is an important hub for the fishery industry in Pakistan, and major fishing ports include Karachi and Korangi Fishing Ports. About 300,000 people are

connected with the fishing industry; subsidiary industries provide employment for another 400,000 people. (USAID/IMMAP undated)

5.3.7 Public Health

305. Public Health System facilities in Karachi include:

- Outreach and community-based activities that focus on immunization, malaria control, maternal and child health, family planning and the Lady Health Workers program;
- Primary care facilities that focus on outpatient care;
- Taluka and district headquarters hospitals for basic inpatient and outpatient care;
- Tertiary care hospitals; and
- Teaching hospitals and centers of excellence

306. Vaccination rates are good indicator of attention to public health. Rates given for Karachi (2011) for children 12-23 months that have been immunized (by type of antigen (%)) are as follows:

BCG (TB)	DPT1	DPT2	DPT3	POLIO1	POLIO2	POLIO3	MEASLES
97	97	96	94	92	91	88	92

307. According to IMMAP, 74.5 % of children under 12 are fully Immunized (2011-2012), and 91 % of pregnant women have received tetanus toxoid Injection. Mortality statistics are given in Table 5-13.

Table 5-13: Mortality Statistics of Karachi and Nationwide

Sr.	Type of Mortality	Number of Lives	National Average*
1	Infant Mortality	81/1000	64/1000
2	Maternal Mortality	314/100,000	178/100,000
3	Under 5 Mortality	101/1000	79/1000

* The World Bank data at https://data.worldbank.org/indicator/SH.STA.MMRT.

308. Karachi mortality rates are higher than the national average on all three indicators.

HIV/AIDs

309. HIV has shown to be a serious and tenacious problem for Pakistan. However, as reporting in NACP/UNAIDs 2015, conservative religious values and cultural normative systems have contributed to keeping the epidemic from becoming generalized, remaining concentrated in key populations, persons who inject drugs (PWID), men who have sex with men (MSM), transgender persons (TG), and female sex workers (FSW). In general Pakistan has done poorly in controlling HIV and AIDs, and following a 2013 Mid-Term review of its program in meeting UN general assembly goals, Pakistan was found not to be on target for over 50 per cent of their targets. A report in the national news gives a gloomy performance of the Sindh Aids Control Programme, wherein “only five treatment centres are working in the entire Sindh province, with Karachi leading the patient burden. Non-availability of medicines is another crucial hindrance in tackling the disease.”(Geo TV 2016) According to one report (Memon 2012), Karachi’s HIV prevalence in risk groups in 2011 was 5.9% among MSW (male sex workers), 12.3% for HSW (Hijra sex

workers), 1.9% for FSW (female sex workers) and 42.2% among IDUs (intravenous drug users). From 2003 to 2007, HIV prevalence among IDUs in Karachi rose from 0.3% to 23% in 2004 and has reached 42% in 2011. (Samo et.al. 2013).

5.4 Physical Cultural Resources

5.4.1 Religious, Historical, Cultural and Archeological Sites

310. A number of mosques can be found along University Avenue, and the Mausoleum for M.A. Jinnah. Mazar-e-Quaid (Urdu: مزار قائد), also known as the Jinnah Mausoleum or the National Mausoleum, is the final resting place of Quaid-e-Azam ("Great Leader") Muhammad Ali Jinnah, the founder of Pakistan. Designed in a 1960s modernist style, the mausoleum also contains the tomb of his sister, Māder-e Millat. The mausoleum is set back some 130 m from the edge of the right-of-way. Mosques within the area of the alignment include the Al-Raheem Mosque, Jama-Masjid-Taqvee, M-Ibn-Tamiayah Mosque, Masjid Bait-ul-Mukaram, and other lesser known mosques. Other than these structures, there is no specifically historical or archeological structure or site on the alignment.

311. Historical and archeological sites can be affected by excess ground vibrations, and must be sufficiently accounted for to avoid vibration damage. See Sec. **6.6** for further comment on the effect of vibration on historical structures.

5.4.2 Visual, Aesthetic and Recreational Resources and Scenic Qualities

312. Open spaces and parks are found along the alignment. The Safari Park, a theme park emphasizing broad water bodies and captive animals for viewing. Karachi Safari Park (Urdu: کراچی سفاری باغ), opened in 1970, and is a publicly funded 'family-only' park covering an area of 148 acres, located in Gulshan-e-Iqbal, adjacent to the alignment. It has a zoo, geared with viewing facilities like a chairlift and safari tracks, as well as two natural lakes. A privately funded amusement park, Go Aish, is located in the Safari Park's vicinity.

313. There are three parks located adjacent to the alignment. Mir Usman Park, which contains some captive wild animals, the Wildlife Aquarium and Askari Park, which is built on the site of old Sabzi Mandi (Fruit & Vegetable Market). Askari Park was inaugurated by President General Pervez Musharraf and is a family park. It has a staff of around 170 people with standby generators and desalination water plant onsite. Most of the park is monitored by surveillance cameras. The adjacent aquarium is air-conditioned and has a large collection of fish with excellent maintenance. There is also a reptile house. Hakeem Saeed Playground, also located along the alignment, is a family-only playground named after Hakim Mohammed Said who was a medical researcher, scholar, philanthropist, and the Governor of Sindh Province from 1993 until 1996.

6. Anticipated Environmental Impacts and Mitigation Measures

6.1 EIA Methodology

314. The methods that are used for assessment of impact are based on a structured approach that:

- considers the factors that are incorporated into the ADB's SPS and regulatory requirements for the assessment of environmental effects as defined by the SEPA;
- builds upon the initial environmental examination (IEE) prepared during the project preparation-technical assistance for the Project, as well as the scoping that took place in that effort;
- considers issues raised by the public and other stakeholders during consultation and engagement activities;
- integrates engineering design and programs for mitigation and monitoring into a comprehensive environmental planning and management process.

315. The EIA focuses on environmental values of particular concern in both biophysical and human environments, and addresses Project-related and cumulative environmental effects. Project-related effects are changes caused by a project or activity arising as a result of the proposed principal works; whereas cumulative effects are changes are caused by an action associated with the Project in combination with other projects or activities.

316. Mitigation measures are proposed, and residual effects after mitigation are are set out in the context of a discussion on the combined significance of an effect in terms of criteria such as magnitude, extent, duration, and other factors. Some aspects of the assessment are set out using data tables to facilitate the evaluation.

317. The majority of impacts occur due to construction activity, and the success of mitigation depends on compliance by the construction contractor with environmental controls and effective monitoring.

318. Categories of potentially affected environmental values that were identified through scoping include: air quality; noise; vibration; traffic and transport; community and occupational health and safety; water use, quality and drainage; solid wastes and hazardous materials; historical, cultural and archaeological monuments and artifacts; vegetation and wildlife; public infrastructure and utilities; socioeconomic issues related to operations including female vulnerability, job displacement and affordability; mitigation and adaptation aspects of climate change; and cumulative impacts.

319. Existing environmental conditions are characterized in the context of the impact analysis contained in the following sections. Environmental effects are assessed by superimposing the Project onto the existing environment and evaluating potential effects through descriptions of how an environmental effect will occur, or how the Project will interact with the environment, and how mitigation measures reduce or eliminate the environmental effect. Impacts are assessed across construction and operation phases. Follow-up measures that are recommended to assess the effectiveness of the planned mitigation, as well as any required monitoring.

6.2 Screening of Potential Environmental Impacts

320. Screening is conducted using the ADB Rapid Environmental Assessment (REA) Urban Development Checklist as shown in Appendix B. Preliminary Screening for Climate Risk was also done using a checklist provided by ADB.

321. The project is classified as category A due to the potential for diverse impacts occurring in a built up urban environment. Significant adverse impacts may occur during construction from air pollution, noise caused by construction equipment, and traffic congestion. Environmentally sensitive areas are located along the construction zone including schools, hospitals and mosques. Excavations along the route alignment threaten to interrupt cross traffic and cause major disruption in daily movement of people in the absence of pre-planning. Dust generated by construction equipment, hauling of large quantities of earth and road building materials, and the constant movement of mixed traffic nearby construction areas will cause significant impact if not mitigated over the duration of the construction activity. Some cumulative effects are possible in conjunction with other ongoing development activities. Operations impacts, primarily having to do with excessive noise, are possible in the area around depots.

322. In addition, climate risk screening has led to a scoring of “Not Likely” across all aspects, considered a low risk project in respect to climate risk.

6.3 Design and Preconstruction Phase

323. A screening process has been conducted in accordance with ADB policy. As demonstrated by the REA Screening Checklist, no critical habitat, environmentally sensitive area or physical cultural resource is encroached upon or affected by the project.

324. The environmental assessment takes into account alternatives in location and design. Impact mitigation, public consultation and disclosure are being carried out. The Project aims at pollution prevention by selection of the most practical means of motive power for the buses, within the range of affordability. Community and occupational health and safety are incorporated into early planning and design.

325. Strategic decisions related to alignment, off-network services and integration are resolved along with detailed design. Features that complement environment, health and safety are incorporated into the project during the design phase. Preconstruction planning for traffic management, occupational health and safety, and utility relocation reduce vulnerability to impact during actual construction.

6.3.1 Planning and Facility Location

326. Depot locations and alignment alternatives are described in Chapter 4. These demonstrate the proponent’s intention to evaluate the viable alternatives within the original scope of the Project, alternatives that incorporate environmental objectives alongside economics, social benefits and practicalities for integrating the Red Line with other elements of the Karachi BRT system, both planned and in progress. Tie in with the Green Line on the western end drives the selection among alternatives at that location. Provision of service to outlying communities and the airport factors in the selection of alternative alignments and extensions on its eastern extent.

6.3.2 Environmental Aspects of Design

327. Principles related to health and safety, energy conservation, environmental, and access/use for women and disabled have been incorporated into the design. Specific design factors to reduce women's vulnerability during use of the BRT are listed in Section 6.14. Various aspects of the system support access for the disabled. Overhead bridges spanning traffic lanes and providing access to stations; and vehicles will be equipped with an electronic "boarding bridge" at the median doorways and a manual boarding bridge at the curb-side doorways. A boarding bridge is a ramp extension that eliminates any gap between the platform and the vehicle, which enables safe boarding and alighting of disabled persons and other vulnerable passenger groups, such as small children, the elderly, and parents with prams. For curb-side doorways, a manual pull-out boarding bridge is used that is manually put into place by the driver when there is a special needs passenger who requires the boarding bridge.

328. Vehicles are specified to provide an onboard wheelchair bay that will be designated a priority area for wheelchair patrons as well as other disabled persons and customers with prams. The wheelchair bays will have signage indicating this prioritization. A pictogram indicating this priority will also be placed adjacent to the exterior of the doorway nearest to the wheelchair bay.

6.3.3 Utility Relocation Planning

329. A utility survey was undertaken during the detailed design through consultation with utility service providers. Its verification is an essential part of project implementation, followed by relocation prior to award of contract. Overall, utility relocation involves the following steps:

    i. Identification of utility agencies involved along the alignment (see Table 6-1)
    ii. Collection of underground utility data from the concerned agencies
    iii. Plotting the utility data on topographic alignment CAD drawings
    iv. Review of data by utility agencies
    v. Checking of major subgrade infrastructure to avoid shifting major utilities
    vi. Field verification by GPR system/trench excavation
    vii. Identification of utilities for relocation
    viii. and relocation of utilities

330. It is typically the responsibility of the Detailed Design Engineer to coordinate utility relocation prior to start of construction. The agencies that have utilities that could be affected by construction of the BRT are listed in Table 6-1. Meetings have been conducted with these agencies and information gathered that is collated by the MML team. Data received from all agencies have been superimposed on drawings. Utility survey and verification continues in parallel with civil design work, including field verification of critical utility locations. The preliminary outcome of utility relocation should serve as a basis for further work by the construction contractor. Design teams are weighing costs and design options where conflicts appear unavoidable. The effort provides a high degree of certainty regarding locations and means for resolving utility conflicts. To mitigate disruption in utilities the contractor will endeavour to provide new services prior to dismantling of existing services. Similarly to minimize traffic jams caused by excavations, relocations of utilities, material handling and storage of necessary materials etc, a traffic management plan will be prepared and communicated to the concerned utilizing the best information system and networking available. The Contractor will be

responsible for preparing and implementing Utilities, Telecommunications Relocation Plan, Material Handling & Storage Plan, Dust management Plan, Traffic Management plan and a Communication Plan as part of its SSEMP that will include an emergency response plan for repairing damaged utilities and restoring service in the shortest time possible. (See Sec. 6.13.)

Table 6-1: Interface Agencies for Utility Relocation

SN	Authority	Concerned Utility
1	Cantonment Board (CB)	Water, Electric, Gas Line and communication lines
2	Karachi Metropolitan Corporation	Street lighting (overhead), Road-side drain, Signaling cables.
3	Karachi Water and Sewerage Board	Water, Sewerage & Drainage Pipelines.
4	Karachi Electric Supply Corporation (KESC)	Electric Lines, over-head & underground
5	Sui Southern Gas Company (SSGC)	Gas pipelines
6	National Telecommunication Corporation	Telephone lines (copper cables and optical fiber cables) servicing primarily government
7.	Pakistan Telecommunication Company Ltd (PTCL)	Mobile, telephone exchanges and fixed-line network
8	Others	

6.4 Air Quality

6.4.1 Standards/Criteria

331. Air pollutants have potential adverse impact on human health and maintenance of surfaces, structures and outdoor space. The dominant air pollutant during construction is suspended particulate matter (SPM) measured as total SPM, or PM_{10} or $PM_{2.5}$ (respirable fractions of SPM). The dominant form of pollutant during operations may be any one of the gaseous pollutants discharged with diesel exhaust (NOx, HC, and CO) along with diesel particulate, a particularly noxious form of SPM due to the presence of potentially carcinogenic polycyclic aromatic hydrocarbons (PAHs).

332. Ambient pollutant concentrations are regulated under the SEQS reproduced in Table 6-2 Note that the 24-hr values for PM_{10} and $PM_{2.5}$ correspond to WHO interim – I values for these pollutants (WHO 2005), which are approximately 3 time higher than the recommended guidelines of the WHO **Table 6-3**). Limits on vehicle emissions also are regulated, as shown in Table 6-4 in accordance with the Tier II Pakistan standard, which corresponds with the EU-II standard.

Table 6-2: Sindh Environmental Quality Standards for Ambient Air

Pollutant	Time-weighted Average	Concentration in Ambient Air	Method of Measurement
Sulphur Dioxide (SO_2)	Annual Average	80 µg/m^3	Ultraviolet fluorescence method
	24 hrs	120 µg/m^3	
Oxides of Nitrogen (as NO)	Annual Average	40 µg/m^3	Gas phase chemiluminescence
	24 hrs	40 µg/m^3	
Oxides of Nitrogen (as NO_2)	Annual Average	40 µg/m^3	Gas phase chemiluminescence
	24 hrs	80 µg/m^3	
O_3	One hr	130 µg/m^3	Non-dispersive UV absorption
Suspended Particulate Matter (SPM)	Annual Average	360 µg/m^3	High Volume sampling
	24 hrs	500 µg/m^3	
Respirable Particulate Matter (PM_{10})	Annual Average	120 µg/m^3	B ray absorption
	24 hrs	150 µg/m^3	
Respirable Particulate Matter	Annual Average	40 µg/m^3	β ray absorption

Pollutant	Time-weighted Average	Concentration in Ambient Air	Method of Measurement
($PM_{2.5}$)	24 hrs	75 µg/m^3	
Lead (PB)	Annual Average	1 µg/m^3	AAS method
	24 hrs	1.5 µg/m^3	
Carbon Monoxide (CO)	8 hrs	5 mg/m^3	Non-dispersive infrared method
	1 hr	10 mg/m^3	

(from EPA/TECH/739/2014)

Table 6-3: WHO Air Quality Guidelines (2005)

Pollutant	Time-weighted Average	Concentration in Ambient Air
Sulphur Dioxide (SO_2)	10-min average	500 µg/m^3
	24 hrs	20 µg/m^3
Oxides of Nitrogen (as NO_2)	Annual Average	40 µg/m^3
	1 hr	200 µg/m^3
O_3	8 hr	100 µg/m^3
Respirable Particulate Matter (PM_{10})	Annual Average	20 µg/m^3
	24 hrs	50 µg/m^3
Respirable Particulate Matter ($PM_{2.5}$)	Annual Average	10 µg/m^3
	24 hrs	25 µg/m^3

Table 6-4: Emissions Standards for New Vehicles (g/kWHr)

Type of Vehicle	Category/ Class	Tier	CO	HC	NO_x	PM
Heavy Duty Diesel Engines	Buses	Pak-II	4.0	1.1	7.0	0.15
European standards for comparison						
Euro II	diesel trucks and buses	EU-II	4.0	1.1	7.0	0.15
Euro III		EU-III	2.1	0.66	5.0	0.10

333. In addition, black smoke and carbon monoxide (CO) are regulated as shown in Table 6-5 these standards may also be used as the project standard applicable to construction equipment working onsite.

Table 6-5: Sindh Environmental Quality Standards for Motor Vehicle Exhaust and Noise

Parameter	Standard (Maximum Permissible Limit)	Measuring Method
Smoke	40 % on the Ringelmann scale during engine acceleration mode	Comparison with chart at >6 m
Carbon Monoxide	6 %	Under idling conditions; non-dispersive infrared detection
Noise	85 dBA	Sound meter at 7.5 m from source

6.4.2 Air Quality Impacts during Construction

334. Construction activities generate SPM (mostly dust) that can become entrained in the air depending on prevailing site and meteorological conditions. The problem is made worse due to the generally dry conditions that prevail in Karachi. Mud and particulates from trucks may be deposited along main transport corridors and in residential neighbourhoods where construction

trucks are routed, either from uncovered loads or by shedding from the undercarriage. If uncontrolled, particulate is bothersome to pedestrians and people passing in open vehicles, especially cyclists; small diameter particulates contribute to respiratory disease.

335. Heavy trucks and construction equipment powered by gasoline and diesel engines generate CO and NOx in exhaust emissions. These emissions are temporary and limited to the immediate area surrounding the construction site. Heavy trucks and construction equipment are expected to conform to the Sindh Environmental Quality Standards for Motor Vehicle Exhaust provided in Table 6-5. Contractors will be required to certify their equipment and heavy trucks in use at the jobsite that the equipment conforms to Sindh environmental quality standards for noise and air emissions. The process of certification may be by submittal of manufacturer's certificates for new or nearly new equipment. Equipment more than two years old should be tested and certified to produce emissions within the prescribed limits.

336. Particulate matter is by far the most important air pollutant during construction, and arises primarily from dust along roadways and open excavations. A number of causes for high particulate levels were observed at a typical roadway construction site in Karachi, including dirt stockpiled along the roadway near driving lanes; failure to keep driving lanes free of dirt and dust; broken and torn-up road conditions for lanes still in use; materials storage in ROW; mud-laden water pumped from excavations and allowed to cross the roadway; and failure to contain the construction work within clear boundaries. These and other construction-related factors lead to high dust levels throughout the alignment where work is in progress and much inconvenience to the public, which has to share the space. Ambient conditions may be poor even before the start of construction, yet can deteriorate significantly when coupled with dust entrainment and exhaust emissions from equipment operations at construction sites and SPM and exhaust emissions from transport vehicles traveling on broken roadways.

6.4.3 Mitigation measures during Construction

337. Air quality impacts associated with construction activities will be minimized by progressive application of the following measures:

- Remove spoil materials and excavated dirt quickly or stockpile away from trafficked areas; prevent wind from entraining particulate from stockpiles through watering or covering.
- Clean exposed surfaces using dry methods at or near work sites along the alignment, along haul routes and at other locations where dust is a problem.
- Maintain roadway surfaces adjacent to the ongoing work on the alignment to prevent the development of broken pavement and potholes
- Remove mud and windblown dust deposited on roadways at construction sites and haul routes
- Spray water at work sites and on unpaved surfaces within work spaces and fabrication yards
- Cover and/or wet down materials onsite at regular intervals
- Maintain slow speeds (<15 km/hr) for vehicles traveling on unpaved roads in construction zones
- Cover loads during transport of loose sand, aggregate and spoil materials by truck
- Provide washing facilities at the gates of casting yards and materials storage sites if necessary to remove mud from wheels and undercarriages

- Provide certification that construction equipment brought onto the job complies with Pak-II exhaust emissions standards, and assure equipment is properly maintained.
- Concrete batch and asphalt plants must be located at a distance of more than 500m from any sensitive receptor (i.e. schools, hospitals and residential areas).
- Utilize specialized water spraying techniques for suppression of dust during construction, and develop a methodology for optimizing dust suppression using water spraying as a part of the Dust Control Plan

338. These mitigation measures shall be implemented by the contractor as necessary to limit airborne dust and exhaust emissions in the vicinity of worksites. The CSC through the Resident Engineer may require any other measures deemed to be practical and effective for controlling airborne dust. The Contractor is required to address systematically air emissions abatement at the outset of construction work through preparation of a Noise and Dust Control Plan that will form part of the Site Specific EMP (SSEMP).

