# INTERNATIONAL STUDIES IN ARCHITECTURE, PLANNING AND DESIGN

*June 2023*

**EDITORS**

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# Chapter 1

## CONTEMPORARY BUILDING SYSTEMS AND ADDITIVE MANUFACTURING AS AN ALTERNATIVE SYSTEM

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The word building implies the system of a building which contains the method of building, the action of building, and the process of building. The building system is the composition of building elements forming a whole. Therefore, it includes units, processes, and applications of construction (Hasol, 1979; Türkçü, 1975, as cited in Kızıldeli, 2002).

There are various building systems ranging from primitive systems to modern systems that can be classified in various ways where function, economic factors, safety, or aesthetics are determinative (Kızıldeli, 2002). However, within the context of this chapter, building systems are divided into three categories that are wet process building systems, dry process building systems, and additive manufacturing.

## 1.1. DRY PROCESS BUILDING SYSTEMS

Dry process building systems refer to systems that do not use an adhesive such as plaster and mortar when assembling the building elements (Hasol, 1979). Although, it is difficult to make a distinct classification between dry process building systems as the systems are intertwined in some cases (Kızıldeli, 2002). Dry process building systems covered in this chapter are divided into three categories which are wooden construction systems, steel construction systems, and prefabricated construction systems.

### 1.1.1. WOODEN CONSTRUCTION BUILDING SYSTEM

The wooden construction building system is the creation of a wooden carcass system for vertical and horizontal loads (Bostancioğlu & Düzgün Birer, 2004). It is a versatile building system that can be constructed in a variety of forms with minimal tool investment. Additionally, the wooden construction building system increases the sustainability of construction regarding its production, implementation, and transportation (Švajlenka, Kozlovská, & Pošiváková, 2018).

The load-bearing system of wooden construction can be created by wooden frames and panels (Kızıldeli, 2002). The frame system is composed of repetitive use of wooden elements such as studs, joists, and rafters where the deficiencies of the material such as flammability of the material in case of ignition, decomposition in case of exposure to dampness and behaviors of expansion and contraction in case of humidity changes which can be addressed by detail design solutions (Allen & Iano, 2019).

There are two common types of wooden frames which are balloon frame and platform frame. The balloon frame is constructed entirely from closely spaced slender wooden elements. The studs are used from foundation to roof at full length. Unless they are sealed off with fire blocking at each floor, the hollow spaces between slender studs serve as chimneys in a fire. The platform frame, as a development to overcome the deficiencies of balloon frame, is constituted by platforms and wooden wall connections where the ground floor is constructed by building loadbearing walls on a floor platform and the first floor is constructed by building loadbearing walls on a second platform constructed on ground floor walls. Similarly, the walls of the first floor are used to construct the attic and roof. In short, the load-bearing walls are built on a floor platform at each level. While the natural fire-blocking effect of floor platforms and more convenient use of lumber elements are the main advantages of the system, the main disadvantages of the system are the settlement of the frame and distress of the finishing surfaces due to the behavior of the wood (Allen & Iano, 2019).

The foundation of the wooden frame buildings can be spread footing, basement, crawlspace, and slab on grade made out of masonry or reinforced concrete. Openings in walls such as windows, and doors, openings in floors such as stairs, chimneys, and openings in the roof such as skylights, dormers, and chimneys are mitigated by additional framing to support framing elements around those openings (Allen

& Iano, 2019). The vertical and horizontal bearings on the foundation can be further supported by cross elements to make the frame extremely rigid (Yardımlı, Dal, & Mıhlayanlar, 2018). Additionally, the sheathing provisions structural continuity of the frame by increasing the resistance of the frame to lateral forces. It covers the exterior of frame members by nailing usually oriented strand board (OSB) or plywood (Allen & Iano, 2019). Therefore, a wooden frame act as a wooden panel with load-bearing features (Kızıldeli, 2002).

### 1.1.2. STEEL CONSTRUCTION BUILDING SYSTEM

Steel construction is a building system installed with steel elements and components. As a material, steel is strong, stiff, resilient, predictable, and dense (Allen & Iano, 2019; Macdonald, 2018). A structural task that would require a larger quantity of another material can be completed with a small amount of steel (Allen & Iano, 2019). Therefore, steel elements are slender elements resulting in a lightweight appearance (Allen & Iano, 2019; Macdonald, 2018). In other words, in comparison to the supported building's total volume, the structure has a small volume (Macdonald, 2018). Additionally, steel is suitable for repetitive frame creation and precise architectural detailing (Allen & Iano, 2019).

