Climate Risk and Vulnerability Assessment

Project Number: 48289-002
March 2017

Islamic Republic of Pakistan: Peshawar Sustainable Bus Rapid Transit Corridor Project

A Checklist for Preliminary Climate Risk Screening

Country/Project Title: PAK Peshawar Sustainable BRT Corridor Project
Sector : Transport
Subsector: Urban transport Division/Department: CWRD\CWTC

Screening Questions		Score	Remarks
Location and Design of project	Is siting and/or routing of the project (or its components) likely to be affected by climate conditions including extreme weather related events such as floods, droughts, storms, landslides?	1	The eastern area of the project is subject to moderate 50-yr flood hazard (See Appendix A). Peshawar has also historically been subjected to flooding events, particularly in the monsoon season[1]. Road drainage system will likely account for projected climate change-driven increases in rainfall volume and extreme events[2]
	Would the project design (e.g. the clearance for bridges) need to consider any hydro-meteorological parameters (e.g., sea-level, peak river flow, reliable water level, peak wind speed etc)?	1	
Materials and Maintenance	Would weather, current and likely future climate conditions (e.g. prevailing humidity level, temperature contrast between hot summer days and cold winter days, exposure to wind and humidity hydro-meteorological parameters likely affect the selection of project inputs over the life of project outputs (e.g. construction material)?	1	Climate change is projected to increase mean annual temperatures in the Northern regions of Pakistan, thereby likely impacting choice of materials.
	Would weather, current and likely future climate conditions, and related extreme events likely affect the maintenance (scheduling and cost) of project output(s) ?	0	
Performance of project outputs	Would weather/climate conditions, and related extreme events likely affect the performance (e.g. annual power production) of project output(s) (e.g. hydro-power generation facilities) throughout their design life time?	1	Flooding or landslides will likely affect availability and performance of infrastructure.

Options for answers and corresponding score are provided below:

Response	Score
Not Likely	0
Likely	1
Very Likely	2

[1] Peshawar floods in the news:

- (August 2015) Pakistan flash flood kills 118 people: Flooding has affected more than 800,000 people, disaster management authority says. http://www.cbc.ca/news/world/pakistan-flash-flood-kills-118-people-1.3177840
- (April 2015) Peshawar floods: At least 44 killed after heavy rain, flooding in Pakistan: http://www.abc.net.au/news/2015-04-27/at-least-44-killed-after-heavy-rain-flooding-in-peshawar/6423246

[2] UNDP Climate Change Country Profiles: Pakistan. http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Pakistan/

Responses when added that provide a score of 0 will be considered low risk project. If adding all responses will result in a score of 1-4 and that no score of 2 was given to any single response, the project will be assigned a medium risk category. A total score of 5 or more (which include providing a score of 1 in all responses) or a 2 in any single response, will be categorized as high risk project.

Result of Initial Screening (Low, Medium, High): Medium

Other Comments: In light of rating, it is recommended that project undertakes additional climate risk and vulnerability assessment and fills in a Climate Risk Assessment and Management Reporting Template.

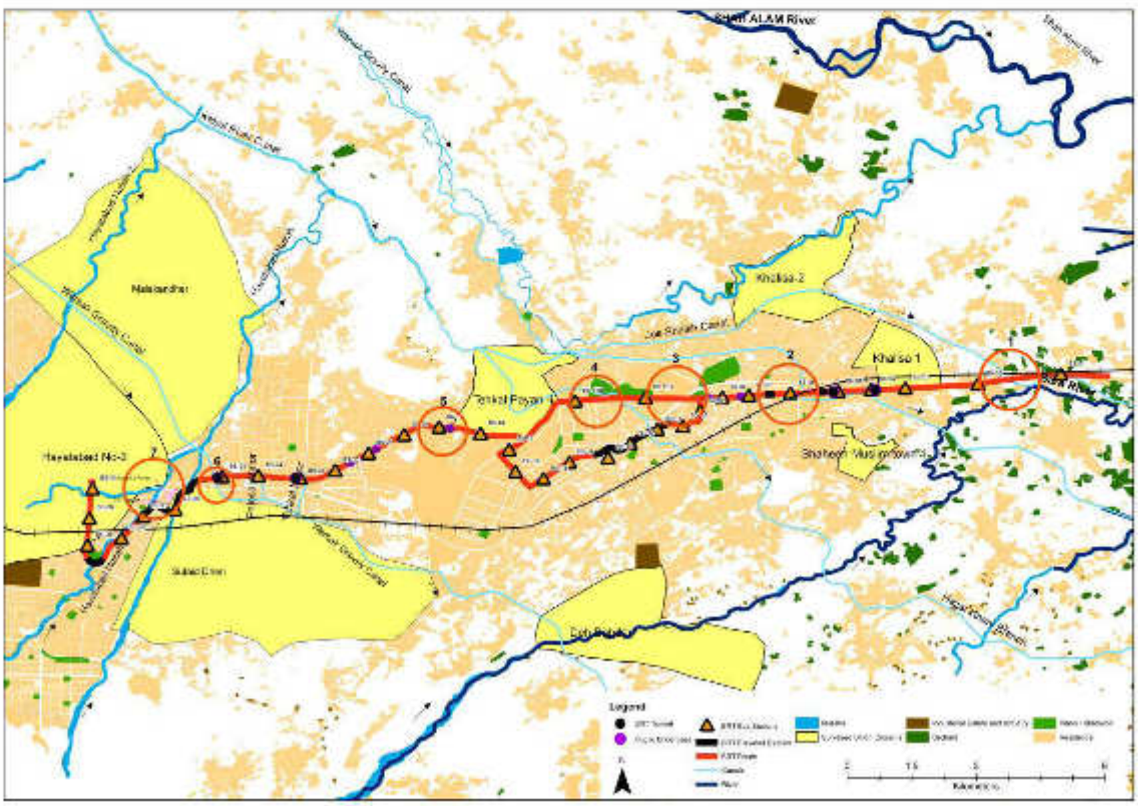
Nathan Rive

Prepared by: Nathan Rive
Date: 4 April 2015

ADB

SC 107707-PAK

Climate Risk & Vulnerability Assessments Study of Peshawar Bus Rapid Transit (BRT) System



FINAL REPORT

March 2017

Report submitted by:

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Asian Development Bank

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I. EXECUTIVE SUMMARY

1. Climate change will place greater pressure on the existing constraints in urban development and planning common to cities in Khyber Pakhtunkhwa, Pakistan; these include: (i) steadily accelerating, hitherto unplanned and uncontrolled urbanization, some of which is attributable to the migration push factors of increased vulnerability to climate change, (ii) severe deficits in appropriate and adapted urban infrastructure provision and basic service delivery resulting from financial constraints, (iii) planning instruments that either have not existed or are inadequately adapted to climate change and disaster risk management, lack an implementation-orientation and/or are unenforced, (iv) the growth in urban poverty and lack of inclusiveness in municipal planning, with the burden of vulnerability falling disproportionately on the urban poor, and (v) severe constraints in local government capacity, governance structures, and municipal finances all of which impact on the ability of cities to respond to climate change. The increase of the future severity of storms will increase the potential storm related damages as well as causing additional soil erosion from the over-topping of roads and embankments.

2. Temperature, rainfall and high winds are the key climate variables for Peshawar city that needs to be considered for BRT climate risk and vulnerability assessment. A summary of these climate variables is provided below:

3. **Temperature:** historical trends are as follows:

- Monthly mean temperature rise of 0.9°C was observed during 1951-2015.
- Warm nights are increasing significantly
- The highest maximum temperature recorded for Peshawar was 50°C on 18th June 1995 and
- The lowest temperature was -3.9°C on 7th January 1970

Climate models project that the:

- *maximum temperature* in Peshawar under emission scenarios RCP4.5 and RCP8.5 respectively is expected to rise by:
  - 1.28-1.5 °C during 2011-2040,
  - 1.86-2.5 °C during 2040-2070 and
  - 1.71- 2.6 °C during 2070-2100.
- *minimum* temperature in Peshawar under emission scenarios RCP4.5 and RCP8.5 respectively is expected to rise by:
  - 1.25 -1.5 °C during 2011-2040,
  - 1.9 - 2.5 °C during 2040-2070 and
  - 1.7 - 2.6 °C during 2071-2100

However, the more important aspect of high temperature with respect to climate impact on the BRT infrastructure and particularly with regards to operation and maintenance is the occasions of extreme heat waves and their period.

4. **Rainfall**: historical trends are as follows:

- 281 mm rise in annual precipitation occurred during 1951-2016 (last 66 years)
- Maximum precipitation increase occurred during monsoon seasons
- The annual average rainfall during 1951-2016 is 454.4 mm. Whereas the heaviest annual rainfall recorded was 903 mm in 2003 and the heaviest monthly rainfall was 409 mm in July 2010.
- The heaviest 24hrs record-breaking rainfall of 274 mm was recorded in July 2010

beating an earlier record of 187 mm in April 2009.

Climate model project that for Peshawar:

- under emission scenario **RCP4.5** annual rainfall is projected to:
  - decrease slightly from base of 454 mm to 418 mm during 2011-2040,
  - 411 mm during 2040-70 and then
  - increase again to 440 mm annual during 2070-2100
- under emission scenario **RCP8.5** annual rainfall is projected to:
  - reduce to 352 mm during 2011-2040
  - Increase to 468 mm during 2040-2070 and again
  - slight decrease to 432 mm during 2070-2100.

5. **High Winds:** During the months of April and May each year, when the days are relatively warmer and the nights are cooler, sudden rise and fall in terrestrial temperatures causes low air pressures, bringing whirling winds. A study[1] shows that the frequency of wind storms is higher in these month as compared to other seasons. From the limited data, available to the team for the city, the following is notable:

- A windstorm of 110km/hrs. was recorded on 26 April 2015, which claimed around 31 human lives and damaged infrastructure and private property in Peshawar district.
- Projecting future strong wind pattern is challenging since these wind systems are not well resolved by global or regional climate models. However, the best possible maximum wind speed projections from the CORDEX[2] data, available to the team, are not showing any increase in intense wind storm events.
- None of the areas along the BRT route were found to be at particular risk from tunneling high wind effects. As such it is difficult to propose any infrastructure design criteria to be followed along the BRT route. However, it is proposed that the BRT infrastructure especially signboards, tall structures, lighting fixtures at terminal stations need to be able to sustain future intense wind storms of at least windstorms of 110km/hr. which occurred in the past

Future Climate Extremes Projections:

6. Temperature: towards the end of the 21st century, a number of summer hot days (with maximum temperature *greater* than 25°C and *greater* than 45°C) and frequency of heat waves are expected to increase significantly on an annual basis such as:

- On average, number of days per year with *greater than* 45°C maximum temperature are projected to **increase** by 6 days during 2041-2070 under high end emissions scenario.
- Duration of heat waves (annual count of days with at least 6 consecutive days when maximum temperature is *greater than* 90th percentile of the 30-year data) will also **increase** by 15 days during 2041-2070.
- Conversely, cold waves duration (annual count of days with at least 6 consecutive days when minimum temperature *less* than 10th percentile of the 30-year data) will **decrease** by 21 days during 2041-2070.

7. Rainfall: Projected patterns show high inter-annual variability with amount of total precipitation in individual years showing an increase towards the end of century such as:

[1] Ata Hussain , Hazrat Mir & Muhammad Afzal (2005). Analysis of dust storms frequency over Pakistan during 1961-2000, Pakistan Journal of Meteorology Vol. 2: Issue 3: (March 2005) 49

[2] The Coordinated Regional Downscaling Experiment (CORDEX) is a program sponsored by World Climate Research Program (WCRP) to develop an improved framework for generating regional-scale climate projections for impact assessment and adaptation studies worldwide within the IPCC AR5 timeline and beyond.

- No significant trend is found in frequency and occurrence of very high (*greater* than 50 mm/day) and extremely high (*greater* than 100 mm/day) precipitation events.
- Overall model projections indicate 4 such events during 2011- 2070 under both emission scenarios.

Key Climate Change Impacts on the Peshawar BRT

8. BRT detailed design needs to cater for projected increase in Peshawar temperature and intense heat-waves. Furthermore, even though intense precipitation and intense wind storm events along the BRT route are considered rare by the team, this should be catered for in the design.

9. Some of the possible impacts of climate change on Peshawar BRT infrastructure, operation and maintenance due to increasing temperature, intense heat waves, heavy precipitation events and intense windstorms are summarized in the following table.

Table E1: Summary of possible climate change impacts on the Peshawar BRT infrastructure

Potential Climate Change Stressor	Impacts on Peshawar BRT Infrastructure, operation and maintenance
Increase in the number of “very hot days and heat waves” (Extreme recorded heat wave temperature was 50°C on 18th June 1995)	Peshawar summer higher temperatures are projected to be *greater* than 45°C. Whereas sustained air temperatures of above 32°C considered vulnerable for transport infrastructures. As such sustained projected higher temperatures in Peshawar are likely to cause traffic related rutting and softening of BRT road paved surfaces and at temperatures of 50°C may even result in the softening and spread of liquid asphalt. (*London M25, 2013 and 2003, BBC*) Very hot temperatures in Peshawar can also cause thermal expansion of joints of bridges and underpasses in concrete infrastructures
Intense precipitation events (Extreme recorded event was 274mm rainfall in 24hrs on 28th July 2010)	Although Peshawar future precipitation projections are indicating a decrease in total annual rainfall, the intensity of past extreme rainfall event needs to be considered for the design process. Such extreme precipitation events can overload the urban storm drainage systems particularly at the indicated hotspot locations along BRT route (see Figure 4) causing inundation, damage to roads and underground tunnels, due to flooding. Increase erosion and damage of road base and bridge support structures cannot be ruled out.
Intense future wind storms (Extreme recorded wind storm was 110 Km/hour)	Intense future wind storms, though may be rare, can cause increased threat to stability of sign boards, tall structures, lighting fixtures along BRT route and particularly at the elevated terminal stations.

15. This report has been developed after site visits and consultations with community groups in the vicinity of the BRT route, Urban Planning Unit, Peshawar BRT Company (PBRTC), Nazims, the team of the ADB funded Urban Resilience Assessment (URA) project in KP and the Pakistan Metrological Department.

II. INTRODUCTION

A. Objectives and Purpose of the Assignment

10. The proposed projects, Peshawar Sustainable Bus Rapid Transit Corridor (PSBRTC) and Karachi Bus Rapid Transit (KBRT), will contribute to developing sustainable urban transport systems in Peshawar and Karachi, Pakistan, through the delivery of bus rapid transit (BRT) corridors. The purpose of the projects' will be to develop sustainable urban transport systems in Peshawar and Karachi. The projects' outcomes will be to improve public transport in Peshawar and Karachi, benefiting a total population of 2 million.

11. The projects will consist of two interlinked outputs respectively: (i) full restructuring of corridors selected for the BRT infrastructure; and (ii) effective project management and sustainable BRT operations through institutional and organizational developments. The projects are economically justified by major time savings for future BRT passengers, vehicle operating cost savings and savings in vehicle emissions which will in turn contribute to mitigate climate change and improve the health of Peshawar and Karachi's citizens. The project will also contribute to making Peshawar and Karachi more liveable and safe, greening urban infrastructures, boosting private sector investment, and fostering gender equity.

12. Both projects are being prepared in three stages respectively:

- First Stage – Project Preparatory Technical Assistance (PPTA, grant): The following key outputs are expected under the PPTAs: (a) conceptual plans for Peshawar and Karachi's BRT networks, NMT, Parking, traffic management and transit-oriented development; (b) preliminary engineering designs, cost estimates and full due diligence for the Phase 1 BRT corridors; (c) initiation of Peshawar and Karachi's bus industry transition and BRT initial operational models; (d) project implementation roadmap; (e) support to the provincial governments of Sindh and Khyber Pakhtunkhwa in establishing Urban Mobility Authorities and BRT Companies; and (f) potential use of "waste-to-fuel" technology.
- Second Stage – Project Design Advance (PDA): A US$10 million advance loan under the PDA facility will be approved by ADB in 2016 to take the PPTA work further and conduct notably (a) detailed engineering designs and cost estimates; (b) final bus industry transitions, BRT operational plans and business models; and (c) selection of contractors for civil works and equipment. All activities under PDA have to be implemented within a maximum period of 24 months.
- Third Stage – Contracts Signing and Construction: In parallel with activities under PDA, ADB will approve the loans in 2017, contracts for civil works and equipment will be signed with selected contractors and construction works will start in 2018.

13. Both Projects have been screened as 'Medium' to 'High' risk using the ADB climate risk checklist and the third-party AWARE tool. As such, and in line with the ADB Climate Risk Management Framework, a further climate risk and vulnerability assessment (CRVA) will be performed to inform the respective project detailed design processes under the Project Design Advance (PDA) facility.

14. The BRT corridor will include construction of (i) a BRT route along corridor 2; (ii) sidewalks, on-street parking, mixed-traffic lanes, and non-motorized transport lane along the BRT; (iii) a high-capacity drainage system along the corridor; (iv) BRT depot; (v) improvement of access roads for NMT and feeder services; and (vi) energy-efficient streetlights and intelligent transport systems for traffic management.

15. In order to have sustainable BRT operations, there will be a requirement for: (i) developing institutional capacity of Peshawar BRT Company (PBRTC) and Peshawar Urban Mobility Authority (PUMA) and Sindh Mass Transit Coordination Authority (SMTCA); (ii) designing the BRT operational plan and business model; (iii) facilitating a bus industry transition

through negotiations with private bus operators selected to operate the BRT; (iv) setting up a fleet scrapping program and compensation mechanism for non-participating operators; (v) structuring and delivering viable public-private partnership arrangements through transaction advisory service; (vi) developing capacity of the traffic police to enforce parking, hawkers' policy and other traffic rules; and (vii) implementing a transit-oriented urban development strategy.

B. Scope of Works

16. Assess and report on the climate risks to the infrastructure and operation & performance of the project investment, and in collaboration with the respective PDA teams, assess, recommend, and report opportunities to reduce these risks through adaptation interventions.

17. Support the ADB project team in preparing documents for a funding application to the Green Climate Fund or another relevant fund.

C. Detailed Tasks and/or Expected Outputs

- Develop an inventory of climate data required for the CRVA study, based on the agreed CRVA methodological framework and in close consultation with the domain/sector experts.
- Collate baseline climate data.
- Collect and develop detailed climate scenarios based on climate change variables as required for future time horizons pertinent to the needs and objectives of the project (e.g. using CMIP5 data or other national and international sources as appropriate) and methodological approaches; including documentation of scenario method, data sources, uncertainties and caveats.
- Develop a simplified "best estimate" and "high case" scenarios for the key climate parameters and associated hazards including implications for project performance and operation under climate change during the lifetime of the project, using most current and relevant regional climate projections available.
- Provide guidance on how the climate data projections and information should be interpreted and applied in the CRVA study within the context of the Investment Program with recommendations of structural and non-structural options approaches and interventions.
- Assessment of the project's climate vulnerabilities and the associated risks to the structural component of the project.
- Highlighting uncertainties of climate scenarios.
- Assessment of additional adaptation cost where possible.

III. APPROACH AND METHODOLOGY

A. Approach

18. Climate change impacts consideration on transport infrastructure is relatively a new concept and decision maker for guidance are trying to explore existing tools and approaches for making such assessments. In our CRVA study we will be using the following well recognized transport decision makers three broad approaches for future climate change impacts: vulnerability assessment, risk assessment and adaptation assessments.

- **Vulnerability assessment** of transport sector start with the consideration of existing climate particularly extreme weather stressors and how climate change will add new stressors in the future. This assessment findings can then help to prioritize, and address vulnerabilities.
- **Risk assessment** consider the probabilities of climate-induced impacts on transportation infrastructure. Generally, this assessment will be based on the exposure and vulnerability probabilities. This assessment provides quantitative climate change associated risk to transport infrastructure.
- **Adaptation assessment** provide options available to adapt climate change impacts on transport infrastructure effectively and to reduce its vulnerability to enhance its resilience

19. The above-mentioned approach that will be used to conduct the vulnerability assessment is further explained and shown below in Figure 1. Threats are identified at the city level local (project site in Peshawar).

20. ***Sensitivity*** is assessed for specific components of the proposed BRT route.

21. ***Impact*** is a function of the threat and sensitivity and considered as changes to (i) the integrity of project assets (i.e., damage); (ii) performance or use of the BRT route; (iii) maintenance requirements over the project life; and (iv) the project's compliance with design standards or regulations.

22. The ***vulnerability*** of the BRT and its infrastructure components is the combination of the impact and the adaptive capacity of the project, in terms of both the technical aspects of design and financial and the management capacity to define and respond to change. The response to climate change impacts varies depending on the type of impact.

23. For example, impacts that may prevent compliance with Pakistan national law or design standards must be avoided regardless of cost. Some other impacts could potentially be absorbed with little change to design and/or operation; others may require adaptation at different phases throughout the design and maintenance life. Figure 1 identifies the key steps of the vulnerability assessment approach for the BRT route and its various components. Figure 2 and 3, illustrate the methodological framework and steps to be undertaken by team. Once the steps are completed, this will lead to the development of the CRVA.

Figure 1: BRT Vulnerability Assessment Approach

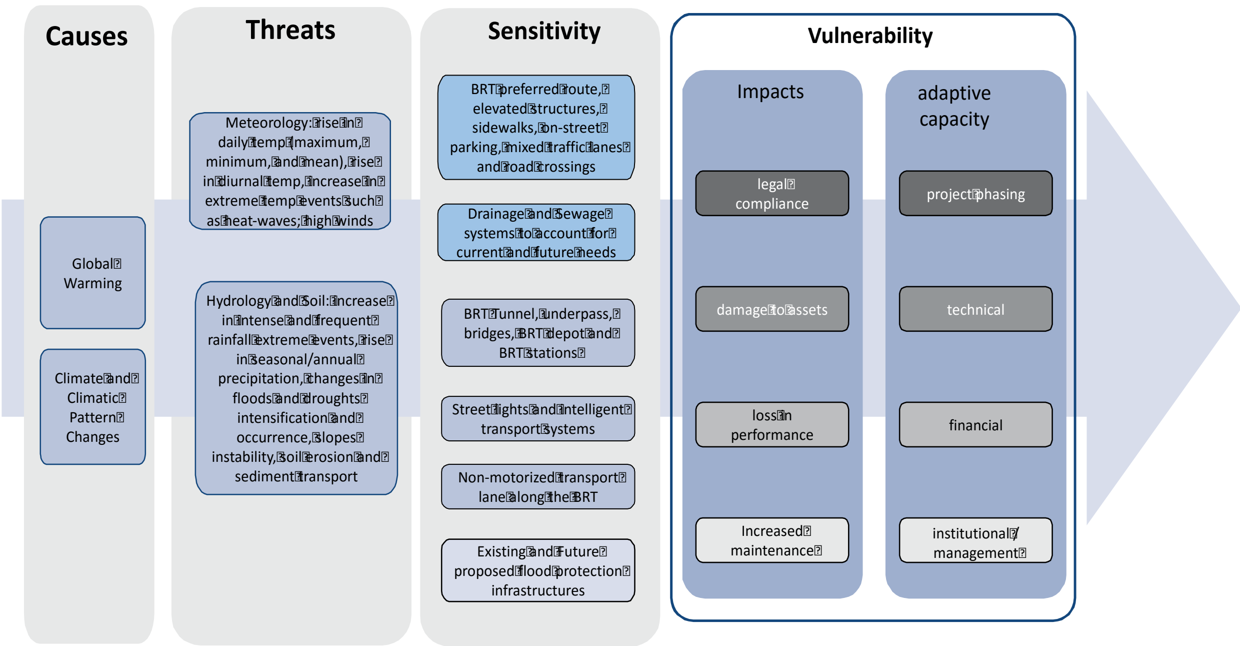


Figure 2: Methodological Framework for BRT Vulnerability Assessment

Set of Activities

1. **Project screening and scoping:** How is the proposed project (project characteristics) vulnerable to the impacts of climate change over its life span? What are the climate parameters of most interest to the project? Is sufficient information available to undertake an assessment? Who are the main stakeholders?

2. **Impact assessment:** What are the current and historical trends in climate? How is climate projected to change in the future and in what ways? How will this affect natural and human systems of interest? What are the root causes for predicted impacts? What reasonable assumptions (quantitative and qualitative) can be made about climate change and its impacts?