6.4.4 Construction Monitoring

339. The Contractor will be required to monitor particulate matter in the vicinity of construction sites, temporary sites including construction yards and storage areas, and access routes. Baseline conditions along the alignment often exceed SEQS standards[12], which should be taken into account when evaluating air quality conditions during construction. If community complaints arise, the contractor will intensify use of mitigation measures to minimize air quality impacts. In addition, the Contractor is required to certify emission controls on construction equipment and vehicles.

340. The relevant standard may not be particularly important under actual conditions, as dust will be a perennial problem and the contractor will be enjoined to control dust by every practical means.

6.4.5 Cement and Asphalt Batch Mixing Plants

341. The contractor may purchase pre-mix concrete or asphalt hot mix from established suppliers, or set up facilities for production at temporary plants. These typically occupy a site for not more than 180 days, depending on the length of the project, and supply concrete for a single project (or related project segments), producing at rates that generally do not exceed 300 m3/hr. For these facilities, controls are needed to prevent nuisance dust situations and to protect the health and safety of the public.

342. For cement mixing facilities, particulate matter, consisting primarily of cement and pozzolan dust but including some aggregate and sand dust emissions, is the primary pollutant of concern. All but one of the emission points are fugitive in nature. The only point sources are the transfer of cement and pozzolan material to silos, and these are usually vented to a fabric filter or “sock”. Fugitive sources include the transfer of sand and aggregate, truck loading, mixer loading, vehicle traffic, and wind erosion from sand and aggregate storage piles. The amount of fugitive emissions generated during the transfer of sand and aggregate depends primarily on the surface moisture content of these materials. (US EPA 2011)

343. Hot mix asphalt (HMA) facilities can be broadly classified as either drum mix plants or batch mix plants, according to the process by which the raw materials are mixed. In a batch mix plant, the

[12] SPM ambient standard of 500 µg/m3 (24 hr average), and PM10 ambient standard of 75 µg/m3.

aggregate is dried first, then transferred to a mixer where it is mixed with the liquid asphalt. In a drum mix plant, a rotary dryer serves to dry the aggregate and mix it with the liquid asphalt cement. After mixing, the HMA generally is transferred to a storage bin or silo, where it is stored temporarily. From the silo, the HMA is emptied into haul trucks, which transport the material to the job site. (US EPA 2000)

344. The primary emission sources associated with HMA production are the dryers, hot bins, and mixers, which emit particulate matter (PM) and a variety of gaseous pollutants. Other emission sources found at HMA plants include storage silos, which temporarily hold the HMA; truck load-out operations, in which the HMA is loaded into trucks for hauling to the job site; liquid asphalt storage tanks; hot oil heaters, which are used to heat the asphalt storage tanks; and yard emissions, which consist of fugitive emissions from the HMA in truck beds. Emissions also result from vehicular traffic on paved and unpaved roads, aggregate storage and handling operations, and vehicle exhaust. (US EPA 2000)

345. The PM emissions associated with HMA production include PM-10 and PM-2.5, hazardous air pollutant metals, and organic compounds. The gaseous emissions associated with HMA production include sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC).

346. As mentioned earlier, the contractor may elect to purchase from already established facilities for which emission controls are in place. In the event the contractor sets up temporary facilities, these must be established at least 500 m from any sensitive receptor (schools, hospital or residential area).

347. Dust emissions controls need to be in place for fugitive dust, as outlined for other project development locations. In order to limit dust emissions, maintenance of general site operations should include:

- Maintaining dust collection equipment to prevent any leaks
- Developing a buffer zone that surrounds operations that generate dust
- Instituting a whole management approach for plant operations, as well as the delivery system
- Checking regularly for leaks in filter fabric, cartridge filters, and suctions and shrouds
- Installing audible alarms on storage silos to avoid overfilling
- Keeping sand and aggregates under cover so that materials are not dispersed by wind
- Using an enclosed batch mixer and spray to limit dust emissions

6.4.6 Air Emissions during Operations

Emission Source

348. The potential increase in air emissions during operations will be principally due to bus vehicle exhaust. However, these need to be balanced against vehicles taken off the road as a result of BRT operations. According to the ODBM interim report (EE 2017), buses may either be based on a diesel or an all-electric/hybrid propulsion system. For the diesel-fueled option, the vehicle must meet a minimum EURO III emission standard, but must be capable of operating with EURO II fuel, e.g. sulphur content and ash are higher than with a Euro-III fuel. The latter is because currently only diesel fuel meeting a EURO II emission standard is available in Pakistan. Hence,

EURO II fuel would need to be utilized in the vehicles until such time as a cleaner fuel is available and full benefit can be gained by a propulsion system capable of meeting a EURO III emission standard.

349. While it is unclear whether the Euro-III emission standard will be met, the Pakistan Tier II standard is achievable, and is comparable to the Euro-II standard, as set out in Table 6-4. The Tier II standard properly can serve as a benchmark for emission levels from the buses once they are in operation.

350. The issue of fuel and propulsion system is not yet decided; however, the combination engine type capable of operating on Euro-II fuel, combined with a hybrid propulsion system (such as regenerative braking), causes problems since few suppliers manufacture such equipment. The preferred choice of fuel and propulsion is CNG-hybrid, which may be possible if certain constraints can be overcome: a) a prohibition on fleet use of CNG can be abrogated for public service vehicles (such as the BRT); and b) a reliable supply chain can be established for CNG, which is imported from Qatar. TMTD would also need to petition for permission to establish a CNG fueling station; which is currently prohibited.

Predicting Emissions during Operations

351. Sophisticated models such as the suite of air emissions models associated with Breeze software are based on the original methods advanced by Pasquill and Turner and then later developed by the US EPA.

352. These models incorporate detail related to emissions from a suite of sources, atmospheric and terrain conditions, and rely on the statistical spread of pollution in orthogonal directions according to standard deviations of Gaussian distributions and modifying factors. During operation modelling of air quality should be undertaken to characterize the existing situation and calibrate the model using inputs of actual ambient air quality as measured under differing atmospheric conditions, in order to determine the effect on air quality.

353. The need to describe the modal shift in vehicle use due to introduction of the BRT is the limiting factor. Traffic of some types can be expected to reduce, resulting in a reduction of emissions. It may also be that private vehicle traffic will grow to fill the space vacated by improved public transport. Nor is it clear how much of the modal shift involves vehicles that currently run on CNG, which is not available for use by the new fleet of buses. Performing calculations to quantify these variables depends on accurate data for future time horizons that is not expected to be available from any of the ongoing planning efforts. For these and other reasons, a more simplified approach has been used, as described in the following

354. The prediction is based on comparison of daily ridership for various modes of transport with and without the project, combined with available emission factors for primary pollutants. Average annual daily traffic counts at nine equally spaced locations along the alignment were obtained under an EPCM service contract (the ‘traffic study’). Using these data, an analysis was performed as follows:

- Modal shares for passenger transport is determined for four categories of vehicle (motorcycle, private auto, minibus, and large bus), using passenger car units (PCUs) derived from these data.

- PCUs are distributed based on the modal share of observed traffic both without (existing) and with the project; with the latter considered a base-year ridership (e.g. no phase-in period).
- The percentage of trips (private and public) done by means of the BRT is variable. This is the modal share captured by the BRT. In the present analysis, a range of values is assumed, from 20% to 40%, to characterize how modal share affects emission levels.
- Emission factors taken from the literature are combined with vehicle use for existing and base year BRT operations, the difference between these values representing the expected change in pollutant levels as a result of the project.

Emission Factors

355. Emission factors are taken from reports available through the World Bank (Faiz 1990, 1996) (Table 6-6) along with comparative data for buses fueled by CNG, diesel and hybrid propulsion systems (Bradley 2013).(Table 6-7)

Table 6-6: Road Vehicle Emission Factors (Historical Data)

Category of Area/Zone	gm/vehicle-km				
	CO	HC	Nox	Sox	PM
Motorcycle (4-stk)	20.00	2.39	0.15	0.01	0.03
Passenger car	33.66	2.63	1.05	0.21	0.33
Small bus/van	47.18	5.81	1.88	0.26	--
Large bus (diesel)	7.66	5.50	12.37	15.27	0.75
	gm/vehicle-km				
	CO	HC	Nox	Sox	PM
Motorcycle(4-stroke)	20.00	2.39	0.15	0.01	0.03
Passenger car	33.66	2.63	1.05	0.21	0.33
Small bus/van	47.18	5.81	1.88	0.26	--
Large bus(diesel)	7.66	5.50	12.37	15.27	0.75
	gm/vehicle-km				
4-s MC <250 cc	15	1	0.21		0.02
MC (Thai)	19	2.9			
1984 buses (US)	27.4	1.71	12.4		2.46
NY Transit buses		5.22	34.89		2.66
Autos 1400-2000 CC	7.8	1.5	1.5		
Private care (Chile)	28	1.5	1.4		0.06
India (1994 data)					
Car/Jeep	23.8	3.5	1.6	0.1	
Taxi	29.1	4.3	1.9	0.1	
Two-wheeler	8.2	5.1			
Auto-rickshaw (3-wheeler)	12.5	7.8		0	
Light-duty vehicles	40	6	3.2	0.08	
Motorcycles	17	10	0.07	0.02	
Diesel (Table A2.2.12)					
Light-duty vehicles	1.1	0.28	0.99	0.39	2
Heavy-duty truck	12.7	2.1	21	1.5	3

Source: Faiz 1990, 1996

Table 6-7: Emission Factors, Buses: Mean and Median Values tested in USA

		Gm/km		
		CO	HC	NOx
Mean	CNG	4.69	0.02	0.29
Median	CNG	4.16	0.02	0.28
Mean	Diesel	0.10	0.02	0.73
Median	Diesel	0.08	0.01	0.67
Mean	Hybrid	0.10	0.00	0.70
Median	Hybrid	0.09	0.01	0.53

Traffic Count and Distribution among Modes

356. Summary traffic count data are shown in Table 6-8. While summarizing traffic across all categories of vehicle, only four types comprising public transport are included in the distribution. These give rise to some 1.14 million PCUs for the daily average, which are distributed according to the percentages for private autos, motorcycles, mini-buses and large buses for the existing or 'without project' scenario, and then including the metro, assuming a variable share of ridership (starting at 20%) in Table 6-9

Table 6-8: Average Annual Daily Traffic at Nine Locations along the BRT Corridor (MMP Traffic Survey)

AADT (vehicles)	Motor cycle	Car	Rickshaw	Pickups	Mini Bus	Large bus	2-Axle	3-Axle	4-Axle	5 or More-Axle	Bicycle	Animal Cart
Jail Chowrangi	32,123	28,199	5,943	1,050	151	110	305	37	0	0	0	0
Chandni Chowk	163,418	107,624	33,562	13,299	3,290	792	3,348	512	58	52	67	129
Edhi Center	117,859	77,934	25,188	28,422	1,724	449	7,340	121	3,326	2	2	5
Hassan Square	144,012	99,823	30,154	9,236	3,001	423	3,551	708	78	23	46	105
Bait ul Mukaram	25,107	16,198	5,591	2,031	41	18	214	16	4	0	3	65
Karachi University	1,247	1,404	322	246	10	11	27	39	0	0	1	5
Mausamiyat	56,184	48,386	14,457	6,693	1,452	355	2,584	594	155	42	30	51
Safoora	47,415	41,674	10,241	6,295	1,243	368	2,877	454	66	57	10	16
Tank Chowk	64,213	81,295	5,625	7,848	1,417	700	6,632	1,192	537	192	42	22
Total	651,578	502,537	131,083	75,120	12,329	3,226	26,878	3,673	4,224	368	201	398
PCU Factors	0.5	1	0.75	1	2	2.5	3	3	3.5	3.5	0.2	4
Total PCUs	325,789	502,537	98,312	75,120	24,658	8,065	80,634	11,019	14,784	1,288	40	1,592
% of total	28%	44%	9%	7%	2%	1%	7%	1%	1%	0%	0%	0%

Table 6-9: Distribution of PCUs to Transport Modes, with and without the BRT

					PCUs				
	w/o BRT		BRT share =	20%	PCUs=	1,143,838	Vehicle-segments		
	raw	normalized	W/ BRT		w/o	w/	PCUf	w/o	w/
Motorcycle	28%	38%	30%		432,786	346,229	0.5	865,572	692,458
Car	44%	58%	47%		667,582	534,066	1	667,582	534,066
Mini Bus	2%	3%	2%		32,756	26,205	2	16,378	13,103
Large bus	1%	1%	1%		10,714	8,571	2.5	4,285	3,428
BRT	0%	0%	20%		-	228,768	15	0	15,251
	75%	100%	100%						

357. The estimate utilizes emission factors made up of the 1990 values provided by the World Bank along with bus emission factors derived from testing in the USA. Assuming an average trip length of 4 km, and variable capture of ridership by the BRT from 20 to 40%, emission reductions (tons per day) on the order of those shown in Table 6-10 are possible.

Table 6-10: Emission Reduction due to BRT for Primary Pollutants

	T-pollutant/day				
% Ridership for BRT	CO	HC	NOx	SOx	PM
20%	32.46	3.15	0.70	0.18	0.20
30%	48.70	4.73	1.05	0.27	0.30
40%	64.93	6.31	1.40	0.36	0.40

358. While this analysis cannot be considered conclusive, it indicates that introduction of new buses built to a higher standard of pollution control, and given their adoption by the public, results in improved air quality in the vicinity of University Rd.

359. A detailed study of the effect on air quality stemming from BRT is described in the literature. (Bel and Holst 2012) Mexico City's bus rapid transit (BRT) network, Metrobus, was introduced in an attempt to reduce congestion, increase city transport efficiency and cut air polluting emissions. In June 2005, the first BRT line in the metropolitan area began service. Using statistical regression techniques and extensive monitoring, an impact assessment of the BRT system on air polluting emissions was completed. The air pollutants considered were carbon monoxide (CO), nitrogen oxides (NOX), particulate matter of less than 2.5 μm (PM2.5), particulate matter of less than 10 μm (PM10), and sulfur dioxide (SO2). The analysis uses real field data from air quality monitoring stations for periods before and after BRT implementation. Results show that BRT constitutes an effective means for reducing emissions of CO, NOX, PM2.5 and PM10.

360. BRT is generally expected to result in a reduction of air emissions by removing older and less efficient vehicles from the roadway, while introducing newer vehicles that carry more passengers per unit of fuel consumption, with less unannounced stops. This is just one of the overarching justifications for introducing BRT; the work by the ODBM consultant, in particular, bears out the conclusion that BRT is justified on its own merits, including reduction of air emissions. BRT is a cost-effective way forward for public transport, with added benefit due to reduced air emissions as part of the package.

361. Further to the work of understanding the impact on air emissions and greenhouse gases, the ADB commissioned a study by Grutter Consulting (Germany) aimed at a rapid assessment of bus technology options for the BRT Karachi and of the GHG and air quality impacts related to these technology options. The overall conclusions of this study concerning the average reduction of primary air pollutants over a 12-year period are shown in Table 6-11 and are in general comparable to the findings of the EIA, in which the range of NOX and SOX reduction is 250—510 TPA and 64—129 TPA, respectively.

Table 6-11: Annual Net Reduction of Primary Pollutants Associated with BRT Operation

Parameter	Unit	Diesel buses	CNG buses	Diesel hybrids	CNG hybrids
NOx reduction	tNOx	225	558	306	572

$PM_{2.5}$ reduction	tPM2.5	-2.5	4.8	-1	4.8
SO_2 reduction	tSO2	7	15	9	15

362. The report summarizing the results of the study are found in Appendix C See also section 6.17 for discussion of its findings related to GHG emissions.

6.5 Noise

6.5.1 Impact Scenarios

363. Construction: Noise impacts can occur during removal of existing pavement, construction of BRT driving lanes, excavation of underpasses, construction of overpasses and cross-structures that bridge the driving lanes, and site preparation and construction of the depot and other ancillary facilities. Trucks involved with materials transport and spoil removal generate noise along haul routes. Noise impacts are due to the operation of equipment either as 'fixed plant' (onsite stationary equipment), 'mobile plant in a defined area' (onsite, performing repetitive actions), or 'mobile plant using a regular well-defined route' (e.g. haul roads) (BSI 2009).

364. Operations: Diesel-hybrid buses will run in dedicated lanes on either side of a centerline median along New MA Jinnah Rd, University Rd, Malir Link Rd and MA Jinnah Ave that constitute the alignment for the Red Line. Underpasses will provide crossings at some locations, depressed 5-6 m below grade to effect the passage and provide U-turn and access for mixed traffic. Existing flyovers are in place at major intersections, and other elevated sections will be constructed. The width of right-of-way (ROW) varies, but in general is 50 m; point of impact for both noise and vibration effects is the edge of right-of-way, or alternatively the face of the nearest building, whichever is greater[13]. Presence of the carriageway along the median forces mixed traffic outward closer to the edge of the ROW, potentially increasing noise levels from mixed traffic at the point of reception. The path of travel for noise and vibration involves deflection around objects (for noise) and, in depressed sections up and over embankments or sidewalls of the traffic lane as it passes through these transitions. While sound travels through the air, vibration waves travel through the ground.

365. Noise impacts at depot sites for construction and operations are addressed in Section 6.15.3.

6.5.2 Noise Standards and Criteria

General

366. Ambient noise standards are set by Sindh EPA/TECH/739/2014 published in the Sindh Government Gazette on 28 Jan 2016 and are set out in Table 6-12. In addition, under the Sindh Environmental Quality Standards for Motor Vehicle Exhaust and Noise, issued under the same proclamation, a noise limit is set, applicable across all categories of vehicle (in-use, diesel vehicles of all types (passenger car, light duty, and heavy-duty diesel engines) and petrol vehicles) of 85 dBA measured at 7.5 m from the sound source. No particular noise standard is set for construction, nor does the SEQS provide any qualification of its standard for conditions surrounding construction activity. Motor vehicle exhaust and noise emissions standards might be construed to apply to equipment operating within a construction zone. This is contrary to

[13] Point of impact is the location of a receptor, assumed to be an occupied structure. Many buildings along the alignment are set back from the roadway. In practice right-of-way is the point where a noise impact is assessed.

what is often practiced in other countries where construction noise limits are distinguished from other standards, as described in the following section.

Table 6-12: Sindh Environmental Quality Standards (SEQS) for Noise

S.N.	Category of Area/Zone	Limit in dBA (Leq[1, 2])	
		Day (6:00am-10:00pm)	Night(10:00pm-06:00am)
1	Residential Area (A)	55	45
2	Commercial Area (B)	65	55
3	Industrial Area (C)	75	65
4	Silence Zone (D)	50	45

[1.] Limits came into effect since 1 Jan 2015.

[2.] This is taken to be a one-hr Leq.

Notes accompanying the original proclamation:

Silence zone: Zones which are declared as such by the competent authority. An area comprising not less than 100 m around hospitals, educational institutions and courts.

Mixed categories of areas may be declared as one of the four above-mentioned categories by the competent authority

367. The WB/IFC Environmental, Health and Safety Guidelines set out noise level guidelines (Table 6-13) that are themselves derived from the Guidelines for Community Noise, World Health Organization (WHO), 1999. IFC also specifies that additional noise sources should not "result in a maximum increase in background levels of [greater than] 3 dB at the nearest receptor location off-site.

Table 6-13: WB/IFC Noise Level Guidelines (from IFC EHS Guidelines 2007)

Category of Area/Zone	One Hour Leq (dBA)	
	Day	Night
Receptor	07:00—22:00	22:00—07:00
Residential; institutional; educational	55	45
Industrial; commercial	70	70

Standards for use in Construction

368. Construction noise is not regulated by a separate standard in the NEQS of Pakistan; in general, SEQS ambient noise limits should apply; however, these are often exceeded in practice by baseline, or background, noise conditions. Ambient noise levels along the BRT corridor (see Figure 6-2) already exceed SEQS noise limits in most cases.

