*The following innovations are of particular importance in modern construction and will be further discussed in later Units.*

**Modular construction** of home systems first materialised in 1933 with the Winslow Ames House by Robert W. McLaughlin and his firm, American House Inc. Cemesto, a panel board made from sugarcane, patented by the John B. Pierce Foundation, was used and in 1942 the US government employed Skidmore, Owings, & Merrill (SOM), to come up with a scheme called "Flexible Space". One of the most remarkable prefabricated, modular megastructures remains the Habitat 67, by Moshe Shafdie for the Expo in Montreal. The market is projected to increase from $92.18 billion in 2018 to $130 billion in 2030.

**Development of CAD** (Computer Aided Drawing) software can be traced back to the development of PRONTO, the first commercial numerical-control programming system by Dr. Patrick Hanratty in 1957, and to the first 'Robot Draftsman' or SKETCHPAD application developed by Ivan Sutherland's during his doctoral work at MIT in 1963, that used a GUIA graphical user interface that facilitated human-computer interaction through visual aids or icons.

**BIM** (Building Information Modeling) as a concept can be traced between 1970-1990 to the first software tools developed for modelling buildings, i.e., the Building Description System, GLIDE, RUCAPS, Sonata, Reflex and Gable 4D Series. The term 'Building Information Model' first appeared in a 1992 paper authored by van Nederveen and Tolman, but it was only in 2003 that Jerry Laiserin, acknowledged the contributions of Autodesk, Graphisoft and Bentley systems and standardized the term as a common name for the digital representation of the building process.

**Construction 3D Printing** is the technology of using additive manufacturing technique through computer-controlled activities of; sequential extrusion of material, such as, 3D concrete, powder bonding and additive welding, through Autonomous Robotic Construction systems (ARCs) or Freeform Construction. While empirical development of this technology started out in early 2000s, it may be traced back to the 1950's when robotic bricklaying and on-site automated fabrication was being explored. Presently various applications, such as, fabrication of houses and construction components, building bridges and canals, and even artificial reefs are being made (*Refer KNOW MORE Section to know about India's Research in this area*)

**Smart buildings and Building Automation systems** are terms used in conjunction today to refer to buildings that use IoT technology to monitor and connect various devices, sensors, hardware, software to manage various building services, such as, HVAC, lighting, fire protection, security, and access control, etc.

While various innovations have transformed design, engineering and construction, good old-fashioned soundness of the principles of civil engineering remains fundamental to the success of a built-environment and the hallmark of a good engineer. This is elucidated by the infamy of the Tower of Pisa, popularly called the ***'Leaning Tower'***, near Florence Italy, and the remarkable team that saved it from collapsing. The 56m freestanding *campanile*, or bell tower, began to lean within five years of work

commencing in 1173, caused by shallow foundations in unstable sub-soil. It took 200 years to complete, all the while continuing to tilt, until 1993 when it was reportedly at an alarming 5degree tilt. This lean was corrected by a team of experts that devised a solution called 'soil extraction', where a series of tunnels on the side opposite to the tilt was dug to drain the soil and remove small amounts of soil, while reinforcing the foundations with 15m concrete pillars and harnessing with steel cables to pull it back in position, till it self-corrected by 2001.

*Every breakthrough and innovation, however, has profound consequence associated with it. These impacts maybe positive, like development of civic amenities, transport facilities, telecommunication, and global trade; or negatives, like deforestation, loss of indigenous flora and fauna, colonisation, poor labour conditions and poverty; and are increasing at a global level with the advent of globalisation and enhanced connectivity. Civic life is nested on Society, Economy, and Ecology (or Environment), known as the three pillars of Sustainability, with the overarching intent to improve quality of life for today's populace and future generations.*

## 1.3 SUSTAINABLE DEVELOPMENT: PRESENT DAY WORLD AND FUTURE PROJECTIONS

With Industry 5.0 on the horizon, a long-term, sustainable point of view for development is the need of the hour. The concept of 'Sustainability' was first introduced in the context of development in the book '*Our Common Future'*, popularly known as the Brundtland Report, from the World Commission on Environment and Development (WCED), published in 1987 by the United Nations. It defined the term as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" and propagated the principles of 'Sustainable development' that focuses on environmental protection and social equality along with economic growth. This eventually laid the foundation for formulating global Sustainable Development Goals (SDGs) in 2015, adopted by 193 committed member states of the United Nations with the projection of meeting the goals by 2030.