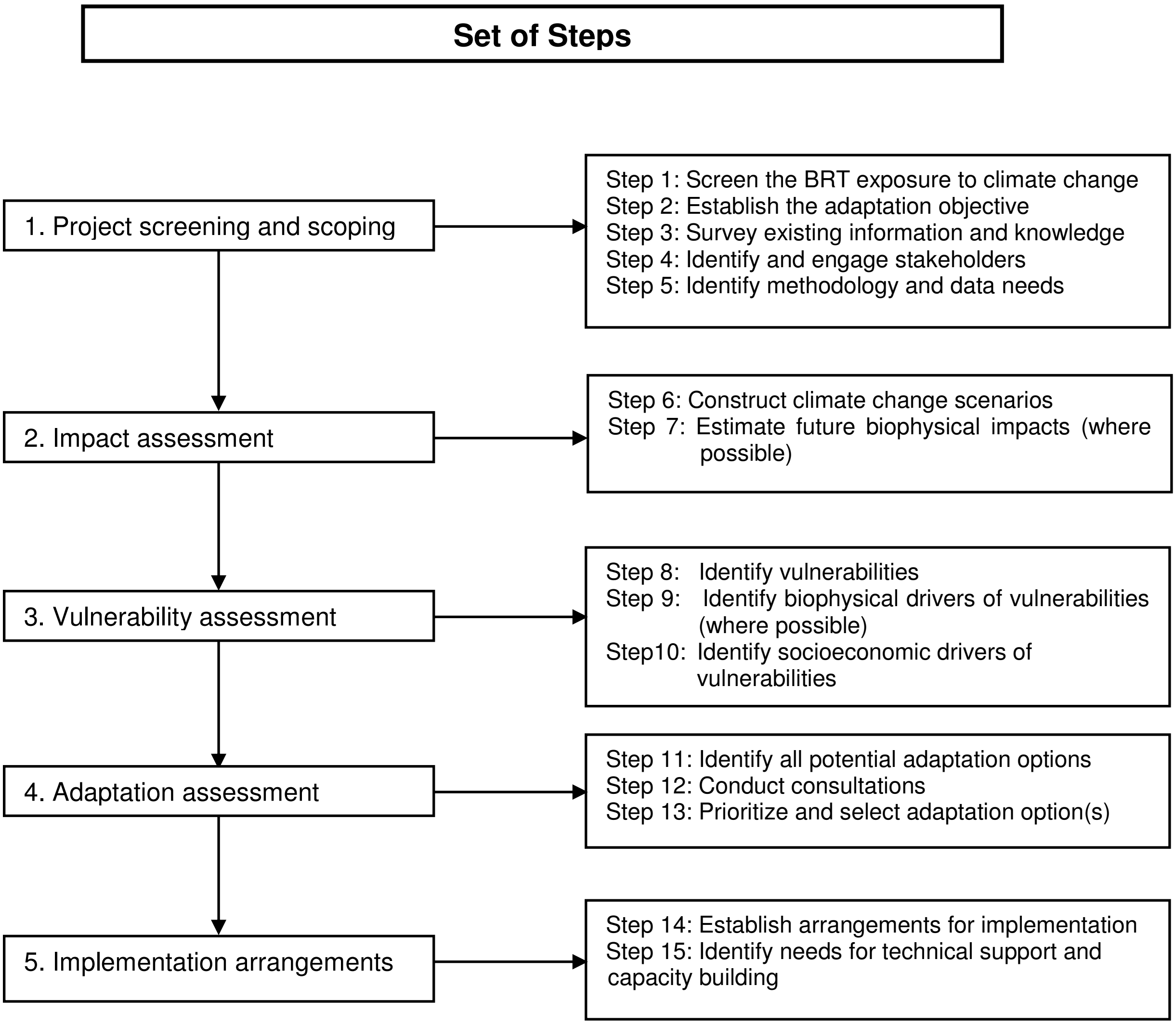
3. **Vulnerability assessment:** How have people historically coped with heavy rainfall, floods, storm surges, and other weather events? Where are the most vulnerable areas? Who are the most vulnerable populations?

4. **Adaptation assessment:** What adaptation solutions are technically feasible to address projected climate vulnerabilities? What are the benefits of these options? What are the preferred options in the context of the BRT project?

5. **Implementation arrangements:** Who has the capacity to implement the selected adaptation option(s)? Are there additional key stakeholders that need to be brought into the project? Is there a need for additional capacity building?

Source: Adapted from ADB Guidelines for Climate Proofing Investment in the Transport Sector – Road Infrastructure Project, 2011

Figure 3: Steps to be undertaken in Methodology



Source: Adapted from ADB Guidelines for Climate Proofing Investment in the Transport Sector – Road Infrastructure Projects, 2011

IV. PROJECT SCREENING AND SCOPING

A. Project screening and scoping

Introduction

24. Peshawar is the provincial capital and largest city of the Khyber Pakhtunkhwa province. It lies in the southwestern part of Peshawar valley close to the Pak-Afghan border, between 33° 44′ to 34° 15′ Northern Latitude and 71° 22′ to 71° 42′ East Longitude. The city is located at an altitude of 1,178 ft. above mean sea level and stretches over a land-area of 1,257 km^2.

25. For administrative purposes, Peshawar is awarded the status of a City District[3] and is divided into four towns[4]. Town 1 and Town III are mostly composed of urban area[5] while Town II and Town IV primarily consist of rural suburbs. Each town comprises a group of union councils (UCs) and all together there are 92 UCs in the district.

26. Peshawar is connected to rest of the country through a network of roads, railways and airway. Main transport infrastructure in the city is provided by: the Peshawar International Airport; two major railway stations (city and cantonment) operated by Pakistan Railways; three main highways (Motorway (M1); the Grand Trunk Road (N5); the Indus Highway (N55), and links to several other highways.

Physical Condition

27. Peshawar district is irrigated by various canals of the Kabul River and by its right tributary, the Bara River. Discharge from the Kabul River, which is the main source of surface water body in the Peshawar basin, is mainly snow fed and seasonal. The Kabul River floodplains[6] have water-table at moderate depth due to seepage from the river and the irrigation system, since the irrigation is quite intensive. Seepage from the irrigation channels has also raised water-table in the piedmont basins. The meander flood plain extends from Warsak in the northwest towards southeast in the upper northern half of the district[7].

Relevant Municipal Services and Infrastructure

28. Municipal services in Peshawar are generally managed by the Peshawar Municipal Corporation (PMC) in urban UCs and District Councils (DC) in rural UCs of the district. In the Cantonment and Hayatabad localities, services are provided by the Cantonment Board and Peshawar Development Authority (PDA) respectively. To amalgamate water, sanitation, and solid waste management services under one entity, the Government of KP has established an independent utility by the name of Water and Sanitation Services Company Peshawar (WSScP). Currently the WSScP serves 45 urban UCs in Peshawar city and is planning to extend their services to a further 66 peri-urban union councils.

Water Supply:

29. Surface water bodies in the Peshawar basin mainly comprise Kabul River, Bara River and some nallas. Main source of public water supply in Peshawar city is groundwater that is extracted through a network of tube wells. There is one treatment plant (Bara Water Treatment Plant) that treats water from the Bara River for meeting partial demand of the Cantonment area. There are also numerous private tube wells across the urban areas to serve the needs of individual households, industry, hospitals, educational institutes and parks etc.[8] Most of the district has a piped water supply system that is generally old and deteriorated. Normally water quality at source (tube wells) is safe but due to leaking and damaged pipes bacterial

[3] Administrative Structure of Pakistan, 2001
[4] Administrative towns of Peshawar are: Peshawar Town I, Peshawar Town II, Peshawar Town III, and Peshawar Town IV
[5] In addition, the city's urban areas include the Cantonment and new housing schemes including Hayatabad and Regi Lalmah
[6] The floods plains in Peshawar are the areas between Kabul River and Budhni Nallah (mostly a seepage drain flowing along adjacent northern boundary of the city).
[7] Master plan Vol. 1, Water Supply, Treatment and Distribution, DRAFT Main Report, USAID, 2014
[8] Master plan Vol. 1, Water Supply, Treatment and Distribution, DRAFT Main Report, USAID, 2014

contamination has been found in the distribution network. According to Pakistan Council for Research in Water Resources (PCRWR), about 77 percent of drinking water sources in Peshawar are unsafe due to bacterial contamination and metal concentration[9].

30. Water filtration plants, mostly installed on tube wells, were first introduced in the Cantonment area in 1995. Of 33 existing filtration plants in urban UCs, 24 are functional and 9 are non-functional[10]. Most of the functional plants are located within the Cantonment area and are properly maintained. The major reason for non-functioning of plants is the lack of maintenance and non-replacement of the clogged filters.

Solid Waste Management:

31. The Municipal Corporation Peshawar (MCP), Peshawar Development Authority (PDA) and the Cantonment Board provide waste management services in urban areas of the city. These services are provided to residential areas, commercial areas and institutions by way of secondary collection. Services are not provided to industrial areas or construction and demolition activities. Residual material from industrial estates gets recycled via private services.

32. While no formal landfill arrangements exist in the city, two sites - Hazar Khwani and Lundi Akhune Ahmed - are presently being used for final solid waste disposal[11]. Additionally, PDA dumps waste in a depression in Hayatabad Phase VII while the waste from the Cantonment area is dumped at a site in Regi Lalma where trenches are dug and covered when filled.

33. Existing systems use manually loaded tractor trolleys, open body trucks besides mechanical loaded multi-loaders and compactors for transportation of waste.

34. The MCP provides primary & secondary collection and downstream service to residential areas, commercial areas and institutions in the city area. For primary collection, the PDA provides door to door waste collection service to the residents. Residential solid waste is usually deposited on sides of streets which are cleared by sweepers using handcarts and donkey carts and taken to waste depots.

Sewerage and Drainage Systems:

35. The existing sanitation/storm water systems serving the Peshawar area are mostly combined systems that convey domestic, commercial and industrial wastewater along with surface runoffs during rain events. The flows are mostly conveyed by open or covered drains except only a few areas where flows are conveyed through underground sewers. While there are three public wastewater treatment plants (WWTP) in Peshawar, none is functional, resulting in the flows being discharged into rivers (Bara and Shah Alam), irrigation canals, khawars or agricultural land, and thereby contributing to a severe environmental and public health hazards[12].

36. Trunk sewers that were built to convey flows from the tertiary / secondary system segments are mostly clogged and their manholes are being used as a repository for solid waste. The three pumping stations within the city are not properly designed or constructed. Pumps are placed on top of a collection tank as temporary arrangements for conveying flows from low lying areas. In addition to the untreated domestic and commercial sewage, these canals also become a repository for solid waste[13].

Urban Planning:

37. As with other major cities in Pakistan, Peshawar is confronted with challenges of rampant urbanization, rapid population growth, and continuing degradation of the natural environment and its associated services. Regional instability and security problems over recent decades and the influx of Afghan refugees and internally displaced people (IDPs) has further exacerbated

[9] ibid
[10] ibid
[11] Master plan Vol. 3, Solid Waste Collection and Disposal, DRAFT Main Report, USAID, 2014
[12] Master plan Vol. 2, Sanitation / Storm Water Collection Disposal and Treatment Distribution, DRAFT Main Report, USAID, 2014
[13] ibid

pressure on the urban economy and infrastructure, and stretched the coping capacity of local systems. The growing threat of extreme weather events and climatic stressors are set to further compound problems for urban dwellers and managers.

38. While different governments have tried to direct, and regulate urban expansion, there has been little progress. There have been several failed attempts since 1960s at developing a city master plan, including a (i) Peshawar Master-Plan prepared in 1965, (ii) Structural Plan, led by UNDP, in 1986 and (iii) Structure Plan of 2002. None of these came into effect due to weak political support and lack of adequate institutional and legal provisions. A city-wide master-planning initiative faces similar challenges today. Current efforts to reign in Peshawar's urban growth and development includes a USAID supported Peshawar Master Plan project for water supply, sanitation, and solid waste management in 66 UCs of the district. A Strategic City Development Planning initiative is also being pursued by the KP Urban Policy Unit in seven divisional headquarters, including Peshawar.

39. In the absence of planning and regulation, the city has been expanding in all directions along main road corridors. Due to the non-availability of major radial roads and alternate feeder roads, the city has grown in a linear direction, with the trend most pronounced in the east-west direction along the GT road. As a result of this linear expansion most of the unoccupied vacant land pockets in between or adjacent to the built-up area have remained undeveloped and may get ultimately converted to urban slums given the absence of infrastructure and services in these areas[14].

40. The trend of development along the GT road has also become a source of serious road congestion in Peshawar, with much of the city's educational, administrative, and commercial activity based along or near the main road. The GT road enters the city at Chamkani from the eastern direction and runs all along the urban built-up area for about 23 km up to Karkhano market in the west. This road catches almost 90% of the traffic movement in the city as there is no alternate feeder available to the road users in the city except Southern Ring Road[15]. Traffic congestion resulting from the daily vehicular load on the GT road is also a major contributing factor to the increasing problem of air pollution in the city. As per a report by Peshawar Foundation "Peshawar is the most polluted city of Khyber Pakhtunkhwa province with carbon dioxide emission reaching up to 23 particles per million (ppm) against the World Health Organization guidelines of 10ppm," owing to emissions from vehicles, industries and brick kilns; massive burning of solid waste/refuse, domestic burnings and use of ill-maintained vehicles[16].

41. Without adequate zoning regulation and plans, there is generally mixed land-use pattern in Peshawar. While planned commercial centres and markets exist in the city, these are few and it is common to find commercial and residential use combining in many localities (even in the same buildings), especially along main roads. This is particularly true for the densely populated inner areas of the city. Peshawar currently lacks a designated trade zone and most of the commercial enterprises including trade centres and wholesale are scattered across the city, adding to congestion problems in inner city areas[17]. The absence of proper zoning and holistic planning is also evident from the location of the Hayatabad Industrial Estate which is situated next to a major township developed and managed by the Peshawar Development Authority (PDA).

42. Another adverse land use trend is the diminishing availability of green spaces and parks in the city and the resulting increase in heat island effect. This is especially true for the densely populated walled city area once known for its gardens but now almost completely concretized. Like other metropolitans across the world, Peshawar city too would need to make adequate provision for green spaces and cooling areas to offset the effects of increasing urban densification and built-up area. This is especially critical in the context of global warming and climate resilient development

[14] Peshawar Landuse Report (2013-2033), Urban Policy Unit, GoKP
[15] ibid
[16] ibid
[17] ibid

Bus Rapid Transit (BRT)

43. The project is to be undertaken by the Government of Khyber Pakhtunkhwa as a high priority project conceived by CDIA pre-feasibility study and PPTA feasibility study (both undertaken through ADB grant). These studies were completed in December 2015 and September 2016. The Chief Minister, KPK in a meeting held on 29 November 2016 decided the implementation of the BRT project. The project will be implemented through PDA soft loan by ADB and counterpart funding will be provided by KPK Government. The sustainable BRT project aims to alleviate the severe traffic congestion problem in Peshawar and improve the quality of life of daily commuters by improving the existing transport system

44. Option 4 in the PPTA report, that travels through Hospital Road and Khyber Bazaar Road at-grade is referred to as the preferred option.

45. The BRT full alignment option starts from Chamkani, near the Chamkani train station. It goes along the GT Road at-grade until the junction with Ashraf Road where it will go into a tunnel connecting both approaches of GT Road, Malik Saad Shaheed Road, and Cinema Road. After the tunnel, the main BRT route follows Cinema Road at-grade where it goes elevated to bypass the junction with Hospital Road. It stays elevated on Khyber Bazaar Road and Railway Road, and pass the Soekarno and Suba Chowk, the two most congested intersections in the Khyber Bazaar area. After the railway road, the elevated BRT section turns right at Anwar Saeed medical centre to cross the railway station, where a BRT-only bridge will be constructed. After crossing the railway station, the BRT goes at-grade again and join Saddar road just after Peshawar Press Club.

46. On the preferred alignment, the BRT stays at-grade on Saddar Road, turns right to Khadim Hussein Road and Sir Sayed Road to go to Amman Chowk, where the BRT goes on BRT-only tunnel to cross Amman Chowk. The corridor continues through GT Road and Jamrud Road where it goes into an elevated BRT only corridor above a dried-up river bank before the Bab-e-Peshawar Marco Polo Bridge until it joins the Habib Jalib Road towards Tatara Park and joins the Ring Road. In this alignment option, total length of BRT is 30.8 km, in which 25.8 km will be built in Phase 1, and 5 km in Phase 2. Out of the 30 km, there are some segments that will be built elevated, which is 4.1 km long, and tunnel with 3.5 km long.

47. This will leave the at-grade BRT segment at 23.3 km long for both phase. In this option, 31 BRT stations will be constructed, with an average distance of 922m between stations.

Design Specification

48. Route Details:

- i. Total BRT alignment: 25.8 km (phase I)
- ii. At-Grade: 16.9 km
- iii. Elevated: 4.2 km
- iv. Tunnel: 4.7 km
- v. Total stations: 31 Stations
  - a. At-grade: 28 stations
  - b. Elevated: 3 stations
- vi. Minimum curve radius: Main Grand Trunk Road 120 m, and on intersections 12m with tight curve with speed of maximum 20km/h
- vii. Maximum gradient: 3.5% on ramps

Irrigation canals and rivers crossing the BRT route

49. Three main canals and two minor canals are crossing the BRT route. Warsak Gravity Canal has been found to be the main source of urban flooding during maximum precipitation. The area near to Shaheen town and the population on canal road are frequently exposed to flooding. The area along the BRT route where the canal crosses the BRT route are slum areas.

Very poor vulnerable Afghan refugees are predominantly living in this area. Major cause of flooding is due to choking of canals in downpours and high precipitation.

50. Another important canal which crosses BRT route at two points is Khazar Khwani Branch which originated from Kabul river canal. This canal crosses the BRT route about 10km from the starting point of BRT route in the east of the city. Kabul river canal also crosses the BRT near the fruit market. This canal crosses the BRT route at 5km from the starting point of BRT near Chamkani.

51. Joe Sheikh canal is also another main canal which crosses the BRT route 1km away from the starting point of BRT near northern bypass and Chamkani.

52. The BRT route was examined by the team for exposure to climate change. This was undertaken through discussions with community groups near the BRT route, site location visit by the team and through discussion with city officials (Nazims, Urban Planning Unit, Peshawar BRT Company), and the team of the ADB Urban Climate Change Resilience Trust Fund (UCCRTF) funded Urban Resilience Assessment (URA) project in KP. Table 1 highlights the key salient points.

Table 1: Issues observed in the vicinity of the BRT route

Climate Change Events / Major Impacts	Issues observed in the vicinity of the BRT route, through community consultations, site visit and through secondary sources
Urban flooding during heavy rainfall inundation	• More inflow from upstream water channels • Embankments do not appear to be deep enough and construction appears to be weak to resist erosion • Not enough tree plantations for protection • Drain design capacity appears to be insufficient to cope with increased flows • Many drains covered with solid waste (especially plastic bags) • Emergency water pumping facility missing or insufficient • Base infrastructure in some cases appears to be below inundation level • Sludge drying areas and solid waste landfill sites appear to be below flood inundation level or not protected with embankments or linings • In certain locations, roads do not appear to be properly cambered
Temperature rise and greater evaporation Increase in per capita water consumption/demand	• Roads are mainly bituminous. Increase in temperature has already started damaging these roads surfaces. Maintenance requirements are increasing day by day. . • With higher temperatures surface water is rapidly evaporated, affecting irrigation and household water supplies. Open water bodies may dry up and dependence on piped water supplies will increase. Due to heat, overall per capita water needs will increase as consumers will drink more water and may wash more frequently. • Drought

B. Community Consultation Meetings

53. Community consultation meetings were conducted in 6 Union Councils (UC) identified by the District Administration (see Table 2) as being highly vulnerable to disaster risk and climate change. Proximity to flood channels and position along the planned BRT route were criterion in the selection of community consultation location. The meetings were held in Pashto to connect with local people effectively. Most of the people had heard about some intervention that the Provincial Government was initiating regarding a metro bus but they had no idea of the BRT location and its proposed route.

Table 2: Union Councils for BRT Community Consultations

Union Council	Female	Male	Grand Total
Khalisa 1	27	18	45
Malkan Dher		8	8
Safaid Dheri	27	12	39
Shaheen Muslim town 2		15	15
Tahkal Payan	9	19	28
Malakandher		8	8
Grand Total	**63**	**90**	**143**

54. It was explained to the community groups that the BRT route is planned along the main artery passing through Peshawar from Chamkani to Hayatabad. When asked as to the key problems that communities were facing, the following is a summary of the 6 union councils.

Drainage

55. The existing drainage network is not efficiently working as observed by community members in the surveyed union councils. People complained about the existing damaged pipes. They informed that the Abazai drain and Ganda Venrhay are crossing the BRT route. Three main canals one branch and 2 minor irrigation canals are also passing through BRT route which have now become a de-facto drainage network due to the failure of outdated drainage network in Peshawar city. The drainage network proposed along the BRT needs to consider the existing system in mind so that it may minimize the drainage problems of the surrounding unions councils along BRT route.

Air pollution

56. People in Malakandher union council near BRT route main concerned was the burning of solid wastes in Katcha garhi by contractor. There is considerable air pollution which is affecting people's health and causing respiratory problems. The general air and noise pollution caused by public transport is another environmental issue raised by community. They have the view that BRT buses will help in reducing air and noise pollution. Gasoline engines should be used instead of diesel engines in BRT buses for minimizing air pollution.

Drinking Water

57. It has been observed that in surveyed union councils tube wells are not catering the water demand of communities. Most of the tube-wells are not functioning and water distribution pipes are rusted and leaked. There were no over-head tanks in most of the union councils leading to water shortage in summer when there is electricity load-shedding. People have no access to clean drinking water in all the localities. The ground water level in surveyed union councils is 30 to 35 meters. Community has the view that authorities should consider the water distribution network and properly revamp it along the BRT union councils for uninterrupted clean water supply.

Health

58. There are three main hospitals i.e. Khyber teaching hospital, Hayatabad medical complex and Lady Reading hospital. There were no prominent health facilities centres in surveyed union councils. People are relying on public transport for reaching to these hospitals and specialized health clinics. The proposed BRT route is passing through all the main hospitals of Peshawar city which will greatly help local as well as people from other district for reaching those hospitals.

Education

59. Community has the opinion that the government schools are not adequate to accommodate all the students at their doorsteps. The universities and girl higher secondary schools were mainly not present in surveyed union councils. Most of the students are relying on transport to reaching out to schools, colleges and universities. BRT route will help them reaching out to their education institutes and will save their money and time.

Economic Impacts

60. Most of the people of the surveyed union councils were labourer, daily wagers belonging to low income group. About 60 % of population were labourers in each union council. They have the opinion that the BRT will greatly help students, government servants and labourer in reducing their transport expenditures. Some people argue that it will have a negative consequence on transporters who may lose their jobs due to availability of quality transport at subsidized rates. Alternative routes must be assigned to transporters and existing drivers and conductor from local areas must be inducted to ensure their jobs.

Job creation

61. It has been observed from the community discussion that the construction of BRT will create more jobs for local community. Mobility will be increased enabling labourer to move daily from Chamkani to Hayatabad and Karkhano markets on affordable fares.

Traffic Congestion

62. Peshawar is currently facing acute traffic congestions. The city centre is congested with frequent traffic jams. The proposed BRT will help in minimizing traffic congestion and will greatly reduce travelling time. Besides the proposed bicycle lane in BRT may help reviving cycling culture in Peshawar. The graded section on university road may create further traffic congestion for ever increasing private vehicles if encroachments and traffic management issues are not properly addressed.

Road Crossing accidents

63. After meeting with community members of surveyed union councils, the main problem faced by the community are road accidents. It has been observed that availing health facilities and education facilities road frequent unsafe road crossing due to non-availability of safe crossing points results frequent accidents. The woman and children are more vulnerable to road accidents. People have the view that BRT management must ensure safe crossing points and increase bus stations for commuters.