369. The SEQS for ambient noise is overly restrictive for construction activity. Standards used in other countries, and how these standards account for ambient noise conditions, should be considered. These are summarized in Table 6-14. For each country the levels are based on different methodologies, dependent on local conditions, but in virtually every case, the recommended standard for construction activity is higher than the corresponding SEQS ambient standard.

370. Based on these considerations, it is appropriate to set a project construction noise standard that is in general higher than the noise limits set by the SEQS.

Table 6-14: Noise Criteria and Standards Considered in Setting Limits for BRT Red Line

	Standard or Criteria	Day Time (Leq)	Night Time (Leq)
Japan	Using heavy equipment with high noise level (piling, excavating etc.)	85 dB (Maximum)	-
Singapore	Hospitals, schools, institutions of higher learning, homes for the aged sick, etc.	60dB (7 am-7 pm, 12 hrs)	50 dB (7 pm-7 am, 12 hrs)
	Residential buildings located less than 150m from the construction site where the noise is being emitted	75 dB (7 am-7 pm, 12 hrs)	60dB (7- 10 pm, 55 dB)
	Other Buildings	75 dB (7 am-7 pm, 12 hrs)	65 dB (7 pm-7 am, 12 hr)
UK	In rural, suburban and urban areas away from main road traffic and industrial noise	70 dB (8.00-18:00)	-
	Urban Areas near main roads	72 dB (8.00-18:00)	-
USA criteria	Residential	80 dB (8 hrs)	70 dB (8 hrs)
	Commercial	85 dB (8 hrs)	85 dB (8 hrs)
	Urban Area with high ambient noise level (>65 dB)	Ambient Noise Level +10 dB	
	Noise Regulation Act, Japan (law no 98, 1968, Amended No 33, 2006)		
	Environmental Protection and management Act in Singapore (Chap. 94 A, Section 77, revised in 2008)		
	British standard BS5228-2009 +AL1:2014 "Noise and vibration control on open and construction sites"		
	Transit Noise and Vibration Impact Assessment, U.S. Department of Transportation, 2006		

371. Target noise limits are therefore set for construction as follows:

- Construction activity near residential areas and hotels where it is necessary to sleep shall comply with a standard of 75 dB and 60 dB, for day and night times, respectively (similar to Singapore).
- Silence zone will correspond to a standard of 60 dB and 50 dB, for day and night times, respectively[14].
- Noise levels at commercial and industrial areas shall be limited to 85 dB, applied to day and night, since these are not residential areas, as recommended in both Japan and US standards.
- Where ambient noise levels are high, the noise standard of "existing ambient level + 3 dB" is adopted, in accordance with IFC noise guidelines.

372. Table 6-15 summarizes the standards proposed for construction noise control for the Project. These target noise levels are similar to noise standards for construction in use in other countries.

Table 6-15: Target Noise Level at Construction Phase (dBA)

Category	Day Time (Leq)	Night Time (Leq)
Residential Area (A)	75	60
Commercial Area (B)	85	85
Industrial Area (C)	85	85
Silence Zone (D)	60	50

[14] Whether this general limit protects hospitals and hotels sufficiently, and whether courts and schools need protection at night, will need to be assessed on a case by case basis.

Areas with ambient noise level (>65 dB)	Ambient Noise Level +3 dB	Ambient Noise Level +3 dB

Notes: Evaluation point is at boundary of buildings
Daytime: 6:00-22:00, Night time: 22:00-6:00
Silence zone: typically, hospitals, educational institutions and places of religious worship

373. Despite the use of standards, construction noise is difficult to regulate. The Contractor should take all reasonable steps to reduce noise to the lowest practical level, while recognizing that some periods of high noise may be unavoidable. Local citizens should be advised in advance of possible high noise (and vibration) activity and informed of a complaint/query system which should investigate all complaints and recommend control measures where necessary. There should also be flexibility to permit by agreement higher noise levels for shorter durations where otherwise general disturbance of construction works would be increased by extended quiet working, as, for example, residents may prefer two disturbed nights of loud demolition to two weeks of demolition just below the limit.

374. As inferred above, local citizens affected by noise can register a complaint through the project's grievance redress mechanism, providing the means to identify a specific problem that otherwise would not be apparent, and enact control measures directed specifically at the problem.

6.5.3 Procedure for Estimating Noise Impacts

375. Noise levels can be predicted for both construction and operations using similar means. A Sound pressure Level (SPL) from combined sources[15], combined with distances from sources to receiver, and modified by the presence of screening by barriers, reflection of sound, and soft-ground attenuation, produces an equivalent noise level over a standard monitoring interval (generally one hour). Specific aspects of this procedure may differ, but in general US and British approaches are similar in the overall approach, as are construction and operations noise predictions.

376. Calculated noise levels are compared with baseline noise levels existing along the alignment, obtained through monitoring. A comparison is made to determine whether the added burden from noise sources increases the perceived noise level, and whether noise due to construction is expected to exceed the project noise standard.

377. The FTA guidance document "Transit Noise and Vibration Impact Assessment" provides methods and software for predicting construction and operations noise for transit projects, which are generally applied herein.

6.5.4 Baseline Noise Levels within Project Area

378. Noise levels were determined through two rounds of monitoring along the alignment at locations listed in Table 6-16 These locations were selected due to the presence of sensitive receptors – schools, parks, hospitals and mosques – in the nearby vicinity. Monitoring was conducted at the property boundary with the roadway at the closest point orthogonal to the receptor in relation to the noise source (the roadway). Data were taken by SUPARCO and are provided in Table 6-18. Temperature varied from 11 to 28 C during the sampling, with an average of 18-21 C. Humidity varied widely, from 12 to 88%. Barometric pressure was consistently in the range of 110—120

[15] FTA TNVIA uses sound pressure levels (SPL), measured in decibels (dB), whereas UK BS5228 provides SPL and sound power level (SWL) data.

kPA. Noise data are provided as one-hour Leq values across a 24-hour cycle. In comparison with SEQS ambient noise limits, 69 % of 552 values exceeds the standard for commercial land use, and 90 % for residential land use.

379. These data are combined to show the maximum Leq for daytime (6 AM to 10 PM), and night (10 PM to 6 AM) in Figure 6-2. With only one exception (night time value at Mir Usman Park), maximum Leq's recorded for day and night periods exceed ambient standards for both commercial and residential land uses. If average values are considered, the average of nighttime (10 PM to 6 AM) recorded noise levels exceed the SEQS standard for commercial use at 13 of 23 locations at the time and date noise levels were measured, whereas the average of daytime recorded noise levels exceed the standard for commercial use at 3 locations. None of these averages (daytime or nighttime) at 23 locations is within the standard for residential use (day or night).

Table 6-16: Noise Monitoring Locations

1	Mazar e Quaid	14	Nadeem Medical Center
2	Jamia Masjid Tayyab	15	Karachi National Mgt. Institute
3	Dawood Engineering college	16	Andlus Modern Hospital
4	Mir Usman Family Park	17	Chiniot Islamia Public School
5	Askari Park	18	Karachi University
6	Babar Hospital	19	Shiekh Zaid Islamic Centre
7	Civic Center	20	Govt Girls School
8	Hasan Sq.	21	Rehmania Mosque
9	Ashfaq Memorial Hospital	22	Gulistan-e-Johar Bus Depot
10	Federal urdu university	23	GBGP School
11	Jamia masjid Akbar	24	Tank Chowrangi
12	Sir Syed University	25	Malir Bus Depot
13	NEPA		

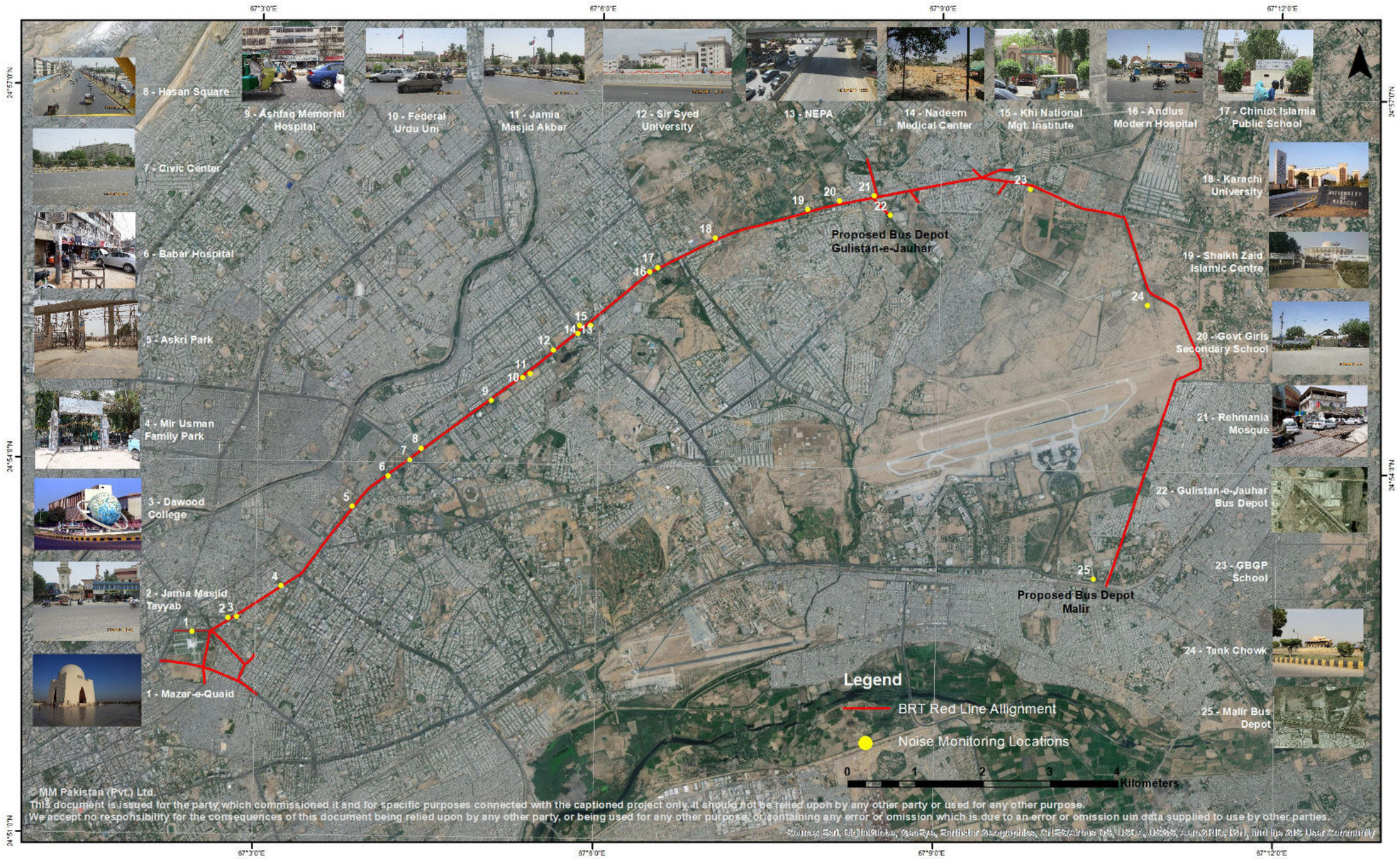
6.5.5 Noise analysis and distance

380. The distance from one noise intervention point to the subsequent noise location of concern monitored is depicted in Table 6-17 below.

Table 6-17: Distance between subsequent noise monitoring points

Site No.	From	To	Distance
Site 1	Mazar e Quaid	Jamia Masjid Tayyab	0.63 km
Site 2	Jamia Masjid Tayyab	Dawood College	0.12 km
Site 3	Dawood College	Mir Usman Family Park	0.79 km
Site 4	Mir Usman Family Park	Askri Park	1.60 km
Site 5	Askri Park	Babar Hospital	0.68 km
Site 6	Babar Hospital	Civic Center	0.41 km
Site 7	Civic Center	Hasan Sq.	0.25 km
Site 8	Hasan Sq.	Ashfaq Memorial Hospital	1.27 km

Site 9	Ashfaq Memorial Hospital	Federal Urdu University	0.58 km
Site 10	Federal Urdu University	Jamia Masjid Akbar	0.11 km
Site 11	Jamia Masjid Akbar	Sir Syed University	0.51 km
Site 12	Sir Syed University	NEPA Roundabout	0.43 km
Site 13	NEPA	Nadeem Medical Center	0.10 km
Site 14	Nadeem Medical Center	Karachi National Mgt. Institute	0.11 km
Site 15	Karachi National Mgt. Institute	Andlus Modern Hospital	1.18 km
Site 16	Andlus Modern Hospital	Chiniot Islamia Public School	0.13 km
Site 17	Chiniot Islamia Public School	Karachi University	0.95 km
Site 18	Karachi University	Shaikh Zaid Islamic Centre	1.43 km
Site 19	Shaikh Zaid Islamic Centre	Govt Girls Secondary School	0.48 km
Site 20	Govt Girls Secondary School	Rehmania Mosque	0.51 km
Site 21	Rehmania Mosque	Gulistan-e-Jauhar Bus Depot	0.20 km
Site 22	Gulistan-e-Jauhar Bus Depot	GBGP School	2.17 km
Site 23	GBGP School	Near Tank Chowk	2.70 km
Site 24	Tank Chowk	Malir Bus Depot	5.20 km
Site 25	Malir Bus Depot		



Consultants	**Client**	**Financing Agency**	**Rev**	**Date**	**Drawn**	**Description**	**Ch'k'd**	**App'd**	**Title**
MOTT MACDONALD / MMP REGIONAL DESIGN CELL Dolmen Estate, 1st Floor, 18-C Union Commercial Area Shaheed-e-Millat Road Karachi Tel: (92) (21) 34320527, 34385312 Fax: (92) (21) 34524819 E-mail: bdu.kh@mmpakistan.com	Sindh Mass Transit Authority (SMTA), Transport & Mass Transit Department (TMTD), Government of Sindh	ADB ASIAN DEVELOPMENT BANK **Project**: Detailed Engineering Design, Procurement and Construction Management (EPCM) - Karachi BRT	00	24-05-18	HHK	Location and Pictures	AM	MAS	25 Noise Monitoring Locations Karachi BRT - Red Line
									Drawing No. Location Plan

Designed	Hammad Hayat
Drawn	Hammad Hayat
Checked	Aqeel Magsi
Approved	M.A. Shishmahal
Sclae. 1 : 50,000	
Rev 0	Status FINAL

Figure 6-1: Noise Monitoring with sampling interventions

Table 6-18: Hourly Leq Noise data taken over 24 hours on 22-27 Jan and 14-16 Feb 2018

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Site Name	Mazar e Quaid	Tayyab Masjid	Dawood Engineering College	Mir Usman Family Park	Askari Park	Babar Hospital	Civic Center	Federal Urdu university	NEPA	Hasan Sq.	Ashfaq Memorial Hospital	Jamia Masjid Akbar	Sir Syed University	Nadeem Medical Center	Karachi National Mgt. Instute	Jamia Madrasat-ul-Islam	Chiniot School	Karachi University	Shiekh Zaid Islamic Centre	Govt Girls School	Rehmania Mosque	GBGP School	Tank Chowrangi
Lat	24° 52' 36.94"	24° 52' 43.8" N	24° 52' 44.53"	24° 52' 59.58"	24° 53' 38.35"	24° 53' 53.22"	24° 54' 1.17"	24° 54' 41.64"	24° 55' 3.17"	24° 54' 6.83"	24° 54' 30.4" N	24° 54' 43.55"	24° 54' 55.11"	24° 55' 5"	24° 55' 7.06"	24° 54' 33.23"	24° 55' 35.46"	24° 55' 50.1" N	24° 56' 4.41"	24° 56' 8.84"	24° 56' 11.44"	24° 56' 15.62"	24° 55' 20.3"
Long	67° 02' 27.05"	67°02' 45.8" E	67° 02' 50.41"	67° 03' 13.69"	67° 03' 50.85"	67° 04' 9.51"	67° 04' 20.89"	67° 05' 20.1"	67° 05' 49.17"	67° 04' 26.83"	67°05' 3.7" E	67° 05' 23.92"	67° 05' 36.21"	67° 05' 49.93"	67° 05' 55.63"	67° 06' 26.7"	67° 06' 30.84"	67°07' 1.1" E	67° 07' 49.88"	67° 08' 6.57"	67° 08' 25.1"	67° 09' 47.7"	67°10' 50.5"
Time																							
0	60.1	65.1	58.1	46.8	50.5	51.1	49.0	56.3	52.8	59.2	65.6	50.1	53.5	51.3	49.8	50.0	51.8	61.5	63.7	61.3	48.8	65.1	56.5
100	60.6	59.6	56.8	48.1	50.1	52.8	48.5	56.6	50.5	48.1	61.0	45.5	54.0	51.4	48.3	51.0	51.9	56.3	59.8	63.7	45.0	61.6	59.8
200	57.7	61.8	54.5	43.5	51.0	50.8	43.8	50.3	48.5	46.2	63.3	46.5	49.5	49.0	45.3	48.3	50.3	52.6	55.0	58.5	46.5	61.0	57.0
300	53.5	58.3	56.3	42.5	45.3	49.1	42.8	49.3	50.3	43.5	60.8	45.4	49.5	43.8	42.8	46.8	48.5	57.8	53.7	56.4	44.6	57.3	58.6
400	50.7	56.9	50.8	44.1	44.1	49.0	42.8	46.8	51.0	50.1	57.9	47.5	44.4	41.1	44.4	44.0	47.3	52.4	53.9	54.1	42.0	53.8	55.5
500	51.1	54.2	51.8	47.1	48.1	44.7	47.1	46.5	47.6	54.5	56.2	46.3	38.8	41.1	41.1	45.0	43.8	55.9	51.1	49.8	43.5	49.7	53.3
600	57.0	59.4	60.1	46.2	48.1	47.8	45.8	50.5	48.5	61.6	58.4	45.8	39.8	46.0	43.8	45.8	45.8	60.6	46.8	46.1	44.0	48.2	52.4
700	61.5	63.9	62.1	51.0	50.6	51.8	73.8	54.8	64.8	63.0	66.4	52.1	52.7	48.8	45.6	49.8	44.6	65.9	57.0	51.0	48.7	54.9	54.9
800	69.1	67.2	70.6	51.1	56.2	53.3	77.6	70.5	59.1	68.0	78.5	54.3	71.0	58.7	47.2	58.7	55.1	67.3	59.9	58.3	50.4	62.1	53.3
900	73.8	74.6	73.1	50.5	58.1	52.5	78.1	73.1	54.3	72.5	77.1	60.1	70.5	63.5	51.8	61.0	56.0	69.2	61.3	60.4	52.3	61.3	70.1
1000	77.1	76.5	79.1	52.8	60.1	54.1	83.0	76.8	77.1	75.5	72.8	64.1	71.8	71.8	53.1	65.9	61.1	62.7	63.3	63.8	62.5	67.4	63.3
1100	79.7	68.9	82.5	55.8	62.3	59.1	82.3	80.3	80.6	75.9	68.2	72.0	69.9	75.7	59.1	64.5	68.9	68.2	64.4	66.0	57.3	65.8	64.9
1200	77.5	65.7	82.4	57.8	63.3	61.8	83.1	82.8	76.6	72.9	71.6	74.1	71.8	79.3	65.8	66.4	71.4	65.6	64.7	67.2	64.7	71.9	67.4
1300	79.6	70.5	82.3	59.5	66.1	65.1	83.8	77.5	82.3	76.6	68.2	75.7	80.5	78.6	69.8	68.6	73.9	66.7	72.1	72.7	69.0	70.4	71.1
1400	77.6	66.3	77.6	69.5	64.8	66.2	82.3	77.3	78.8	78.5	70.1	78.8	78.2	79.4	73.5	68.0	70.7	64.3	74.9	71.1	67.9	75.0	65.8
1500	79.8	67.8	80.5	67.8	67.1	69.1	78.5	80.3	81.2	79.5	66.9	76.6	69.0	78.5	71.7	69.5	72.7	67.5	73.5	71.0	69.4	68.1	69.3
1600	82.0	72.9	82.3	69.8	72.3	73.8	79.8	81.1	81.1	81.1	68.5	82.3	77.2	80.8	76.0	74.7	75.9	68.7	76.9	74.5	72.6	75.9	78.4
1700	82.3	74.7	84.6	70.8	72.3	76.5	83.3	75.3	77.1	79.0	72.4	78.5	80.8	81.8	75.9	78.3	77.1	70.3	78.3	76.5	71.8	74.7	77.1
1800	77.6	78.1	82.1	72.8	76.2	77.5	76.5	75.7	77.6	77.6	80.6	79.1	80.8	79.1	76.5	73.5	76.1	72.8	75.9	76.4	69.3	70.5	75.9
1900	77.8	79.5	80.8	70.3	76.6	77.6	78.1	74.3	76.5	70.0	69.3	70.5	76.8	77.8	72.4	72.8	71.8	68.2	75.1	74.1	65.1	69.0	74.7
2000	73.8	74.7	79.8	66.8	77.5	79.1	75.8	69.6	72.3	76.8	70.6	72.5	80.0	77.5	72.0	71.1	70.3	65.6	71.3	71.7	60.8	70.1	71.4
2100	69.5	73.5	76.0	60.0	71.8	73.1	72.5	66.5	70.6	72.3	75.1	69.5	72.7	73.1	70.6	68.5	71.5	70.1	68.3	69.0	58.8	65.5	71.3
2200	63.6	73.4	74.0	53.3	69.5	68.5	68.5	60.0	67.0	70.3	72.8	64.6	69.5	68.9	70.1	64.3	65.6	67.8	68.2	66.5	60.2	67.9	61.8
2300	62.3	75.3	60.0	50.5	59.2	59.0	59.5	56.8	63.8	64.8	76.8	59.2	61.8	65.5	68.6	55.0	59.7	69.9	65.1	62.3	54.4	65.0	62.1