### 1.3.1 The steady erosion of Sustainability and Mitigative Actions

Following the world wars and the advent of the Third Agricultural revolution, two evocative pieces, namely, '*The Silent Springs*' (Carson, 1962) which argued against excessive use of pesticides like DDT and its harmful impact on several species, and '*Scarcity and Growth'* (Barnett and Morse, 1963) which empirically established the burden on natural resources, can be noted as the beginning to a paradigm shift at a global level to address issues of sustainability at the intersection of social and environmental or natural ecosystems. However, the impending ecological crisis was first noted in the previous century, with Swedish scientist Arrhenius, in 1896, predicting the change in surface temperature owing to greenhouse effect caused due to increased fossil fuel use, later corroborated by Guy Callendar in 1938 who connected carbon dioxide increase in earth's atmosphere to global warming. Research across 1940's through the 1960's revealed the implications of $CO_2$ emissions; with Plass reporting that $CO_2$ in atmosphere captures infrared radiation, otherwise lost to space, and Keeling producing concentration curves

for atmospheric $CO_2$ showing a downward trend in annual temperatures. The 60's was a decade of ecological strife, with Monaco opposing French plan to dump radioactive waste in the Mediterranean Sea, and catastrophes such as, the Torrey Canyon oil tanker spillage off the coast of England and the Santa Barbara oil spill. These findings and events led to the first Earth Day celebration in 1970 and the creation of the US Environmental Protection Agency (EPA). Further, an inter-governmental conference of experts for Rational use and conservation of Biosphere (UNESCO, 1970) was convened, and in 1990 **Earth Day** went global.

India, too, saw its share of conservation movements. The *Chipko Movement* of 1973 was a non-violent social and ecological '*andolan*' by rural villagers, mostly women, protesting government backed logging in the Himalayan regions of Uttarakhand, India. Inspired by the Bishnois of Khejari, who were killed trying to protect their sacred trees in 1730's in the kingdom of Marwar, the Chipko protestors stood hugging trees and in 1987, this movement was recognised with the Right Livelihood Award for its conservational efforts. This further inspired several other similar conservation movements across Rajasthan, Bihar, Himachal Pradesh, the '*Appiko movement'* in Karnataka and the Western Ghats in 1983, as well as campaigns to protect the canopies planted along the Grand Trunk Jessore Road in West Bengal, as recent as 2017. India enacted the *Wildlife (protection) Act* in 1972, *Water (Prevention and Control of Pollution) Act* in 1974, *Air (Prevention and Control of Pollution) Act* in 1981, followed by the *Environment (Protection) Act* in 1986. The 21st century has seen several amendments and additions, such as, special regulations to Environment Act for ozone-depleting substances in 2000 and Coastal zone notification in 2018, The *Energy Conservation Act* 2001, and *Biological Diversity Act* 2002. While most of these aimed at protection and conservation of natural Environment, in 2006 the enactment of the Forest Rights Act (FRA) for scheduled tribes and other traditional forest dwellers, recognised the interdependency within the socio-ecological ecosystems and introduced an unprecedented reform at the intersection of the Ecology and Social dimensions of sustainable development.