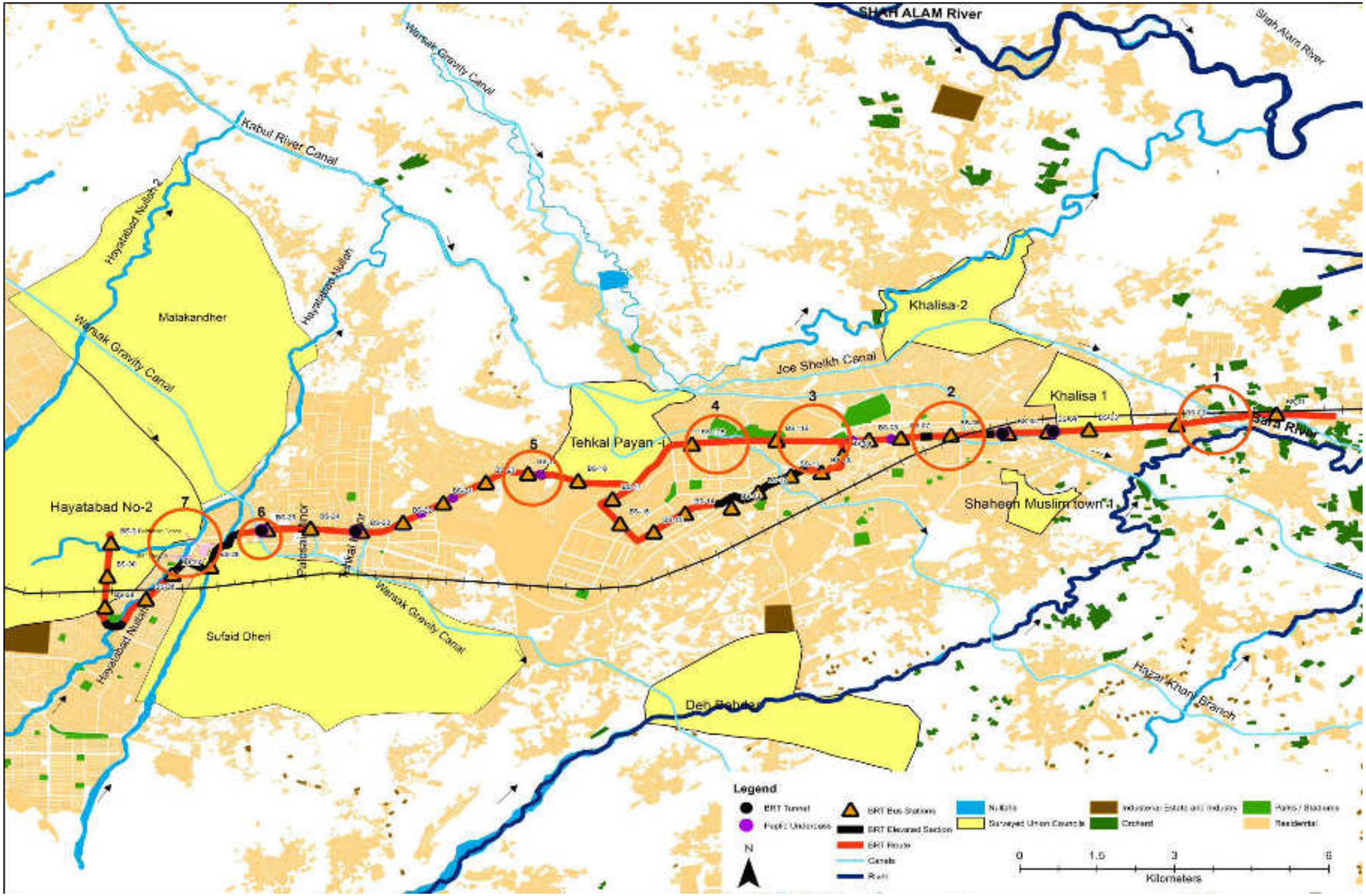
Urban Flooding

64. The Communities identified 7 critical flooding locations and these are indicated in Table 3 and also in Figure 4

Table 3: Community identified critical flooding locations

	Critical Flooding Location on Proposed BRT route	PPTA plates
1	Near BS2, Sardar Garhi (in UC Wadpaga and UC MusaZai)	2
2	Near BS6, Sikander Town (in UC Sikander Town and UC Gulbahar)	3
3	Near BS-11B (in CANTT area)	7
4	Near BS-12B (in CANTT area)	8
5	Near BS19 Tehkal Payan (in UC Tehkal Payan and CANTT area)	14
6	Near BS-25 Islambia University (in Shaen Town)	18
7	Under Elevated section BS26, Board, (in UC Hayatabad-1 and UC Sufaid Dheri)	19, 21

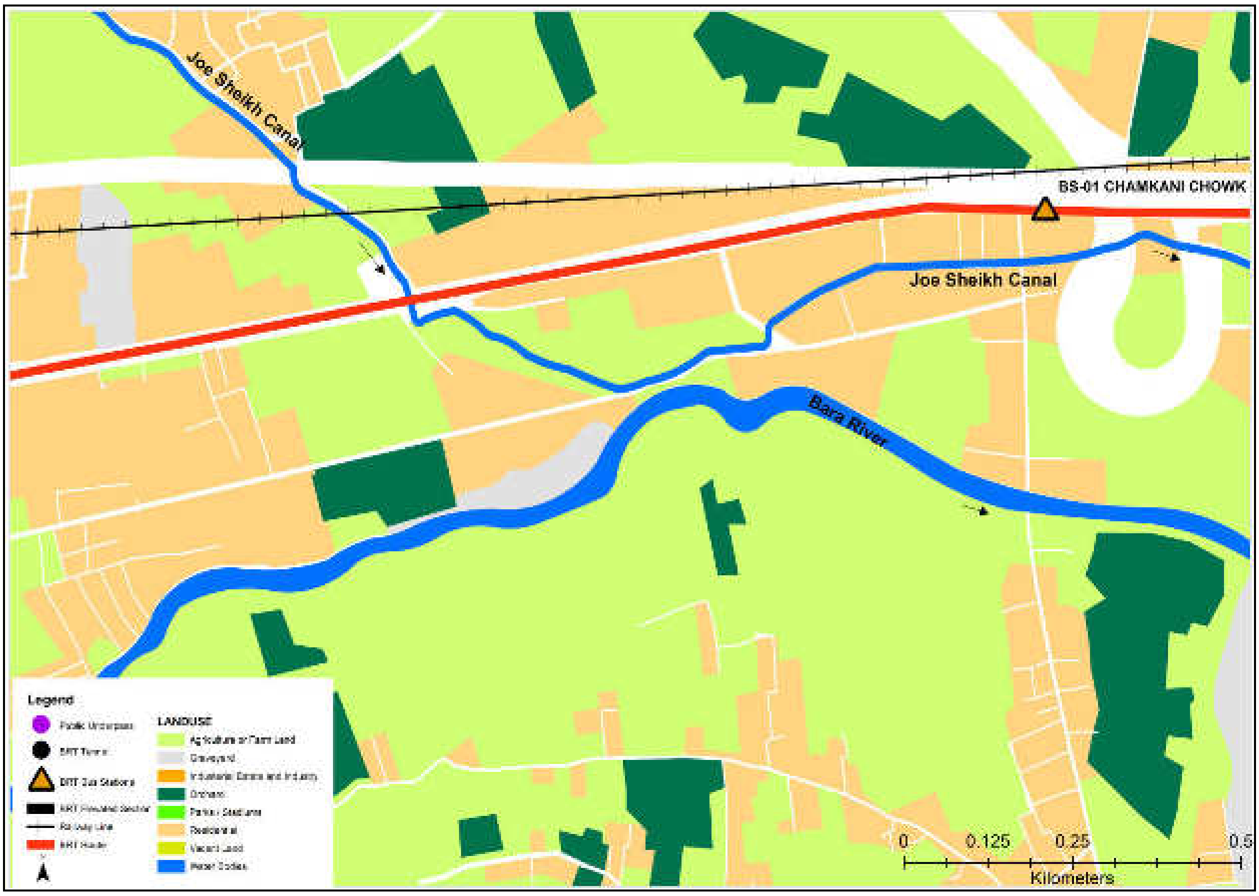
Figure 4: Location of 7 key flooding hotspots



Detailed Description of each of the locations as voiced by community groups

65. *Location 1*: The main Joe Sheikh canal is passing through BRT near Sardar Garhi. The nearest BRT bus station is BS-02 Sardar Garhi at 661m from Joe Sheikh canal crossing point. Joe Sheikh canal is originating from Kabul River which is flowing to the north east of Peshawar city. Joe sheikh canal flows south west and ultimately ends in Bara River near lala kilay. To the south of BRT Bara River is flowing parallel from west to east at 200m from BRT. Green orchards and agricultural fields are predominant land use features followed by settlement patterns along BRT route in this locality. This locality is considered the suburb of the Peshawar city.

Figure 5: Location 1

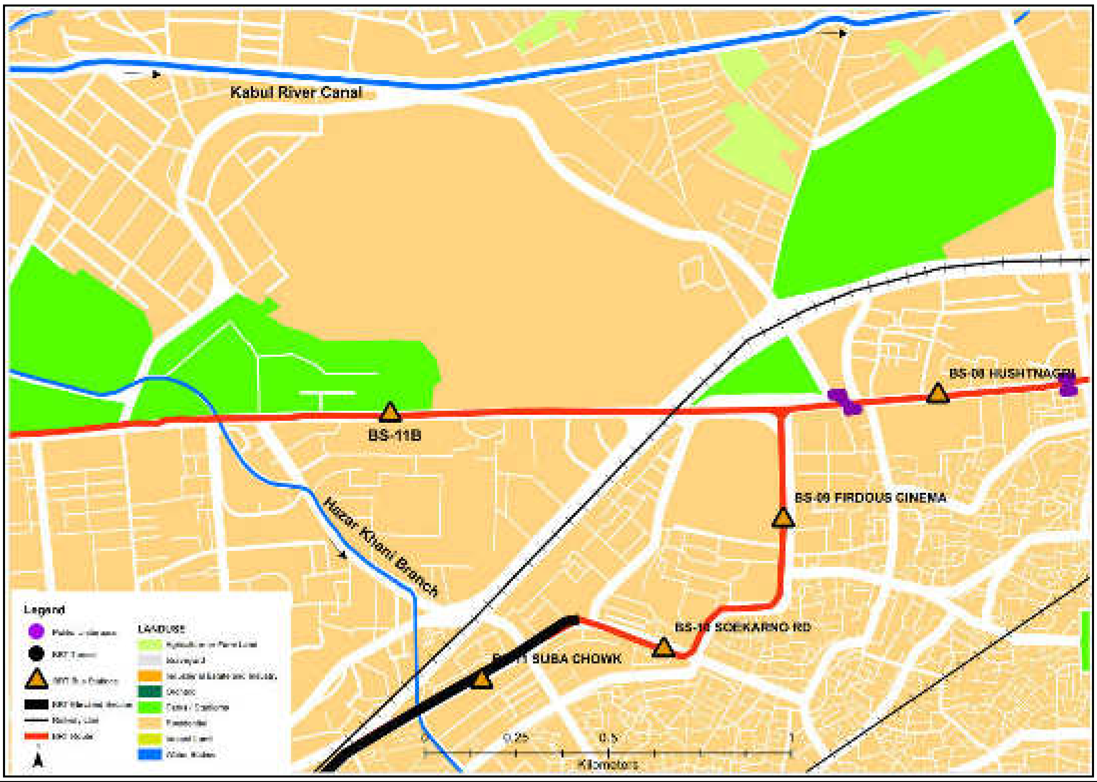


66. *Location 2*: The Kabul River canal is originating from Kabul River. The main Kabul canal bifurcates to the north of tehkal, The Kabul river flow east west while hazar khwani branch flows to the south. The Kabul river canal crossing BRT near nishtar abad fruit market and change direction from southward to eastward. The nearest station to the crossing point of Kabul river canal is sikandar town on 180m distance. The proposed elevated section on BRT is 280m east of Kabul river crossing. The under-construction municipal service program (MSP) drain project will greatly solve urban flooding problem in this locality. Whole of the locality are urban with congested buildings however some farmland green patches are also found.

Figure 6: Location 2

67. *Location 3*: The suri pul area in front of provincial assembly are frequently inundated by either chocked drainage network or in high precipitation. The area near Malik Saad fly over under suri pul and Charsadda road are mostly affected. There is no canal passing through this locality however choked drains are the main concern for inundation and water stagnation during rainy seasons.

Figure 7: Location 3



68. *Location 4*: The Khazar khwani branch are originating from Kabul river. The khazar khwani branch flows south-wards after bifurcating from Kabul river canal. It enters cantonment area and will cross BRT route near sahibzada abdul qayyum road. The khazar khwani branch after crossing BRT flows south east and end up near hakim garhi.

Figure 8: Location 4

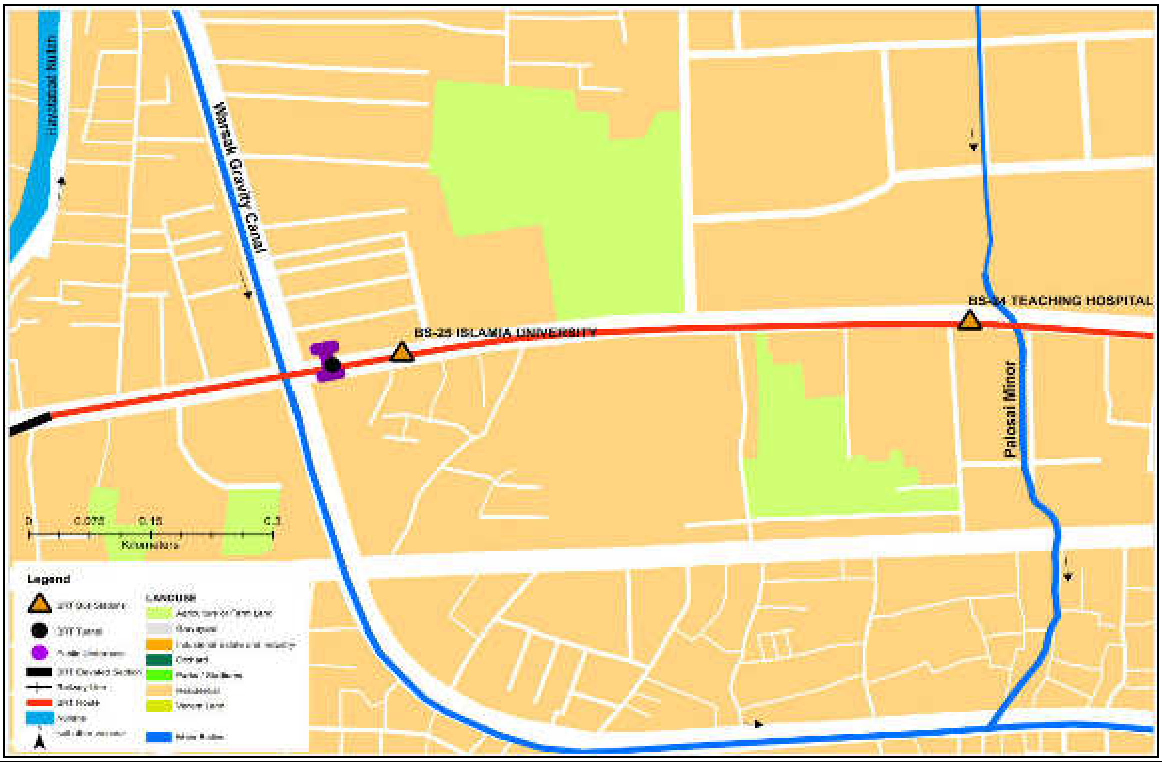
69. *Location 5*: The main drain named Ganda Venrhay (translated as “Dirty Drain” in English) is passing through Tehkal payan causing frequent flooding in the locality. It comes from Hayatabad bringing all the hospital wastes of Hayatabad medical complex and Khyber Medical Complex (two of three main hospitals catering the whole of Peshawar and Khyber Pakhtunkhwa). The drain then enters Tambwano morh after passing through Peshawar only airport. It turns north in Tehkal Payan and then falls in Budni Nulla. All the people complained about the drain as un-treated hospital wastes and that the drain was a major concern spreading many diseases like Hepatitis B and C; skin disease and other water-borne diseases.

70. When there is rainfall, Ganda Venrhay outflows creating flood like situation in surrounding localities. As the drain passes through the main street, it has been paved (covered by concrete) for broadening the street and making into a road. This is being using by Union Council Tehkal Payan population. Ganda Venrhay is the cause of frequent flooding in Tehkal Payan locality.

Figure 9: Location 5

71. *Location 6*: Warsak gravity canal is an irrigation canal which passes beneath the Hayatabad drain near malakandher union council. The canal then enters to congested bazar of board area and by crossing BRT it flows in the centre of bazar. The locality is an unplanned slum where afghan refugees are residing. The canal entered Tajabad slum where two small canals meet with Warsak gravity canal. Due to frequent throwing of wastes and plastic bags it chokes in high precipitation leading to outflows and inundations extreme scenario. The nearest BRT bus station to Warsak gravity canal is BS-25 Islamia College.

Figure 10: Location 6



72. **Location 7**: The BRT route turns south and travels along the Hayatabad nullah. The BRT section along the Hayatabad nullah is elevated. There is a proposed BRT depot at the oxidation ponds' land, to the west of the Hayatabad nullah near proposed BS-26 bus station. The nullah originates from Hayatabad Bara Road area (from the foot hills) and travels north-east ending in Shah Alam river (sub-branch of Kabul river). To the east of nullah, Tajabad slum is located. There is an encroachment of nullah from Tajabad side and these encroached settlements are exposed to nullah flooding during high precipitation.

Figure 11: Location 7

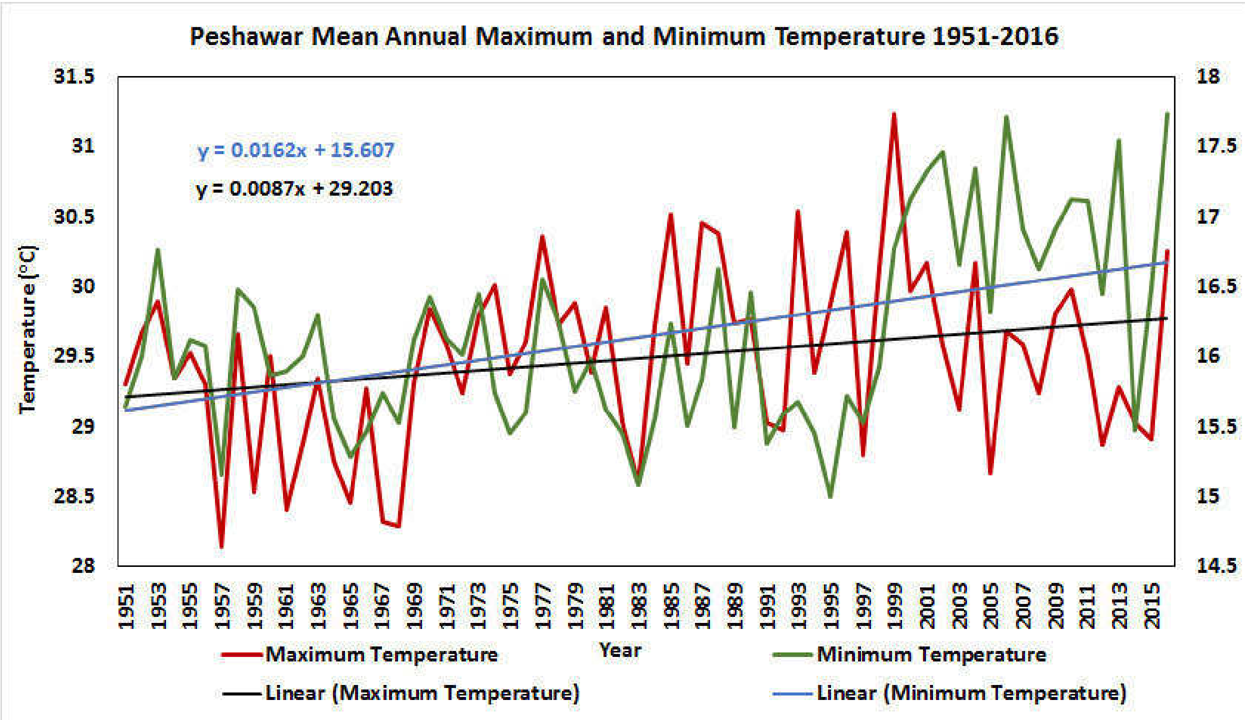
V. IMPACT ASSESSMENT

A. Observed Past Climate Trends

Past Changes in Temperature

73. The historic data of Peshawar (1951-2016) was analysed for this study (Figure 12). Mean annual maximum Temperature (°C) remained in the range of 28-31.2°C while the mean minimum temperature is found to be in between 15°C and 17.7°C. Both maximum and minimum temperature show increasing trend particularly during 1980s. Overall maximum temperature has increased by 0.57°C during the last 66 years while minimum temperature has increased by 0.49°C.

Figure 12: Peshawar mean annual minimum and maximum temperature period 1951-2016

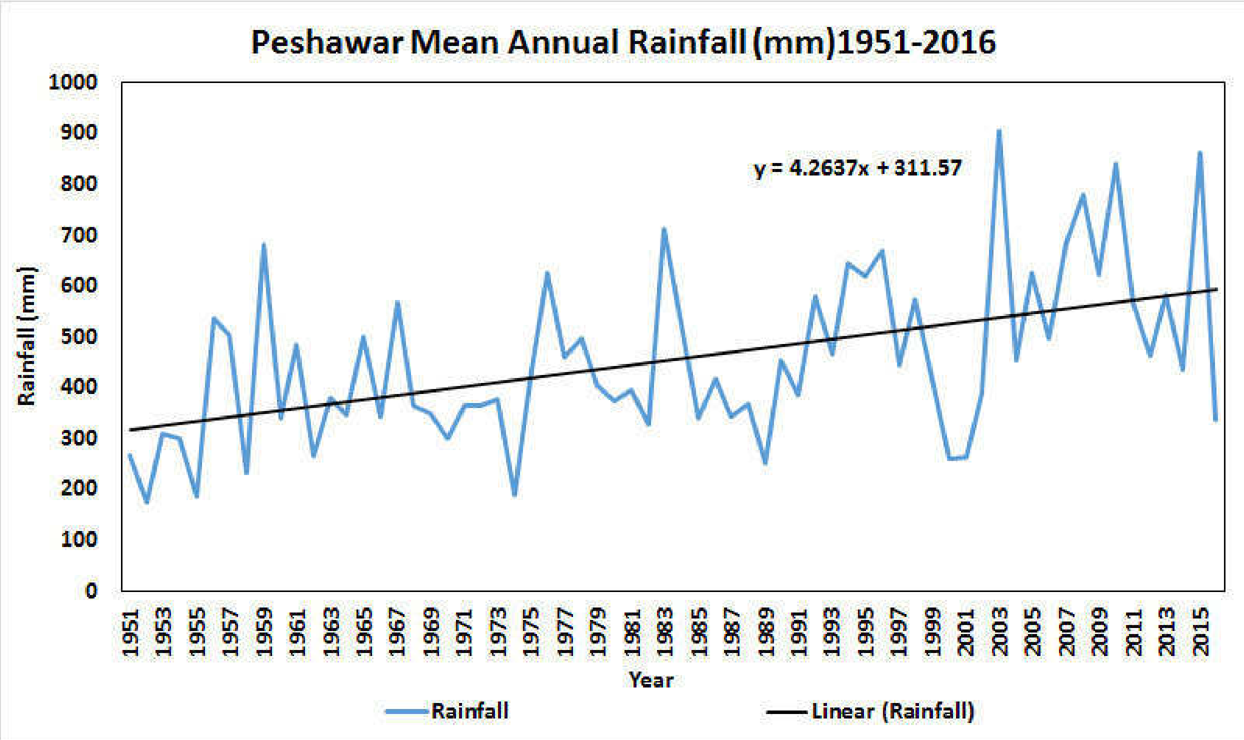


Source: Pakistan Meteorological Department

Past Changes in Precipitation

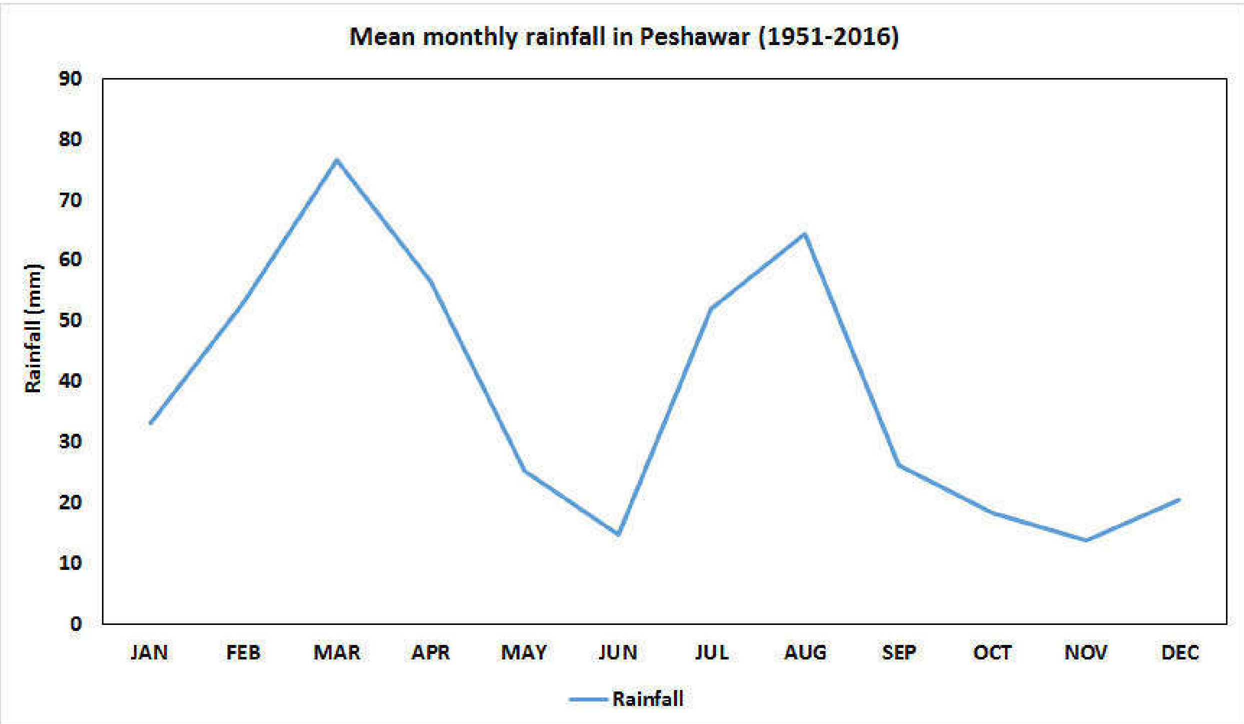
74. A record of 66 years of rainfall data for the Peshawar city from (1951-2016) shows average annual rainfall for the city is 454.4 mm (Figure 13). The city receives most of the rain during the months of March, April and August with maximum yearly rainfall value of 904.5 mm during 2003 (Figure 13). The pattern of rainfall is bimodal with two distinct regimes: the rain starts slowly from November and reaches to the maximum in March, it then starts gradually decreasing up to June. In the second regime, it increases from June to August and then starts decreasing up to November (Figure 14).

