UNIT 12 INFRASTRUCTURE

Structure

12.1 INTRODUCTION

The evidences of climate change are increasing frequency and intensity of extreme climatic events, heat waves, rise in sea level and storm surges and intense precipitation. The population is facing challenges due to impacts of climate change on infrastructures like buildings, transportation. In this unit, we would endeavour to discuss the impacts of climate change on buildings and transportation; impacts of sea level rise on infrastructure; and the implications of climate change on energy sector. Further, we would discuss the measures of climate resilient infrastructure.

12.2 OBJECTIVES

After studying this unit, you should be able to:

- describe the impacts of climate change on buildings and transportation;
- explain the impacts of sea level rise on infrastructure;
- discuss the implications of climate change on energy sector; and
- explain the measures of climate resilient infrastructure.

12.3 GLOBAL CHANGES IN TEMPERATURE AND PRECIPITATION

According to IPCC (2018), the human beings are responsible for 1.0°C rise due to global warming. This rise was with respect to pre-industrial levels. The estimated range of this rise is of 0.8°C to 1.2°C. They also confirmed that if this rate of increase prevails, there is chance of reaching 1.5°C between 2030 and 2052. The observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (likely between 0.75°C and 0.99°C) higher than the average over the 1850–1900 period. The estimated anthropogenic global warming is currently increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade due to past and ongoing emissions.

The changes occur in the water cycle by two means. The heat which is trapped by the atmosphere causes more evaporation and more precipitation creating hotter or drier conditions. Another is that, warmer atmosphere holding more water vapour which also traps the heat due to its warming potential (USGCRP, 2009). There were strong reports of global change in surface temperature and variation in rainfall pattern and intensity over the last few decades (Vose et al. 2012; National Oceanographic Centre (2014); NOAA, 2016).

12.4 IMPACT OF CLIMATE CHANGE ON BUILDINGS

The energy consumption in buildings and construction is around 40 percent of global total energy usage (2010). The emission of greenhouse gases from energy consumption in buildings is around 39 per cent. The direct total anthropogenic greenhouse gas (GHG) emissions in 2010 from different economic sectors namely electricity and heat production, agriculture, forestry and other land use, buildings, transport, industry and other energy use contributes 25 percent, 24 percent, 6.6 percent, 14 percent, 21 percent and 9.6 percent respectively. And the indirect GHG emission contribution were 12 percent, 11 percent,1.4 percent, 0.87 percent, 0.3 percent from buildings, industry, energy, agriculture, forestry and other land use and transport respectively.

The energy consumption in buildings in 2050 is supposed to double or triple from present usage. The estimates state the annual increase in carbon dioxide emission during 1971-2004 for commercial buildings and residential buildings were 2.5 percent and 1.7 percent respectively. The energy use by buildings has increased from 119 exajoules in 2010 to nearly 125 EJ in 2016. The annual carbon emission from buildings in 2016 was 9.0 $GtCO_2$ (IEA, 2017). The emissions from building construction were 3.7 $GtCO_2$ (IEA, 2017). The floor area in the world continued to grow by 2.3 percent and so is the future the energy demand from building sector and its emissions will be difficult to manage.

The energy consumption pattern is different for developed and developing countries. Similarly, the energy consumption in building sectors of those countries also vary. The energy consumption in buildings in developed countries are higher. For example the energy consumption in buildings in USA (in 2008) by source are 73 percent from electricity, 21 percent natural gas, 4 percent petroleum and 2 percent by others (EIA, 2009).

The 25-33 percent of black carbon and two-thirds of halocarbons are emitted from building sector (Ürge-Vorsatz et al., 2012). The compounds used for refrigeration and insulation and other appliances in the buildings also contribute to halocarbons which are more potent greenhouse gases.

The different factors that are essential for the urbanization and urban development are directly linked to pollution and climate change. This bounces back and affects the wellbeing of the urban population. The urban areas are more exposed to extreme temperatures. It results in increased cooling requirements and hence more energy consumption. In cold areas, the rise in temperature reduced the demand on heating the building. At many places, shortening of summer season was observed. In the changing climate, it is difficult to maintain a temperature of acceptable comfort level at indoors.

The urban areas near coastal zone are more prone to inundation and under threat of increased coastal floods. The extreme damages may lead to rehabilitation and resettlement of urban population. These areas are vulnerable to drought, floods causing loss of lives and properties.

Check Your Progress 1

Note: 1) Use the space given below for your answers.

2) Check your answers with those given at the end of this unit.