While development remained the key motivation, various strategies, policies and acts were established between 1967- 1987 to further the sustainability discourse in the West. The *Clean Air or Air Quality Act* (1967), the *National Environmental Policy Act* (PEA, P.C.E.A., 1969) and the *Endangered Species Act* (1973) were passed by the US Congress; and legal action for environmental damages was pursued by Environment Defense Fund (EDF 1967, www.edf.org). Several books and papers, such as, '*Only One Earth*' (Dubros and Ward, 1971), '*Limits to Growth'* (Meadows et al., 1972), '*Polluter Pays Principle'* (OECD, 1972) , '*World Conservation Strategies*' (Talbot, 1980, released by IUCN), '*Global 2000 Report'* (Barney, 1980 and Council on Environmental Quality), and UN's '*World Charter for Nature'* (un.org) were published; and various events, such as, '***Habitat'*** - the UN Conference on Human Settlements in 1967, the International Conference on Environment and Economics by OECD in 1984, and the UN General Assembly of 1987, where the foreword of '*Our Common Future'* was presented, took place. This culminated into the '*Agenda 21 Declaration of Environment and Development'* (UNCED, 1992), an action plan proposed for the 21st century in the 1992 Rio Earth Summit. The UN Conference on Sustainable Development or ***Rio+20*** was held twenty years later in 2012, where the process to develop measurable goals and targets as a set of Sustainable Development Goals (SDGs) was adopted, along with green economy policies, and in 2015 the fifteen-year plan to '*2030 Agenda for Sustainable Development*', bearing the

17 goals and 169 targets were committed to by 193 member nations. Currently, between October and December 2022, the Rio +30 conference is being organised.

### 1.3.2 Sustainable Development Goals and Global Impact

The present condition, post pandemic, with respect to each SDG (sdgs.un.org) is as follows:

1. **No Poverty** – COVID 19 pushed 8 million workers into poverty worldwide and working poverty rate climbed for the first time in two decades. Furthered by inflation, wars and political crisis, and disaster there is an ongoing migration and refugee crisis making ending poverty the foremost priority.
2. **Zero Hunger** – 1 in 10 people worldwide are suffering from hunger and 1 in 3 people lack regular access to adequate, in addition, food shortages and soaring food prices affected 47% of countries in 2020, up from 16% in 2019. Ending hunger, achieving food security and improved nutrition, and promoting sustainable agriculture are some of the primary targets.
3. **Good health and well-being** – The COVID 19 led to 15 million deaths and essential health services in 92% of countries got disrupted (2021), leading to reduction in global life expectancy and prevalence of anxiety and depression. Thus, ensuring healthy lives and holistic well-being at all ages is a critical goal.
4. **Quality Education** - Between 2020-21, over half of in-person instruction at schools were missed by 147 million children, and it is estimated that 24 million learners worldwide, from pre-primary to university level, may never return to school. At the same time, many countries have started improving classroom infrastructure as 25% primary schools still lack electricity, drinking water and basic sanitation, and around 50% lack computers and internet access. In addition, skill and competence development is a driver for industry readiness, improved economy and social upliftment, making quality education a major goal.
5. **Gender Equality** - While there was a rise in women employment in 2019, the 45% global employment loss in 2020 set back the equal representation pace. It was also revealed through a 15 year survey, that 1 in every 4 women, accounting to 641 million women, were subject to violence at least once in their lifetime. Therefore, exalting women is decisive towards a better and inclusive future generation.
6. **Clean water and sanitation** – World's water ecosystems are degrading at alarming rates, with over 85% of wetlands being lost, while 733+ million people live in countries with high and critical levels of water stress. This goal aims to ensure availability and sustainable management of water and sanitation for all, as 4 times increase in requirement is estimated by 2030.
7. **Affordable and clean energy** - While progress in energy efficiency is underway, and total renewable energy consumption has increased, the annual energy-intensity rate needs to go up from 1.9% presently to 3.2% by 2030. The key hurdles are; slowdown in electrification due to the challenge of reach, the use of inefficient and polluting cooking systems, and decline in financial flows to develop countries for renewables, making affordable and clean energy a priority.
8. **Decent work and Economic growth** – While global unemployment plummeted, child labour worldwide continues to account to 1 in 10 children. Presently annual growth rate of global real GDP per capita got affected by rising inflation, supply-chain disruption, policy uncertainties,

etc. Thus, full, and productive employment is crucial for decent work and sustainable economic growth.