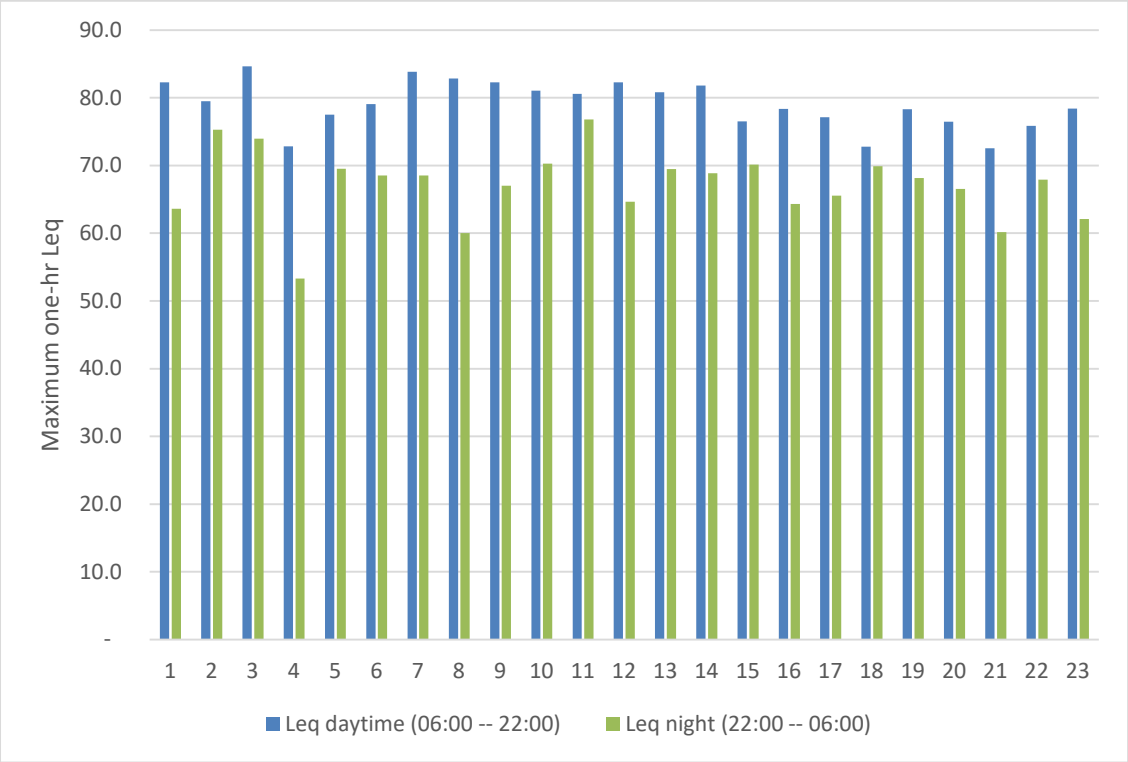


Figure 6-2: Noise Levels, 22-27 Jan and 14-16 Feb 2018

6.5.6 Estimation of Noise from Construction Activity

381. The calculation of construction noise levels expected from various combinations of equipment is based on methods provided in FTA 2006. This is considered a general though quantitative assessment as defined in the guidance manual. Maximum noise levels are obtained by combining the noise generated by the nosiest two pieces of equipment operating simultaneously at a site, using the noise emission levels for items of equipment required to perform the work expressed in dBA (Leq measured at 50 ft (16.2 m) from the point of generation—see Table 6-19). The point of impact on the receptor is taken to be approximately at the face of the nearest building, as determined by actual conditions, or as a default value, 25 m from the sound source. While other sensitive receivers may be present at a greater distance from the noise source, this represents a worst-case condition, which, if met, would indicate other receptors would not be affected.

382. Noise emission levels for the two noisiest pieces of equipment are combined, and this value is compared with the existing noise level at the location to determine the contribution of equipment noise to existing or background noise. As a practical matter, existing noise is taken to be an average of the one-hour Leq's measured over the respective time duration (daytime: 06:00—22:00; nighttime: 22:00—06:00). A comparison is also made with the project standards for construction noise.

383. Noise levels at the point of reception are calculated using the following formula:

L*eq*(*equip*) = E.L. + 10 log(U.F.) – 20 log(D/50) – 10G log(D/50), where

Leq (equip) is the Leq at a receiver resulting from the operation of a single piece of equipment over a specified time period

E.L. is the noise emission level of the particular piece of equipment at the reference distance of 50 feet (16.2 m)

G is a constant that accounts for topography and ground effects (assumed to be 0 in a general analysis)

D is the distance from the receiver to the piece of equipment, and

U.F. is a usage factor that accounts for the fraction of time that the equipment is in use over the specified time period. The usage factor is considered to be 1, since full power operation over a period of one hour is common for most construction equipment, and the equivalent noise level is averaged over one hour.

384. Noise emission levels from individual items of equipment are added logarithmically, and the formula applied to determine the noise level at the receptor.

Table 6-19: Noise Emission Level per Equipment Type

Air Compressor	**81**	**Paver**	**89**
Backhoe	80	Pile-driver (Impact)	101
Compactor	82	Pile-driver (Sonic)	96
Concrete Mixer	85	Pneumatic Tool	85
Concrete Pump	82	Pump	76
Concrete Vibrator	76	Rail Saw	90
Crane, Derrick	88	Rock Drill	98
Crane, Mobile	83	Roller	74
Dozer	85	Saw	76
Generator	81	Scarifier	83
Grader	85	Scraper	89
Impact Wrench	85	Shovel	82
Jack Hammer	88	Truck	88
Loader	85	From FTA 2006, Ch 12.	

385. The analysis provides a means for determining whether the construction activity contributes significantly to existing noise levels or exceeds proposed noise limits at a given location. As such it is considered a screening, or initial assessment, method.

386. While there are a variety of activities underway at these locations, those that engage the noisiest types of mobile and stationary gasoline, diesel and pneumatic equipment operating concurrently will generate the highest noise levels. Since noises from multiple sources are combined according to the log of their intensity, noise levels are dominated by the noisiest two pieces of equipment (FTA 2006).

387. According to the conceptual plan provided by the ODBM consultant, the alignment consists of at-grade and depressed sections where BRT lanes pass underneath cross traffic both to facilitate BRT movement and provide U-turns for mixed traffic. Two stations also will be constructed below grade. The Safoora Intersection requires an elevated roundabout for BRT movement[16]. Also, bridge spans will need to be installed across below-grade sections to carry mixed traffic. On this basis, the construction activities considered in the analysis are as shown in Table 6-20.

[16] An alternate scheme involves an elevated section near Mazar – e – Quaid as well as one other location.

This table shows the various types of construction work expected along the alignment and at the depot sites, equipment noise emission levels, and combined noise emissions produced by equipment working in tandem.

388. Other activities along the alignment, such as construction of the stations/bus stops, and development of the related infrastructure such as pedestrian walks and other types of NMT facility will generate lower noise levels, and hence these activities do not require analysis at this stage.

Table 6-20: Heavy Equipment Noise Emission Level and Combined Leq

Component	*Kind of Construction*		*Heavy Equipment Used*	*Leq at 16.2 m*	*Comb.L_{eq}*
Depot Area	Clearing and grubbing		Dump Truck	88	91.5
			Scraper	89	
	Depot Construction		Concrete Mixer Truck	85	89.8
			Crane, Derrick	88	
Alignment at-grade	Pvmt breaking		Scraper	89	91.5
			Jack hammer	88	
	Repaving		Grader	85	90.5
			Paver	89	
Alignment below-grade section	Ground Preparation		Scraper	89	90.0
			Scarifier	83	
	Excavation		Jack Hammer	88	91.0
			Truck	88	
	Paving		Grader	85	90.5
			Paver	89	
	Cross-spans		Crane, Derrick	88	89.8
			Concrete Mixer	85	

6.5.7 Results of the Analysis

389. A spread sheet was developed to perform these calculations, and results are shown in Table 6-21.

Table 6-21: Construction Noise Levels Above Existing Average Noise Levels

	Mazar – e – Quaid	Tayyab Masjid	Dawood College of Engnrng	Mir Usman Family Park	Askari Park	Babar Hospital	Civic Centre	Hasan Sq roundabout	Ashfaq Memorial Hospital	Federal Urdu University	Jamia Masjid Akhbar	Sir Syed University
Max Leq from Equipment	84	83	89	89	84	85	77	86	84	84	84	84
Ambient Average(7am-10pm),Leq	74	71	77	60	65	65	77	72	72	74	71	69
Total Noise Burden	84	83	89	89	84	85	80	86	84	84	84	84
Amt increase (C-B)	10	12	12	28	18	20	3	14	12	10	13	15
% increase (E/B%)	13.4%	17.2%	15.6%	47.1%	27.7%	31.2%	4.1%	19.7%	16.3%	14.0%	17.9%	21.5%
Applicable Standard	85	85	85	75	85	85	85	85	85	85	85	85
Combined noise exceeds standard	0	0	4	14	0	0	0	1	0	0	0	0
Land Use	C	C	C	R	C	C	C	C	C	C	C	C
Daytim Std	85	85	85	75	85	85	85	85	85	85	85	85
Night time std	85	85	85	60	85	85	85	85	85	85	85	85
Where ambient noise above std then	85	85	85	75	85	85	85	85	85	85	85	85
Equals to Ambient Noise plus 3 dB	85	85	85	63	85	85	85	85	85	85	85	85

	NEPA roundabout	Nadeem Medical Center	Karachi National Mgt. Inst	Jamia Madrasat-ul-Islam	Chiniot Islamia PS	Karachi University	Sheik Zayed Islamic Center	Gov't Girls Secondary School	Rehmania Mosque	GBGP School	Tank Chowk
Max Leq from Equipment	84	77	82	84	84	83	83	84	83	84	84
Ambient Average(7am-10pm),Leq	71	72	64	66	66	67	68	67	61	67	67
Total Noise Burden	84	78	82	84	84	83	83	84	83	84	84
Amt increase (C-B)	13	6	17	18	17	16	15	17	22	17	16
% increase (E/B%)	17.6%	8.8%	26.7%	26.7%	25.9%	23.7%	22.7%	25.1%	35.1%	24.8%	24.4%
Applicable Standard	85	75	85	75	75	85	85	75	75	85	85
Combined noise exceeds standard	0	3	0	9	9	0	0	9	8	0	0
Land Use	C	R	C	R	C	C	C	R	R	C	C
Daytim Std	85	75	85	75	75	85	85	75	75	85	85
Night time std	85	60	85	60	60	85	85	60	60	85	85
Where ambient noise above std then	85	75	85	75	75	85	85	75	75	85	85
Equals to Ambient Noise plus 3 dB	85	75	85	69	69	85	85	70	64	85	85

390. The increase in noise levels over existing average[17] noise levels measured during recent rounds of monitoring ranges from 4% to 47%, with an average of 21%. Locations with increased noise greater than 10% include all locations other than Civic Center and Nadeem Medical Center. Among the most seriously affected include Mir Usman Family Park, Askari Park, Babar Hospital, Karachi University (not the university itself, which is set back from the alignment, rather developments across the roadway would be subjected to noise), Government Girl's Secondary School (which is also set back from the roadway, the second tier of buildings, and should receive a noise adjustment of -5 dB), and Rehmania Mosque. Of these, the two parks are affected due to outdoor activities, and Rehmania Mosque because of the large-scale below-grade excavation for Shumail Station and direct service connecting lines. The noise level is calculated at the entrance to the parks, whereas interior space (space within the park) would experience less noise in proportion to the distance removed. These locations were evaluated in the field with the following results:

a) Askari Park: this is primarily an indoor venue (the Wildlife Aquarium) set back some 30 m from the R.O.W. with a porous outer wall that could support a temporary noise barrier if necessary. Existing traffic lanes are close to the wall and existing traffic noise is considerable. The fact that there is little outdoor use at the park reduces the impact of construction noise. The operational hours of the park are 5.00 Pm – 12.00 midnight. Currently the park is under renovation Figure 6-3.

Figure 6-3: Under renovation Askari park (5.00- 12.00 midnight)

b) Babar Hospital: The hospital services include maternity facilities offering pre- and post-natal outpatient and inpatient services also. The ground floor at the front of the building is given over to auto repair shops and the main entrance to the hospital is at the back via an internal

[17] This analysis uses the average of daytime LAeq-one-hour values. Results are considerably more favorable if the maximum daytime Leq value is used as the reference

courtyard. The rooms toward the front of the building on the first floor facing the roadway were mostly occupied at the time the base line survey was undertaken. Figure 6-4 and Figure 6-5

Figure 6-4: Babar Hospital Signage's along university road

Figure 6-5: Babar Hospital actual entrance on side road

c) Rehmania Mosque: the mosque is part of a small shopping arcade (Rehmana Center) along a narrow roadway off from the main traffic lanes. Small commercial shops occupy the ground floor at the side of the mosque. The main entrance is along SUPARCO road. The building is being extended through additional floors. KBRT red line construction work in the area should be suspended during time of prayers at the mosque. Figure 6-6

Figure 6-6: Rehmania Mosque

d) Educational buildings (NED, KU, Sheikh Zayed Islamic Center): buildings are exclusively set back from the roadway 40—100+ m and in some instances surrounded by an intervening wall to further mitigate noise impact. Figure 6-7

Figure 6-7: Main entrance Karachi University (KU)

391. The combined noise levels exceed the construction standard for Dawood College and for Mir Usman Park, as well as a few other instances. The average of daytime one-hour Leq noise levels measured at Dawood University was 77 dBA, so additional noise from at grade carriageway construction contributes 12 dB added noise. At Mir Usman Park, the average of daytime measured noise levels is 60.4 dBA, so construction noise potentially contributes 28 dB, based on these projections. The operational hours of the park are 5.00 Pm – 12.00 midnight.

392. Mitigation measures to reduce noise impacts from construction are to be used progressively, as required by the situation:

- Use heavy equipment with built in noise abatement, especially pavement breakers, crawler cranes, excavators and concrete cutters
- Utilization of noise control devises such as temporary noise barriers and deflectors
- Site noisy equipment at construction sites and yards as far away as is practical from noise-sensitive sites
- Construct walled enclosures around especially noisy activities or clusters of noisy equipment
- Combine noisy operations to occur in the same time period if possible

- Avoid night-time activities where there is sensitivity to noise, such as hospitals and residential areas
- Provide noise-dampened equipment, such as quieted and enclosed air compressors and properly working mufflers on all engines
- All construction equipment and vehicles shall be well maintained, regularly inspected for noise emissions, and shall be fitted with appropriate noise suppression equipment consistent with applicable national and local regulations. Vehicles and equipment shall be registered and have necessary permits.
- Truck drivers and equipment operators shall minimize the use of horns.
- Limit noisy construction-related activities during the night near sensitive receptors (e.g., residential areas). Such activities should be restricted to daylight hours.
- Impose speed limits on construction vehicles to minimize noise emission along areas where sensitive receptors are located (residential areas, etc.).
- Activities should be planned in consultation with local communities and they should be given prior notification regarding the schedule of construction activities,.
- Contractors must ensure that activities with the greatest potential to generate noise are planned during periods of the day that will result in least amount of disturbance.

393. The Contractor is required to address noise abatement at the outset of construction work through preparation of a Noise Control Plan and this must be part of contractor's SSEMP. This must also be included in the bidding documents and will be binding on the contractor, at risk of penalty for non- compliance. Charges will be deducted from contractor for unsafe act or conditions.

6.5.7.1 Conclusion

394. Construction activities include pavement breaking and removal, repaving, pier and span installation for elevated sections, excavation of underpasses, site preparation and construction for the depot, staging area, park-and-ride facilities, stations/stops and ancillary facilities, and dirt hauling. Some of these activities pose risk related to excessive noise, and these have been analyzed in the context of existing high noise levels. A project noise standard is proposed for controlling construction noise, based on a review of standards for construction noise in use elsewhere in the world.

395. The combination of equipment noise and noise from other sources (background noise) is likely to exceed the project standard in eight (8) instances. Three locations may be significantly affected. Still, mitigation measures will be employed progressively to minimize noise. These involve scheduling times of operation, shielding pieces of equipment, and altering construction approaches. Construction noise impacts will need to be closely monitored during the construction cycle to identify specific problem locations.

396. Excessive noise will trigger the use of increased measures, as listed above, for limiting noise impact in a given situation. The proposed measures are considered to be technically sound; additional information will be provided in the final EIA regarding the application on those measures for each sensitive receptor, since the circumstances under which a specific measure should be applied over another requires a better understanding of site conditions and construction-related factors than is available at present. Overall, a review of land use classifications along the alignment and a closer look at site-related factors for sensitive receptors

is needed to provide a basis for improved specification of noise reduction options. This activity will be performed in the upcoming period before August and included in the final version of the EIA. Possibly the noise impacts at all sensitive receptors can be addressed using 'soft' options (equipment certification, timing of activities etc.), but if not, inclusion of provisional sums for temporary noise barriers and equipment enclosures in the bill of quantities may also be provided as part of the construction specification. In time for the final EIA, additional effort will be directed toward evaluating the efficiency of proposed noise mitigation measures, proposing additional measures that are considered effective, and strengthening the in-house monitoring of noise by the contractor. Regardless of the quality or completeness of information provided, the contractor is still responsible for describing the means for noise impact mitigation in its SSEMP, which should be regularly updated to reflect lessons learned, new evidence, and actual conditions at work sites. This is seen as the most effective way to regulate construction noise given the need to implement the Project, the temporary nature of activities generating noise during construction, and the situations in which noise control issues arise

397. The contractor will be required to carry out mitigation measures as necessary to limit noise in the vicinity of worksites. Citizens should be made aware of their right to complain and seek redress through the grievance mechanism set up under the Project.

6.5.8 Operations-related Noise Emissions

398. The US Federal Transportation Administration (FTA) Noise Screening Model is used to assess noise impacts during operations (FTA 2006). The method is based on a rated Sound Emission Level (SEL) for buses, headway, or frequency during day and night operations, land use classes specific to the approach (Table 6-22). A nomograph (Figure 6-8) is used to determine if total noise exposure exceeds the FTA impact criteria. The approach is automated through use of a spreadsheet for calculating total noise exposure in comparison with existing (ambient) conditions, the FTA Noise Impact Assessment Spreadsheet. Results are shown in Table 6-23.