1. Why buildings are major emitters of greenhouse gases?

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2. How the intense precipitation affects the infrastructure?

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12.5 IMPACT OF CLIMATE CHANGE ON TRANSPORTATION INFRASTRUCTURE

The climate change increase the risk of delays, disruptions, damage, and failure across roadways, ice roads, vehicles, and railways. Roads are considered as lifeline for economic and agricultural livelihood. The benefits of roads are they are directly connected with economic development of a country. In developing countries, these roads are lifeline of agricultural livelihoods. The indirect benefits are easy access to healthcare facilities, education and improves standard of living. The climate change impacts of temperature, rain, snow and ice, wind, fog, and coastal flooding on roads are (NRC, 2008; USGCRP, 2014):

- Softening and expansion of roads further leads to rutting and potholes. It is common in high-traffic areas. It also exerts stress on bridge joints.
- Flooding from heavy rains disrupt traffic, erode or wash out the soil and culverts that support roads, tunnels, and bridges.
- Heat waves and flooding delay construction activities and so increase cost of construction.
- Shortened life expectancy of roads due to exposure to flooding and extreme snow events.
- Coastal flooding from sea level rise and storm surges.
- Winter flooding from winter precipitation as rain.
- Landslides and wash-outs.
- Drought induced wild fires reduce visibility.

The warming temperatures reduced the number of days for active frozen routes of ice roads in Alaska and limits transportation accessibility (USGCRP, 2014). The expansion and buckling of rail tracks due to rising temperature result in frequent track repairs or speed restrictions to avoid derailments (NRC, 2008). The heavy precipitation, tropical storms and hurricanes can cause disruption in rail travel and rebuilt of rails.

The sea level rise and storm surges can cause inundation of rails and subways in nearby coastal zones. The subway and commuter rail systems of New York City and New Jersey with a 14-foot storm surge were affected in 2012 by Hurricane Sandy.

The air travel was also affected by heavy rains, floods, hurricanes in the form of delays, restrictions, flight cancellation and airport closure. Example: Gulf Coast during Hurricane Katrina and throughout the North-East during Hurricane Sandy.

The climatic impacts of extreme events like floods cause degradation of road structures, connectivity loss, and reduction in its lifespan. The impact is on the infrastructure itself, its connectivity and demand on transportation. It increases necessary maintenance and repair imposing a costly hazard that requires adaptation and mitigation steps. The impacts depend on frequency, duration, and severity of the hazard. The heat waves are increasing the wild fires that also damage transportation infrastructure. During drought, the water level get reduced and it affect freight movements. Example: Drought of 1988 in Mississippi River.

There are some benefits or positive impacts of climate change on infrastructure like more open seas in the Arctic, creating new and shorter shipping routes and reducing transport time and costs. In cold regions, rising temperatures could reduce the costs of snow and ice control and would make travel conditions safer for passenger vehicles and freight.

12.5.1 Flash Floods

The flash floods are common and occur rapidly as a result of intense precipitation. This flash floods disrupts the transportation sector (DfT, 2014). Some of the examples of flooding induced transportation disruption are:

- Flooding in eastern China in 2011 damaged 28 rail links, 21,961 roads, and 49 airports, and power supply (Xi, 2016).
- Flooding along 500 miles of the Mississippi and Missouri River systems in 1993.

12.5.2 Sea-level Rise Impacts on Transport Infrastructure

The global sea level rise has drastically increased after industrialization by affecting the stable ice sources. This is mainly by the melting of ice sheets, glaciers and thermal expansion (IPCC, 2014). The impact of sea level rise gets hiked from the combined effect of strong winds and low atmospheric pressure with storm surge. The high tides accelerate the effect of surges (Haigh et al., 2010). In the winter of 2013/2014, United Kingdom's North Sea coast, had highest recorded storm reaching 2m above high tide and cause damage to east England (BBC, 2013; National Oceanographic Centre (NOC), 2014a; Huntingford et al., 2014). Thermal expansion, glaciers, Greenland ice sheet, Antarctica ice sheet are the major drivers of global mean sea level rise (IPCC 2013; 2014). IPCC 5th Assessment Report predicts a global rise by 52-98 cm by 2100 (IPCC, 2013).