9. **Industry, innovation and infrastructure** – While global manufacturing has bounced back and is on a steady rise, over the COVID crisis it was noted that high-tech industries are more resilient than lower-tech counterparts, with small scale industries lacking financial support and loss in manufacturing jobs. Therefore, building resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation is key.
10. **Reduced inequalities** - The pandemic caused a first rise in between-country income inequality, and global refugee figures hit a record high. In addition, discrimination on at least one of the grounds prohibited under international Human Rights Law is still faced by 1 in 5 people, making reducing inequality a major global goal.
11. **Sustainable Cities and Communities** - As rapid urbanisation occurs, issues of; polluted air breathed in by 99% of urban population, municipal solid waste of which only 55% is managed, and 1 billion slum dwellers indicate the need to make cities and human settlements inclusive, resilient, and sustainable.
12. **Responsible Consumption and production** – With reliance on natural resources increasing over 65% globally from 2000-2019 and large amounts of food is either lost between harvesting and reaching markets, or wasted at the consumer level, making sustainable consumption a pivotal goal.
13. **Climate Action** – Droughts estimated to displace 700 million, extreme weather, and other natural disasters estimated to increase by 40% by 2030, climate catastrophes are surmounting. 70-90% of coral reefs have diminished and $CO_2$ emissions have gone up to its highest in 2021, while climate finance has dropped with a shortfall of 100 billion dollars in 2019; showcasing the grim state of affairs and the urgency for climate action as a global goal.
14. **Life below Water** - Oceans are our planet's largest ecosystem and is endangered due to ocean warming, eutrophication, acidification, over-fishing, and plastic pollution; with over 17+ million metric tons of plastics choking the ocean and acidification hindering the ocean's capability to absorb $CO_2$ emissions to moderate climate change. Conservation and sustainable use of marine resources is a necessity.
15. **Life on Land** – Almost 90% of global deforestation is due to cropland expansion and livestock grazing, and around 40,000 species are at the risk of extinction. Protecting, restoring, and promoting sustainable use of terrestrial ecosystems, managing forests sustainably, combating desertification and address land degradation and biodiversity is our moral duty.
16. **Peace, Justice and strong Institutions** – With a quarter of the world's population living in conflict-affected countries and corruption and bribery rampant, providing justice for all, and building effective, accountable, and inclusive institutions at all levels is imperative for peaceful societies.
17. **Partnerships for the Goals** - Post pandemic, with rising debt burdens threatening developing countries and global Official Development Assistance (ODA) declining for SDG data, it is vital to strengthen the means of implementation and revitalise the global partnerships for sustainable development.

Each SDG has a number of **Targets**, each measurable by indicators; for example, Target 1.1 '*By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less that $1.25 per day*' can be measured through the **indicator** 1.1.1 '*Proportion of population living below the international poverty line by sex, age, employment status and*

*geographical location (urban/rural)*'. India, as the fifth largest economy and the second largest in population in the world, plays a crucial role in the achievement of Agenda 2030 and the future. The ***SDG India Index***, an aggregate measure presented in a comprehensible, interactive dashboard (2020-21; http://sdgindiaindex.niti.gov.in ), for 16 goals with 115 quantitative indicators and a qualitative assessment of SDG 17, tracks and monitors progress of all states and union territories.


Fig. 1.8 : Sustainable Development Goals (source : www.sdgs.un.org)

*As the world moves towards sustainable development, the role of civil engineering becomes pivotal, needing to shoulder the responsibilities of designing and developing sustainable solutions.*

## 1.4 EVALUATING FUTURE REQUIREMENTS

Brundtland's Commission (1987), in its definition of Sustainable Development, stressed on the "*future generations" and the ability to "meet their needs*". These needs and whether or not the ability to attain them by future generations can be assessed by sustainability indicators attributed to each SDG and its respective targets and are measured with various monitoring applications that capture quantitative data, further collated and represented in Indices to offer a holistic view on sustainable development.