Table 6-22: Land Use Categorization used in the FTA Noise Screening Model

Land Use Category	Noise Metric (dBA)	Description of Land Use Category (per FTA Guidance Manual)
1	Outdoor Leq(h)*	Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included are recording studios and concert halls.
2	Outdoor Ldn	Residences and buildings where people normally sleep. This category includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor Leq(h)*	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds and recreational facilities can also be considered to be in this category. Certain historical sites and parks are also included

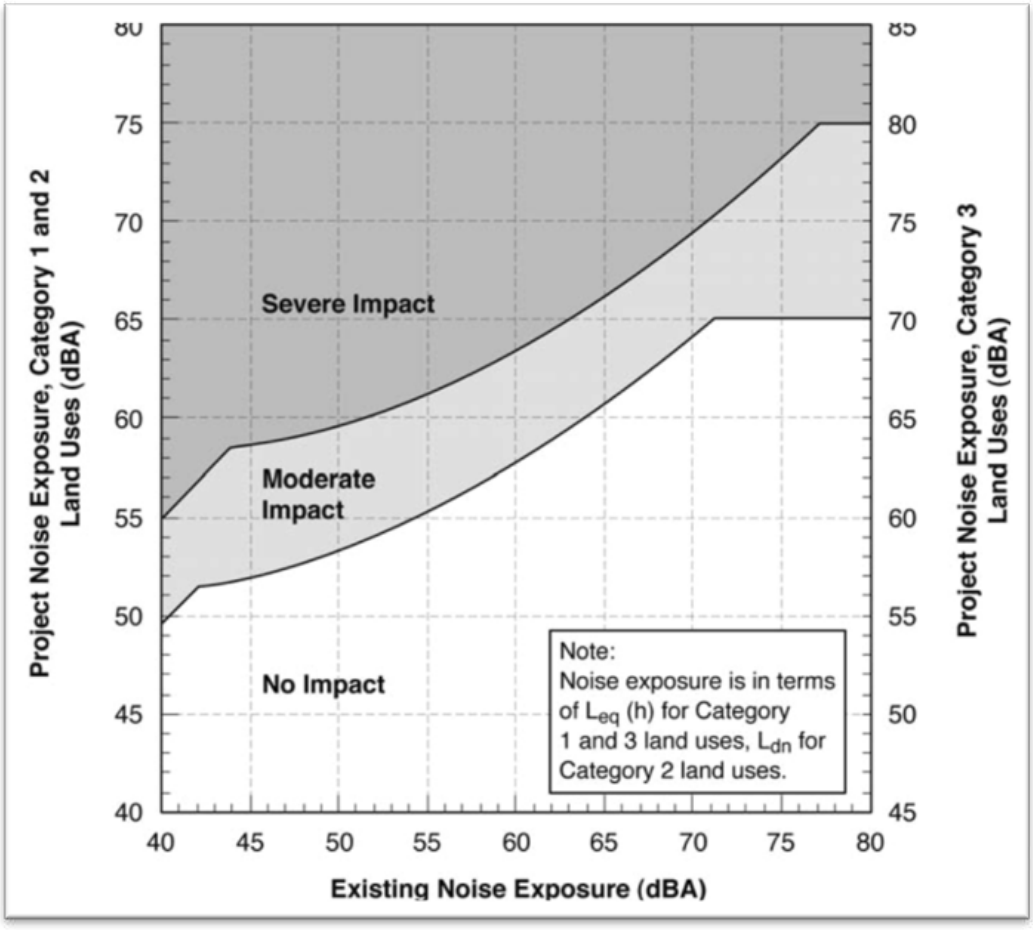


Figure 6-8: Noise Impact Criteria for Transit Projects

Table 6-23: FTA Noise Impact Assessment Spreadsheet Results

Receiver Number	Land Use Category[1]	Distance to Bus Lane feet	Existing Noise Level Aver Leq, 1-hr 6-22:00	Criteria, Moderate / Severe, dBA	Project Noise Level, Leq (Ldn)[1], dBA	Cumulative Noise, Leq (Ldn)[1], dBA	Increase in Cumulative Noise, dB	Noise Impact?
1.	3	50	74.1	70-77/>77	55	74	0	No
2.	3	50	71.0	70-75/>75	55	71	0	No
3.	3	35	77.1	70-80/>80	57	77	0	No
4.	1	35	60.4	57-64/>64	57	62	2	No
5.	1	50	65.5	61-67/>67	55	66	0	No
6.	2	40	65.1	61-66/>66	58	66	1	No
7.	3	80	76.6	70-80/>80	52	77	0	No
8.	2	50	72.1	65-71/>71	56	72	0	No
9.	3	50	72.1	70-76/>76	55	72	0	No
10.	1	50	73.6	65-72/>72	55	74	0	No
11.	1	50	71.0	65-70/>70	55	71	0	No
12.	3	50	68.9	69-74/>74	55	69	0	No
13.	3	65	71.4	70-75/>75	53	71	0	No
14.	3	80	71.7	70-76/>76	52	72	0	No
15.	3	55	64.4	65-71/>71	54	64	0	No
16.	3	50	66.0	66-72/>72	55	66	0	No
17.	3	50	66.4	66-72/>72	55	66	0	No
18.	3	50	67.1	67-72/>72	55	67	0	No
19.	3	50	67.7	68-73/>73	55	68	0	No
20.	3	50	66.8	67-72/>72	55	67	0	No
21.	3	50	61.5	63-70/>70	55	63	1	No
22.	3	50	67.0	67-72/>72	55	67	0	No
23.	3	50	67.2	67-72/>72	55	67	0	No

The set of input parameters used in spreadsheet are shown in Table 6-24.

Table 6-24: Parameters Used in Applying FTA Bus Noise Model to the KBRT Red Line

Criteria	Details
Land use category	As described in Table 6-15
Distance to centerline of nearest BRT lane	50 – 80 ft (1/2 of variable ROW width)
Bus vehicle type: Reference SEL	Diesel-powered bus, 82 dBA*
Speed	25 mph
Average number of daytime buses per hour	20
Average number of nighttime buses per hour	3
Buses per hour during peak BRT activity	20
Existing noise levels	Average daytime Leq 1-hr determined for the receptor

Daytime hours are 6 am to 10 pm; nighttime hours are 10 pm to 6 am.

* This is the FTA's reference noise level for a diesel-powered bus. Diesel units specified for the KBRT would be held to a reference SEL of less than 85 dBA; however, CNG-hybrid buses emitting lower noise levels is the preferred power option.

399. Results of the assessment methodology indicate that there is no impact from buses operating on the given frequency of 20 buses per hour along the carriageway. In part this is because baseline noise levels are high throughout; however, even if the existing noise level were in the range of 40 dB, noise from buses in service is not enough to cause serious impact at the face of adjacent buildings. Noise exposure never exceeds 58 dB because the combined Leq for a series of noise events (SELs) of magnitude 85 dB at 50 ft (15 m) does not exceed the existing noise levels. It is possible to verify this conclusion by calculating Leq for combined buses at the reference distance of 50 ft with the following equation (FTA 2006, p. 5-8):

$$L_{eq} = SEL_{ref} + 10Log(V) + C_sLog(S/50)-35.6$$

Where:

SEL_{ref}, is 85 for diesel-powered buses

V = hourly volume of vehicles of this type, in vehicles per hour, taken here to be 20

C_s = 15 for diesel buses

S = average vehicle speed, in miles per hour (25)

400. The result, using the given parameter values, is 57.8 dB, similar to the result given with the spreadsheet for "Project Noise". Since the majority of locations are located at a distance approximately equal to the reference distance of 50 ft, there is no need to apply a distance adjustment. The physical placement of the BRT lanes along the median of the roadway will tend to force mixed traffic toward the outside, closer to the R.O.W., reducing the distance between mixed traffic and noise receptors. In terms of the model, this could result in higher existing, or ambient noise levels, amounting to an induced impact that is not accounted for in the previous analysis. However, there is an argument that this effect will not occur because of the project's façade-to-façade development component (improved sidewalks and a bicycle lane) along the R.O.W. that acts as a countervailing force maintaining the original (or close to the original) distance between the flow of traffic and adjacent buildings.

401. The conclusion is that there is no significant impact from bus noise during operations that would contribute to an exceedance of the SEQS ambient noise standards, especially (but not only) due to the fact that existing noise levels exceed SEQS noise limits along the roadway.

Mitigating Noise Impacts during Operations

402. Still, it will help to dampen noise levels (from whatever sources) by maintaining as much vegetation along and adjacent to the thoroughfare as is practical, in green areas near driving lanes and stations to dampen noise levels.

6.6 Vibration

403. The following terms are used in this section for describing vibration. The peak particle velocity (PPV) is defined as the maximum instantaneous positive or negative peak of the vibration signal. The root mean square (rms) amplitude is the vibration signal averaged over one second, describing the "smoothed" vibration amplitude. PPV and rms velocities are described in inches per second in the USA and meters per second in international units. Vibration decibels, or VdB, is a decibel notation that provides an exponential scale more suited to human perception. Lv in the following equation shows the relation between PPV and VdB:

$$L_v = 20 \times \log_{10}\left(\frac{V}{V_{ref}}\right)$$

Where V_{ref} is 1 X 10^{-6} in/sec, and L_v is vibration decibels (VdB) given in RMS velocity.

404. Since much of the available literature originates in the USA, a mix of English and international units are used herein to describe vibration impacts.

6.6.1 Construction-related Activity

405. Construction activity can result in varying degrees of ground vibration, depending on the equipment and methods used. The operation of construction equipment causes vibrations that spread through the ground and diminish in strength with traveled distance. Buildings in the vicinity of construction may be affected, with resulting damage in the most severe cases.

406. Vibratory rollers would be the most dominant sources of overall construction vibration for this project. Bridge piers will be installed on screw piles that do not induce any significant vibration. The vibration levels created by the normal movement of vehicles including graders, front loaders, and backhoes are comparable in order-of-magnitude to ground-borne vibrations created by heavy vehicles traveling on streets and highways. Building damage can be cosmetic or structural. Fragile buildings such as some historical structures are generally more susceptible to damage from ground vibration.

407. Normal buildings that are not particularly fragile would not experience any cosmetic damage (e.g., plaster cracks) at distances beyond 8 m, based on typical construction equipment vibration levels. However, the distance can vary depending on soil makeup and building structural properties.

408. As shown in Section 5.4.1, there is no historical building close to the alignment to sustain damage from construction vibrations. Buildings adjacent to the ROW are constructed according to modern building codes. While damage is not likely to occur, the purpose of this section is to

assess the potential for damage and to put into place a means for enforcing a vibration standard in the event monitoring of vibrations for potential building damage is necessary.

Vibration Criteria

409. There is no vibration standard in Pakistan. Vibration criteria for different countries are shown in Table 6-25. Values are stated in a mix of units, including peak particle velocity (PPV), in in/sec and mm/sec, and in RMS vibration decibels (VdB).

Table 6-25: Vibration Criteria for Construction in Different Countries

Country	Standard
India (CMRI)	
Historical buildings	2 mm/sec PPV
Domestic site development	5 mm/sec PPV
Industrial site development	12.5 mm/sec PPV
Australia	
Historical buildings	2 mm/sec PPV
Residential development	10 mm/sec PPV
Commercial development	25 mm/sec PPV
USA (Construction Vibration Damage Criteria, FTA 2006)	
Type I building	0.5 in/sec (12.7 mm/s, 102 VdB)
Type II building	0.3 in/sec (7.6 mm/s, 98 VdB)
Type III building	0.2 in/sec (5 mm/s, 94 VdB)
Type IV building	0.12 in/sec (3 mm/s, 90 VdB)

410. US FTA criteria is related to different building types, as described in the following paragraphs. These criteria can be used to monitor vibration during construction and determine the potential for impact.

411. On the basis of the above review, a vibration limit of 3 mm/sec measured as PPV is proposed for use on the project, equivalent to the most stringent standard applicable for Class IV building types in use in the USA. Such measurement would be taken at the face of the nearest building orthogonal to the vibration-inducing activity, or the property line (or ROW), whichever is closest.

Conditions Leading to Vibration Impact

412. The FTA vibration criteria is keyed to four different types of buildings in terms of their susceptibility to vibration damage: Type-I is reinforced-concrete, steel or timber (but with no interior plaster or stucco); Type-II is an engineered concrete and masonry structure also without plaster; Type-III refers to non-engineered timber and masonry buildings, and Type-IV indicates buildings that are extremely susceptible to vibration damage such as weak-jointed stone or masonry historical structures. . Commercial, multi-storied buildings are generally of Types I and II. Wood-framed residences fall under Type-III (atypical in Asia), while structurally fragile buildings, as previously stated, are more likely to be historical in nature, and are Type-IV structures. There are buildings of historical significance along the project alignment, but none have been identified as sufficiently sensitive to vibration impact to fall under the Type-IV category.

413. The vibration levels generated by construction equipment are shown in Table 6-26, and calculations were performed to determine distances at which vibration impacts would occur according to the FTA criteria presented in Table 6-25 Results are shown in relation to building category as the maximum distances at which short-term vibration impacts could occur. Close monitoring, and potential mitigation of impact, would be required if construction equipment were to operate within the distances shown in Table 6-26.

Table 6-26: Vibration Source Levels and Building Damage Impact Distances for Construction Equipment

Equipment	PPV[1] at 25 ft, in/sec	L_v at 25 ft. (VdB_{RMS})	Impact Distance for Building Category, ft		
			I	II	III
Vibratory Roller	0.210	94	14	18	25
Loaded Truck	0.076	86	7	10	14
Jackhammer	0.035	79	4	6	8
Small Dozer	0.003	58	1	1	2

Source: FTA, 2006

Notes:

1. Peak Particle Velocity
2. RMS velocity in decibels (VdB), re: 1 micro-inch per second

Monitoring and Mitigation

414. Background levels of vibration measured during the EIA preparation were low, as shown in Figure 6-9 Only one value approaches the accepted norm for vibration with potential for damage, which stands out as an anomaly in the data collection (something jarring the instrument) or a one-off event in the near vicinity. Overall, vibration levels are only 1/100th of the vibration level (3 mm/sec) expected to do damage to excessively fragile structures. Vibration is clearly not a problem under the existing case, reflecting the fact that given generally favorable subsurface conditions, rubber-tired vehicles (and to a lesser extent construction equipment) are unlikely to create a vibration hazard in the future. Figure 5-15 depicts the locations where vibration intervention was conducted.

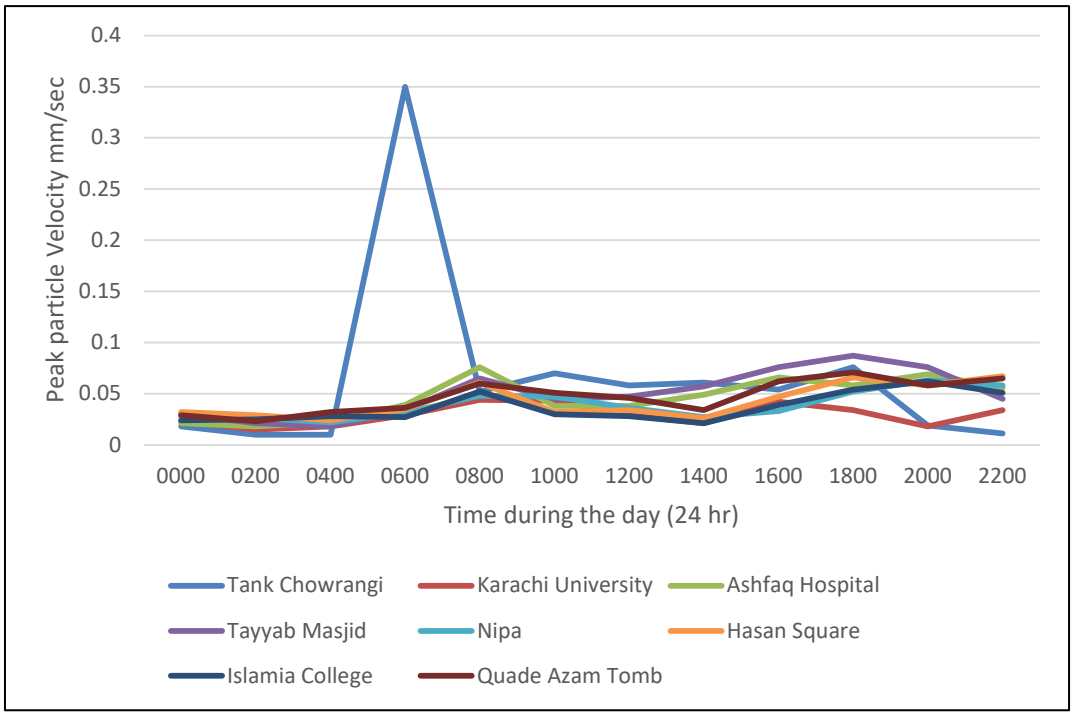


Figure 6-9: Recorded Vibration levels along the Alignment 24 -- 26 Jan 2018

415. Still, the contractor will monitor vibration during the conduct of work if conditions indicate that damage to buildings could occur due to vibration inducing activities.

416. Such monitoring will be triggered by a vibration-inducing activity in proximity with a building that could be susceptible to damage. Measurements will be taken at the face of the building while work is underway, and a record kept of measurements. Pre- and post-condition surveys may be required if vibration levels are expected to exceed threshold criteria, in order to ascertain the extent of damage.

417. The contractor is obligated to maintain vibration levels at the faces of buildings within the specified project criteria of 3 mm/sec PPV.

418. If the criteria are exceeded, and damage occurs to buildings, the contractor may be obligated to pay damage claims. Monitoring vibration level and the condition surveys are essential elements for determining liability for vibration damage.

6.6.2 Vibration Levels induced by Operations

419. Significant vibration impact from rubber tire-fitted vehicles is extremely rare. This is because rubber tire-fitted vehicles are not massive, and are typically well-isolated by the vehicle suspension design and rubber tires, both of which act as barriers to vibration transmission between the carriage and the ground. Potential vibration impact from rubber tire-fitted vehicles such as those used in BRT projects can be reasonably dismissed under general conditions.

420. Most problems with bus-related vibration can be directly related to a pothole, bump, expansion joint, or other discontinuity in the road surface. Smoothing the bump or filling the pothole will usually solve the problem.

421. Problems may occur with buses operating inside buildings. Vibrations can be caused by sudden loading of a building slab by a heavy moving vehicle or by vehicles running over lane divider bumps. A bus stop/transfer station or depot may experience annoying vibration caused by bus operations. (FTA, 2006). Since these vibration impacts are within the premises of the depot, there is no effect on the external environment. No further impact analysis is needed for vibration assessment during operations.

6.7 Traffic and Transport

6.7.1 Traffic Management during Construction

422. Traffic Congestion in construction zones as addressed by the EPCM consultant has resulted in specifications aimed at directing attention to traffic management problems that must be taken up in detail by the Contractor. (see Appendix D). The effort emphasizes various aspects of traffic problems that may develop along the alignment during construction. Because traffic management involves the cooperation of a number of agencies, the planning process is likely to continue until start of construction. Some recommendations are set forth in this section, with the idea that individual measures will be implemented as feasible under prevailing constraints.

423. The Contractor is required to address systematically traffic management at the outset of construction work through preparation of a Traffic Management Plan as part of the Contractor's SSEMP (SSEMP).

424. Traffic demand, traffic behavior patterns and insufficient capacity, and specific problem-areas along University Rd. have been evaluated with the overall objective to maintain traffic flow on roads in the vicinity of construction. The evaluation has resulted in interventions that can reduce traffic congestion:

Specific Provisions for Intersections

i. The Contractor will prepare construction staging plans for each segment to maintain cross-flow of traffic during the construction of carriageways and excavation of underpasses.
ii. The Contractor will adhere to staging plans, provide overarching real-time supervision during implementation, and modify plans as necessary to maximize traffic flow.
iii. The Contractor will monitor traffic flow continuously in order to troubleshoot problems.
iv. The Contractor will debottleneck traffic flow beforehand at key intersections by any of the following measures, to enhance the capacity of the Intersection:

General Provisions

i. Reduce demand for space by promoting use of public transportation
ii. Develop temporary pullouts for buses to reduce stoppage in traffic lanes
iii. Restrict Qingqi rickshaws or three-wheelers from entering the main thoroughfare
iv. Restrict roadside parking and loading at locations where construction is underway and during peak traffic periods
v. Provide diversions (where possible) of private and bus traffic around construction zones.

425. Detailed staging of this construction sequence will need to be developed by the contractor, and approved by the supervising engineer. Other recommendations address the general problem of reducing traffic congestion at intersections and along the alignment. Other measures to maintain the general flow of traffic include:

Maintaining the Free Flow of Traffic

i. Traffic police should be present during rush hours at sites of congested traffic.

ii. The Contractor will station flagmen where work is underway in the line of traffic, at the start of construction, and points of vehicle access into the work site.

iii. The Contractor will keep operations within the workplace boundaries, to the extent possible.

iv. The Contractor will keep traffic lanes free of obstruction by removing excess spoil and debris.

v. The Contractor will pay special attention to maintaining the free flow of traffic during rush hours and heavy daytime use.