While the structure being lightweight, the work being nearly free of errors, the assembling process being rapid, and the frame enabling permeable and flexible spaces within are the main advantages of steel construction (Campos, 2015 as cited in Campos & Bernardo, 2020), there are also some disadvantages of construction steel which is produced to transfer various cross-section effects in an economical way (Kızıldeli, 2002). Since steel is chemically unstable, it is vulnerable to corrosion (Macdonald, 2018). Although steel construction is noncombustible (Allen & Iano, 2019), steel loses its mechanical properties in fire (Macdonald, 2018). Although carbon steel is more prevalently used as structural steel, stainless steel is also utilized in many construction applications due to its residual value, resistance to corrosion and fire, durability, ductility, and sustainability (Baddoo, 2008; Gardner, 2008). Additionally, structural steel can produce a frame only and is unable to form a complete building enclosure with some exceptions. Masonry, panel system, or glass are used to create the building enclosure (Allen & Iano, 2019).

Steel structures comprise a combination of columns, beams, and bars to bear the load. To resist lateral forces, braced frames, moment-resisting frames, and shear walls are used unaided or together. While a braced frame is constituted by diagonal bracing which creates a rigid triangular configuration, moment-resisting frames impart stiffness to the whole frame by leaning beams and column connections. Shear walls are steel, reinforced concrete frames or masonry solid walls providing stiffness (Allen & Iano, 2019). The floor and non-load-bearing elements can be designed in various ways and materials as long as they work together with the load-bearing system (Kızıldeli, 2002). The most common applications are the use of concrete poured on top of metal decking for the formation of a complete floor and the use of a roof deck unaidedly with more closely spaced corrugations for the roof. (Allen & Iano, 2019). Additionally, insulation or thermal breakdown is applied to frame elements to avoid thermal bridges and therefore heat loss (Allen & Iano, 2019). Two types of steel construction are steel frame construction and light gauge steel frame construction.

The entire process of steel frame construction necessitates attentive planning (Campos, 2015 as cited in Campos & Bernardo, 2020) since it involves many steps in the construction process. Firstly, the design professionals create a rough sketch of the frame. Secondly, structural drawings which show the exact locations, shapes, loads, and approximate sizes of the members are completed as a result of calculations. Thirdly, the fabricator prepares drawings demonstrating the dimensions and connections of steel elements precisely and sends them for the approval of the design professionals. When they approve, the steel components are fabricated to be delivered to the construction site (Allen & Iano, 2019). The production process is completed in the factory (Kızıldeli, 2002). Lastly, the erector assembles the steel frame on the construction site based on the drawings of the fabricator (Allen & Iano, 2019; Kızıldeli, 2002).

Light gauge steel construction can be considered a noncombustible equivalent of wooden frame construction since steel elements are closely spaced, insulated, wired, sheathed, and finished in the same way as wooden frame construction. Steel members are produced in standard size and cut into size on the construction site. While roofs and load-supporting walls are framed by load-bearing members, partition walls are framed by non-load-bearing members (Allen & Iano, 2019).

### 1.1.3. PREFABRICATION BUILDING SYSTEM

Building a structure with readymade elements or components is defined as prefabrication (Hasol, 1979; Kızıldeli, 2002). In prefabrication, the standardized elements or prefabricated components are assembled based on a specific plan (Mengüç, 2009). It brings significant differences to the organization and process of construction (Kızıldeli, 2002). The prefabrication transfers some of the operations on the construction site to the factories or workshops, diminishes seasonal dependence of construction processes, enables simultaneous execution of various activities, enhances quality and precision, and provides savings in resources such as time, material, and labor (Hasol, 1979; Ayaydın, 1981 as cited in Kızıldeli, 2002). Different materials such as wooden, plastic, steel, and concrete can be used to make prefabricated components (Kızıldeli, 2002).

Kızıldeli (2002) categorizes prefabrication building systems into three categories as the frame system, the load-bearing system built with surface bearers, and the hybrid system. Firstly, the frame system is composed of vertical bearers such as columns and shear walls, main bearer elements spanning distance -beams-, façade walls, and roofs. Secondly, the load-bearing system built with surface bearers includes a small number of similar components to load-bearing and space-enclosing functions. Reinforced concrete façade components for walls such as ribbed plates, folded plates, and shells are combined with ribbed slabs, folded slabs, and shells for the roof (Ayaydın, 1981 as cited in Kızıldeli, 2002). Lastly, the hybrid system makes frame elements with or without façade walls bear the surface bearers -which span distances and establish roof surfaces. As it enables spanning long distances in both directions, requires a similar and small number of components, and makes roof elements address both loadbearing and surface creation functions, it is widely used (Ayaydın, 1981 as cited in Kızıldeli, 2002). Six types of prefabrication as open prefabrication, closed prefabrication, heavy prefabrication, light prefabrication, partial prefabrication, and total prefabrication are defined in the work of Hasol (1979). While open prefabrication is the type of fabrication where standard-sized building elements are used, custom size building elements are prefabricated in closed fabrication. Heavy prefabrication includes preparing heavy concrete building elements in a factory and putting them in their places with heavy construction vehicles. Light prefabrication is applied with wooden, metal, or plastic materials based on lightweight components. While partial prefabrication refers to the prefabrication of some building elements, all building elements are fabricated in total fabrication (Hasol, 1979).