### 1.4.1 Sustainability Indicators

**Sustainability indicators** are measurable aspects of the three dimensions of sustainability – social, environmental, and economic, and are essential for monitoring and calibrating the performance and quality of the sustainability goals. In addition, these help in decision-making by providing aggregated information to incorporate physical and social science into actionable items and help in predicting early warnings to prevent setbacks.

Division of Sustainable Development (DSD) and Statistics, under the UN Department of Economic and Social Affairs drafted the first set of indicators, which was later collated with

methodology sheets for each indicator into a single publication known as the 'blue book' (1996). The same was revised in 2001 having 58 indicators, classified into themes, such as, poverty, governance, health, education, demographics, natural hazards, biodiversity, consumption, and production patterns, etc. Every theme, in turn was categorised into sub themes with core indicators, for example – Poverty is sub-thematised into; '*income poverty*' measured by the indicator 'proportion of population living below national poverty line', and '*income equality*' measured by the indicator 'ratio of share of national income of highest to lowest quintile', etc. Certain sub-themes maybe measured by several indicators, such as, '*Education level*' is indicated by: 'gross intake ratio to last grade of primary education', 'net enrolment rate in primary education', 'adult secondary (tertiary) schooling attainment level'. Interestingly, several indicators have links to more than one theme, such as, 'proportion of population with access to safe drinking water' is primarily applicable to Poverty and Health, but also has secondary linkages to governing water utilities, and in turn, to Governance theme.

### 1.4.2 Monitoring: Methodology and applications

**Monitoring** is a major task for assessing the implementation and impact of a strategy for sustainable development. A variety of data and statistics are required for monitoring and to capture this, methodologies to measure the indicator, collect the data accurately and timely, outline the apt unit of measure and method of computation, etc are developed by three key bodies, namely the UNSC, HGL-PCCB, and IAEG-SDGs. The latter has selected custodian agencies, such as, UNEP, WHO, World Bank, FAO, UNESCO, OECD, etc, for periodically collecting and updating data on indicators, across themes, at global, regional, and national levels. **Ten principles for Global monitoring indicators** (UNSDSN, 2015) entail;

1. Limited in number and globally harmonised,
2. Simple, single-variable indicators, with straightforward policy implications,
3. Allow for high frequency monitoring,
4. Consensus-based,
5. Consensus-based, in line with international standards and system-based information,
6. Constructed from well-established data sources,
7. Disaggregated (by sex, age, location, income, spatial - rural/urban)
8. Universal,
9. Mainly outcome-focused,
10. Science-based and forward-looking,
11. A proxy for broader issues or conditions.

**Indicators** to be measured are categorised with respect to global, national and thematic, and Data in turn, is sourced from census data and *Household surveys* (Demographic and health surveys, Fertility and Family Surveys, Reproductive health surveys, Labor Force survey, R&D Surveys etc); *Administrative data* (formal waste collection and management data from municipalities, National production, international trade statistics); Civil registrations

(birth certificates, death certificates, etc), *Vital statistics* and *health records*; *School-based or citizen-led learning assessments*; as well as from *Geographic Information Systems* (GIS) that uses remote sensing, GPS (global positioning system), aerial photographs, LiDAR (Light Detection and Ranging) and satellite imagery from US Geological Survey/NASA Landsat data, for mapping and surveying.