The thermal expansion contributes to more than half of the sea level rise. The current rate of thermal expansion leads to about 3 mm of sea level rise per year. The sea level rise is also due to retreating glaciers and thawing of ice. The studies says that climate change induced melting of ice caps increases the sea level by 0.97 m in 2100 (Church et al., 2013). The flooding from sea level rise and from extreme precipitation events increase the threat to coastal transport infrastructure (Hooper and Chapman, 2012)

The sea level rise increases the exposure of settlements and infrastructure in coastal areas and islands. The 80 percent of Maldives is less than 1m above mean sea level. So, the sea level rise combined with the storm surges could easily sweep over entire islands. The melting of glaciers and entire ice at Antarctica and Greenland could increase the sea level by 70 m.

12.5.3 Coastal Flooding

The phenomenon of flooding in dry, low-lying land by seawater is referred to as coastal flooding. It is a coastal process where waves, tides, storm surge, or heavy rainfall from coastal storms cause the flood. The frequency and severity of coastal flooding was increased by coastal storms and storm surge. The topography of the coastal land determines its degree of impact by sea water inundation. The coastal zones are affected by direct flooding, overtopping of a barrier and breaching of a barrier. The direct flooding is common in low lying areas. The overtopping of barriers occurs during storms or high tides and breaching occurs during high waves. The occurrence of extreme events like hurricane has great impact on coastal flooding.

NOAA (2016) reported the average number of floods increased during 2010–2015 in comparison to 1950-59 period in the U.S. Coasts. There was an increase in the average number of days per year in which coastal waters rose above the local threshold for minor flooding especially at 27 sites along U.S. coasts. The shoreline erosion and degradation, amplified storm surges, permanent inundation, saltwater intrusion are major risks to coastal areas.

12.6 IMPACT ON ENERGY INFRASTRUCTURE

The increased number of extreme climatic events and its severity affect the energy sector. The impact is more for the renewable energy systems.

- **Solar Energy:** The increase in cloudiness affect solar technologies; severe storms cause damage to solar equipment. There is reduction in efficiency of solar panels.
- **Wind Energy**: Damage to wind farms and distribution lines.
- **Biomass Energy**: The climate change impact on agriculture reduce the crop yield and quality.
- **Hydropower**: Reduced output from hydropower generation.
- **Coal Industry**: The open pits were filled with water during heavy rainfall and cause floods and landslides. The output from thermal power plants are decreased due to insufficient cooling water.
- **Oil and Gas Sector**: Tropical cyclones with potentially severe effects on offshore platforms and onshore infrastructure, leading to more frequent production interruptions.
- **Energy Transmission Infrastructure** such as pipelines and power lines, are also likely to be affected by higher temperatures and extreme weather events. The pipelines are also at the risk of coastal flooding, thawing permafrost in cold regions, landslides, fires by heat waves in hot regions.
- **Power lines** are affected by heavy winds.
- **Flooding** of electricity substations (land based).
- **Coastal floods** affect the sites and technology of energy production, transmission lines and distribution lines by inundation of sea water.

The increase in production cost of energy due to dry climatic conditions. The hydropower generation in Africa reduced by USD 83 billion and it increased the cost for consumers (Cervigni et al., 2016).

12.7 IMPACT ON TELECOMMUNICATION

The telecommunication and broadcasting are affected by climate change. The study by researchers at the University of Wisconsin-Madison and the University of Oregon (2018) reported that the sea level rise may inundate thousands of miles of buried fiber optic cables in densely populated coastal regions of the United States. The impacts of climate change on telecommunications (Horrocks et al., 2010, Ofcom, 2010, ClimAID, 2011) are:

- The heat waves from rising temperature demand for keeping equipment cool at exchanges and base stations. There are many reports of frequent and longtime shut down of stations.
- Increase in operating temperature, reduces the life span and premature failure of telecommunication system.

- Coastal floods can affect telecommunication cables, network equipment, and base stations.
- Power outages get increased which results in increased cost of energy supply.

12.8 IMPACT ON WATER INFRASTRUCTURE

The climate change affects the design, construction, and maintenance of water sector infrastructure. The natural disasters during 1990 to 2000 period affected annual GDP in developing countries by 2 - 15%. The clean supply of drinking water is essential for maintaining health. The water is required for agriculture, energy production, navigation, recreation, and manufacturing. Water stress will be more prominent in Central and Southern Europe and 44 million people may be affected by 2070.

The operation of water reservoir is affected by climate change. The water quality is deteriorated by siltation, sedimentation and act as potential source for diseases. The reservoirs used for control of flood become the source for upstream floods. The climate change increases frequency and magnitude of floods.

It can reduce hydropower generation and increases cost of electricity production. Madani and Lund (2010) estimated reduction of 1.3% and 19.7% in California's high-elevation hydropower system under a warming-only scenario and a dry warming scenario.