426. Special provisions are set out for the movement of over-weight/over-length (OW/OL) loads:

Over-Weight/Over-Length (OW/OL) Loads

i. The Contractor will plan and clearly mark routes through urban areas for movement of over-weight/over-length (OW/OL) loads of heavy equipment and other types of transport vehicles.

ii. The Contractor will provide front and rear escort vehicles, equipped with flashing light, for movement of OW/OL vehicles, and auxiliary flagmen along the route and onboard to assure clearance.

iii. Movement of OW/OL loads preferably will be done at night.

6.7.2 Traffic Conditions during Operations

427. Data are not available to estimate how traffic might change with the introduction of the Red Line BRT. Less road space will be available for mixed traffic, and travel will be pushed to the periphery of the right-of-way (BRT runs in the median), causing more noise and congestion along the edge of the road. Still, numbers of vehicles could be less in comparison with a (modeled) base case. On the other hand, mixed traffic could increase to fill the space vacated by BRT riders.

428. Perhaps the overriding factor could be better tarmac conditions that would assist traffic flow.

6.8 Community/Occupational Health and Safety

6.8.1 Construction Impacts on Community-use Values

Impact Scenarios

429. Community space can be affected adversely by poor performance across a number of factors by a contractor uncommitted to environmental management. The World Bank/IFC EHS Guidelines defines community health and safety in terms that guarantee as-built infrastructure conforms to

acceptable standards (structural safety, flood and fire risk), water supply sources are of suitable potable quality, emergency response planning is in place for built environments, traffic safety provisions are enforced alongside transport hazard assessment and mitigation, and disease prevention measures are taken.

430. Community health and safety in the context of the KBRT project refers to protection of the community environment near work areas by assuring access to residences and places of work and business, pedestrian and vehicular movements, air quality, reduced congestion and overall safety.

431. The alignment for the BRT during remains a public space during construction that must be occupied both by the contractor and the public. A combination of factors can render areas near construction uncomfortable and dangerous. Poor housekeeping, failure to finish out work, and unwillingness to restore sites and services where they have been disrupted, cause difficulties for the public. Noise, dust, traffic congestion and community inconvenience/hazard merge into a single bad experience for any public exposed to it.

Mitigation Measures

432. Mitigation measures put forth in previous sections, specifically those related to control of dust, noise and traffic, can eliminate some of these hazards and inconveniences. Additional measures include:

- The Contractor will clearly barricade work areas to prevent access by the public, while ensuring passage by providing safe pathways for pedestrians around construction zones
- The Contractor will exclude parking, waiting vehicles and vendors from areas adjacent to the work by means of clearly marked barricades and posted signage.
- The Contractor will remove excavated earth, spoil, rubble, cut vegetation and refuse whether generated by the project or discarded by third parties from areas within the construction zone.
- Spoil will be removed daily from the construction zone where it has potential to interfere with the public or generate dust.
- Any earth or material stockpiles in the construction zone will be covered or watered regularly to control dust; and shall not be left in place longer than a week before used in infilling, except as approved by the Supervising Engineer.
- The Contractor will place flagmen at the start of construction zones, at points where construction vehicles enter and exit the construction zone, and intersections along haul routes.
- The Contractor will provide clear, visible signage to communicate risks at the start and at regular points along the construction zone.
- The Contractor will provide temporary lighting along roadways and pedestrian walkways where lights have been removed to facilitate construction
- The Contractor will remove hazardous conditions on construction sites that cannot be controlled effectively with site access restrictions; and will barricade any excavations and materials placed in public space.

- The Contractor will avoid blocking access to land, homes and businesses; where unavoidable, the Contractor will provide safe and effective temporary access to affected properties, and will reinstate permanent access on completion of work in the immediate area.
- The Contractor will promptly reinstate any services and reinstall any physical facilities that are cut, disconnected or damaged during construction, and maintain or provide temporary services that are interrupted by construction. The Supervising Engineer will inspect and certify the adequacy of all reinstated services and facilities.

433. Any environmental condition that is disagreeable to the public and causes an avoidable nuisance can be addressed with additional provisions over and above those described above, as determined necessary by the Supervising Engineer.

434. These requirements will be incorporated into the bidding specification and contract documents, and will be binding on the contractor, at risk of penalty for noncompliance, as charges to be recovered from contractor for unsafe act or condition.

6.8.2 HIV/AIDs Prevention

435. HIV awareness and prevention in the project context is at the interface between workers and the community. HIV is a serious problem for Karachi, but seems primarily embedded in specific high-risk groups. Two such groups that might overlap with construction workers include Pakistani men who have been employed in third countries (high prevalence of HIV), and truck drivers, another high-risk group. The degree that an HIV program is needed for the KBRT depends on how effective it will be in contributing to the HIV control program for Sindh Province. Practical measures to prevent the spread of HIV are recommended to be implemented by the Contractor:

- The Contractor will provide HIV screening for workers employed at the site.
- The Contractor will provide HIV/AIDs education and awareness among workers through use of training sessions, videos and other appropriate means.

436. The HIV detection and awareness program will be part of the Occupational Health and Safety proposal.

6.8.3 Occupational Health and Safety

437. The health, safety and welfare of personnel working on the Project and the general public, and the avoidance of damage to property, are important issues in themselves and to Project sponsors. The contractor is expected to give consideration to Occupational Health and Safety (OH&S) aspects of construction, so that operations are conducted in a manner that eliminates risk to persons and property. The Contractor is expected to treat safety as a high priority in his activities while executing the work.

438. Contractors will not permit or cause unsafe conditions that pose a hazard during construction. Perceived risks will be addressed at the outset by way of adequate and concrete mitigation measures. The Contractor will prepare an Occupational Safety and Health Plan that conforms to requirements set out in the Sindh Occupational Safety and Health Bill (2017), and that aims to eliminate or minimize unwanted hazards and risks to personnel and the public during construction, and to achieve ‘Best Practice’ within the project context, establishing a work

environment that conforms to international standards with respect to health, safety and emergency response.

439. The Contractor's Occupational Safety and Health Plan will address the following key elements:

- The Contractor will provide as a minimum of safety training addressing 1) general safety awareness; 2) first aid procedures; 3) emergency procedures; and 4) use of personal protective equipment.
- The Contractor will conduct weekly site safety inspections and preparation of site safety reports in relation to the contract.
- The Contractor will provide a system for recording all accidents and dangerous occurrences, regardless of whether or not personnel injury occurs, including any incident involving a member of the public.
- The Contractor will investigate accidents in order to ascertain the facts with a view to prevent future and possibly more serious occurrences.
- The Contractor will collect accident data to show trends, identify how problems arise, and enable accident prevention efforts to target problem areas.
- The Contractor's plan will include a Safety and Emergency Preparedness Plan to address foreseeable emergencies that may arise during the construction activity. Guidance in preparing this plan is found in Appendix B.
- The Contractor will propose safety signage for display around the sites in both Urdu and English, to address use of PPE, dangerous conditions, smoking prohibition, first aid station, and prohibited entry.
- The contractor will provide means for maintaining healthy working conditions for workers related to the effects of noise, dust, use of chemicals, by removal of the cause and use of suitable Personal Protective Equipment (PPE), to be provided to workers. The Contractor will ensure that workers are properly trained in the use of PPE and that adequate supervision is provided to ensure its proper use.

440. The Occupational Safety and Health Plan should address, as necessary, working at height, excavations, lifting operations, machinery, work adjacent to roadways, and work in the line of traffic.

441. The Plan should include checklists, inspection report forms, accident reporting forms, induction training recordkeeping, pre-clearance forms for working at height and in excavations, statistics record reporting, and other types of reporting forms.

442. The Plan prepared will be prepared by the Contractor and will include a Safety and Emergency Preparedness Plan sufficient to assure the safety of construction workers, engineers, and citizens. The Construction Supervision Consultant (CSC) will enforce implementation of the Manual by the Contractor.

443. The Occupational Safety and Health Plan is expected to comply with Pakistan Labor Law, Sindh Occupational Safety and Health Bill (2017), and relevant sections of the International Finance Corporation (IFC) General Environmental Health and Safety Guidelines (WB/IFC 2007)

applicable to the BRT Red Line Project. The reader is referred to those documents for further details on their contents.

444. Regarding emergency response during operations, the ODBM consultant will prepare a Red Line - Incident and Emergency Response Plan under Output 8.4 of its TOR due in Sept 2018.

6.8.4 Worker Camps

445. Requirements regarding onsite worker housing are set out below:

- Provisions for workers should conform to requirements of the Sindh Occupational Safety and Health Bill (2017) and relevant standards of the International Labor Organization (ILO). [18]
- The Contractor is required to maintain accurate counts of workers living offsite and those housed at onsite facilities.
- The Contractor will provide and implement a plan for suitable housing for workers living onsite. Housing should meet ILO specifications in respect of the nature and standard of the accommodation and facilities to be made available.
- The Contractor will provide for those living onsite food preparation and sanitation facilities, potable water supply, common dining rooms, canteens, rest and recreation rooms and health facilities, and solid/liquid waste management in accordance with Sindh Government regulations and ILO standards.

6.9 Water Use, Quality and Drainage

6.9.1 Drainage Design

446. A drainage strategy has been developed based on the concept design, aimed mainly at upgrading the existing nullahs (side ditches) along the corridor together with construction of new drainage channels at locations where the proposed BRT will physically about the existing nullahs.

447. A hydraulic model is used to reconcile runoff from the receiving watersheds and capacity of existing nullahs. The model takes into account existing dry weather flow generated by grey and foul water observed running in the Nullahs along the route. Nullah upgrade requirements are included in the construction works.

448. In order to enhance overall drainage performance along the route, the design will identify constrictions in the existing drainage system and outfalls, and implement sustainable solutions along the BRT route. Use of infiltration systems to absorb run-off along the BRT route is being considered, depending upon the practicality of the site location and outfall requirements. The use of an infiltration system will reduce outflow from the main outfalls which in turn reduces peak flow rates, and also recharges the aquifers. Where such approach is not considered appropriate the design will discharge to the adequately size nullahs while ensuring that outfalls have adequate capacity.

[18] The ILO is party to numerous conventions and standards regarding labor and worker protections. See www.ilo.org/dyn/normlex/en/ Where possible National and Sindh State Law should prevail.

449. The drainage design shall give special consideration to drainage around underpasses to ensure that adequate discharge points are present in these high-risk areas. During construction the contractor will have to ensure that any dewatering activity are controlled during deep excavation works.

6.9.2 Construction-related Issues

450. Impacts may occur due to water availability and its use on the project, and from uncontrolled drainage from work sites during rainfalls or dewatering of excavations. There are no known natural flow channels crossing the alignment, hence the potential for contamination of surface water is low, though constructed drains could become clogged due to excess sediment.

Water Availability

451. Use of water for construction purposes such as dust suppression and provisions at worker camps may come into conflict with existing uses. There is a water point near the Safoora Chowrangi that services tankers delivering water to communities that are not served by the piped water system. The Contractor is able to purchase water at this location for project use.

452. Karachi faces a chronic problem of shortage in supply to meet the constantly growing demand, and the requirements of the project, say at 30,000 gpd, is significant in view of existing shortages. Both price and availability of water, and the availability of tanker trucks to deliver water, may all be issues on the project. Delivery costs can skyrocket and the cost of water may be inflated at any given time.

453. Depending on the numbers of workers housed onsite, the main use may be watering of roadways for suppression of dust and for achieving correct water content for compaction of fill. The Contractor will need to factor the cost of these uses in its bid price, and curtail use by maintaining site cleanliness, in order to control dust by means other than the use of water sprays.

454. Abstraction from water resources may be permitted after prior approval from TMTD/SMTA in consultation with local authority leaders and local utility. Water for project use should be negotiated with the local authority and the utility provider in the pre-construction stage.

Uncontrolled Drainage and Potential for Contamination

455. Runoff from construction sites during rainfalls could transport silt into existing drainage works, resulting in loss of capacity and clogging. By maintaining site cleanliness, the Contractor can minimize the loss of sediment to drains. Surface and subsurface water resources near the Project could be contaminated by fuel and chemical spills, or by solid waste and effluents generated by kitchens and toilets at construction campsites, and by runoff from construction camp maintenance areas, workshops and equipment washing-yards.

456. Standing water and flooding in the vicinity of homes and work sites can be prevented by providing positive drainage to a point of discharge into a natural or man-made drainage channel. Suspended solids entrained in runoff that can soil surfaces and clog drainage systems. Water crossing roadways is a hindrance to both pedestrians and motorists.

457. Drainage from construction sites needs to be controlled to prevent water crossing road-ways or interfering with pedestrian movement. Drainage water needs to be discharged to a free point of discharge. Muddy water produced by dewatering subgrade excavations in the event of rainfall should be routed to a point of discharge.

458. Construction yards and haul routes: The Contractor should maintain a work site free of standing water, mud and silt so that these materials are not transported offsite on the wheels of trucks, and deposited along roadways; and overall drainage needs to be routed a point of discharge in order to avoid affecting surrounding land uses.

459. Construction sites present special problems during a heavy rainfall event. So long as the site is kept clean and free of mud/silt, runoff from rainfall can enter the local drain system without negative effect. Spillage and leakage of fuel, crankcase oil and drilling fluids at work sites is strictly prohibited. The Contractor will follow a risk avoidance approach that minimize standing water, sediment loss and spillage of waste oil and fuel. The contractor will need to minimize impacts through use of mitigation measures to the satisfaction of the superintending engineer.

Mitigation Measures:

- At the start of construction, a Site-Specific Drainage Management Plan for construction sites, construction yards, materials storage areas and administration/worker housing shall be developed by the Contractor as part of its SSEMP. The Plan shall address the impacts and mitigation measures described in this section, and be approved by the Supervising Engineer.
- Discharge of waste water into water bodies is prohibited as is the discharge of wash water from concrete trucks to waterways.
- Concentrated solids will not be washed into receiving drainage structures or open channels.
- Sediment and fine debris will be removed as solids by cleaning/scraping work areas and removing piles of debris in a solid form, in order to prevent sediment loss to drainage channels.
- Portable sanitation facilities will be set up at construction sites and regularly cleaned by vacuum truck.

Temporary Construction Yards

- Construction yards and material storage areas where vehicles operate or materials are stored should be established on well drained fill.
- Free-flowing points of discharge for storm water should be identified nearby the boundaries of materials storage/construction yards for gravity or pump-assisted dewatering and yard drainage.
- Local drainage channels should have sufficient capacity for handling discharge flows, with clear discharge points to open drainage courses.
- Water discharged to constructed drains should contain a minimum quantity of suspended solids.
- Temporary worker quarters and erection yards should include self-contained waste treatment with removal of excess by vacuum truck or approved discharge point.

- Drainage from fuel storage tank locations, refueling areas, and equipment service areas should be segregated from other runoff; discharge should be routed through an oil/water separator.
- Fuel storage tanks should be surrounded by secondary containment equal to at least half the volume of the tanks.

Monitoring

460. Contractors will be required to observe drainage conditions during dewatering operations and storm events to assure positive drainage. If flooding occurs along roadways or in neighborhoods, or community complaints arise, the contractor will undertake a combination of the above mitigation measures to minimize drainage and water quality impacts.

461. The contractor will monitor total suspended solids (TSS) of outfalls from construction sites where these discharge to local drainage channels, and comply with a limit of 200 mg/L TSS, as specified in the Sindh Environmental Quality Standards for Municipal and Liquid Industrial Effluents (2015).

6.9.3 Drainage during Operations

462. Design of a comprehensive drainage system for carriageways, stations, depot areas and underpasses is underway by the EPCM consultant. Systems and equipment for dewatering/drainage of underpasses is required to keep them functional during heavy rainfall. The design will augment existing drainage structures to the extent needed to assure free passage of water to a final outfall. Drainage design should incorporate allowance for peak rainfall of at least 10% over the amounts derived through a standard TOC-intensity-duration relationship for Karachi, to account for climate change effects.

6.10 Solid Wastes and Hazardous Materials

6.10.1 Construction

463. Alignment: Minor amounts of solid waste will be generated during construction of the bus lanes and stations. A large quantity of earth will be spoiled in the excavation of the grade separations at intersections. Broken pavement, brick and curb stones will also be spoiled in the process of constructing bus lanes. Installation of drilled pilings used for support of cross-structures at grade separations also generate a quantity of waste. An initial estimate of quantities of different types of spoil materials generated during construction are shown in Table 6-27.

Table 6-27: Inventory of Materials Generated in Construction of BRT (m3)

Source Materials	Estimated Quantity (m^3)
Augur cuttings and bentonite slurry from piling installation	500
Earth removal from median strip	26,000
Deep excavation for installation of underpasses at intersections (loose rock and earth)	105,000
Brick and curb stones from removal of median strip	19,000

Bituminous scrap from removal of old roadway pavement	43,000
Total	193,500

464. Construction Yards: Minor amounts of solid waste will be generated during site occupancy, including trash, construction debris, and discarded and unused materials. Hazardous waste could be generated consisting of waste oil, parts cleaning fluid, oily rags and discarded containers.

465. Countermeasures for disposal of spoil, solid waste and hazardous materials during construction include:

General

- Contractors are required to prepare a Spoil and Solid Waste Disposal Plan (SSWDP) that identifies the following: material types, estimated quantities and methods for disposal; locations onsite for collection and storage; locations for disposal. A recordkeeping system for all wastes and a tracking and manifest system for hazardous and recycled materials will be included in the plan. Necessary enclosed facilities, containers and equipment will be provided in keeping with the Plan. The Plan should be updated as necessary with actual quantities, locations for disposal and additional information in accordance with the Plan.
- Waste will be segregated in recordkeeping and physically, at construction sites, into the following general categories: spoil, construction debris and drilling mud/cuttings (Class C non-putrescible wastes); trash and other forms of degradable but non-hazardous wastes (Class B); hazardous wastes and spent materials, including liquids (Class A); materials determined to be recyclable with identified takers (Class R).[19]
- Class A waste material containers will be stored on a raised platform in dry condition for no longer than one week unless kept in an enclosed and secured location, in which storage of up to 3 mo is allowed.
- The Contractor will promptly collect, store, transport and dispose of Class B solid waste generated at the project site. No solid wastes will be allowed uncollected at the jobsite or accumulated in storage for periods in excess of a month. Transport and disposal will be by recognized means approved by the Engineer.
- Class C spoil materials, cuttings and wastage from the site that are unsuitable for use in construction shall be disposed of at locations specified in the SSWDP and approved by the Engineer. Methods of placement and compaction, and limits on the types of materials to be placed therein are subject to prior review and approval by the Engineer, who may at times require testing of materials to verify the absence of chemical residue, excess organic matter and other forms for admixing of wastes. Such review and restriction can occur at any time during the spoil placement activity at a site.
- Deposition of spoil materials shall be approved where clear land titles are in place, in areas designated as suitable for fill, and in line with guidance provide by the Supervision Engineer and the Local Government Agency. In no case shall spoil materials be placed in or near rivers, drainage channels, lakes and other forms of permanent wetland.

[19] These classes are solely for use on the KBRT project, and are not intended to reflect broader Government policy.

- Class R recyclables may be stockpiled for up to one month while identifying a taker; otherwise the materials will be treated as a waste product and removed from the site.
- Material Safety Data Sheets (MSDS) for purchased chemical additives, reagents and compounds will be kept at the work site.
- Maintain trash receptacles at construction sites, and designate areas for stockpiling used/discarded materials temporarily.
- The Contractor will handle and dispose of, or recycle, unused and spent hazardous materials at a licensed facility, such as the Alico disposal facility, to prevent losses to the environment.

Alignment

- Quantities of spoil, construction debris and drilling mud/cuttings will be estimated beforehand, and locations for disposal identified and agreed with the Superintending Engineer. Most of these materials can be used as fill, or as cover material in a landfill; prior agreement with overseeing bodies or land owners is required; contact information for entities agreeing to take the materials will be provided for verification purposes.
- Solid waste, trash, broken forms and equipment parts, waste oil, and oil-soaked rags, soil and absorbent will not be disposed of along with earth spoil.
- Vegetation (trees, branches etc.) cut or removed from the alignment during construction will not be allowed to remain stockpiled at the worksite, and will be disposed of or put to proper use immediately upon cutting.
- No waste materials will be stored at a construction site for periods longer than one day. The Contractor will prohibit materials being discarded by others along the alignment during the period of construction; it will be the responsibility of the contractor to dispose of properly any such materials so placed.
- The Contractor will assure that used materials, debris and solid waste are removed daily from construction sites along the alignment, and that no such material is allowed to accumulate onsite, or to interfere with the passage of traffic or construction work.