**GIS** is an application that uses geographical and spatial data in conjunction with attribute (additional information in tabular form) data to map, analyse and assess indicators. It uses imagery data-type, which includes aerial photos, satellite images, thermal images digital elevation models, scanned maps, land maps, land classification maps, etc. Satellites are used to scan the earth, either through - scanning mirrors that scan quickly, back and forth over an area while taking an image, as used by Landsat or Multispectral scanners, called '*whiskbroom scanning'*, or via '*push broom*' scanning where a row of silicon detectors take images as the satellite flies over an area. GIS not only aids in cartography but helps geospatial mapping and analysis of real-world problems to offer insights through visualisations. The '*Global Geodetic Reference Fame*' (UNDESA) allows the precise determination of locations and quantification of changes, useful for various indicators through mapping physical infrastructure, buildings and settlements, population distribution, transport networks, elevation and depths, water and land cover and use, etc.

### 1.4.3 Human Development Index and Ecological Footprint

While SDGs are a tool for addressing developmental progress, there are other indices that also help measure the impact of human development.

One such, is the **Human Development Index (HDI)** that offers an "*alternative, single number measure of capturing progress in three basic dimensions of human development: Health (life expectancy at birth), Education (expected and mean years of schooling) and Living standards (Gross National Income per capita)*" as defined by the Human Development Report (UNDP). This index was further refined and reintroduced in 2010 as '*Inequality adjusted HDI*' (IHDI) accounting for the inequalities between the various nations, noting that HDI maybe perceived as a potential while IHDI reflects the reality. Another important indicator is the **Ecological Footprint (EF)** that measures the human - a person or a group, demand on natural capital. It estimates the productive land and sea area needed to support a population in terms of its consumption of renewable resources and absorption of waste generation. It shows whether a country is living within the biocapacity of its own territory or is drawing on the ecological capital of other nations. Both HDI and EF have attracted criticism owing to aggregation as a single number upon summation of different indicators, each having different units, and in turn, missing the finer details that represents the scenario realistically.

*The upcoming decades, bound by a common developmental discourse since the industrial revolution, and further today, by digitisation and globalisation, faces the inadvertent need to strive towards Sustainable development and to understand the importance of innovation and social responsibility, particularly through Civil engineering in shaping and impacting the world.*

## UNIT SUMMARY

*The Unit covers, in brief, the developmental history from ancient to pre-industrial era, giving an overview of the pockets of civilisations across the world and their prowess in engineering, architectural and construction capability. The Unit further traces the oncoming of the second agriculture revolution and how it prompted the first industrial revolution, followed by decisive events and occurrences termed as further revolutions – green revolution, digital revolution, etc., and culminates the discussion with the impact of the above on the natural environment and social welfare, leading to the importance and need for sustainable development, and how present measures have been instituted to achieve the same.*

## EXERCISES

### I. Multiple Choice Questions

Q. 1.1 What is the system of transporting water from aquifers and wells to the surface through underground aqueducts, found in Persia and Mesopotamia?

(a) Baoli
(b) Qanat
(c) Reservoir
(d) Hammam

Q. 1.2 When did the 'Green Revolution' take place?

(a) late 19th century
(b) early 20th century
(c) 10,000 BC
(d) mid 20th century

Q. 1.3 Who coined the term "Gilded Age"?

(a) Mark Twain
(b) FD Roosevelt
(c) Henry Ford
(d) Earnest Hemingway

Q. 1.4 Under who's leadership was C-DOT (Centre for Development of Telematics) established in India?

(a) JRD Tata
(b) Manmohan Singh
(c) Sam Pitroda
(d) Sundar Pichai

Q. 1.5 In which year was the '2030 Agenda for Sustainable Development' adopted?

(a) 2020
(b) 2015
(c) 1987
(d) 2000

***Answers of Multiple Choice Questions:*** 1.1 (b), 1.2 (d), 1.3 (a), 1.4 (c), 1.5 (b)

**II. Short and Long Answer Type Questions**

Q. 1.6 What is Sustainable Development? What are the SDGs?

Q. 1.7 What are the different modes of monitoring SDGs? Enlist the Ten principles of Global monitoring indicators as per UNSDSN (2015)?

Q. 1.8 Define Human Development Index (HDI) and Ecological Footprint? What are the shortfalls of these indices?