Figure 13: Peshawar annual rainfall and mean temperature 1951-2016



Source: Pakistan Meteorological Department

Figure 14: Monthly Rainfall Pattern for Peshawar (1951-2016)



Source: Pakistan Meteorological Department

Extreme flooding of 2010

75. The 2010 floods in Khyber Pakhtunkhwa had affected more than 2.25 million population. As per official figures, this was the worst flood in history of Khyber Pakhtunkhwa since 1929. Heaviest monthly rainfall was recorded in July 2010 totalling to 409 mm whereas during the flooding event a total of 341 mm was recorded in Peshawar city in three days from 28 to 30 July, 2010. Highest one day's rainfall also occurred during the event which was 274 mm on 29 July (**Source**: Pakistan Meteorological Department).

Extreme wind storms in Peshawar

76. A dust storm is defined to be a windstorm that sweeps clouds of dust across an extensive area." For meteorological purposes, however, such a windstorm can only be reported as a dust storm if wind speed becomes 22 knots or more and surface visibility reduces to less than one kilometre. On April 26, 2015 at around 1900hrs, District Peshawar was struck by an unusual and unprecedented intense cyclonic wind storm. The wind storm was accompanied by torrential rains, hail storm and whirling winds at a speed of 110km/hr. Pakistan Meteorological Department (PMD) declared it third of its kind in the history of Pakistan and first ever in Khyber Pakhtunkhwa. According to PMDA, the windstorm badly affected Peshawar city and its adjoining areas Whirling winds at a speed of 110Km/hr played havoc with mud houses, boundary walls and uprooted trees and electric poles in several areas. Most of the deaths, injuries and property losses were observed in rural areas where the resilience level to such winds was very low. The storm resulted in 31 causalities in Peshawar district while 203 people were injured. Another windstorm hit Peshawar on 4th June 2016. speed of the windstorm in Peshawar was around 65 km/hr. (**Source**: Pakistan Meteorological Department).

77. A study was conducted by Hussain et al., 2005[18] who analysed the long-term data (1961-1990) records of PMD weather station in Peshawar for the assessment of dust storms frequency. They found that the overall frequency of dust storm was lowest in the KP province as compared to other regions of Pakistan. However, highest number of dust storms were observed in Pre-monsoon season with 4 such events per year. The second highest frequency was seen in monsoon season with an average of 3.5 wind storms per year. During winter and post monsoon season the dust storm frequency was less than 1. However, on annual basis the dust storm frequency in Peshawar was 9.8 days during 1961-1990.

78. The study also compared the dust storm frequency during 1991-2000 with the normal period and found that on average there was -2.4 days reduction in storm frequency.

Extreme temperature record in Peshawar

Table 4: Highest Maximum and Lowest Minimum Temperature Record of Peshawar City from 1930-2014).

Extreme Temperature Record of Peshawar City		
Month	**Highest Maximum Temperature** (°C)	**Lowest Minimum Temperature** (°C)
January	27.0 (30/2007)	-3.9 (07/1970)
February	30.0 (09/1993)	-1.0 (08/1978)
March	36.0 (19/1974)	1.7 (--/1945)
April	42.2 (29/1941)	6.7 (02/1968)
May	47.2 (31/1984)	11.7 (07/1960)

[18] Ata Hussain, Hazrat Mir & Muhammad Afzal (2005). Analysis of dust storm frequency over Pakistan during 1961-2000, Pakistan Journal of Meteorology Vol. 2: Issue 3: (March 2005) 49

Extreme Temperature Record of Peshawar City		
June	50.0 (18/1995)	13.3 (08/1949)
July	46.6 (07/1992)	18.0 (12/1992)
August	46.0 (12/1987)	19.4 (27/1954)
September	42.0 (25/1976)	12.0 (30/1991)
October	38.5 (05/2006)	8.3 (29/1949)
November	35.0 (03/1979)	1.1 (24/1949)
December	29.0 (09/1979)*	-1.3 (25/1984)
Annual	50.0 (18/06/1995)	-3.9 (07/01/1970)
•Event also occurred on 1st & 8th December 1979		

Source: Pakistan Meteorology Department. Climate and Astronomical Data. Islamabad.

Monthly Heaviest Rainfall Record of Peshawar

Table 5: Monthly Heaviest Rainfall Record of Peshawar City from 1930-2014.

Month	Monthly Heaviest Rainfall in (mm)
January	150.3 (1999)
February	236.0 (2007)
March	226.6 (1978)
April	267.0 (2008)
May	119.6 (1965)
June	81.0 (2010)
July	409.0 (2010)
August	280.0 (1976)
September	111.0 (2003)
October	203.0 (1996)
November	111.5 (1959)
December	254.3 (1945)
Annual	904.5 (2003)

B. Overview of Climate Modeling in Pakistan

Modeling Facility

79. The High-Performance Computing (HPC) facility at Pakistan Meteorological Department (PMD) is being used to promote the advancement of scientific research on weather, climate and hydrology in Pakistan. The central component of this facility is a large cluster of high-speed compute nodes, along with multi-terabyte storage. The facility has been in use for climate modelling activities and particularly for generating downscaled future climate projections for Pakistan in the wake of climate change.

80. Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information.

81. Dynamical downscaling uses a limited-area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a domain area of 106 to 107 km^2 and a resolution of 20 to 60 km. Statistical downscaling first derives statistical relationships between observed small-scale (often station level) variables and larger (GCM) scale variables, using either analogue methods (circulation typing), regression analysis, or neural network methods. Future values of the largescale variables obtained from GCM projections of future climate are then used to derive the statistical relationships and so estimate the smaller-scale details of future climate.

Future Projections for Pakistan by dynamical downscaling of general circulations models

82. Numerical modelling unit initially developed high resolution climate change scenarios of Temperature and Precipitation using dynamical downscaling. The numerical experiments were carried out using the ICTP Regional Climate Model version 4 (RegCM4) and Providing Regional Climates for Impact Studies (PRECIS) version 1.9.2 of Hadley Centre at horizontal resolutions of 25km and 50km under A1B emission scenario. The climate simulations defining the 30-year climatology between 1970 and 2000 for baseline and for future projections from 2001 to 2100 were performed using RegCM4 and PRECIS with lateral boundary conditions derived from one GCM—of MPI-ECHAM5[19] as part of Intergovernmental Panel on Climate Change (IPCC) Forth Assessment Report (AR4) simulations.

Future Projections for Pakistan by statistical downscaling of general circulation models

83. Downscaled future climate fields of Temperature and Precipitation for Pakistan were generated using GCMs outputs from CMIP5[20]. The process involved selection of four CMIP5 models and acquisition of baseline (1975-2005) and future (2010-2100) data of selected GCMs for 2 RCPs (4.5 and 8.5)[21].

84. Representative Concentration Pathways (RCPs) scenarios are new addition to the Global Climate Model projections from the Coupled Model Inter comparison Project Phase 5 (CMIP5). The CMIP5 provides a multi-model context for assessing the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds. It also examines climate "predictability" and explores the ability of models to predict climate on decadal time scales, and, more generally, determines why similarly forced models produce a range of responses 3.

85. The RCPs are based on certain scenarios from four modelling teams/models working on integrated assessment modelling, climate modelling, and impacts assessment. RCP4.5 and RCP8.5, both medium and high end emission scenario were used to investigate the impact of subsequent radiative forcing on climate of the region. RCP4.5 is a stabilization scenario in which total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level[22]. While on the high end i.e., RCP8.5, the 8.5 Wm−2 case, carbon dioxide levels rise above a massive 1,300 parts per million by the end of century and are still rising fast.

86. The choice of two particular scenarios among a set of four RCPs has been made in a fashion to find the impacts on regional climate in both cases i.e., extreme climate change scenario and relatively intermediate pathway.

Selection of Models and Scenarios for Peshawar

87. Climate change and impact assessment studies employ the use of environmental models (like hydrological models, crop models etc.,). These models are initialized by the output of the General Circulation or Regional Climate Models (GCMs or RCMs) or both. GCMs are known to have coarse horizontal resolutions with feedback and simulation biases.

88. The dynamically downscaled data was developed using boundary data of a single GCM (ECHAM5) from CMIP3 family under A1B emission scenario of IPCC Special Report on Emissions Scenarios (SRES). Furthermore, the data was archived on monthly scale due to huge volume and was not particularly useful for evaluating future climate extremes.

[19] Roeckner E, Ba¨uml G, Bonaventura L, Brokopf R, Esch M, Giorgetta M, Hagemann S, Kirchner I, Kornblueh L, Manzini E, Rhodin A, Schlese U, Schulzweida U, Tompkins A (2003) The atmospheric general circulation model ECHAM5. Part I: model description, vol 349. Max Planck Institute for Meteorology Report, p 127

[20] Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012. An overview of CMIP5 and the experiment design. Bull. Am. Meteorol. Soc., 93, 485–498.

[21] Moss RH, Edmonds JA, Hibbard KA, Manning MR, Rose SK, van Vuuren DP, Carter TR, Emori S, Kainuma M, Kram T et al (2010) The next generation of scenarios for climate change research and assessment. Nature 463:747–756.

[22] Burhan A, Waheed I, Syed AAB, Rasul G, Shreshtha AB, et al. (2015) Generation of High–Resolution Gridded Climate Fields for the Upper Indus River Basin by Downscaling Cmip5 Outputs. J Earth Sci Clim Change 6: 254. doi:10.4172/2157-7617.1000254

89. A study conducted by Syed et al., 2013[23] using the same dynamically downscaled data show that regional climate models have systematic biases for the mean climate and the inter-annual variability of temperature, precipitation and circulation which are independent from different driving datasets and seems to come from the physics parameterization of the RCMs.

90. For the purpose of projecting robust climate change extremes and its potential impacts with a high confidence in results, this study used the latest available data at national level for impacts assessment of climate change threats. This data is the most up-to-date in terms of compatibility with various international studies because it is produced by downscaling GCM of CMIP5 family under the latest assumption of GHG emissions in Representative Concentration Pathways (RCPs). All CMIP5 Model output in the archive is available for “non-commercial research and educational purposes” subject to terms and conditions.

91. Archived data is hosted by PCMDI – “Program for Climate Model Diagnosis and Inter-comparison” and available online through ESGF gateways. To address the uncertainties posed by use of different models, as a first step data of total 21 GCMs was obtained. In the next step model selection was made by gauging skill of these GCMs to emulate observed Pakistan climatology both for temperature and precipitation.

92. The skill of these GCMs is assessed by three statistical parameters as undertaken by Taylor et al. (2001)[24]. These three statistical parameters are correlation, relative magnitudes of the time series (Standard Deviation–SD) and the normalized error of the models (Root Mean Square Error -RMSE). Hence the criteria to select the GCMs was: correlation is greater than 0.8; the ratio of the GCM SD to the observed SD should be close to 1, and minimum RMSE.

93. A total of 4 models with the best performance statistics with the observations are shown in Table 6 and Table 7. However, only one of these models was chosen for further statistical downscaling at better spatial resolution.

94. Downscaled projections using this model are the most updated and robust national level climate change data for impacts assessments. Therefore, this data was used for the assessment of Climate Risk & Vulnerability of Peshawar Bus Rapid Transit (BRT) System.

95. The Asian Precipitation Highly Resolved Observational Data Integration Toward Evaluation of Water Resources (APHRODITE), has long–term daily gridded precipitation and temperature datasets for Asia available from 1951 and onwards at 0.25x0.25-degree resolution using a dense network of stations which is higher than any other observation dataset available. In this study, the time-period of APHRODITE used for baseline analysis was from 1975-2005.

Table 6: Four GCMs selected for downscaling

Model	Resolution	Institution	Reference
CCSM4	1.25 x 0.942408377	National Center for Atmospheric Research	Gent et al., 2011
GFDL-ESM2M	2.5 x 2.011	National Oceanic and Atmospheric Administration/Geophysical Fluid Dynamics Laboratory	Dunne et al., 2012
HadGEM2-ES	1.875x1.25	Met Office Hadley Centre	Collins et al., 2011
CanESM2	2.8125x 2.8125	Canadian Centre for Climate Modelling and Analysis	Chylek et al., 2011

Table 7: Selected model output statistics under RCP 4.5 and RCP 8.5

Model	RMSE_T	RMSE_P	SD_T	SD_P	CC_T	CC_P
CCSM4	0.04	0.14	0.30	0.28	0.99	0.88
CanESM2	0.05	0.11	0.31	0.28	0.99	0.94
GFDL-ESM2M	0.05	0.14	0.31	0.24	0.99	0.86
HadGEM2-ES	0.04	0.11	0.30	0.24	0.99	0.92

Note: ‘T’ is Temperature, ‘P’ is precipitation, ‘RMSE’ is Root Mean Square Error and ‘CC is Pearson’s Correlation Coefficient.

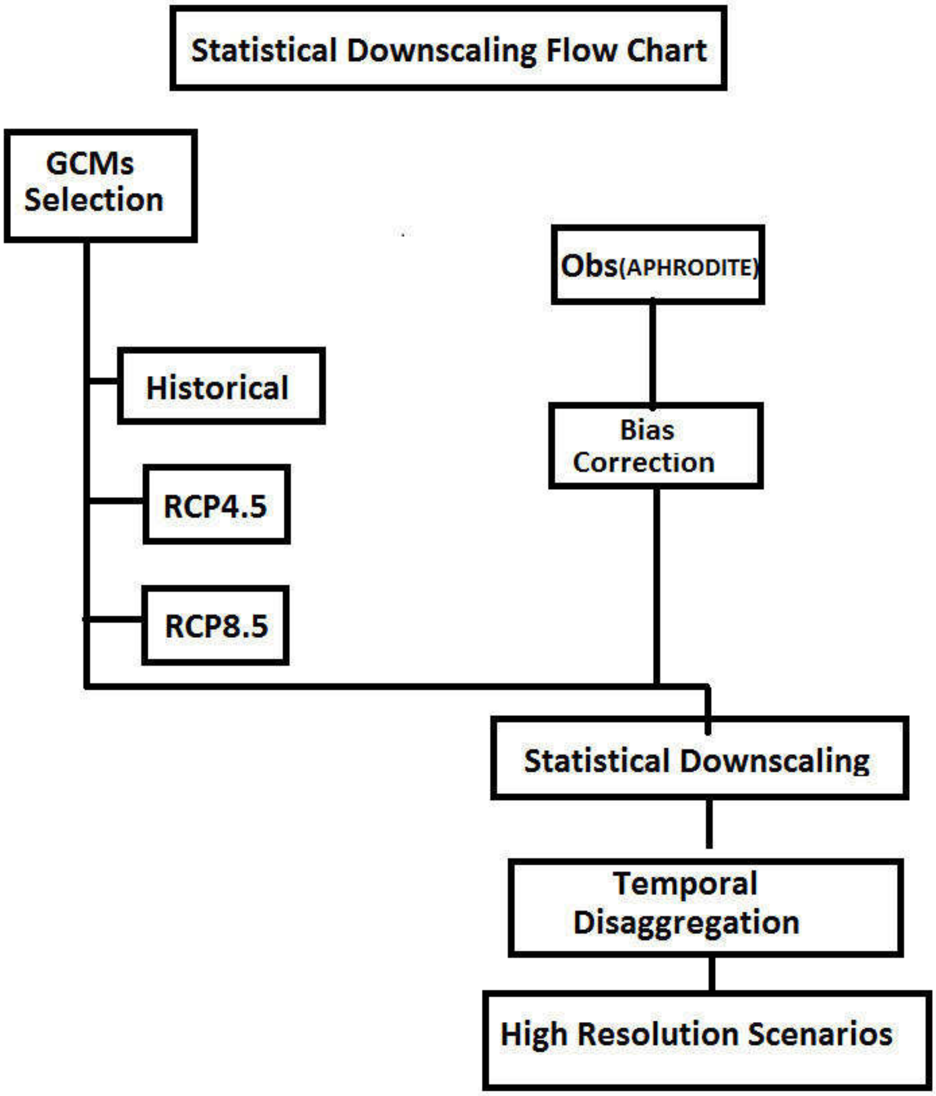
[23] Uncertainties in the regional climate models simulations of South-Asian summer monsoon and climate change", F.S. Syed, W. Iqbal, A. Bukhari and G. Rasul. Climate Dynamics Volume 42, Issue 7-8, pp 2079-2097 DOI 10.1007/s00382-013-1963-x.

[24] Taylor, K. E., 2001. Summarizing multiple aspects of model performance in a single diagram. JOURNAL OF GEOPHYSICAL RESEARCH, Volume 106, pp. 7183-7192.

C. Downscaling methodology, data and uncertainties

96. The downscaling technique employed for generating these climate projections along with associated model uncertainties are discussed in detail by Burhan et al. (2015). However, a brief description is provided here. Figure 15 shows a complete step by step procedure for generation of high resolution future climate information at city level.

Figure 15: Schematics of statistical downscaling procedure for generating future projections



Source: Burhan et al., 2015.

97. Linear Interpolation and Bias Correction Method (LIBC) is a combination of the two methods used by Wood et al. (2004) and Immerzeel et al. (2012)[25].

98. APHRODITE datasets for temperature and precipitation were taken for baseline period 1975–2005. Mean and standard deviation of monthly climatology was calculated and the dataset was re-gridded to a horizontal resolution of 0.25x0.25 degrees for the complete baseline period 1975–2005. Similar procedure was adopted for historical GCM data (1975-2005).

[25] Immerzeel WW, Van Beek LPH, Konz M, Shrestha AB, Bierkens MFP (2012) Hydrological response to climate change in a glacierized catchment in the Himalayas. Climate Change 10: 721-736.

99. Correction factor was determined from the baseline data by the division of climatological values of APHRODITE to the climatological values of GCM. Similarly, signal to noise ratio was obtained by dividing the square root of the variance of monthly observed dataset with the square root of the variance of the monthly GCM reference. The revised climate parameters are computed by multiplying signal to noise ratio of the corresponding month with the deviation between future GCM month and climatology of that month. Subsequently, the element is added to the product of adjusted factor and the respective climatology of that particular month.

100. Same procedure is repeated for every month of GCMs future data to obtain revised monthly GCM values for both temperature and precipitation parameters. The spatially interpolated grid obtained is temporally disaggregated to daily sequences since diurnal variations in the projected data series is important if it is to be used to commute hydrological or ecological models. This technique is an extension of the one used by Wood et al. (2004)[26] where daily sequences are retrieved by employing monthly means of daily time series.

101. For temperature, the methodology is the same except that the adjustment factors are added. The diurnal variation bound from that month is imposed upon all grids of the downscaled monthly values while holding the downscaled monthly mean intact.

D. Climate Change Threat Assessment

102. The objective of the threat analysis is to develop robust causal linkages between changes in global, meso, and local hydrometeorology to specific parameters and attributes of the BRT infrastructure. This has been completed on this assignment through limited primary site investigation and secondary review of international best practice so that detailed design process can be informed.

103. The following threats have been identified as being of direct relevance to the Peshawar BRT Project: rainfall, ambient air temperature, high winds and flooding.

Climate Indices

104. A total of 18 core climate indices were calculated for Peshawar as shown in Table 8. Nine indices are related to the temperature while 9 indices are related to the precipitation. Indices are driven from maximum temperature, minimum temperature, and precipitation. The climate indices are of five different types:

Table 8: Core climate indices calculated and analysed

1	FD	Number of frost days	Annual count of days when TN (daily minimum temperature) < 0oC	Days
2	SU	Number of summer days	Annual count of days when TX (daily maximum temperature) > 25oC	Days
3	TN10p	Cool nights	Percentage of days when TN < 10th percentile	Days
4	TX10p	Cool days	Percentage of days when TX < 10th percentile	Days
5	TN90p	Warm nights	Percentage of days when TN > 90th percentile	Days
6	TX90p	Warm days	Percentage of days when TX > 90th percentile	Days
7	WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX > 90th percentile	Days
8	CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN < 10th percentile	Days
9	DTR	Diurnal temperature range	Monthly mean difference between TX and TN	°C
10	SDII	Simple precipitation intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP>=1.0mm) in the year	mm/ day
11	R10	Number of heavy precipitation days	Annual count of days when PRCP>=10mm	Days
12	R20	Number of very heavy precipitation days	Annual count of days when PRCP>=20mm	Days
13	R50	Number of very heavy precipitation days	Annual count of days when PRCP>=50mm	Days
14	CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days

[26] Wood AW, Maurer EP (2002) Long–range experimental hydrologic forecasting for the eastern United States. J geophys res 107: 6-15.

15	CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
16	R95p	Very wet days	Annual total PRCP when RR>95th percentile	mm
17	R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
18	PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR>=1mm)	mm

Percentile-based indices

105. Occurrence of cold nights, occurrence of warm nights, occurrence of cold days, occurrence of warm days, very wet days, and extremely wet days, are all percentile based indices.

Absolute indices

106. These indices represent maximum or minimum values within a season or a year. Maximum of daily maximum temperature, maximum of daily minimum temperature, minimum of daily maximum temperature, minimum of daily minimum temperature, maximum 1-day precipitation amount, and maximum 5-day precipitation amount, are all absolute indices.

Threshold indices

107. The indices are those in which the number of days on which a temperature or precipitation value falls above or below a fixed threshold. Annual occurrence of frost days, annual occurrence of ice days, annual occurrence of summer days, annual occurrence of tropical nights, number of heavy precipitation days, and number of very heavy precipitation days, are all threshold indices.

Duration indices

108. These indices signify periods of excessive warm, cold, wetness or dryness in the climate. Cold spell duration indicator, warm spell duration indicator, consecutive dry days, and consecutive wet days, are all duration indices.

E. Results and discussion of observed climate extreme indices for Peshawar

Precipitation

109. Historical data for 54 years (1961-2014) shows that in Peshawar, annual total precipitation in extremely wet days i.e., when the daily precipitation amount on a wet day is *greater* than 99th percentile of precipitation on wet days in the 1981-2010 period, is slightly **increased** by 57mm although, the trend is **insignificant** (Figure 16-a).

110. Annual total precipitation in very wet days has also **increased** by 154mm and is statistically **significant** at 95% confidence interval (Figure 16-b).

111. Maximum number of consecutive days with precipitation *less* than 1mm has **decreased** by 8 during the 54-years period (Figure 16-c).

112. In Peshawar, the total precipitation has **increased** by 263 mm, over the past 54 years (significance of trend is at 99% level) (Figure 16-d).

113. Heavy precipitation extremes of rainfall *greater* than 10 mm display **significant increase** in the number of days in Peshawar, with an increase of 4 days (significant at 95 % level) and an increase of 9 days (significant at 99 % level) over the past 54 years (Figure 16-e).

114. Similarly, very heavy precipitation events defined by annual count of days when PRCP id *greater than or equal to* 20mm have significantly increased in Peshawar with slope estimates of 6 days significant at 99 % level of confidence (Figure 16-f).