6.10.2 Operations

466. Depot: Certain types of wastes will be generated during the normal course of operations: trash and canteen waste (Class B); metal parts and cuttings from lathes that will be recycled through metal brokers (Class R); spent solvents from parts washing, waste oil and other organic chemical compounds (Class A).

467. Stations: Litter not directly attributable to operations could increase in the vicinity of stations as a result of human movement. Trash will be discarded by people passing through the stations.

Mitigation measures that apply to solid waste handling and disposal during operations include:

Depot

- The Depot operator will institute a Waste Management System taking into account materials to be disposed of and recycled, estimated quantities and methods for collection, storage,

treatment and disposal or recycling. Material Safety Data Sheets (MSDS) for purchased chemicals, reagents and compounds will be kept current. A recordkeeping system will account for all wastes and recycled materials, and length of time and locations for storage; a tracking and manifest system for hazardous and recycled materials will be maintained.

- The site design and equipment procurement will provide necessary enclosed facilities, containers and equipment for managing wastes.
- The Depot operator will dispose of spent hazardous materials and wastes by means and at locations acceptable to the SEPA and functioning as an approved handler of hazardous wastes.
- The Depot operator will not store hazardous and recyclable materials indefinitely at the site, as this is a hidden liability for the owner. No waste material should remain in storage for more than a year.
- The Depot operator will develop recycling systems and linkages for metal scrap and for waste oil, and will inspect uses and processing beforehand to assure environmental soundness.
- These requirements will be incorporated into contract bidding documents for the bus procurement and operations contracts.

Bus Stations

- SMTA[20] will coordinate with KMC to improve solid waste handling in the vicinity of stations.
- SMTA will assure that station waste receptacles are available and kept in good condition, emptied regularly, and maintained periodically.
- SMTA will maintain the station areas free of trash and refuse, post signs against littering, and keep the bus lanes free of trash.

6.11 Protection of Historical, Cultural and Archeological Sites

468. It is not expected that any Historical, Cultural and Archeological site is present in the line of construction given that it occurs in an existing roadway. One important cultural site exists nearby, outside the construction zone, specifically the Mazar – e – Quaid Mausoleum, but at a distance from the alignment (the mausoleum structure is some 130 m from the right-of-way). There is no other site in the vicinity.

469. The People's Secretariat Chowrangi will need to be entirely excavated to accommodate the Concept Plan for a below grade bus-only interchange at that location. Rebuilding the traffic roundabout at-grade will not account for loss of aesthetic values associated with the existing park-like area within the circular area. This is an urban setting with some historical significance for Karachi.

470. It is possible that relics or artifacts of historical, cultural or archeological interest could be unearthed during construction. The Contractor is required to stop construction on discovery of objects of archaeological origin; and notify the owner, who will contact the Department of Antiquities, Government of Sindh to investigate and, if desirable, undertake recovery. Work must

[20] It is assumed that the Transport and Mass Transit Authority (TMTA) will be functioning by the time operations commence.

remain halted at the specific location until investigation is complete. See Appendix F on Chance Find Procedure for Relics of Ancient Origin.

6.12 Vegetation and Wildlife

Impacts due to construction

471. Habitat loss for birds will occur due to removal of trees along the alignment where the bus lanes will be constructed; bird habitat could be temporarily degraded in nearby 'garden' areas (such as Karachi University campus, Askari Park, Mir Usman Family Park and other natural settings) from construction noise, but this effect is expected to be insignificant; trees may be trimmed on properties or in the right-of-way to make way for NMT improvements (footways, bikeways, etc.), causing temporary loss of habitat. These impacts are of limited extent; no significant impact is likely for any species. Otherwise, no adverse impact on fauna is foreseen due to location of the Project.

472. Consultations with the Department of Parks and Horticulture Authority (DPHA) in Karachi during the feasibility study stage confirmed there are no protected areas that could be affected by the Project. There are rows of trees in the median, as well as isolated trees, and a few trees that form a divider along the service roads on either side of the KBRT alignment in the ROW. There is no national park or nature reserve near KBRT and none of the land or trees in the ROW is protected.

473. Trees found in the centerlines of roadways used for the BRT alignment are relatively small and offer no significant habitat for birds. (Shaukat and Raza 2016) These trees will need to be removed to make way for construction, but can later be replanted along the perimeter of the right-of-way, in the vicinity of stations, or in the median strip. These are unavoidable losses that are made up by growth of trees at other, nearby locations.

474. Some of the trees to the right and left sides of the right-of-way overhang into the roadway and may need to be trimmed to provide clearance for construction equipment and for replacement of footways. It will be up to the contractor to determine locations and extent of tree trimming, and it depends to a great extent on the types of equipment to be used. Some bird habitat may be temporarily sacrificed, but birds are expected to migrate to trees away from the right of way, and rapid re-growth of newly planted trees.

475. Trees to be removed from the centerlines of University Road used for the alignment have been categorized and counted (see **Table 5-8**. It is the responsibility of the Contractor to replant trees according to the quantities and at locations specified in the bid documents. A list of recommended tree species for planting in the median strip beneath the viaduct is provided in Table 6-28. These species were selected on the basis of their common use in urban environments throughout tropical Asia, and their availability and prior use for roadway beautification in Karachi.

Table 6-28: Tree Species Recommended for Urban Planting

Scientific Name	Common Name	Family
Casuarina equisetifolia Forst.	Australian Pine	CASUARINACEAE
Bougainvillea spectabilies Willd.	Bougainvillea	NYCTAGINACEAE
Mimsops elengi L.	Bullet Wood	SAPOTACEAE
Delonix regia Rafin.	Flame of Forest	CAESALPINIACEAE
Cassia fistula L.	Golden Shower Tree	CAESALPINIACEAE
Syzygium cumini (L.) Skeels	Jambolan	MYRTACEAE
Azadirachta indica A. Juss.	Neem	MELIACEAE
Nyctanthes arbor-tristis L.	Night Flowering Jasmine	VERBENACEAE
Michelia champaca L.	Joy Perfume Tree	MAGNOLIACEAE
Caesalpinia pulcherrima (L.) Swartz	Peacock Flower	CAESALPINIACEAE
Lagerstroemia speciosa (L.) Pers.	Giant Crape-Myrtle	LYTHRACEAE
Polyalthia longifolia Thw. cv. Wipping	Telegraph Pole Tree	ANNONACEAE
Gardenia jasminoide	Gardenia Jasmine	RUBIACEAE
Diospyros peregrina	Malabar ebony	EBENACEAE
Spondias pinnata	Hog-plum	ANACARDIACEAE

476. Trees within the ROW can be cut with permission from the DPHA; the authority that must be notified before tree cutting. However, pre-arrangement with DPHA and lodging of a no-objection certificate (NOC) is the first step in a formalized procedure for tree removal generally set out as follows:

    i. Owners of trees removed for construction will be compensated according to market value determined by DPHA. The contractor is responsible for cutting the trees; however, it is the responsibility of the owner to remove the trees and sell or otherwise dispose of the trees.

    ii. The contractor will be required to inventory trees before cutting, resolve any difference with the tree count provided by the consultant, and request permission on a batch-wise basis from the CSC for cutting trees.

    iii. The CSC will notify the owner(s) of the trees of the intent to cut, and request the owner to provide appropriate dispensation of the cut trees.

    iv. Difficulty in removal of and recouping value from trees may arise when the trees or parts thereof including roots and branches are found not to have a value that allows the material to be sold, rather there is a cost associated with removal, storage and disposal. The Contractor is then required to deal with the vegetation as a Class B solid waste.

    v. Trees will be planted as an offset measure to compensate for those cut according to the Government guidelines (5 planted for every single tree cut) at locations specified in the plans, and in case of excess numbers, at locations designated by the DPHA. Types of trees to be planted will need to be decided in consultation with the DPHA.

477. Tree ownership will need to be identified as part of this process, though it is expected that most will be in the jurisdiction of KMC. DPHA office requests that specimen trees or champion trees be avoided wherever possible. DPHA also suggests that the project proponent maintain

remaining trees in the median and elsewhere in the KBRT corridor, including tree trimming, during the operation of the KBRT.

478. Overall, a tree cutting and compensation plan will need to be agreed between DPHA, KMC and SMTA (the Project). Since the Director General of Parks and Horticulture (DGPH) is the authority for cutting trees in the KMC area, there is a need for the DPHA to agree with SMTA on cutting and compensation.

6.13 Public Infrastructure and Utilities

479. Deep road cuts, installation of pier foundations for cross-spans, as well as other sub-grade work can damage existing utilities. The Contractor will avoid interference with and minimize interruption to power, water, gas, drainage and telecommunications ('utilities') systems during the works.

480. Utilities should already be identified, mapped and relocated to the extent necessary prior to the award of contract, or at least ahead of construction. (See Sec. 6.3.3.) Nevertheless, in order to assure minimal interference, the SSEMP prepared by the contractor will contain a specific section (the Utilities and Telecommunications Relocation Plan) to address any additional relocation requirements for power and utilities, and means for protection of utility infrastructure during construction, as follows:

i. Maps and drawings indicating a thorough understanding of utilities in the way of construction.
ii. Record of consultation with utility providers to reconfirm that utilities have been effectively relocated, and the extent to which remaining infrastructure may be damaged or disrupted.
iii. Record of activities undertaken to relocate utilities.
iv. Means for protecting any utilities that may be potentially disrupted or damaged.
v. Contact focal points in all relevant utilities and local authorities in the event of additional relocation requirements or damage/disruption.
vi. Contact information in the local community in case of service interruption.
vii. An emergency response plan including provisions and action plan for immediate repairs to damaged utilities, in order to restore service in the shortest time possible
viii. Approach to coordination of relocation of utilities ahead of construction works with the relevant utility company.

481. The Contractor shall in no instance excavate around or over live buried electrical cable or pressurized gas lines during the construction, or allow such to be suspended across open excavations in a manner that, in the opinion of the Resident Engineer, threatens public or worker safety. Neither shall water lines be left suspended and unsupported across open excavations.

482. Major utilities including K-Electric, Sui Southern Gas, PTCL, NTC, and Engineer 5 Corps have performed site surveys and prepared consolidated cost estimates for relocation of utilities, which are included, along with a 20% contingency, in the Government's PC-1 document as

provisional sums totaling 1,384.11 million Rs. Pending allocation of these funds will insure on-time relocation of the relevant utilities ahead of construction.

6.14 Female Vulnerability[21]

The Risk

483. Public transport which is designed to consider the different needs and concerns of women and men is important for equitable social and economic development, for example, by enabling greater access to education and health services, markets, employment and leisure opportunities to both. Globally, women's limited labour force participation is identified as a factor which constrains economic growth. In Pakistan, lack of safe access to transport has been recognized as a key reason which limits women's labour force participation and, at an individual level, the personal and professional benefits which can flow to women (ADB 2015).

484. Vehicle ownership is a contributing aspect to this. Men are more likely to own a motorbike or a car than women. This means that women need to use public transport to meet their transport needs or are dependent on male relatives who own vehicles to take them where they need to go. Only women who can afford to are able to hire private transport services such as taxis.

485. In Karachi, sexual harassment is a high risk for women, especially young women and girls, who use public transport. Harassment takes many forms such as leering, deliberate groping, verbal and physical gestures, blocking women's way and stalking. It is encountered both while waiting for and also on public transport. In order to avoid sexual harassment, women and girls may change their choice of transport to more expensive, but usually safer, private transport which creates a financial burden for themselves or their families, or, otherwise, they may decide to reduce how much they travel. This has included leaving jobs to take work closer to home or deciding not to work.

486. Media, NGO and donor funded reports include reference to the high levels of sexual harassment faced by women on transport. A 2014 survey of 230 women commuters over the age of 15 in Karachi found that 85% of women workers, 82% of students and 67% of home makers had experienced sexual harassment at least once in the previous 12 months when they were using public transport. Respondents noted that overcrowding was an important factor which provided opportunities for sexual harassment on buses. In the study, over 75% of men who carried out sexual harassment were identified as being commuters, while bus conductors and drivers constituted the remaining 25% (Social Policy and Development Centre 2014). It should be noted that, anecdotally, young boys and members of the transgender community are also exposed to sexual harassment on public transport.

487. In reacting to the fear of sexual harassment, 40% of women students said that they avoided travelling at night which limited their leisure time. In addition, 40-45% of women in all three groups said that they had started to wear the hijab or chadar in an effort to protect themselves from unwelcome male attention (Social Policy and Development Centre 2014).

Mitigation of risk

[21] This section is prepared by the project Gender Specialist.

488. The Red Line BRT Gender Action Plan incorporates features designed to reduce and mitigate the risk of sexual harassment and to encourage use of the BRT by women and minority groups to increase its market. The mitigation activities from the Gender Action Plan target both the physical infrastructure and the institutional settings, and are set out below for reference only (not included in the EMP).

Design of Physical infrastructure

- Separate ticketing counters should be provided to allow separate queuing for women and avoid close contact between women and men.
- Sufficient space on platforms should be allowed for women and men to wait and queue separately.
- Approaches to bus stations and stations should be well-lit at night to discourage sexual harassment and other criminal incidents.
- CCTV should be provided on stations and buses to monitor incidents.
- An emergency help line should be available on stations to report incidents of harassment or other crimes.
- At least 30% of seating at the front of buses clearly marked as reserved for women and people with disability should be provided with a partial partition dividing it from the general passenger section.
- Buses should have a separate door for women who are not with a male companion to enter and sit in the women's section of the bus.
- The bus driver's cabin should be enclosed to protect female drivers or, conversely, to prevent male drivers harassing women passengers.

Institutional aspects during Operations

- The Equal Opportunity, Gender and Social specialist in the PPIU should undertake research to identify women's major concerns, including harassment, and should identify approaches to reduce the risk and encourage greater use of the BRT service by women.
- Contracts with BRT service providers/contractors/third parties should require that staff with direct passenger interaction such as ticketing and station staff are trained about passenger movement management to reduce opportunities for sexual harassment and how to respond to and deal with harassment incidents.
- The BRT system should operate as a network rather than unconnected routes. This will reduce the amount of waiting time for buses which is where some sexual harassment occurs.
- Bus scheduling should be planned and implemented to reduce waiting times and overcrowding on buses and stations which reduces opportunities for sexual harassment.
- A public awareness raising campaign on safety and security should be implemented with an emphasis on behavior change to reduce the sexual harassment of women, children and transgender. The campaign should encourage others to intervene, provide information on how to report incidents and encourage women to report, including assuring confidentiality. In designing and implementing the campaign, there should be coordination with any government agencies and NGOs who are conducting similar outreach activities. Material should be widely

disseminated in Urdu and local languages in public places, on social media and broadcast on FM radio and if possible, TV talk shows and the SMTA/KBRTC website.

- A Complaints and Compliments Mechanism should be established and promoted to the public who use the service. Complaints and compliments should be able to be submitted physically at office counters and through the emergency telephones on stations and digitally on the SMTA/KBRTC website. Complaints, including those concerning sexual harassment, should be dealt with promptly and confidentially by staff who have been appropriately trained, with women staff designated to handle women's complaints. Heavy penalties, including dismissal, should be given to any employees found to have engaged in sexual harassment.
- A database of sexual harassment incidents on or near the BRT should be established. Incidents should be mapped to identify 'hot spots' and strategies devised to address problems.

6.15 Other Construction Issues

6.15.1 Construction Yards and Haul Routes

Construction Yards

489. Construction yards can cause significant inconvenience and hazard for the surrounding community depending on placement, surrounding land use, access, time of use, and activity undertaken at the site. Construction underway in the urban environment often faces a shortage of usable space from which to stage the construction. Noise, dust, traffic, onsite drainage and storage of materials, and the presence of people not familiar to others in the community can lead to disruption of community values.

490. Locations for construction yards are not yet identified. Sites may be selected by the PIU working with the EPCM Consultant prior to award of the construction contract and designated for use by the contractor. Otherwise the contractor will need to locate and obtain clearance from the CSC for the site.

491. A proposed construction site should be of suitable size for the intended use. The site should not be located in areas supporting residential land uses, but if necessary, site access and the site itself should be set back from surrounding residential areas by at least 50 m, except that batch mixing activities should be distanced by 100 m or activities restricted to daytime only. Materials loading and unloading, metal working and other noise producing activities should not be conducted during evening or nighttime hours.

492. Sites should be well-drained with storm water discharge from no more than three locations at the site. Maintenance work, fueling operations, and machinery cleaning and servicing shall be conducted in a manner that prevents spillage of oil, fuel and chemicals to the ground or loss in wastewater flow and drainage. Sites should be kept free of standing water and maintained in an orderly fashion. Solid wastes should be segregated by type, stored in a manner appropriate for the waste, and moved off the site for further disposition in short time frames. Material stockpiles should be maintained in an orderly fashion, and covered as appropriate for the type. Unused, damaged or spoiled materials should be removed from the site.

493. Toilets and washing facilities will be provided onsite. If workers are provided food service, waste flows from the canteen and/or sanitary facilities will be treated prior to discharge by use of an onsite septic tank of suitable capacity to treat waste flows. Discharges should be within the SEQS limits for discharge to the public drain, and will be occasionally monitored for pollutants typical of sanitary wastewater (BOD, TSS, oil and grease, total phenols discharged in a workplace environment).

494. Rules related to worker camp housing and provisions in Sec. 6.8.4 are applicable at locations and in situations where worker camp housing is provided.

Haul Routes

495. Haul routes to and from work site locations for materials, equipment and spoil materials can cause significant impact on land use adjacent to the route. Noise and dust as well as traffic hazards are generated by excessive truck traffic along a route.

496. Roadways used for haul routes during construction, as well as main thoroughfares where the alignment passes, can become degraded from passage of heavy trucks and from fraying and breakage of paved surfaces adjacent to excavations. Existing public infrastructure along the route (overhead walkways, sidewalks and road surfaces) may not be finished out entirely at the completion of construction, and left in semi-usable states.

497. Mitigation measures that minimize construction impacts on public infrastructure include:

- A provisional sum should be included in contract documents for repair and maintenance of roadways used for haul routes and main thoroughfares where the BRT lane passes, to allow mixed traffic lanes to be maintained during construction
- Bill of quantities will include reinstallation of median strips, planting of trees and repair of road pavements prior to completion of contract, and sufficient bid bond to ensure that the contractor finishes and ties in the existing medians, roadways and sidewalks near stations and BRT lanes.

6.15.2 Maintaining Public Space and Community Values

498. The alignment for the BRT remains a public space during construction that must be occupied both by the community and the contractor. A combination of factors can render large areas along the alignment uncomfortable and dangerous for people. These factors are attributed to poor housekeeping and inattention to finishing up where work has started, plus unwillingness to restore sites and services, including repaving normal driving lanes that have been broken by the construction. Factors are difficult to disaggregate; they include high dust levels and air pollution from vehicle exhaust stalled in traffic, interrupted access to property, traffic jams and travel disruption. Dis-amenities are brought about by stockpiles of spoil and excavated dirt left in or near driving lanes, broken and upturned earth that has not been regraded and finished out, lack of flagmen and signage, storage of materials in or near the roadway that are not barricaded, broken and potholed pavement, excavation dewatering that is discharged across driving lanes and pedestrian walks, localized ponding in public space, severance and blockage of driving lanes, side streets, and pedestrian walkways, and lack of accommodation of the need for pedestrians to walk in the vicinity of or across work areas. Here noise, dust, traffic congestion

and community inconvenience/hazard merge into a single bad experience for any public exposed to it.

499. The condition extends to utilities not being relocated before start of construction causing hazard and risk, sections near completion yet left unfinished due to insufficient equipment and labor, and abandoning discarded materials, cut and discarded vegetation and trees, and trash within the work area due to failure to maintain the work space on a continuous basis and finish out the work. This state-of-affairs stems from the contractor's lack of concern for the public and desire to maximize profit. Mitigation measures put forth in previous sections can eliminate these hazards and inconveniences if the implementing agency has the will to enforce measures on the contractor.

6.15.3 Depots

500. Sites designated for the depots are in sparsely settled, mixed-use areas with some residential dwellings nearby (see Figure 3-29 in Chapter 3). Land use for the identified plots (see Figure 6-10 and Figure 6-11) will not change substantially, since past use includes bus storage and maintenance as well as vehicle maintenance undertaken by the Pakistan Rangers, the current occupant of the land parcels. The space is expected to be entirely vacated, with existing structures demolished.