The water demand from agriculture, energy production, industrial uses and human consumption has increased and exerts pressure on ground water. The rapid urbanization reduced the water output in water cycle by exploitation of ground water and solid waste generation. In the extreme rainfall, the municipal sewers over flown into water bodies there by affecting the quality. The shrinkage in water supply occurs by the loss of mountain glaciers, ice sheets and snow cover. The salt water intrusion to the coastal drinking water supplies results from sea level rise and hence affecting water infrastructure. So, in order to adjust with the impacts of climate change the development of climate resilient infrastructure is required.

12.9 CLIMATE-RESILIENT INFRASTRUCTURE

Resilience is defined by UN as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009). The climate resilient infrastructure is a component in any efforts for enhancing resilience against climate impacts. The climate resilience also helps in accomplishing goals of the Paris Agreement, Sustainable Development Goals and reduction of disaster risks. It include management measures such as flexible maintenance timings and adaptive management, adoption of structural measures like increasing height of bridge, sea walls, etc., improvement in building and industrial energy efficiency, emission reduction from buildings, improving energy efficiency in new and existing buildings – Energy Conservation Building Codes (ECBC) and building standards, GRIHA rating and certification, improving the energy efficiency of household and business appliances- standards and labeling, encouraging energy suppliers to support emission reductions using demand-side management (DSM) activities, replacing fossil fuels with renewable energies for example solar panels, and solar water heaters which help in combating climate change.

The retrofitting and rehabilitation of existing infrastructure is one of the key part of climate resilient infrastructure. It helps in reduction of infrastructure for physical vulnerability. Some of the efforts like low impact infrastructure development, low cost engineering solutions, preparedness for extreme events like early warning systems for drought and floods, restoration of natural ecosystems and various adaptation strategies, improved pavement geomaterials for road construction, buildings and structures with resilient design and materials, resilience of transmission and distribution networks against earthquakes help to protect and safeguard population and infrastructures against variable climatic world.

Check Your Progress 2

Note: 1) Use the space given below for your answers.

2) Check your answers with those given at the end of this unit.

1. Why sea level increase is different in different locations?

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2. How can you reduce the impact of climate change on infrastructure?

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3. How resilience differ from adaptation?

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12.10 LET US SUM UP

The infrastructure is affected by the change in climate such as increasing temperatures, shifting patterns of precipitation, increased intensity or recurrence of extreme weather events and rising sea levels. The building, transportation, energy, telecommunications, water supply are under constant threat of climate change. The climate resilient infrastructures have to be developed in order to reduce the impacts and the resilience should be an integral part of government especially in urban planning.

12.11 KEYWORDS

Relative Sea Level	:	Along any coast, vertical motion of either the sea or land surface can cause changes in sea level relative to the land (known as relative sea level)
Storm	:	A rising of the sea as a result of wind and atmospheric pressure changes associated with a storm
Storm Surge	:	It is an abnormal rise in the water that is over and above the regular tide level. Storm surges are caused by wind, waves, and low atmospheric pressure from severe storms, such as hurricanes
Flood	:	It is a general and temporary inundation of normally dry land areas
Flash Flood	:	It is a sudden local flood, typically due to heavy rain.
Rut	:	A rut is a depression or groove worn into a road or path by the travel of wheels or skis.
Water Infrastructure	:	Water infrastructure is a broad term for systems of water supply, treatment, storage, water resource management, flood prevention and hydropower
ECBC	:	Energy Conservation Building Code
GRIHA	:	Green Rating for Integrated Habitat Assessment
Urban Development	:	Urban development is defined as the social, cultural, economic and physical development of cities, as well as the underlying causes of these processes.
Power Outage	:	A power outage is a short- or long-term state of electric power loss in a given area or section of a power grid.
UNISDR	:	United Nations International Strategy for Disaster Reduction

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12.13 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1. The high amount of energy is consumed in the buildings and construction that emits the carbon dioxide. The electrical appliances and insulation releases some halocarbons which are also having high global warming potential.

2. The heavy rainfall and flooding cause damage to life, assets and infrastructure. It results in complete destruction, cause permanent loss, delay in its services.

Check Your Progress 2

1. The sea level rise depends on shifting surface winds, the expansion of warming ocean water, and addition of melting ice that can alter ocean currents. The tides, storms, and El-Nino also influence the sea level.

2. Climate change impacts on infrastructure may be minimised by climate resilient infrastructure and by adopting management and structural measures.

3. Resilience refers to ability of a system to absorb, withstand and bounce back after an adverse event while adaptation seeks to reduce the risk of the event by different means.