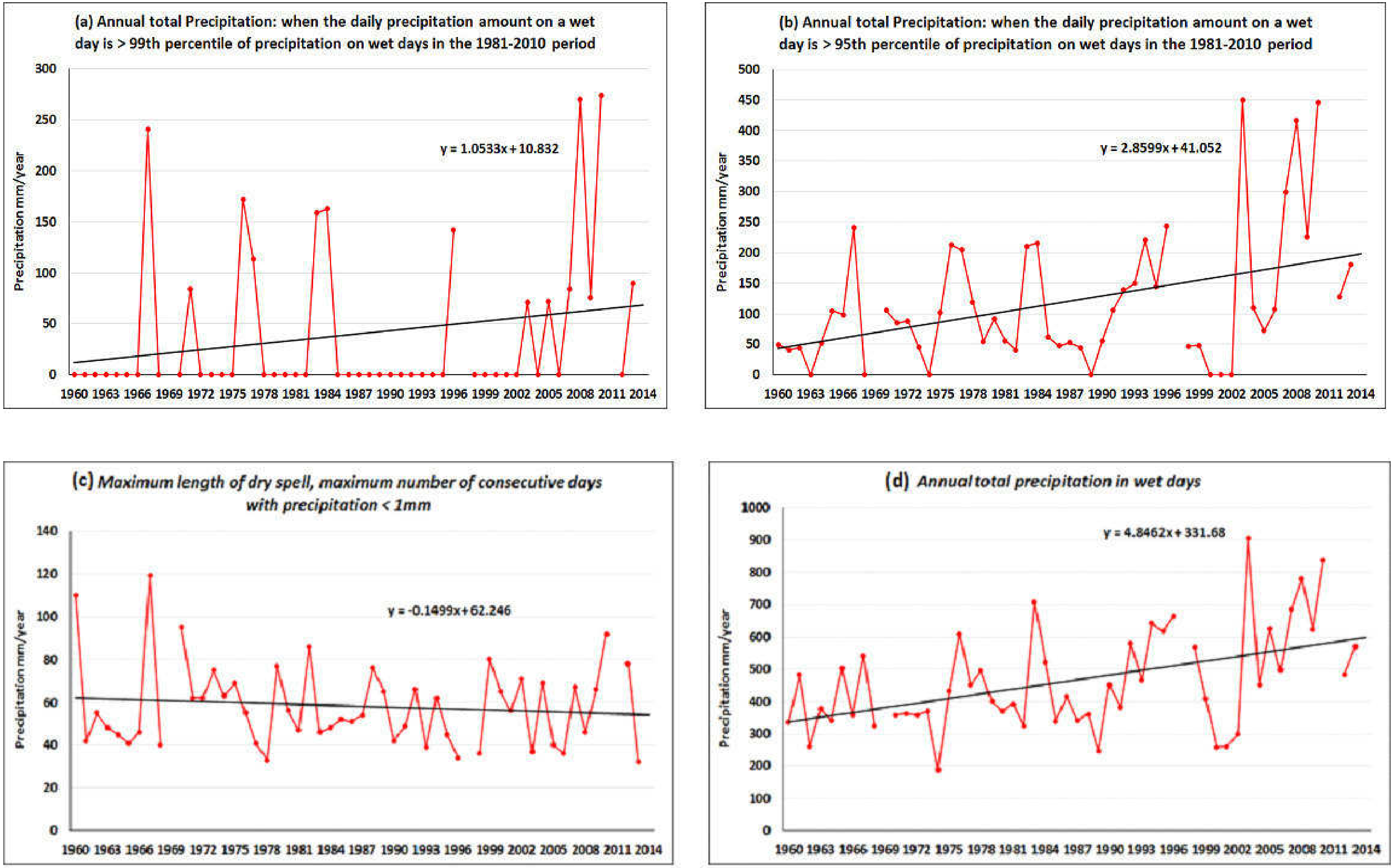
115. However, trend of extremely high precipitation *greater* than 50mm days is **not significant**. Annual total precipitation of very wet days (when rainfall is *greater* than 95th

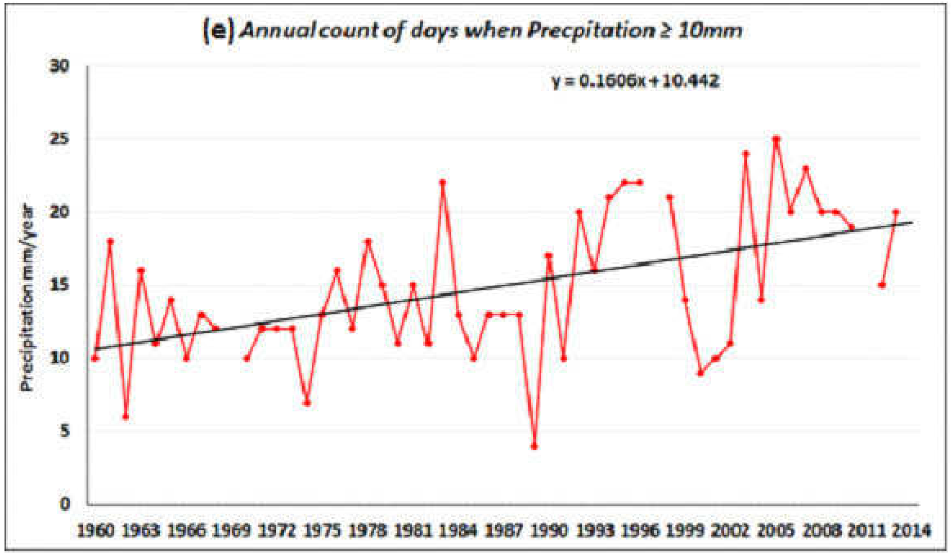
percentile) displays a **significantly increasing trend** in Peshawar with a total of 123 mm increase at 99% confidence level (Figure 16-g).

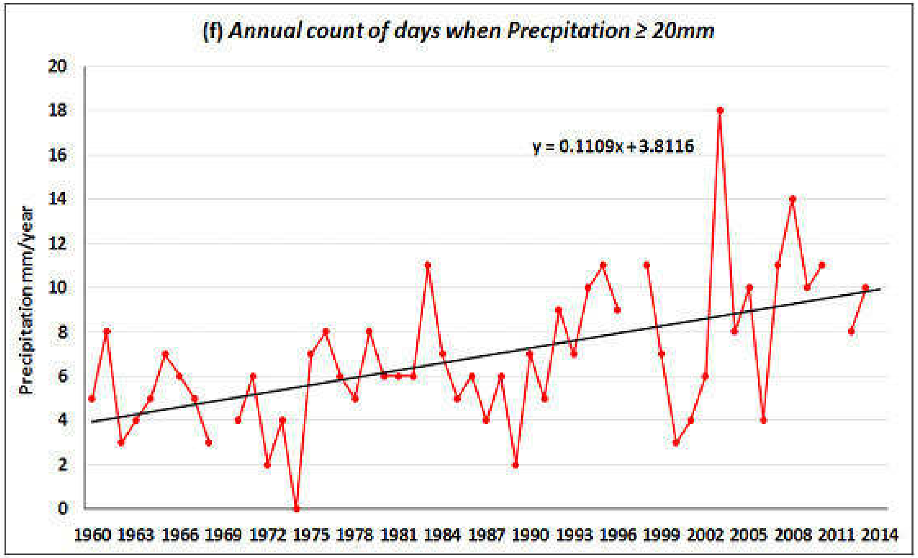
116. Simple Precipitation intensity index has increased slightly during the period (Figure 16-h).

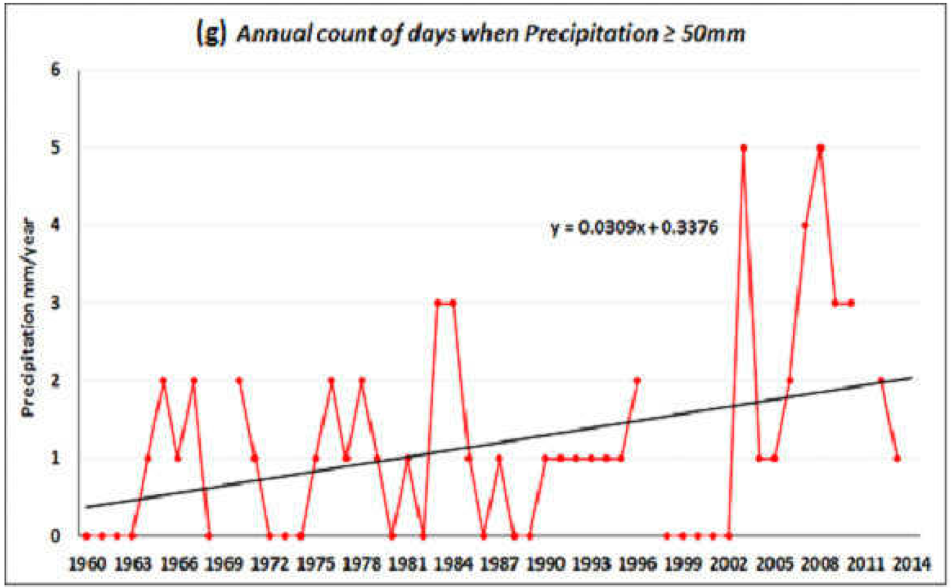
117. No statistically significant trend is observed in frequency of consecutive wet days in KPK over the 1960-2013 past data analysis

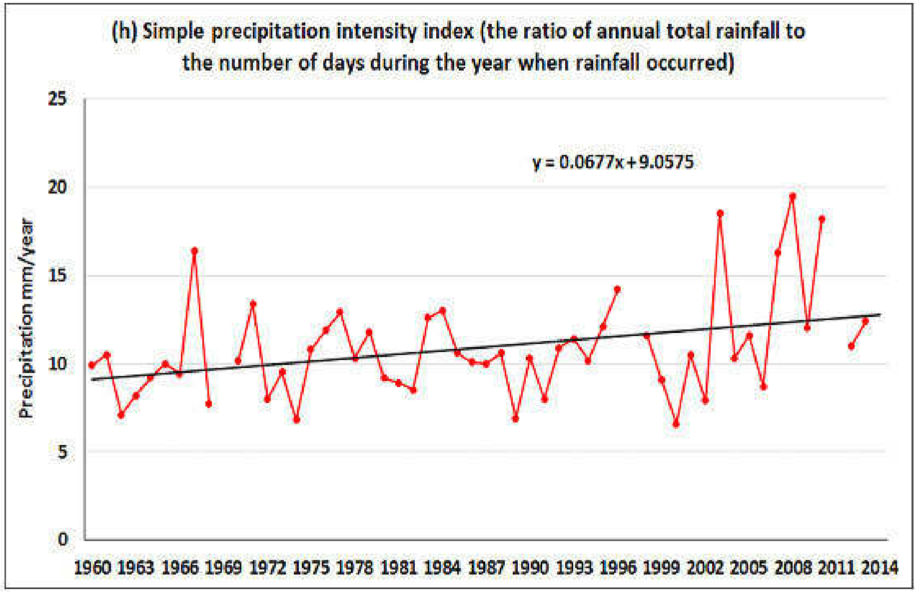
Figure 16: Rainfall Extremes (a to i)




(e) Annual count of days when Precpitation ≥ 10mm
y = 0.1606x + 10.442
Precipitation mm/year
0
5
10
15
20
25
30
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014


(f) Annual count of days when Precpitation ≥ 20mm
y = 0.1109x + 3.8116
Precipitation mm/year
0
2
4
6
8
10
12
14
16
18
20
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014


(g) Annual count of days when Precipitation ≥ 50mm
y = 0.0309x + 0.3376
Precipitation mm/year
0
1
2
3
4
5
6
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014


(h) Simple precipitation intensity index (the ratio of annual total rainfall to the number of days during the year when rainfall occurred)
y = 0.0677x + 9.0575
Precipitation mm/year
0
5
10
15
20
25
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014

Temperature

118. Upon the analysis of frost days in Peshawar, the annual count of days with minimum temperature *less* than 0.0°C taken as a threshold, gives **no significant trend** over the analysis of the past 54 years' data (Figure 17-a).

119. Summer days' index, when the maximum temperature is *greater* than 25°C displays a statistically significant trend towards **increasing** in Peshawar city of KPK province over the past 54-years data. The trend shows an increase of 23 days in the past 54 years in Peshawar with significance at 99 % level (Figure 17-b).

120. However, when the threshold is set at 45°C the trend becomes **insignificant** (Figure 17-c).

121. Number of cool nights have **decreased** annually by 6 in Peshawar i.e., when the minimum temperature is l*ess* than 10th percentile of 1981-2010 data (Figure 17-d). Trend of the mean of the minimum temperature over Peshawar show a significant **increasing** trend of 0.9°C over the past 54-years data analysis. Trend is significant at 99 % level of confidence. Mean of maximum temperature over the past 54-years data display a high confidence in the trends of Peshawar of KPK where 0.9°C increase in the mean of the maximum temperature is seen.

122. Trend of warm nights in Peshawar is significantly i**ncreasing** over the past 54 years. The rate of increase in 54 years is 8 nights with confidence at 99 % level (Figure 17-e).

123. Statistically significant trend in cool-days index is observed in Peshawar with 3 days **increase** in the cool-days index with 99 % level of confidence (Figure 17-f).

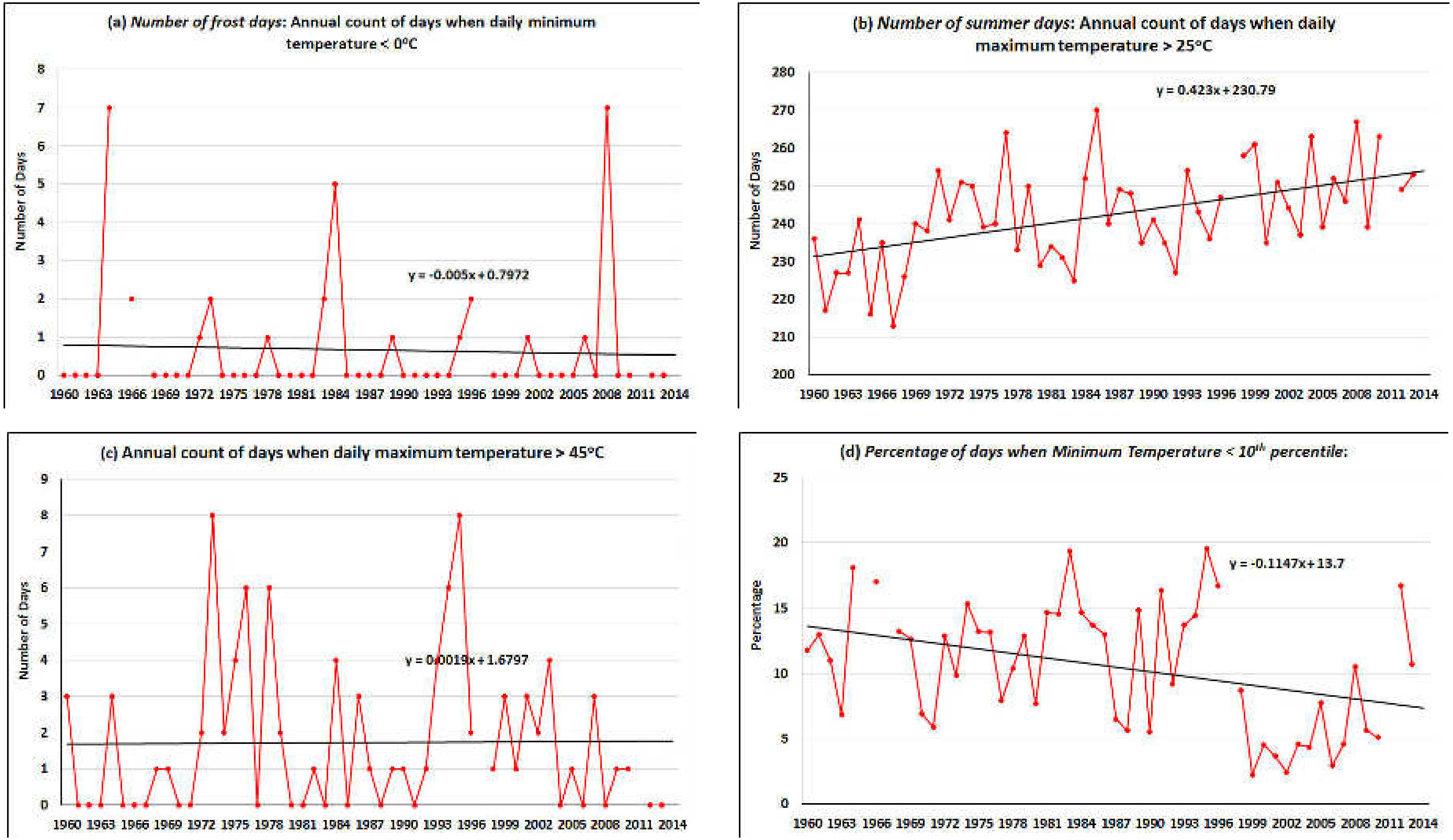
124. The general trend of warm days in KPK is **slightly increasing** over the past 54-years data analysis however for Peshawar the trend **is not significant** (Figure 17-g).

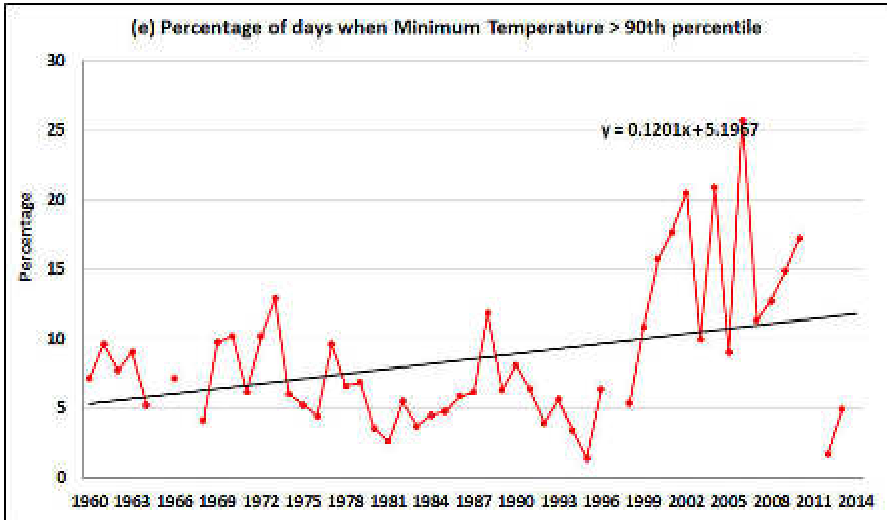
125. The trend of warm spell duration in index has **remained unchanged** overall in Peshawar (Figure 17-h) while cold spell duration index has a general **decreasing trend** which means that cold waves have **decreased** over the past 54 years in Peshawar.

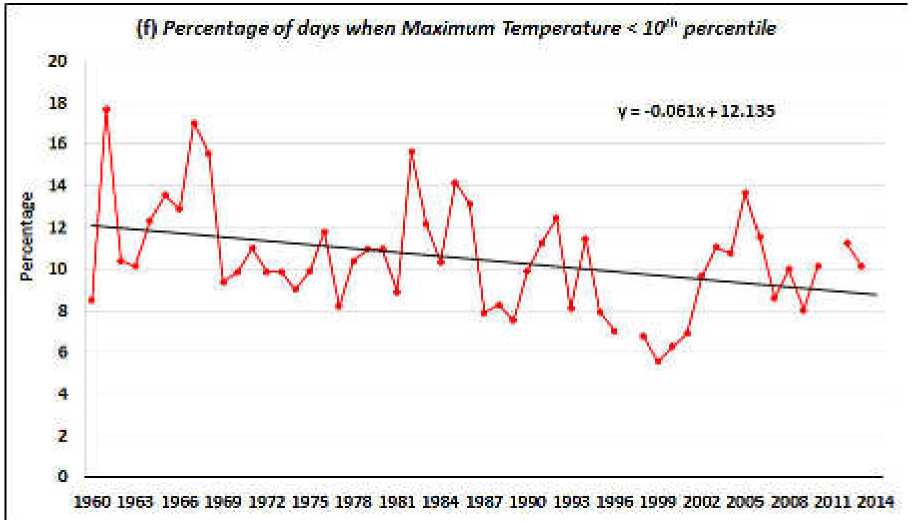
126. A linear trend **decrease** of 12 days (significant at 95% level) in the cold spell duration index, is observed upon the analysis of past 54-years data (Figure 17-i).

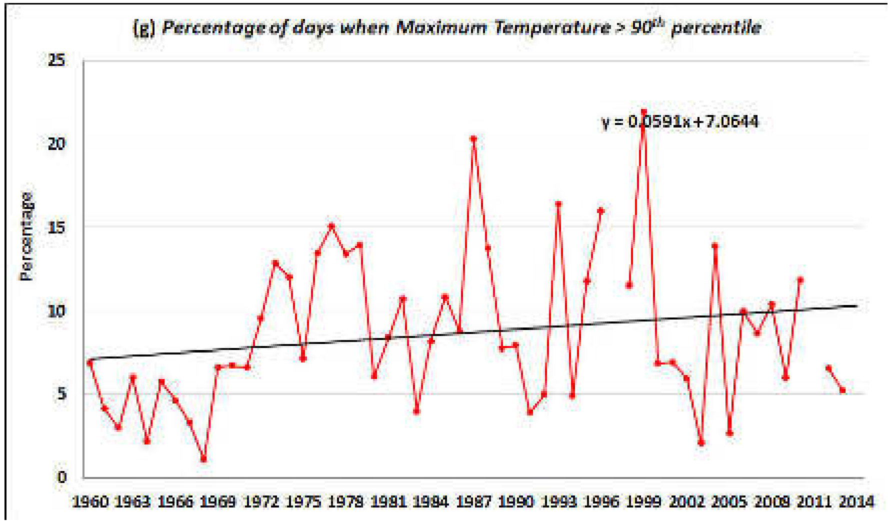
127. Diurnal temperature range in Peshawar show a **slight decreasing** trend but with smaller confidence and smaller statistical significance (Figure 17-j).

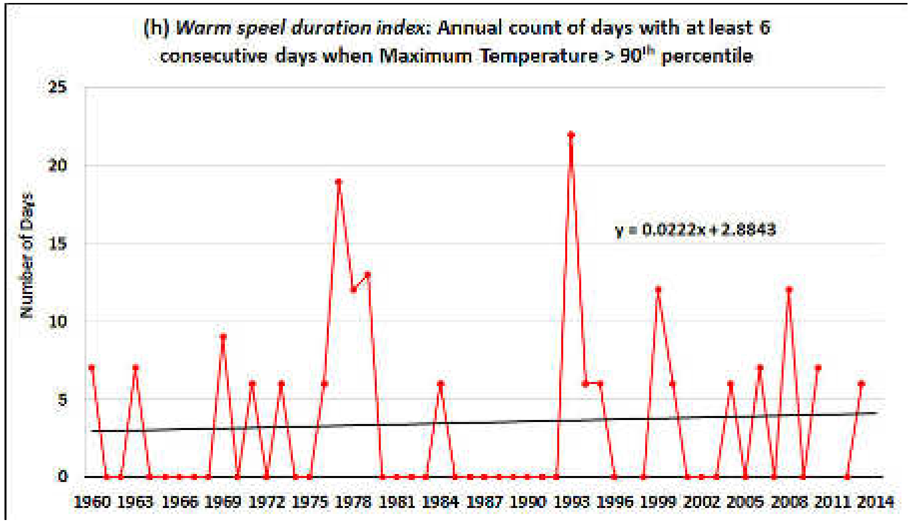
Figure 17: Temperature Extremes (a-j)

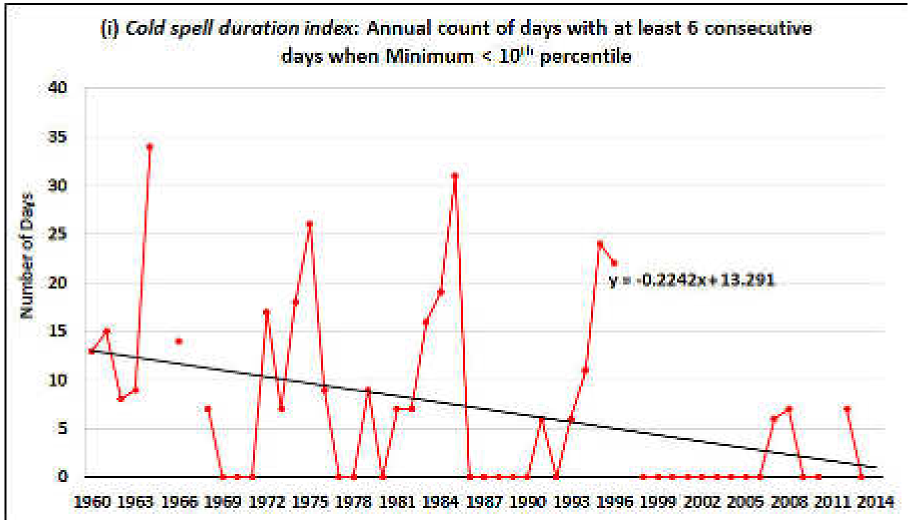


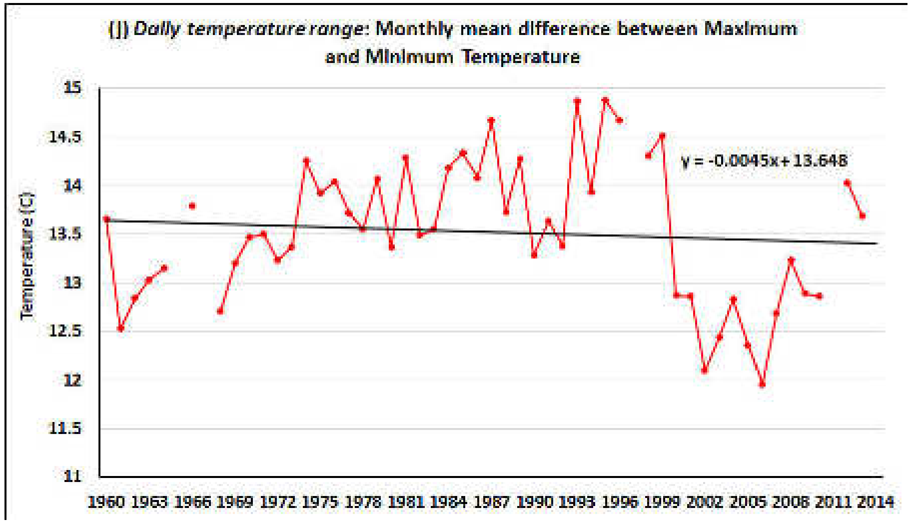

(e) Percentage of days when Minimum Temperature > 90th percentile
y = 0.1201x+5.1967
Percentage


(f) Percentage of days when Maximum Temperature < 10th percentile
y = -0.061x+12.135
Percentage


(g) Percentage of days when Maximum Temperature > 90th percentile
y = 0.0591x+7.0644
Percentage