501. A number of trees are found at the Malir Halt location. Trees will need to be removed, and incorporated into the tree replanting program described in Sec 6.12.

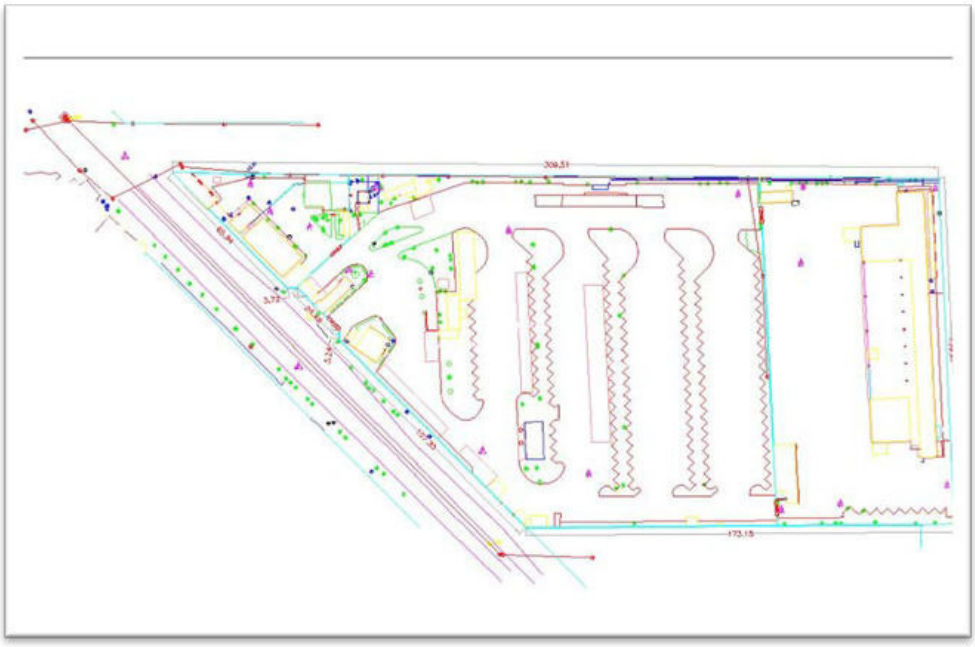


Figure 6-10: Plot Plan (Initial Survey) of Mausamiat Location

Figure 6-11: Plot Plan (Initial Survey) of Malir Halt Location

502. ADB's special requirements related to existing facilities described in SPS Appendix A, para 10 requires that an environmental audit be conducted of these sites to determine the existence of any areas where the project may cause or is causing environmental risks or impacts; and to provide a corrective action plan for each area of concern, including costs and schedule. The due diligence will be performed once access to the sites is cleared by the present occupants.

503. Construction of the depot facilities should follow guidelines set out for other aspects of the Project. Design of depot facilities has not proceeded; it will incorporate the following principles either as design or operations requirements:

Design

504. Incorporation of facilities and infrastructure in basic design for control of chemical spills, fuel and oil leakage, and sanitary flows from toilets, washrooms, dormitories, canteens and vendor areas. This will include but not be limited to:

- Segregated drainage areas within the site perimeter for 'clean' and 'contaminated' storm water runoff.
- Routing of potentially contaminated runoff through oil-water separators and wastewater treatment, as needed.

- Limited discharge locations to offsite drainage, and access points for sampling flows.
- Provision of suitable treatment capacity for sanitary and kitchen wastewater, and for wash water from bus washing operations (these may be combined at some point, but may need separate upstream treatment beforehand)
- Waste oil recovery tank bunkered to prevent spill to ground.
- Fuel storage tanks that comply with National safety standards.

Construction

505. The primary impact during construction of depots is expected to be noise. Noise levels were monitored at the two sites by SUPARCO on 14-16 Feb 2018 (see Figure 6-12), and maximum hourly Leq was found to be 64 dB (Gulistan-e-Jauhar, 15:00) and 66 dB (Malir 09:00).

506. Noise caused by construction activities at depot locations is evaluated using the same approach described in Section 6.3.1. Typical activities include clearing and grubbing (site preparation) using dump truck and scraper (SELs of 88 and 89 dB, respectively), and general construction (concrete truck, crane; SELs of 85 and 88 dB). Impacts are assessed at 30 m distance from the noise source, the distance to the nearest residential dwelling (an apartment block) from the Gulistan-e-Jauhar depot property boundary, and, at Malir, the distance to a nearby government training school (R.T.T.S. Regional Telecoms Training School; previously the Pakistan Telegraph and Telephones Dept.). While some residential developments are found in these areas, the predominant land use is commercial.

507. Table 6-29 summarizes the expected noise exposure during construction at depot sites. Existing noise levels are moderate, and exceeded at a distance of 30 m by equipment noise at 84 dB. Total noise burden is dominated by construction noise, and increase in noise level is 20 dB. However, if the distance is extended to 90 m, approximately the center of the depot site at Gulistan, equipment noise adds only 6% to the total noise burden. If land use in the areas is classified as commercial, total noise burden does not exceed the standard, even at a close distance. However, residential criteria are exceeded under some conditions. The RTTS training school may be subject to inconvenience and excess noise during both construction and operations, since its main building is immediately adjacent to the entry to the Malir site.

508. Construction noise will be intermittent and of short duration, and impacts should be minor other than at the Training School.

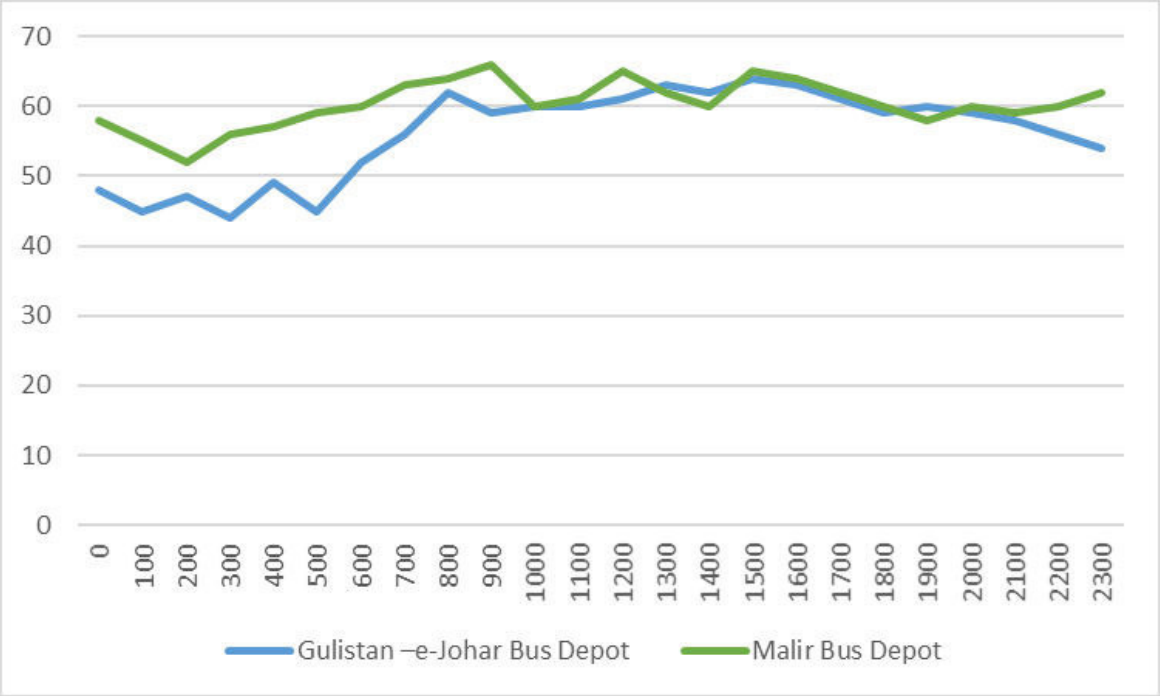


Figure 6-12: Hourly Leq measured at Bus Depot Sites

Table 6-29: Summary of Noise Impacts at Depot Sites due to Construction

		Evaluated at 30 m		Evaluated at 90 m	
		Gulistan-e-Jauhar	Malir	Gulistan-e-Jauhar	Malir
A.	Max Leq from Equipment	84	84	69	69
B.	Ambient Peak (7am-7pm),Leq	64	66	64	66
C.	Total Noise Burden	84	84	70	71
D.	Amt increase (C-B)	20	18	6	5
E.	% increase (E/B%)	30.6%	26.6%	9.9%	7.4%
	Land Use		Residential		Commercial
	Daytime Std	75	75	85	85
	Night time std	60	60	85	85

6.16 Other Operations Issues

6.16.1 Depot Operations

509. As noted earlier, noise may be a problem during operations of the depots. Generally, if sensitive land uses are within 30 m of the access road to the depot location (15 m if there are intervening buildings), then specific impact assessment is warranted; and facilities themselves for bus servicing and maintenance should be located where land uses are compatible up to a distance of 100 m (70 m where there are intervening buildings). There are only a few exceptions to these guidelines at the proposed sites:

Gulistan-e-Jauhar

- Kishwar Heights residential apartment building, an 8-storey building set in generally poorly kept neighborhood. Distance from depot property boundary: 20 m
- Pakistan Meteorological Organization (PMD) headquarters to southwest at distance of 70 m from property boundary.
- Kachi abadi settlement on encroached land to east and south; land ownership not available.

510. Land use, while still undeveloped at this location, is considered compatible with the bus depot.

Malir Depot site

511. The area is dominated by telecommunications agencies. Pakistan Telegraph and Telephones colony is immediately to the west, though the closest building development is about 60 m. Center point of housing is about 200 m. A PTCL warehousing area is located to the east of the entrance access. An undeveloped area owned by PTCL is located east of the site-proper.

512. However, the R.T.T.S. Regional Telecoms Training School is located adjacent to the depot entrance access (the leg stretching south shown in Figure 6-11). The center points of three buildings that make up the school are 100, 40 and 25 m to the access road. The nearest point of the nearest building is within 5 m of the access.

513. There could be significant noise impact on activities at the training school during depot operations, due to the constant coming and going of buses at the depot during daytime. Rooms on the near side of the building would experience noise impact. Shielding may be necessary by erecting noise barriers along the near side of the entrance road.

514. Additional guidelines to be applied during operations include:

- Prevention of impact from storage and use of hazardous materials (cleaning compounds, oil, fuel, solvents etc.) through enactment of a Hazardous Materials Management System (HMMS)
- Good housekeeping program to maintain paved areas free of oil spills and site free of windblown solid waste
- Maintenance of onsite wastewater collection system in good operating condition
- Safety and health programs as needed to assure an accident free and healthy environment.

515. Independent operators will be engaged under integrated contracts for operations and fleet procurement, and will be responsible for operating—and potentially constructing—depot facilities. Preparatory work for these contracts is carried out by the ODBM consultant. The contract specifications should include environmental protection requirements relative to all phases of activity: design, construction and operations, which the successful bidder will be required to carry out as part of its development plan. Technical assistance will be necessary to assure these facilities are designed, built and operated in an environmentally sustainable fashion.

6.16.2 Job Displacement within Transport Sector

516. It is not clear from work done thus far by the ODBM consultant how much job displacement in the transport sector is expected to occur. ODBM has a fleet scrapping plan aimed at

replacement within the public transport sector of Karachi's very old bus fleet. The ODBM Consultant recommends that most vehicles in the current public transport system be scrapped with the startup of the new BRT in Karachi. The Scrapping Plan will include a financial compensation to the vehicles owners, based on the market value of each bus, considering the vehicle's type and age. While the proposal provides some assurance that the old buses will be removed from service and their owners invited "to join the Operator Company as a shareholder", it does not address livelihoods of drivers and fare collectors, and whether these persons will be provided employment with the "Operator Company". This potentially represents loss of livelihood for a cohort group that can be taken up in the Resettlement Plan for the Project.

6.16.3 Affordability

517. The ODBM consultant specifically addresses affordability under its terms of reference related to Fare Structure and Potential Non-Fare Revenue. It reviews current fare structures in use on Karachi's current public transport system, which is composed of Mini Buses, Large Buses and Coaches running under the same distance-based fare structure. Fares range from 10 to 20 rupees for distances from 5 km to 20 km, respectively.

518. Along with types of fare its study considers current and discounted fare levels, along with eligibility and benefits related to discounted fares. The study concludes that discounted fares can be a good incentive to the use of the BRT system for special social groups for reasons of social equity, such as: students, senior citizens and persons with disabilities. The study further recommends that the government subsidize fare discounts by paying the operator the difference between the value received (discounted fare) and the value of the non-discounted fare.

519. However, the ODBM study does not contain a willingness-to-pay analysis, nor does it recommend (at this stage) a rate for use of the BRT, or the amount of any subsidy to be provided. The BRT needs to operate as a financially self-sustaining system; however, it is not clear what rate, or what degree of subsidy, will produce long term sustainability. Ridership may in the long term be enhanced by lower rates and subsidies, and there are external benefits to be had from higher rates of usage.

6.17 Greenhouse Gases and Climate Change

6.17.1 Climate Change Mitigation and Offsets

520. Offset calculations are based on predicted numbers of vehicles displaced from the roadway as a result of the BRT at target dates into the future, say 10, 15 and 20 years, as compared to a case without the project. As described in ADB 2016a, a modal shift to urban transport projects such as bus rapid transit (BRT) leads to "displaced emissions" as travel by private vehicle is reduced. The equivalent greenhouse gas (GHG) emissions from the modal shift are estimated based on the reduced fuel consumption compared with the previous mode options multiplied by the corresponding fuel emission factor."

521. Estimates of reduced private (and other less efficient public) vehicle use are being prepared by the ODBM consultant and should lead to a generalized estimate of GHG emission savings. However, the CDM methodology for BRT (AM00031) is complex and poses numerous monitoring challenges. (Nelson 2008; see also ITDP CU) Calculations for BRT projects in the

USA show that "annual emission reductions might be measured in the hundreds rather than thousands of tons for most projects." However, "projects in developing countries are likely to have far greater potential, as BRT usually replaces a highly inefficient system with aging, small microbuses. Most emission reductions in developing countries are gained from the shift to cleaner and larger vehicles rather than modal shift." (Nelson 2008) Still, estimating GHG emissions in a manner specific to IPCC protocol depends on information not as yet available to the project.

522. An abbreviated approach is used similar to that performed for estimation of primary air pollutants in Sec. 6.4.6, wherein an estimation of the average annual daily traffic is used to approximate the numbers of vehicles present with and without the project, assuming a percentage of ridership (between 20 and 40%) goes over to the BRT. Only CO2 is considered in the line-up of GHGs, and these emission factors are taken from various sources in the literature. Emission factors combined with modal shift give rise to a change in the amount of CO2 emitted. CO2 emission factors are shown in Table 6-30.

Table 6-30: Emission Factors used in Calculation of GHG Reduction for KBRT

	gm/km	Data Source	
Motorcycle (4-stroke)	32	8th SIAM FE Declaration 2016-17	Median of all models
Passenger car	142	8th SIAM FE Declaration 2016-17	Median of all models
Small bus/van	200	WB data	
CNG Bus	1,281	Bradley 2013	Median of all test cycles
Diesel Bus	1,253	Bradley 2013	Median of all test cycles
Hybrid Bus	1,178	Bradley 2013	Median of all test cycles

523. Based on these emission factors, and applying the modal shift estimated in Sec. 6.4.6, in which 20% to 40% of ridership is captured by the Red Line BRT along its alignment, it is estimated that 47 – 94 TPD (tons per day) of CO2 is removed from the atmosphere, equivalent to 17,000—34,000 TPA (Tank To Wheel (TTW) emissions). As a point of comparison, the Grutter Study described in Sec. 6.4.6., which assessed the potential for GHG emissions reduction as a result of the BRT Karachi (average over a 12-year period), estimates potential GHG emissions as shown in Table 6-31, which are roughly comparable to the estimate under the present study. The full results of that study can be found in Appendix C.

Table 6-31: Estimate of GHG Emissions for the BRT Karachi (TTW, WTW)

Parameter	Unit	Diesel buses	CNG buses	Diesel hybrids	CNG hybrids
GHG reduction TTW	tCO2e	57,177	57,253	62,243	62,304
GHG reduction WTW incl. BC	tCO2e	71,126	72,124	78,276	79,074

524. As a point of reference, the World Wildlife Fund of Pakistan was tasked with estimating GHG emission reduction from the various BRT projects underway in Karachi (Ali Dehlavi 2017) and concludes that the potential for removing 17,000 tons annually of CO2-equiv by 2030 exists, of which the Red Line corridor accounts for 17%, or around 2,900 tons. The estimate prepared under the current study is some 6 – 12 times the amount estimated by WWF; however, that work is more detailed, accounts for more factors (including growth in mixed traffic) and incorporates

leakage, according to the protocols of the IPCC. The fact that the two amounts are of the same order of magnitude lends credence to the possibility of substantial GHG emission reduction as a result of the project.

6.17.2 Vulnerability and Adaptation

525. Underpasses constructed for the BRT to bypass major intersections may be vulnerable to flooding. Flash flooding occurs in Karachi occasionally; climate change could bring about a greater frequency and magnitude of these events.

526. The BRT is potentially vulnerable to a flood event, which could interrupt service or, in a worst-case situation, strand passengers in floodwaters. Flooding to any extent in roadways increases the potential for accident.

527. Increased rainfall during storm events above historical levels could exacerbate the problem of flooding; pumping systems should account for increased short-duration rainfall to assure that bus lanes in grade separations are not flooded. Likewise, gravity drainage of at-grade bus lanes need to accommodate increased rainfall in line with what may be expected due to climate change.[22]

6.18 Cumulative Impacts

528. A cumulative effect refers to an impact arising from a synergism among projects, policies and conditions. Transport planning gave rise to the Karachi Red Line within the context of a vision for growth, along with a community vision, expressed in the language of movement: how improved mobility could improve daily life and provide pathways for growth. The accumulating effect is beneficial and was conceived in that light. Still some cumulative adverse impacts are possible in an environment distorted by imperfect social structural mechanisms. The following paragraphs highlight various types of uncontrolled development that should be taken into consideration by the governing bodies for land use.

529. Scenario: The BRT Red Line will be a driver for uncontrolled development of the outlying areas around Askari, Sindhi Town and Chhota Malir. Land use plans for that area may not adequately account for rapid development of the area in the wake of improved public transport. The BRT Red Line will spur further residential development where space remains available in Malir Cantonment, as people are able to use the BRT to access the city center. Commercial activity along University Road and other nearby thoroughfares could intensify as additional infrastructure fills in available space, and utilization is improved. Such intensification puts pressure on other public services: electricity, water and communications.

530. Assessment: This is in the nature of urban development and is anticipated by the fact of improved public transport. Indeed, it can be said that the public transport system is there to stimulate this sort of development, provide opportunity for people, new living space, access to jobs and educational opportunity. While some forms of development may be seen to run counter to environmental values, planned urban development of the type that gives rise to the BRT accommodates environmental values within its framework.

[22] See Kang et. al 2016 for a discussion on how drainage systems are grossly undersized to carry rainfall amounts expected under a RCP 8.5 scenario.

531. Land use planning can reduce the likelihood of substandard development on individual plots of land. There is the possibility such plans will not be in place, or structures will be poorly constructed and maintained. Still, the BRT Red Line would not be the cause of substandard development, rather the implementation of the project mitigates these outcomes by adding value to the area through rapid transport linkages to downtown Karachi. In the short term, the Red Line enhances investment potential and makes it more likely that developments will be built to a high standard.

532. Scenario: The BRT will increase air emissions through the introduction of more buses, without materially affecting the number of private cars on the road.

533. Assessment: The BRT will reduce air emissions by replacing aged vehicles from the roadway and introducing larger vehicles that are more fuel-efficient and provide better transport for the individual passenger. This direct environmental benefit is part of a whole, which is the move toward a more modern, energy efficient, clean and safe urban condition, for which the BRT forms an integral part. While the choice of fuel is not settled, a CNG-hybrid bus is favored, which results in a reduction of all forms of primary air pollutants as well as CO2 in comparison with the base case. This is described in Sec. 6.4.6 of the report. In summary, the overall magnitude and effect of the BRT on air emissions is expected to be positive.

534. There is no quantifiable negative cumulative impact that can be identified for the KBRT Red Line.