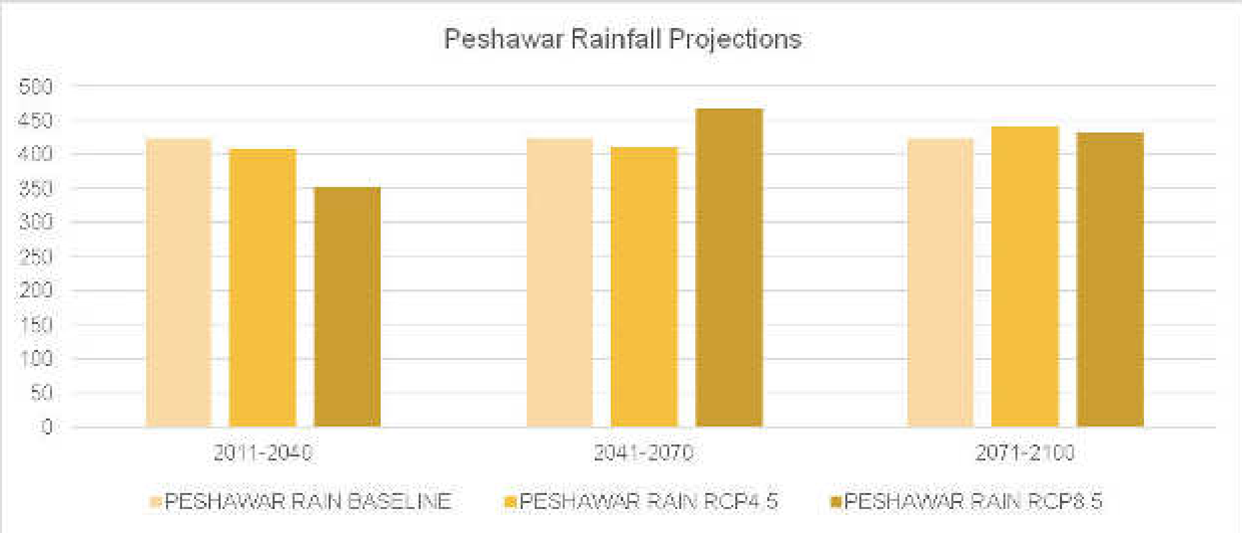

(h) Warm speel duration index: Annual count of days with at least 6 consecutive days when Maximum Temperature > 90th percentile
y = 0.0222x+2.8843
Number of Days


(i) Cold spell duration index: Annual count of days with at least 6 consecutive days when Minimum < 10th percentile
Number of Days
y = -0.2242x + 13.291
40
35
30
25
20
15
10
5
0
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014


(j) Daily temperature range: Monthly mean difference between Maximum and Minimum Temperature
Temperature (C)
y = -0.0045x + 13.648
15
14.5
14
13.5
13
12.5
12
11.5
11
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014

F. Peshawar Climate Projections

Figure 18: Peshawar annual rainfall projections 2011-2100 (RCP4.5 & RCP8.5 emission scenarios)



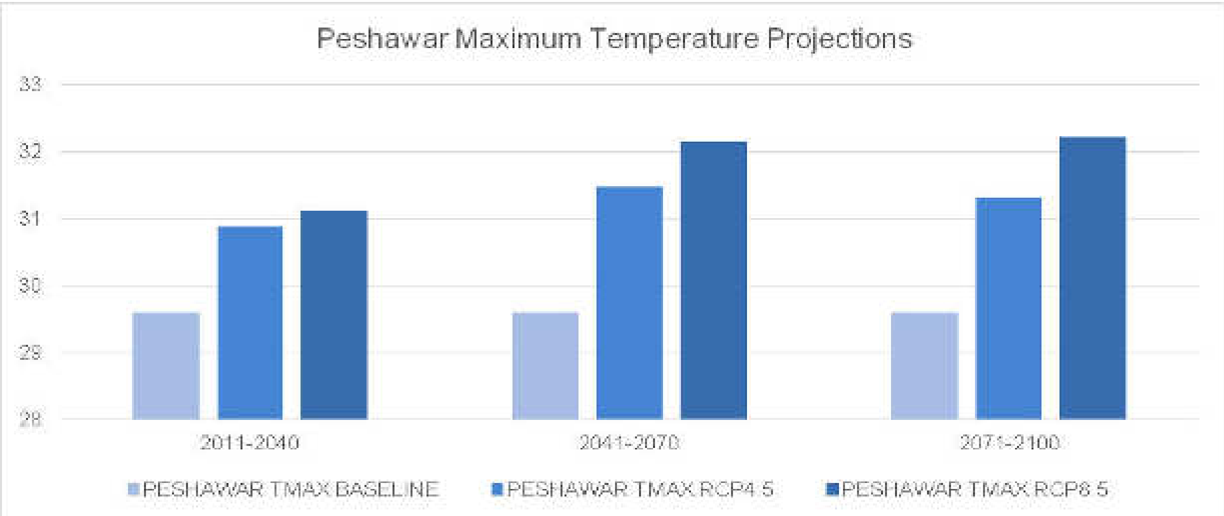
Source: Pakistan Meteorological department

Table 9: Peshawar annual rainfall scenarios highlight

Baseline	Period	RCP4.5	RCP 8.5
423mm	2011-2040	407.8mm	352.2mm
423mm	2040-2070	411.0mm	467.6mm
423mm	2070-2100	440.0mm	431.9mm

Source: Pakistan Meteorological department

Figure 19: Peshawar maximum temperature projections 2011-2100 (RCP4.5 & RCP8.5 emission scenarios)

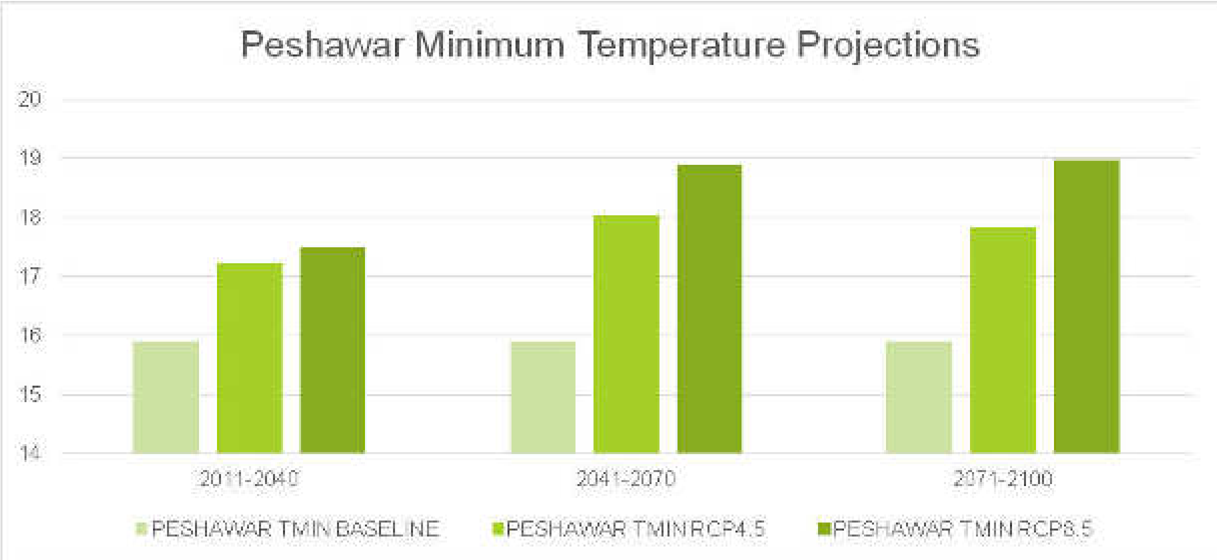


Source: Pakistan Meteorological department

Table 10: Peshawar average maximum temperature scenarios highlight

Baseline	Period	RCP4.5	RCP 8.5
29.6 °C	2011-2040	30.9 °C	31.1 °C
29.6 °C	2040-2070	31.5 °C	32.1 °C
29.6 °C	2070-2100	31.3 °C	32.2 °C

Figure 20: Peshawar minimum temperature projections 2011-2100 (RCP4.5 & RCP8.5 emission scenarios)



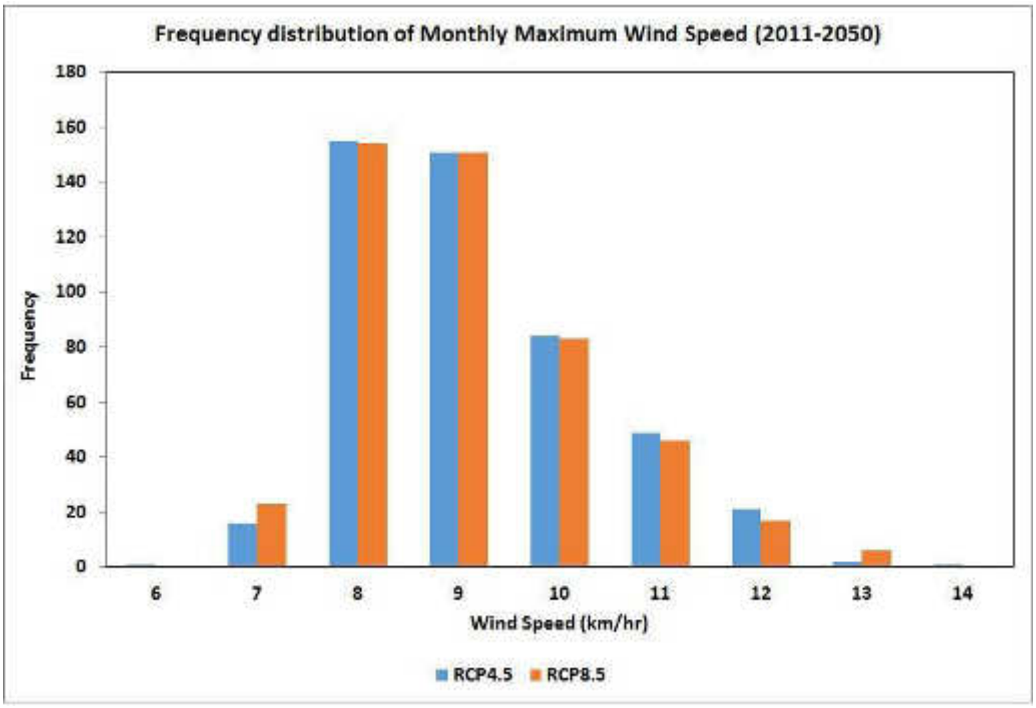
Source: **Pakistan Meteorological department**

Table 11: Peshawar average minimum temperature scenarios highlight

Baseline	Period	RCP4.5	RCP 8.5
15.9°C	2011-2040	17.2 °C	17.5 °C
15.9 °C	2040-2070	18.0 °C	18.9 °C
15.9 °C	2070-2100	17.8 °C	19.0 °C

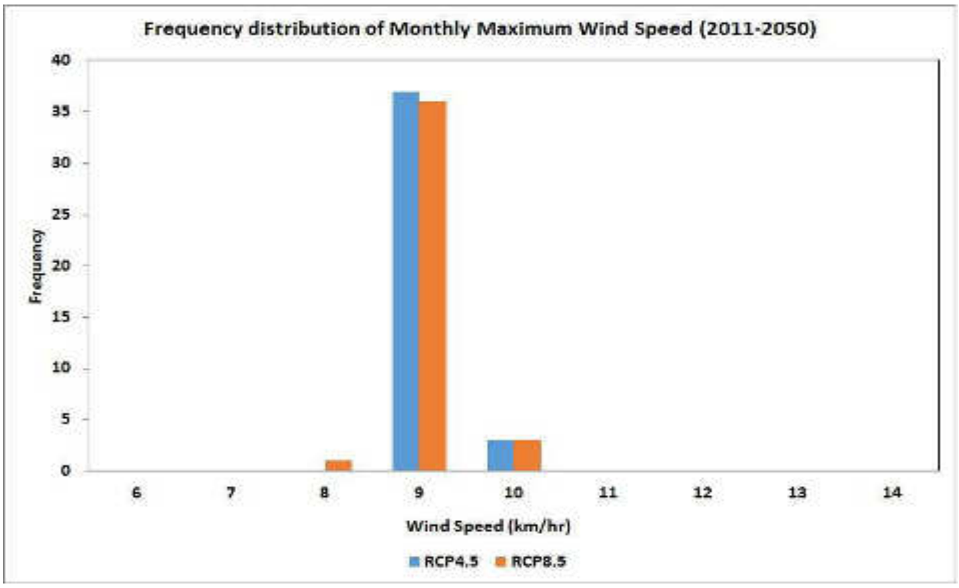
Source: Pakistan Meteorological department

Figure 22: Frequency Distribution of Future maximum wind speed in Peshawar on monthly basis.



Source: Peshawar projected downscaled wind data downloaded from CORDEX-South Asia

Figure 23: Frequency Distribution of Future maximum wind speed in Peshawar on annual basis.



Source: Peshawar projected downscaled data downloaded from CORDEX-South Asia

Projections of Future Wind Storms

128. In the case of wind speed, the required downscaled data was not available from the global climate models. However, for the purpose of impacts assessment the wind speed data used is obtained from World Climate Research Programme (WCRP) Coordinated Regional Climate Downscaling Experiment (CORDEX; http://www.cordex.org/) dataset for South Asia region. The CORDEX South Asia dataset includes dynamically downscaled projections from the 10 models and scenarios for which daily scenarios were produced and distributed under CMIP5. The purpose of these datasets is to provide a set of high resolutions (50 km) regional climate change projections that can be used to evaluate climate change impacts on processes that are sensitive to finer-scale climate gradients and the effects of local topography on climate conditions.

129. Daily maximum wind speed data on monthly temporal resolution was available for both RCPs which was downscaled output of MPI-ESM-LR global model by MPI Regional model 2009. Results for frequency distribution of monthly and annual extreme wind speeds are shown in Figure 22 and Figure 23 respectively. Figures show that during 2011-2050 most frequent wind speed have a magnitude of 8-9km/hr with a total frequency of around 150 under both scenarios. It is difficult to ascertain the return period of these high wind speeds due to limitation of data however no wind storm events with *greater* than 13km/hr wind speed are projected in future.

130. The future climate projections of wind speed are not indicating extraordinary wind storm events in future. Further, projecting future strong wind pattern is not easy either since these systems are not well resolved by global and regional climate models. In the absence of any future certain extreme wind storms projections and that no areas along the BRT route were found to be at particular risk from tunnelling high wind effects, it is difficult to propose any infrastructure design criteria to be followed along the BRT route. Even though the figures from CORDEX are shown as being much less, it is proposed that the BRT infrastructure specially signboards, tall structures, lighting fixtures at terminal stations (particularly at the elevated sections) need to be able to withstand future though rare intense wind storms of at least **110km/hr** that have occurred in the past and recorded.

G. Quantification of future extremes under climate change scenarios.

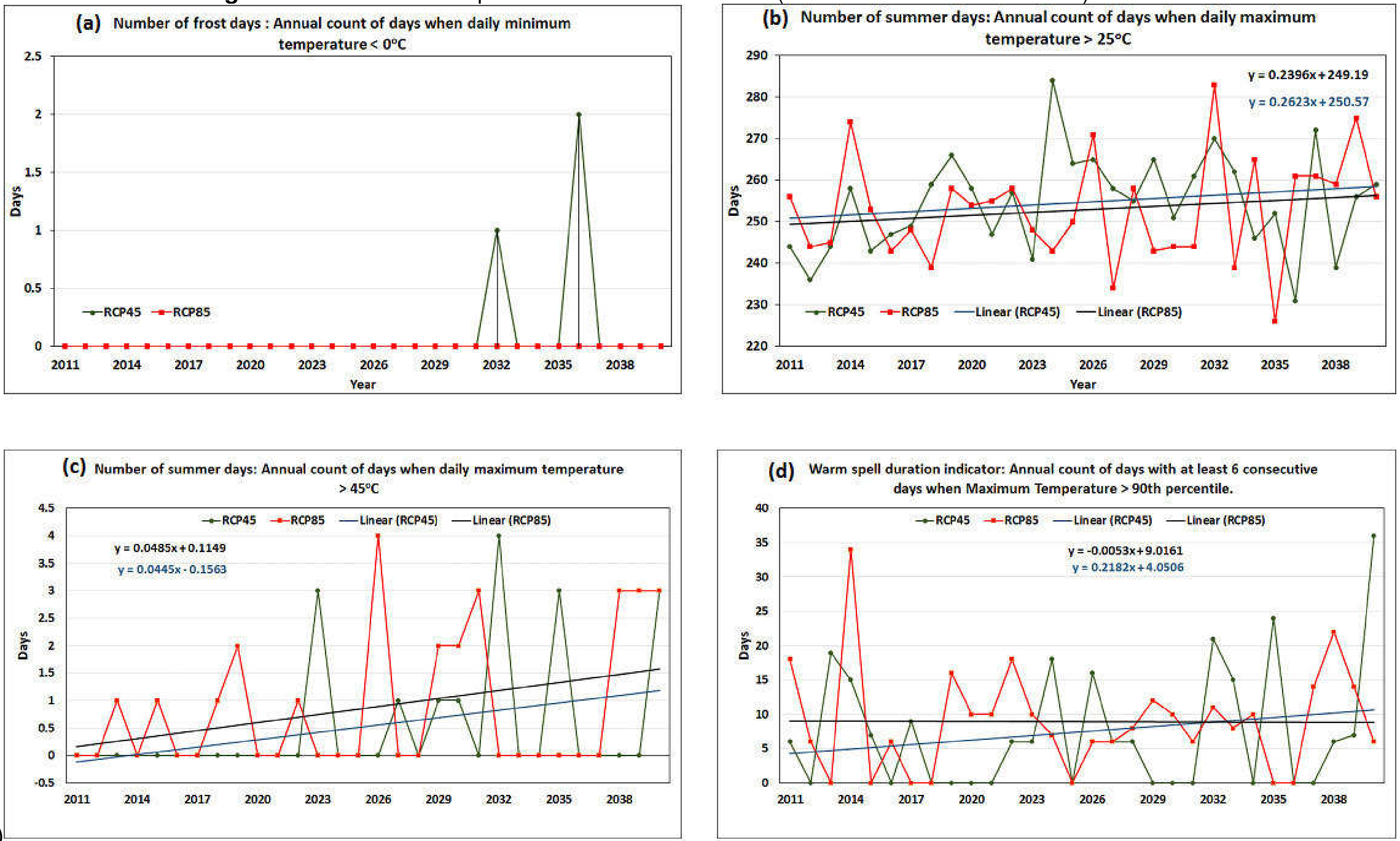
131. Future climate indices are calculated using daily projections of temperature and precipitation for the time-period 2011-2100 under both moderate and high emission scenarios (i.e., RCP4.5 and RCP8.5). Findings of future extreme indices are summarized in the Table 12.

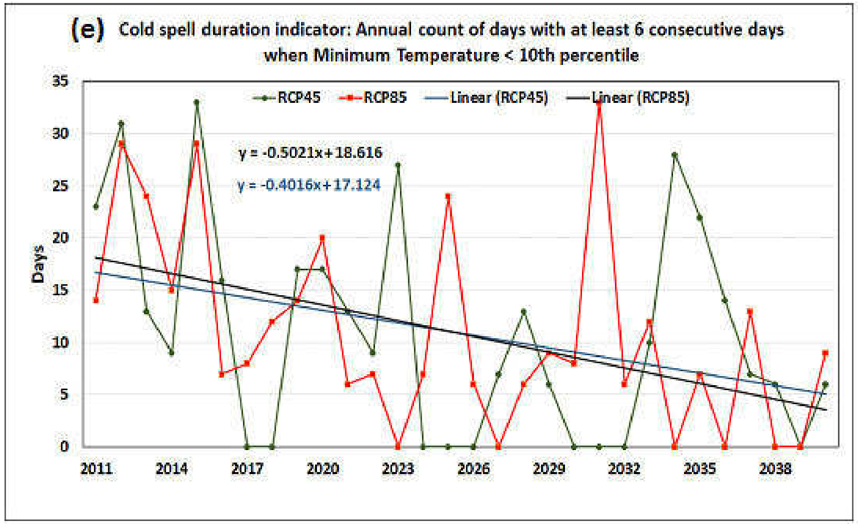
Table 12: Summary of future climate indices for Peshawar

No	Future Climate Indices	2011-2040	2041-2070
1.	**Number of frost days:** Annual count of days when daily minimum temperature *less* than 0^{o}C	Trend not significant	Trend not significant
2.	**Number of summer days:** Annual count of days when daily maximum temperature *greater* than 25^{o}C	On average, 17 days increase in annual number of summer days under both RCP4.5 and RCP8.5 scenarios.	24 days increase in annual number of summer days under RCP4.5 scenario. 34 days increase in annual number of summer days under RCP8.5 scenario.
3.	**Number of summer days (extreme temperature):** Annual count of days when daily maximum temperature *greater* than 45^{o}C	No significant change in the overall present number of extreme hot days under RCP4.5 and RCP8.5 scenario.	2 days and 6 days per year increase in annual days with *greater* than 45^{o}C under RCP4.5 and RCP8.5 scenario respectively as compared to present day.
4.	**Heat wave duration indicator:** Annual count of days with at least 6 consecutive days when maximum temperature *greater* than 90th percentile of the 30-year period.	An annual heat wave duration increase of 6 days under RCP4.5 No overall warm spell duration increase in number of days under RCP8.5.	Duration of heat waves is projected to increase by 3 days under RCP4.5 scenario and by 15 days under RCP8.5 scenario.
5.	**Cold spell duration indicator:** Annual count of days with at least 6 consecutive days when minimum temperature *less* than 10th percentile	Overall cold spell duration is projected to decrease by 12 days and 15 days under RCP4.5 and RCP8.5 scenario respectively.	Overall cold spell duration is projected to decrease by 9 days and 21 days under RCP4.5 and RCP8.5 scenario respectively.
6.	**Diurnal temperature range:**	No Significant Change	No Significant Change
7.	**Simple precipitation intensity index**: Annual total precipitation divided by the number of wet days (defined as PRCP *greater than or equal to* 1.0mm) in the year	Large inter-annual variability but the overall trend is not significant under both scenarios.	Large inter-annual variability but the overall trend is not significant under both scenarios.

No	Future Climate Indices	2011-2040	2041-2070
8.	**Number of heavy precipitation days:** Annual count of days when **PRCP *greater than or equal* to 20mm**	No significant trend	No significant trend
9.	**Number of heavy precipitation days:** Annual count of days when **PRCP *greater than or equal* to 50mm**	Total number of events will decrease by 19 days under RCP4.5 scenario from present day. Total number of events will decrease by 33 days under RCP4.5 scenario from present day.	Total number of events will decrease by 21 days and 14 days under RCP4.5 and RCP8.5 scenario respectively.
10.	**Consecutive dry days:** Maximum number of consecutive days with RR *less* than 1mm	No significant trend	Consecutive dry days are projected to decrease by 53 under RCP4.5 scenario while RCP8.5 show a slight increase of 18 days.
11.	**Consecutive wet days:** Maximum number of consecutive days with RR *greater* than 1mm	No significant trend	No significant trend
12.	**Annual total wet-day precipitation**: Annual total PRCP in wet days (RR *greater than or equal* to 1mm)	Overall precipitation has no significant trend, although inter-annual variability will prevail.	Overall precipitation has no significant trend although, inter-annual variability will prevail

Figure 24: Peshawar temperature indices 2011-2040 (RCP4.5 & RCP8.5 emission scenarios)




(e) Cold spell duration indicator: Annual count of days with at least 6 consecutive days when Minimum Temperature < 10th percentile
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = -0.5021x+18.616
y = -0.4016x+17.124
Days
35
30
25
20
15
10
5
0
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038

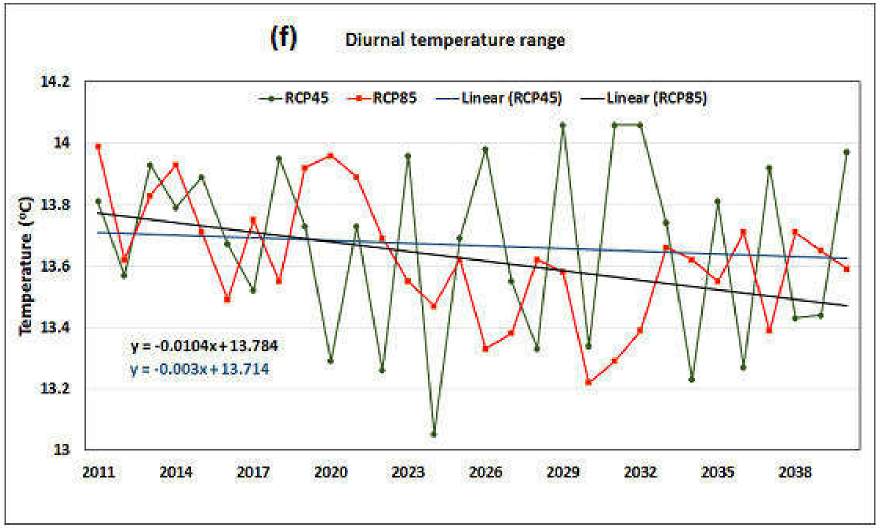
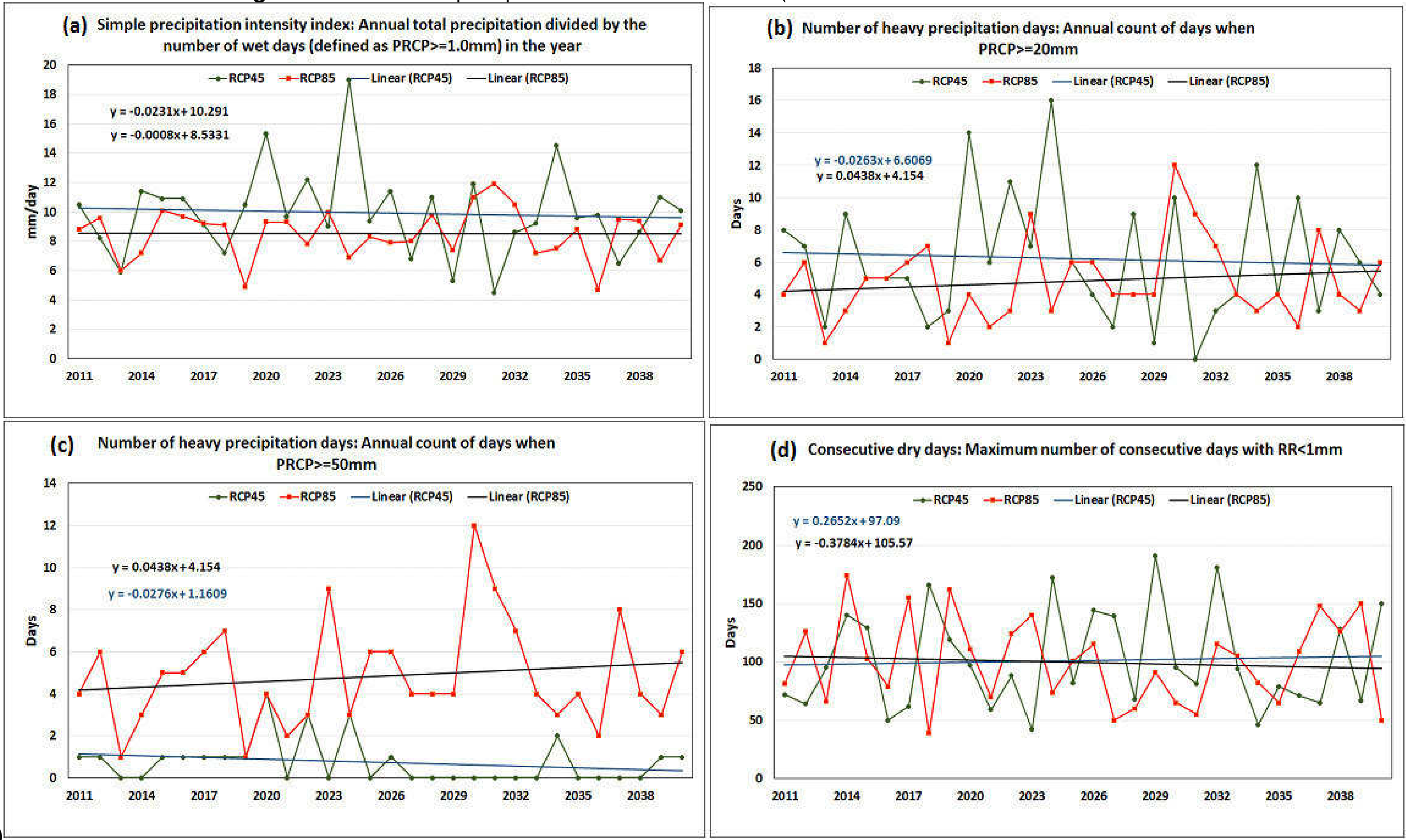
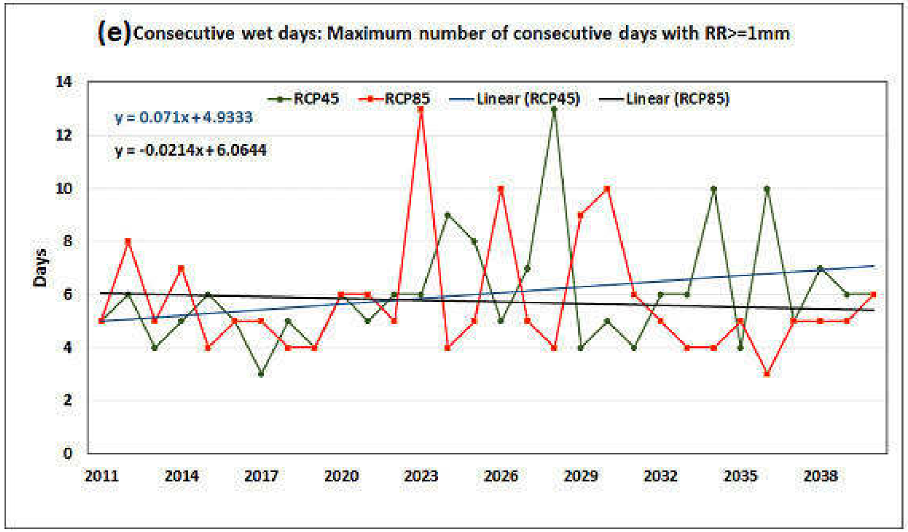

(f) Diurnal temperature range
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = -0.0104x+13.784
y = -0.003x+13.714
Temperature (ºC)
14.2
14
13.8
13.6
13.4
13.2
13
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038

Figure 25: Peshawar precipitation indices 2011-2040 (RCP4.5 & RCP8.5 emission scenarios)




(e) Consecutive wet days: Maximum number of consecutive days with RR>=1mm
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = 0.071x + 4.9333
y = -0.0214x + 6.0644
Days
14
12
10
8
6
4
2
0
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038

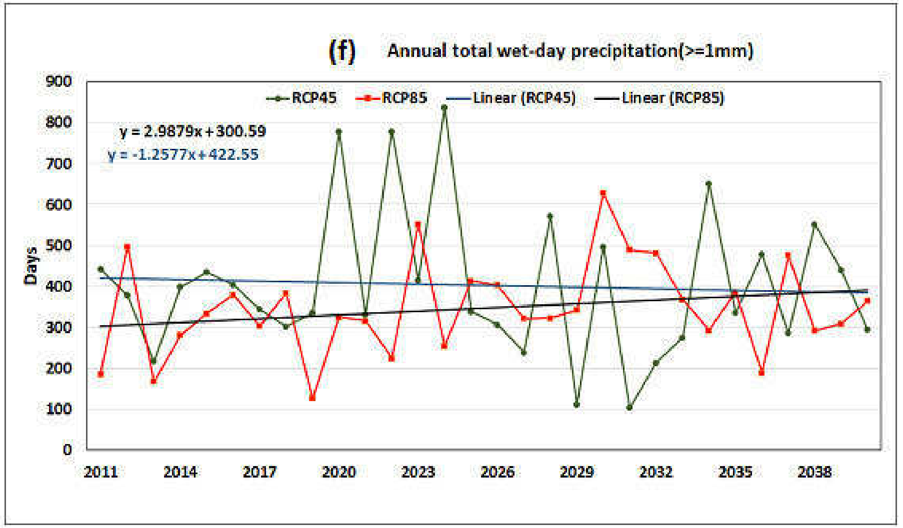
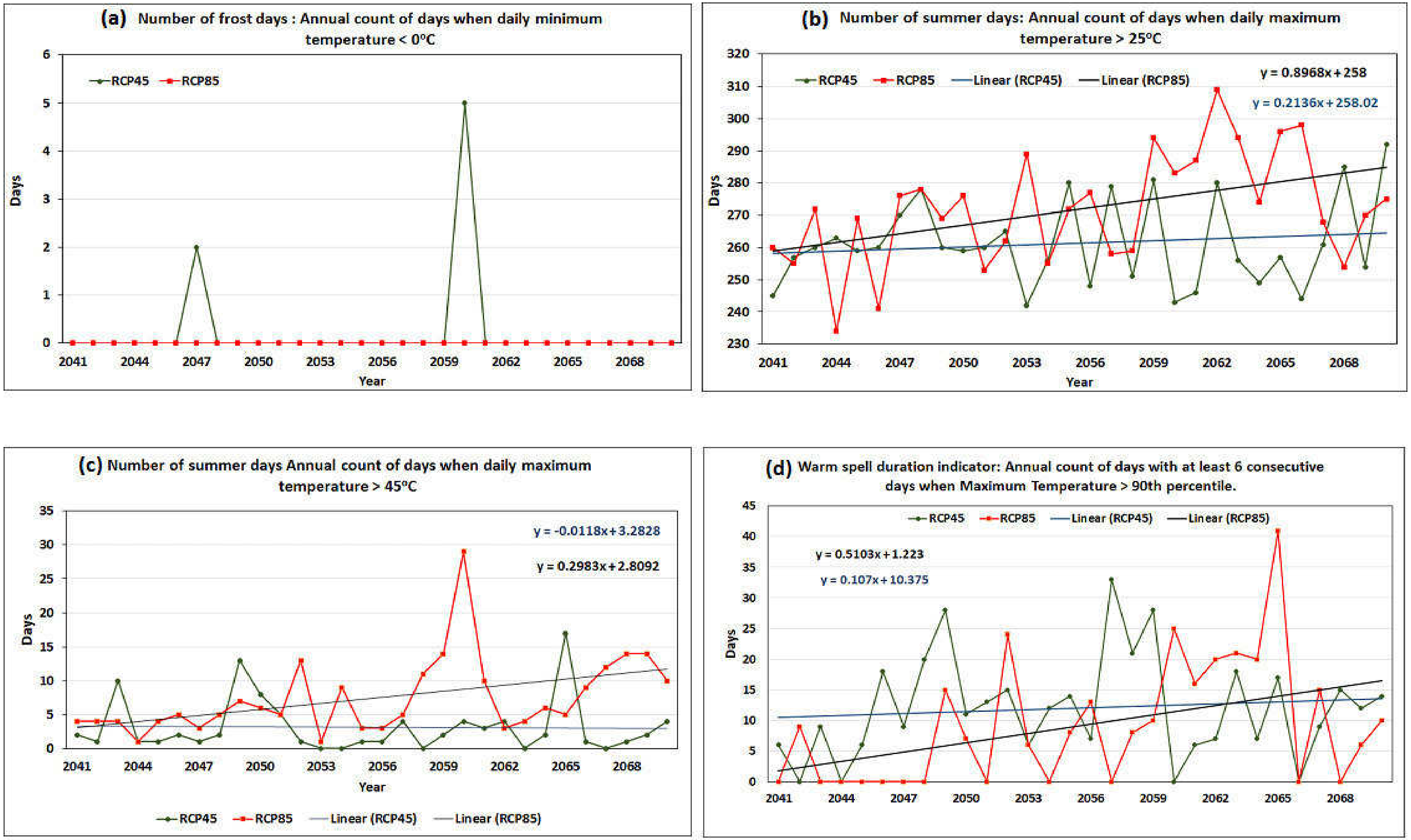
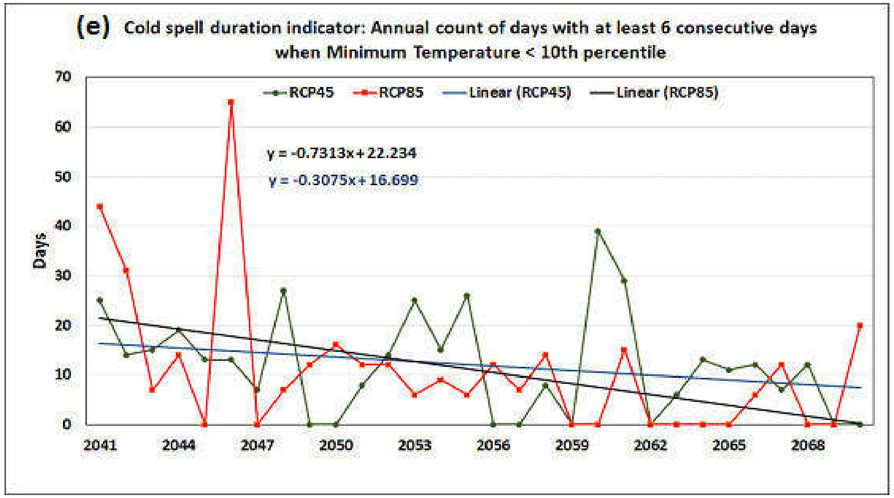

(f) Annual total wet-day precipitation(>=1mm)
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = 2.9879x + 300.59
y = -1.2577x + 422.55
Days
900
800
700
600
500
400
300
200
100
0
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038

Figure 26: Peshawar temperature indices 2041-2070 (RCP4.5 & RCP8.5 emission scenarios)




(e) Cold spell duration indicator: Annual count of days with at least 6 consecutive days when Minimum Temperature < 10th percentile
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = -0.7313x + 22.234
y = -0.3075x + 16.699
Days
70
60
50
40
30
20
10
0
2041
2044
2047
2050
2053
2056
2059
2062
2065
2068

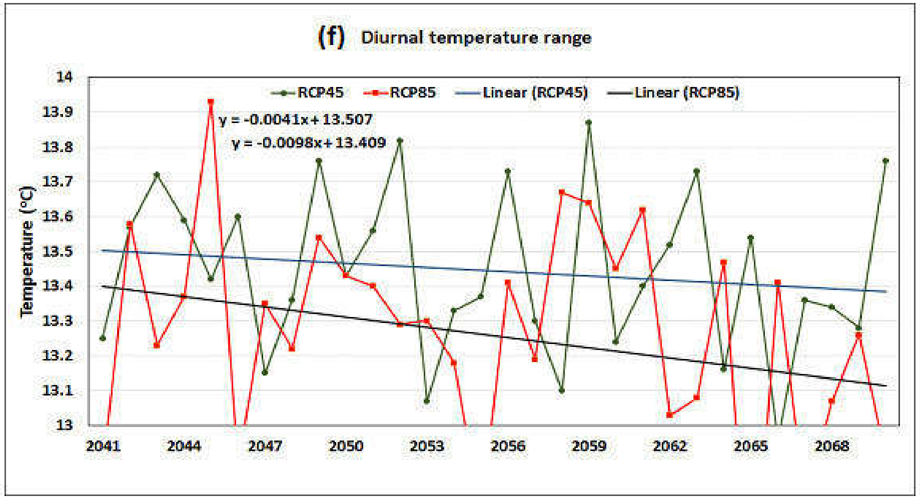
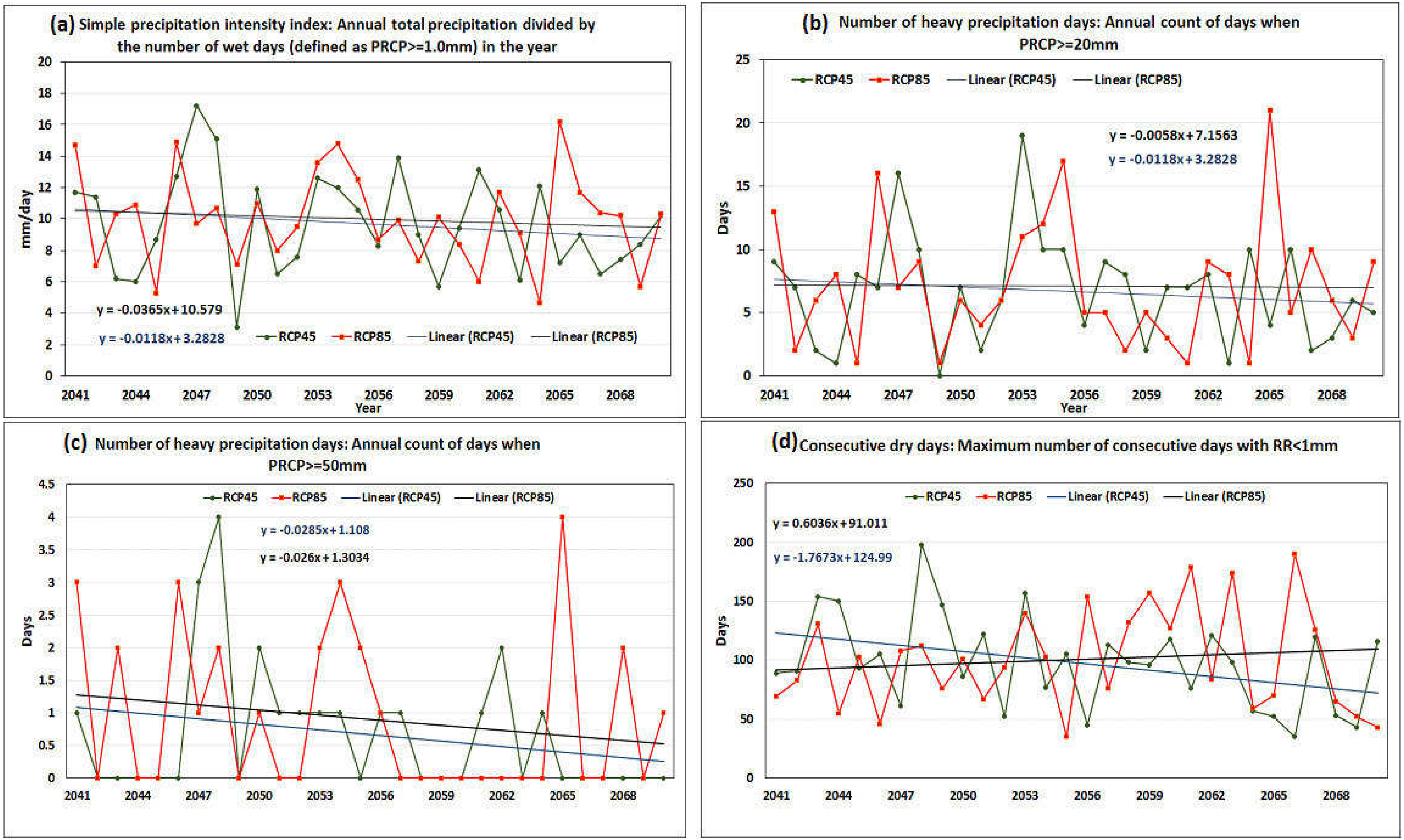
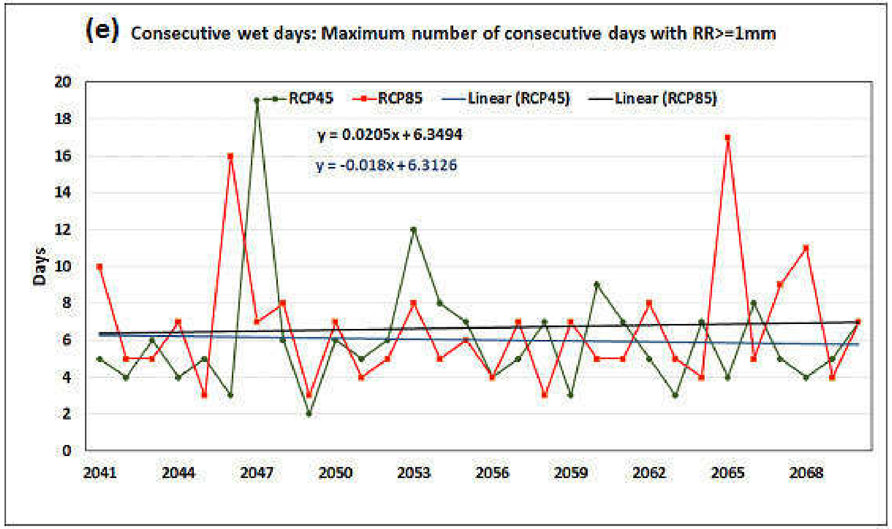
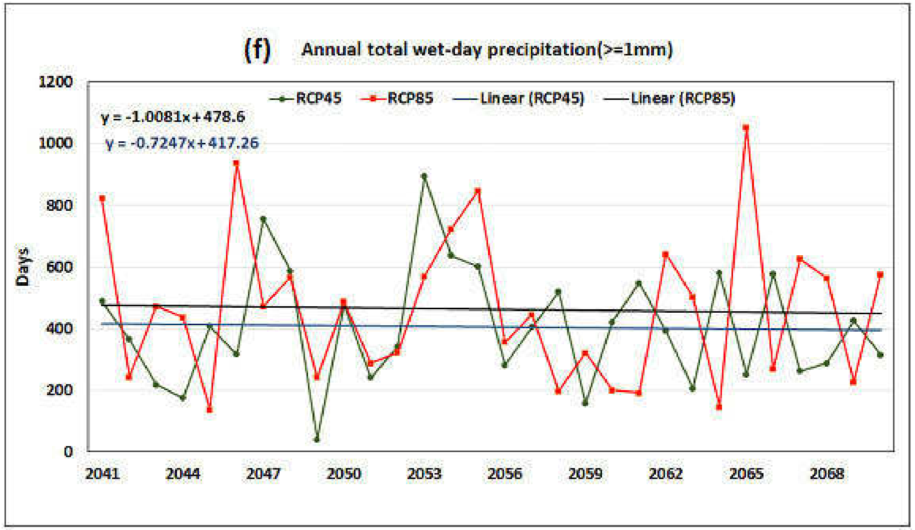

(f) Diurnal temperature range
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = -0.0041x + 13.507
y = -0.0098x + 13.409
Temperature (°C)
14
13.9
13.8
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13
2041
2044
2047
2050
2053
2056
2059
2062
2065
2068

Figure 27: Peshawar precipitation indices 2041-2070 (RCP4.5 & RCP8.5 emission scenarios)




(e) Consecutive wet days: Maximum number of consecutive days with RR>=1mm
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = 0.0205x + 6.3494
y = -0.018x + 6.3126
Days
20
18
16
14
12
10
8
6
4
2
0
2041
2044
2047
2050
2053
2056
2059
2062
2065
2068


(f) Annual total wet-day precipitation(>=1mm)
RCP45
RCP85
Linear (RCP45)
Linear (RCP85)
y = -1.0081x + 478.6
y = -0.7247x + 417.26
Days
1200
1000
800
600
400
200
0
2041
2044
2047
2050
2053
2056
2059
2062
2065
2068

H. Results and discussion of future climate indices for Peshawar

132. The results of future climate indices of temperature during 2011-2040 under both RCP4.5 and RCP8.5 emission scenarios are shown in Figure 24 (a - f). Overall number of summer days (*greater* than 25^{o}C maximum temperature) increase annually under both emission scenarios. Under both RCP4.5 and RCP8.5 scenario average number of summer days per year are projected to be 254 as compared to present day value of 237. However, no significant change is found in frequency of extreme heat days (*greater* than 45^{o}C) in future. Number of heatwaves, when the Maximum Temperature *greater* than 90th percentile of the 30-year period, increase by 6 days annually only under RCP4.5 scenario. Cold waves duration is projected to decrease by 12 days and 15 days under RCP4.5 and RCP8.5 scenario respectively.

133. Rainfall extremes are elaborated in Figure 25 (a – f). It can be seen that projection of all different indices has high inter-annual variability and therefore it is very difficult to establish any particular trend. However, as compared to historical data the amount of annual precipitation is projected to increase in future during 2041-2070 only under RCP8.5 scenario. For example, total precipitation annual may be as high as 1053 as compared to highest total of 904mm as recorded during 2003 in Peshawar. Total number of days with very high precipitation (*greater than or equal to* 50mm/day) are projected to be 22 and 8 under RCP4.5 and RCP8.5 scenario respectively as compared to the present-day value of 41.

134. During 2041-2070 number of summer days will increase significantly under both RCP4.5 and RCP8.5 scenario (Figure 26 a-f). On average, annual number of days with *greater* than 25^{o}C are projected to increase by 24 and 34 days respectively while those with *greater* than 45^{o}C will increase by annually 2 and 6 days respectively, as compared to the current number. Heat waves duration is also projected to increase by 15 days under high emission scenario while cold waves duration will decrease by 21 days.

135. Results for precipitation indices during 2041-2070 are presented in Figure 27 (a – f). Total number of days per year with very high precipitation (*greater than or equal to* 50mm/day) are projected to be 20 and 27 under RCP4.5 and RCP8.5 scenario respectively as compared to the present-day value of 41. Past data (1960-2014) record show a total of 6 events with extremely high precipitation (*greater than or equal to* 100mm/day). Model projections show that a total of 4 such events may occur during 2011-2070 under both RCP4.5 and RCP8.5 scenario.

Key findings:

136. Overall climate projections of Peshawar suggest that Peshawar will become hotter and drier. The annual average temperature is predicted to increase by 1.9 to 2.5 C by 2070. No significant change in present number of extreme heat-wave *greater* than 45C is expected during 2011-2040, but 2-6 days increase in annual heat wave events is projected during 2040-2070. Past hottest day recorded in Peshawar was 50^{o}C in 18th June 1995.

137. Climate models project general reduction in Peshawar annual rainfall in the coming decades. Extreme rainfall event is also projected to decrease, but still 4 extreme rainfall events may occur by 2070. Past intense rainfall that occurred in July 2010 was 274mm in 24 hours.

138. Intense wind storms are not very common in Peshawar and climate projection are also not indicating any increase in frequency of such wind storms by 2070. However, past worst recorded wind storm was 110km/hour in 2015.

139. BRT design needs to cater for projected increase in Peshawar’s temperature. Additionally, the design should also cater for the rare intense precipitation and intense wind storm events that may occur.

I. Highlighting uncertainties of climate scenarios.

140. All climate change projections even those obtained from a new generation of more complex models running scenarios for the IPCC AR5 are subject to certain degree of uncertainty. In fact, a key feature of uncertainty in climate change projections is the degree of precision in the timing, severity and frequency of future weather and climate particularly the extreme events that are difficult to achieve. Where possible these uncertainties have been quantified, but still the numerical as well as qualitative results in this report should be regarded as broad suggestions and used with caution. In addition, general climate models' uncertainties briefly described below.

141. There are four principal sources of this uncertainty in Projections:

a) **The Modelling uncertainty** arises from our incomplete understanding of the climate system, and the climate models also failed to perfectly represent the real system. Use of different global climate models includes the structural uncertainty.

b) Natural climate variability
Climate varies naturally due to internal dynamical and physical processes in the climate system and this can potentially modify some of its characteristics.

c) Emissions uncertainty
This arises from uncertainty in the future man-made emissions of greenhouse gases and aerosols.

d) Contributions to uncertainty from downscaling. The downscaling process accounts for the inclusion of local effects of features such as coastline and mountains in the downscaling process also enhance the uncertainty in climate projections, but it is generally modest.

VI. VULNERABILITY ASSESSMENT

A. Climate Impacts

142. It is now well recognized that climate change impacts on road infrastructure requires a completely revised strategy on how roads are designed, constructed and maintained (Tighe, 2008)[27], particularly considering potential impact on roads pavements. For example, changes in rainfall, temperature and evaporation can disturb the pavement foundation moisture balance affecting their structural strength (Doré et al, 1997)[28]. Whereas increase in temperature can accelerate the ageing of bitumen roads surfaces (Ahmad et al, 1998; Masad et al, 1996)[29 30]. This suggest that climate change is likely to contribute to pavement deterioration (i.e. roughness, rutting, cracking, potholing, revelling and strength).

143. A brief summary of the impacts of increasing temperature, projected intense heat-waves, and particularly rare intense precipitation and wind storms on the Peshawar BRT's operation, maintenance and its infrastructure is given below in Table 13:

Table 13: Climate Change Impact on Peshawar BRT Infrastructure, Operation & Maintenance

No	Climate Change	Possible effect on BRT Infrastructure, Operation & Maintenance
	Climate Stressor - High Temperatures	
1	Monthly Mean Temperature rise: 0.9deg C mean temperature rise observed during !951-2015 Warm nights are increasing significantly Climate Models project that the maximum temperature in Peshawar is expected to rise by: 1.28-1.5deg C during 2011-2040, 1.86-2.5deg C during 2040-2070 and 1.71- 2.6degC during 2070-2100. under emission scenarios of RCP4.5 and RCP8.5 respectively. Minimum temperature is also expected to rise by: 1.25deg C-1.5deg C during 2011-2040, 1.9-2.5deg C during 2040-2070 and 1.7-2.6deg C 2071-2100 RCP4.and RCP8.5 respectively. **Heat wave extreme temperature**: Climate model projections does not show any significant change in the present number of extreme heat days (>45°C) per year during 2011-	Peshawar summer higher temperatures are projected to be higher than 45C. Whereas sustained air temperatures of above 32 C considered vulnerable for road/ transport infrastructures. **Roads/ Pavements** • As such sustained projected higher temperatures in Peshawar are likely to be causing traffic related rutting and softening of BRT road paved surfaces, softening and spread of liquid asphalt. • In case of bituminous carpeting road, road materials will lose bonding and be damaged due to heat • In addition, projected higher temperature can affect bitumen aging and increase cracking resulting embrittlement of pavement surface seals. This would cause loss of water proofing of the surface seal and consequently surface water would enter the pavements causing potholing and rapid loss of surface. **Bridges/ Underpasses/ Elevated portion of BRT** • Very hot sustained temperatures in Peshawar can also weaken the bridges, underpasses and elevated portion of BRT due to their long exposure to heat causing contraction and thermal expansion of joints of bridges and underpasses in concrete infrastructures • Further, new concrete structure constructed during long heat exposure can remain weakened due to poor

[27] Tighe, S. (2008) Engineering Literature Review: Roads and Associated Structures: Infrastructure Impacts, Vulnerabilities and Design Considerations for Future Climate Change, Report prepared for Public Infrastructure Engineering Vulnerability Committee (PIEVC) Secretariat, Engineers Canada (online), Available: http://www.pievc.ca/e/Appendix_C_Literature_Reviews.pdf (23 August 2011).
[28] Doré, G., Konrad, JM. and Roy, M. (1997) 'Role of De-icing Salt in Pavement Deterioration by Frost Action', Journal Transportation Research Record: Journal of the Transportation Research Board, 1596: 70-75.
[29] Ahmad, I., Rahman, M. H., Seraj, S. M., and Hoque, A. M. (1998) 'Performance of plain concrete runway pavement', J. Perform. Constr. Facil., 12: 145–157.
[30] Masad, E., Taha, R. and Muhunthan, B. (1996). 'Finite element analysis of temperature effects on plain-jointed concrete pavements', Journal of Transportation Engineering, 122: 388–398

<table>
<tr><th>No</th><th>Climate Change</th><th>Possible effect on BRT Infrastructure, Operation & Maintenance</th></tr>
<tr><td></td><td>2040, whereas during 2040-2070 it increased by 2-6 days per year under RCP4.5 and RCP8.5 scenario respectively.

Heat wave duration:

Annual count of days with at least 6-consecutive days when Maximum Temperature > 90th percentile of the 30-year period- increase by 6 days annually during 2011-2014 under RCP4.5 scenario and during 2040-2070 by 3 days under RCP4.5 and by 15days under RCP8.5 scenario.

Past temperature record:

The highest maximum temperature recorded at Peshawar was 50deg C on 18th June 1995 and lowest temperature was -3.9deg C on 7th Jan, 1970

But more important aspect of temperature with respect to climate impact on BRT infrastructure, operation and maintenance is the occasions of extreme heat waves and particularly their period.</td><td>curing.</td></tr>
<tr><td></td><td colspan="2">Climate Stressor - Intense Precipitation</td></tr>
<tr><td>2</td><td>Rainfall current trends:

281mm increase in annual precipitation occurred during 1951-2016

Maximum increase occurred during monsoon season

Peshawar annual rainfall under RCP4.5 emission scenario is projected to decrease slightly from base of:

454mm to 418mm during 2011-2040,

411 mm during 2040-70 and then increase again to 440mm annual during 2070-2100

Whereas under emission scenario RCP8.5 the rainfall during: 2011-2040 will be reduced to 352mm, while it would increase to 468mm during 2040-2070 and again slight decrease to 432mm during 2070-2100.

Model projections shows that frequency of extremely high rare precipitation events (>=100mm/day) would not change significantly and be 4-5 such events during 2011-2100 under RCP4.5 and RCP8.5 scenarios

The annual average rainfall during 1951-2016 is 454.4mm. Whereas the heaviest annual rainfall recorded was 903mm in 2003 and heaviest monthly rainfall was 409mm in July 2010.

The heaviest 24hrs record breaking rainfall of 274 mm recorded in July 2010 and an earlier record was 187mm in April 2009.</td><td>Drainage and any flood control infrastructure

• Increased runoff volumes:
o During individual storms
o Overall during season

• Increased urban levels flooding, due to increased runoff volumes

• Increased frequency, area, depth and duration of flooding where:
o Local drain capacity is insufficient due to:
▪ Under-design
▪ Encroachments
▪ Waste dumping
o Local drain capacity is sufficient but is reduced by:
▪ Inadequate capacity downstream, including encroachments, outfall vents
▪ Adverse water levels downstream, due flooding and river level rise
▪ Poor maintenance
▪ Unsuitable operation, e.g. irrigation water
▪ Blockage during operation

Flooding in an adjacent catchment flows into the area, adding to local runoff to be disposed of.

Roads

• Roads damaged due to more flooding and overtopping
• Erosion of embankment faces;
• Pavement edge failure

The changes in projected rainfall intensity would alter moisture balance and resultant pavement deterioration

Further, higher water tables are possible along BRT route susceptible locations no. 1, 2, 4, 6 and 7 as indicated and marked on Figure 4 which can increase the moisture contents of the pavements due to capillary action that can accelerate the pavement deterioration rate.
This can be taken care by raising the level of roads embankments by anticipating water tables in susceptible areas.</td></tr>
</table>

No	Climate Change	Possible effect on BRT Infrastructure, Operation & Maintenance
	Climate Stressor: High Wind Storms	
3	**High wind storms:** The best possible future projections of wind storms are not indicating any increase in frequency of intense wind storm events in Peshawar. Further none of the areas along the BRT route are found to be at particular risk from high wind tunneling effect. . However, keeping view difficulty and uncertainty inherent in wind pattern projections the best strategy is that BRT infrastructure needs to be able to sustain future intense wind storms of at least windstorms of 110km/hrs which occurred in the past.	Though intense wind storms in Peshawar are rare, past data of such storms needs to guide detailed project design. Such intense wind storms can cause increased threat to stability of signs boards, tall structures, lighting fixtures along BRT route and particularly at the elevated terminal stations. Further, as none of the areas along the BRT route are found to be at particular risk from tunneling high wind effect, it is difficult to propose any wind related infrastructure design criteria to be followed along the BRT route. However, it is proposed that the signboards, tall structures, lighting fixtures, signaling particularly at elevated terminal stations, BRT depots and along BRT route need to be able to sustain future intense wind storms of at least 110km/hr which occurred in the past.

VII. ADAPTATION ASSESSMENT

A. Design Consultants

144. Since there is very little information available at the moment on the various BRT infrastructure components, the following are more of a guidance for the design consultants to consider in depth, undertake further studies/surveys and use specifications in line with what is acceptable in Pakistan and/or international best practice.

B. Infrastructure

145. Climate Resilience Options and Measures that should be covered during design work that reflects climate models which project the following: maximum temperature in Peshawar expecting **to rise by 1.2°C to 2.5°C** over the next 53 years (to end of 2070); though the annual precipitation is projected to **slightly decrease to about 418mm** over the same period, but the **intense precipitation 274 mm in 24 hrs** (recorded in 2010), and intense **wind storms events of 110km/hr** (recorded in 2015) needs to be taken into account while designing BRT infrastructure. The direct and indirect adaptation options that needs to be considered when designing a Peshawar BRT are briefly mentioned in Table.14.

Table 14: Impacts of Climate Change on Transport Infrastructure and Adaptation measure

Climate Change Events	Impacts on BRT and Mobility	Adaptation Options
Increase in number of hot days and heat waves	Changes in temperature range and mean temperature cause asymmetric movement, which leads to extended wear and reduces the service life of bearings being used. Change in mean daily temperature: Ambient thermal conditions drive a temperature gradient within the bridge deck structure. Temperatures at the surface can be significantly warmer than internal regions, causing internal stresses in the structure. Warming temperatures, in particular, daily maximum temperatures, will increase the thermal forcing at the surface strengthening the gradient. Impacts from variation in ambient temperatures could include (i) damage due to deflection of the bridge deck; (ii) cracking of deck surface Thermal expansion of bridge joints and paved surfaces Pavement deterioration such as softening, traffic-related rutting, and migration of liquid asphalt, buckling Increased energy costs for BRT facility operations Reduced engine combustion efficiency	Use stiff bitumen and material to withstand heat Use tires with low air pressure, tubeless tyres If continuous reinforced concrete used, there should be provision of temperature reinforcement in CRC pavement to minimize expansion and contraction;
Intense precipitation events	Damage to pavement, underpasses, tunnels and drainage systems due to flooding, scouring and increase in soil moisture levels. Overloading of drainage systems Delay traffic, increase subway flooding, poor vision Increase maintenance costs for roads, utilities and runway and costs for flood control and erosion prevention.	Reduce the gradients of slopes Increase size & height of engineering structures Increase water retention capacity and slow infiltration Raise embankments and add additional drainage capacity Increase monitoring of vulnerable pavement segments Use water capture and storage systems Enclose materials to protect from flood water **Station – Drainage**

Climate Change Events	Impacts on BRT and Mobility	Adaptation Options
		All internal surfaces of the station should be able to drain via channels, drains etc., either by gravity to existing storm water drainage or to wet sumps from where water can be pumped to the new storm water drainage. This system shall deal with all rainwater falling on the station roofs and external areas to be directed into the new storm water drainage system. **Pavement Design** Continuously reinforced concrete (CRC) pavement may be more preferable where there are threats of constant inundation; Important to ensure that there is sufficient sealant between layers, otherwise water may deteriorate the sub-base, which could result in failure of the concrete at the surface. Concrete should be designed for flexural strength of at least 3.5 Mpa. Concrete thickness could vary from 190mm to 260 mm; Concrete should be cured to minimise cracking Provision of temperature reinforcement in CRC pavement to minimize expansion and contraction; Other Pavement material choice that should be considered is the use of lane strips. Advantages of using lane strips include: o Reduces road way material use o Eliminates the need for colourisation on busways / colourisation only required at intersections o Reduces busway noise levels by approximately 40% o Reduces busway drainage requirements If possible, provision of hard shoulder along the pavement where there are threats of inundation Road side RCC drainage (where necessary) should be considered with top slab Construction of RCC Box Culverts/ Cross drains, 250mm diameter uPVC Cross pipe drains as required; Masonry Guide wall to protect erosion and sliding in case of Cement Concrete road; Provision of proper pavement camber (2% ~-3%); Tree Plantation along the roads; **Tunnels** All entrances, vent shafts openings, tunnel portals, service entries and other openings into underground structures and all road thresholds and perimeters to depressed carriageways, underpasses and road tunnels should not be lower than the Design Flood Level. Where drainage or sewerage pipes discharge from the underground structure into the surface system, swan necks or similar should be considered for provision at a level above the Design Flood Level. If gravity drainage provisions are made, the drainage exit points should be above the Design Flood Level to prevent any back flow of water into any possible sub-surface structures during floods.
Increases in drought conditions	Damage to infrastructure due to increased susceptibility to wildfires and mudslides Shortage of water supply for pavement maintenance Poorer quality groundwater	Use flexible pavement structures Increase maintenance, water retention capacity Use matting/erosion control blankets Select materials with high resistance to dry conditions
Intense wind	Wind speeds and alignment determine the horizontal	**Elevated Structures**

Climate Change Events	Impacts on BRT and Mobility	Adaptation Options
storms	and static wind loads. With climate change, higher winds are likely to become more intense and there is a possibility that severe wind events could lead to increased vibrational forcing from wind loading. At present, **evidence is not available** to confirm conclusively whether this will occur. Increase in extreme wind speeds increases horizontal forces for fixed bearings. Increased threat to stability of bridge decks Increased damage to signs, lighting fixtures, and supports Reduced off-road maneuver capacity Increased maintenance costs and increased flood control/erosion prevention measures	Modify the design of supports and anchorages Install projection systems such as windbreaks Wherever possible, plant trees **Tunnels** The length of tunnels along the BRT route are relatively short and it is not considered that these will be adversely affected by extreme precipitation and/or high winds. Increased maintenance costs and increased flood control/erosion prevention measures

Sources: Adapted from Barami (2014), ADB (2014), IPCC (2014), Regmi, Hanaoka (2011) and Team experience in the region.

C. Green Infrastructure and Ecosystem Services

146. Green infrastructure should be encouraged and land permitting, focus should be on the development of multi-functional green infrastructure and open (green) areas (wherever possible) in conjunction with the drainage network and a waste management system. These will serve to diversify the urban form, establish non-structural redundancy[31] in municipal systems, improve air quality, reduce energy use and GHG emissions, improve water quality and increase recreational space.

147. Rainwater harvesting and ecosystem management: wherever possible, harvesting of rainwater for better ecosystem management should be encouraged. Catchment ponds should be identified beginning with identifying natural depressions found in any green spaces in Peshawar for the retention of water. Rainwater harvesting systems in residential, commercial and public buildings should be encouraged and the water should be used mostly for growing plants and other domestic uses.

148. Storm water tree pits should be considered. These consist of an underground structure and above ground plantings which collect and treat storm water using bio-retention. Treated storm water is then infiltrated into the ground or, if infiltration is not appropriate, discharged into a traditional storm water drainage system. However, storm water tree pits generally capture and treat storm water runoff from small, frequently occurring storms but are not designed to capture all runoff from large storms or extended periods of rainfall. Advantages include:

- Reduces storm water runoff volume, flow rate and temperature.
- Increases groundwater infiltration and recharge.
- Treats storm water runoff.
- Improves quality of local surface waterways.
- Improves aesthetic appeal of streets and neighborhoods.
- Provides wildlife habitat.
- Requires limited space.
- Simple to install

149. Bio-swales should be considered near the BRT stations/carparks. Bio-swales are vegetated channels designed to remove silt and pollution from surface runoff. The water's flow

[31] A system is considered structurally redundant if its designed boundary conditions (i.e, designed capacity) are such that failure of a component only changes the capacity conditions but does not result in the collapse of the total system. A non-structural component is one with limited or no engineered elements or structural parts.

path, along with the wide and shallow ditch, is designed to maximize the time water spends in the swale, which aids the trapping of pollutants and silt. A common application is around parking lots, where substantial automotive pollution is collected by the pavement and then flushed by rain. The bio-swale wraps around the parking lot and treats the runoff before releasing it to the watershed or storm sewer. However, a bio-swale is primarily a conveyance system and must be designed to transport water of a specific storm severity without flooding. The main advantages include:

- Traps and breaks down common pollutants.
- Improved water quality in surrounding water bodies.
- Reduced storm water runoff rates and flood prevention.
- Increased green space and aesthetic appeal.
- Recharges surrounding groundwater.
- Provides habitat for aquatic and other wildlife.

150. Solid waste management in urban areas: This BRT project should seek to develop effective systems for the effective management of domestic, hospital and industrial waste in the vicinity of the BRT route. This objective would be achieved by partnering with a local NGO that collects solid waste from urban areas and segregates it into organic and inorganic waste components, developing an integrated site for the segregation of waste, and using biogas technology and composting for waste processing. However, in order to do this properly, this needs to be part of a city-wide waste management strategy.

151. Energy conservation of BRT buildings: This project should seek to decrease energy consumption along the BRT route and infrastructure. This can be achieved by promoting the use of energy saving light bulbs in BRT buildings and street lights.

VIII. IMPLEMENTATION ARRANGEMENTS

A. Non-Infrastructure

152. A 2013 IEG review of global World Bank Group transport projects suggests that the user-pays principle in bus rapid transit systems, such as in Bogota, Colombia, have been effective in enhancing cost recovery. Furthermore, when user charges are collected by the agency responsible for operations and maintenance, the agency has the authority and the incentive to use these revenues primarily for operations and maintenance. Introducing schemes such as advertising in bus shelters can enhance revenues to support transport services[32]

Capacity building - Operation and Maintenance

153. Sanitation Infrastructure: O&M strategies for sanitation infrastructures should include the following measures and activities:

- PBRTC and WSScP staff, particularly sanitary inspector/supervisor, sweepers, cleaners etc. who would be involved in regular monitoring of cleaning, disposal, operation and maintenance of sanitation facilities within the BRT corridor should be well trained and made aware of the key problem areas.
- Their present capacity level should be enhanced so that they can handle and manage their tasks efficiently through providing orientations, awareness building and appropriate on-the-job training (OJT).
- Various options for developing sanitation management and O&M arrangements should be evaluated.
- Private sector participation in managing the existing sanitation management systems should be explored and possible incentives for private sector participation arranged.
- The PBRTC and WSScP operating budget should be assessed, to develop:
- an easy to use spreadsheet model to estimate all financial costs associated with setting up and operation of regional sanitation management facilities;
- suitable and sustainable financial models for managing the O&M of the facilities.

Capacity Building - Drainage and Flood Control

154. Capacity building strategies are outlined below:

- Technical staff and senior management will require relevant training and capacity development in various management, operational and technical fields in order to be more efficient and effective. (Table 15) This type of training also needs to be extended to the Nazims and councillors, particularly on the contents of the LG2013, their own role, responsibilities, rights and obligations and local government affairs and particularly with respect to municipal services and service delivery.
- Capacity building and institutional development to include:
    - strengthening of municipal technical capacity on planning, including zoning, development control framework, and enforcement, and the use of GIS and data management for drainage and flood control (D&FC) infrastructures;
    - climate resilience and disaster risk reduction (DRR) strategies, particularly for floods and evacuation routes and implications for land use planning;
    - intensive interaction between the PBRTC and, PDA (Peshawar Development Authority), WSScP (Water and Sanitation Services Company Peshawar) and other relevant stakeholders

[32] Improving Institutional Capability and Financial Viability to Sustain Transport: An Evaluation of World Bank Group Support Since 2002"; IEG, 2013.

- evidence-based baseline inventories of critical infrastructure assets and facilities, including location, design capacities, O&M schedule and the institutions responsible for their functionality;
- O&M work planning.

Capacity Building- Community based Awareness Program

155. Launch a communication and awareness campaign for a UC-based drain-cleaning program to prevent waste from obstructing drains.

156. Establish a UC-based drain-cleaning program to restore the complete capacity of the existing drainage system and prevent waste from obstructing drains, commencing with UCs in the immediate vicinity of the BRT route.

157. Empower UC Nazims, councillors and local community groups through a formal capacity development program to monitor and enforce zero tolerance of littering among community members.

Gender

158. Mainstreaming gender into the BRT operation will play an important role during project implementation, especially under capacity building and awareness raising activities. During this CRVA study consultations, women were consulted as to how to ensure that female needs are addressed during the BRT project implementation. These consultations identified a need for increased awareness raising on hygiene, sanitation and waste disposal issues. They also identified that gender-targeted information on flood risk and prevention at the household and community levels is necessary.

159. A local level campaign and training should be undertaken to promote a community based approach to improve sanitation behaviour and flood early warning actions. These proposed actions would aim to inform women about better prevention and sanitation practices that lead to reduced health risks.

Table 15: Possible Main Topics and Target Groups for Drainage and Flood Control Capacity Building

Main Topic	Target Group						Learning Objectives, Outcomes
	UC, Nazim and Councilors	Non-tech Exec Officers	Technical Exec officers	Supervisors, operatives, contractors	Industry, commerce, business	Communities, CBOs, NGOs	
Principles of drainage & drain operation	✓	✓	✓	✓	✓	✓	Awareness of possibilities, requirements, constraints, limitations Improved individual and collective attitude and behavior change Increased resource allocations Improved organizational and individual CCR
Environmental, health, social & economic benefits, risks & impacts	✓	✓	✓	✓	✓	✓	Benefits of good operation, effects of poor operation Improved individual and collective attitude and behavior change Increased resource allocations
Detailed drainage planning, design and implementation			✓	(✓)			Improved quality, more integrated, more appropriate & more resilient infrastructure Improved CCR
Improved maintenance resources and techniques	(✓)	(✓)	✓	✓			Reduced accidents Improved O&M productivity Better cost-benefits, including indirect & intangible costs Improved CCR
Planned and preventive maintenance, asset management & work planning	(✓)	(✓)	✓	(✓)			Work analysis, costs & resource planning Improved maintenance and drainage efficiency, effectiveness, productivity Reduced costs Improved organizational and individual CCR
Occupational health & safety	(✓)	(✓)	✓	✓			Organizational OHS policy and actions Improved organizational and individual attitudes and behavior Reduced accidents Improved productivity
Monitoring, data collection & analysis			✓	(✓)			Improved work analysis, costs & resource planning

(✓)signifies 'light' training.

B. Operation and maintenance considerations

Assessment of infrastructure and maintenance planning

160. Investment in infrastructure maintenance and renewal is critical to ensure adequate service delivery and to reduce unforeseen future expenditures. Unmaintained infrastructure deteriorates rapidly and their vulnerability increases, making them susceptible to failure under normal day-to- day operations and during extreme events such as disasters and climate risks.

161. Hence, a systematic condition assessment of infrastructure and maintenance planning is important to reduce contingent liability and ensure sustainable economic growth. This activity should be undertaken so that existing infrastructure is catalogued, their purposes and needs, and investments projects underway identified, by undertaking the following tasks:

- Assess capital development process to identify weaknesses in both policy and contracting;
- Investigate the quality, maintenance and functionality of current infrastructure as well as systems to maintain and improve infrastructure to withstand disaster;
- Identify weaknesses, the costs of the weakness, and the value of repair or replacement; and
- Conduct cost benefit analysis of current approach and of long-term impact on average annual losses.

For structural measures

162. All structural measures should be:

- Designed to minimize maintenance requirements.
- Use local materials and processes where these do not jeopardize construction quality.
- Be procured from reliable suppliers and contractors and not necessarily at the lowest price.
- Constructed under a precise contract adapted to the specific works with enforceable penalty clause(s) for non-compliance.
- Framed to include an extended maintenance element so that the contactor has a responsibility for rectifying any failures resulting from the use of poor materials and construction practices.
- Supervised by independent organizations capable of enforcing the contract without prejudice.

163. It is recognized that these are ambitious objectives but their implementation can improve sustainability by reducing maintenance requirements.

For waste management and drain cleaning

164. There will be a need for continued effective waste management to prevent the restriction and blockage of drains Briefly, this requires the following approach:

- Creating awareness within the community on the adverse effect of poor waste disposal
- Capacity building of PSBRTC and city workers not to deposit waste in the drains
- Wherever, possible, the relocation of informal settlements and encroachments which may hinder the cleaning of the drains
- Developing relevant land use regulations preventing the above from developing and effective enforcement of the same
- The provision of effective waste management services in informal settlements
- Monitoring of drainage effectiveness.

165. Maintenance requirements should be a key element of the design of the structural works. The main drainage channels should be:

- Reduce drain capacity through covering or even infilling of drains. Impair the effective operation of any flood protection measures.
- Designed to allow self-cleaning by maintaining low velocities even during the dry season by “benching” so that low flows are contained within a narrow channel in the center of the drain and larger flows are accommodated by the entire width of the drain.
- Lined channels to maintain flow velocities and prevent erosion, and to deter encroachment and restrict vegetation which would slow flows.
- Designed with access for maintenance by providing a track alongside at least one side of the drain.
- Designed with local materials so that repairs can be made quickly and cost effectively. For example, the use of bricks in Peshawar which are abundant locally; they are cheap and their use is familiar to every laborer
- Specifically affect low-lying areas which are at greater risk of flooding.