## 1.2. WET PROCESS BUILDING SYSTEMS

Wet process building systems refer to the wet construction method for construction of the buildings. Application or installment of building elements through wet conditions using adhesives such as plaster, mortar, and concrete, is called wet construction (Harris, 2005). One of the major limitations of wet process building systems is their slow progress (Ahmad & Sharma, 2020). Under wet process building systems, masonry, and reinforced concrete building systems are examined.

### 1.2.1. MASONRY BUILDING SYSTEM

Masonry is a straightforward building system where small building materials are stacked together to form building elements (Allen & Iano, 2019; Bostancioğlu & Düzgün Birer, 2004). The space between the masonry units is filled with mortar sealing the units from water and wind and adhering units to each other. Therefore, the system works as a monolithic structural unit (Allen & Iano, 2019). In other words, masonry is a type of composite construction in which individual masonry units such as brick, block, and stone are encased in mortar to create building elements (Macdonald, 2018).

In addition to load bearing and space enclosing capacity, masonry building systems perform durability, a high degree of insulation for heat and sound, fire resistance, and exposure protection (Macdonald, 2018; Ramamurthy & Kunhanandan Nambiar, 2004). Therefore, masonry is a low-energy and cost-effective building system (Ramamurthy & Kunhanandan Nambiar, 2004).

The masonry building system is a rich and varied technique (Allen & Iano, 2019; Macdonald, 2018). Main masonry materials are brick, stone, and concrete blocks which are utilized in both load-bearing and non-load-bearing building elements (Allen & Iano, 2019). Brickwork is adaptable to small-scale patterns and geometries due to the small size of brick units. While bricks are molded to shape, the stone is extracted from quarries in raw blocks before being shaped by being cut and carved. Concrete masonry units are molded to shape mainly in three forms that are concrete block, solid brick, and large solid units. Steel reinforcement is frequently used to improve the load-bearing capacity of concrete masonry and its resistance to cracking and seismic loads (Allen & Iano, 2019). Having common physical properties such as minimum tensile strength, moderate compressive strength, and high density, they produce similar structural elements (Macdonald, 2018).

Although addressed by different applications, there are some disadvantages of masonry in terms of its constructional, structural, and functional performance (Ramamurthy & Kunhanandan Nambiar, 2004). Although many construction operations are mechanized, masonry is slow to construct labor-intensive building system (Allen & Iano, 2019; Ramamurthy & Kunhanandan Nambiar, 2004). The presence of mortar joints highly affects the behavior of the system under compression (Ramamurthy & Kunhanandan Nambiar, 2004). Additionally, mortar joints generally serve as leakage points and capillary wicks causing moisture penetration (Grimm, 1982; Hines & Mehta, 1991; Ritchie, 1960).

### 1.2.2. REINFORCED CONCRETE BUILDING SYSTEM

Concrete is a widely used construction material that is commonly manufactured on construction sites. While concrete does not have a distinct form, fine and coarse aggregate creates its content. Propitiously formulated concrete has appropriate proportions and grading of fine and coarse aggregate to enable fine particles to fill in the gaps between coarse particles (Allen & Iano, 2019). Water is added to aggregate and cement to secure complete attachment between particles (Allen & Iano, 2019; Macdonald, 2018).

The advantages of concrete are that it does not rot or burn, has relatively low cost, is suitable for a variety of building applications, and has moderate compressive strength and high density (Allen & Iano, 2019; Macdonald, 2018). Depending on the intended application, several criteria can be used to evaluate the quality of cured concrete (Allen & Iano, 2019). The guidelines for manufacturing high-quality concrete are the use of clean and sound ingredients, mixing them in appropriate proportions, handling the wet concrete correctly, and curing the concrete properly (Allen & Iano, 2019).

While plain concrete has similar attributes to masonry (Macdonald, 2018), concrete and steel combination called reinforced concrete brings about the best structural properties of each material (Allen & Iano, 2019). They create frame systems composed of post and beam arrangements (Macdonald, 2018). In this system, non-load-bearing building elements give their loads to horizontal and vertical load-bearing elements such as beams and columns to transfer live and dead loads to the foundation (Bostancioğlu & Düzgün Birer, 2004).

The application of reinforced concrete frames is a slow process necessitating four main activities to be undertaken. These are the erection of formwork, placement of steel reinforcement, concrete pouring and curing, and removal of formwork (Allen & Iano, 2019). The reinforced concrete wall construction is given in Figure 1 where Steel reinforcement is seen in (a), the erection of formwork is seen in (b) and the pouring and curing of concrete are seen in (c).

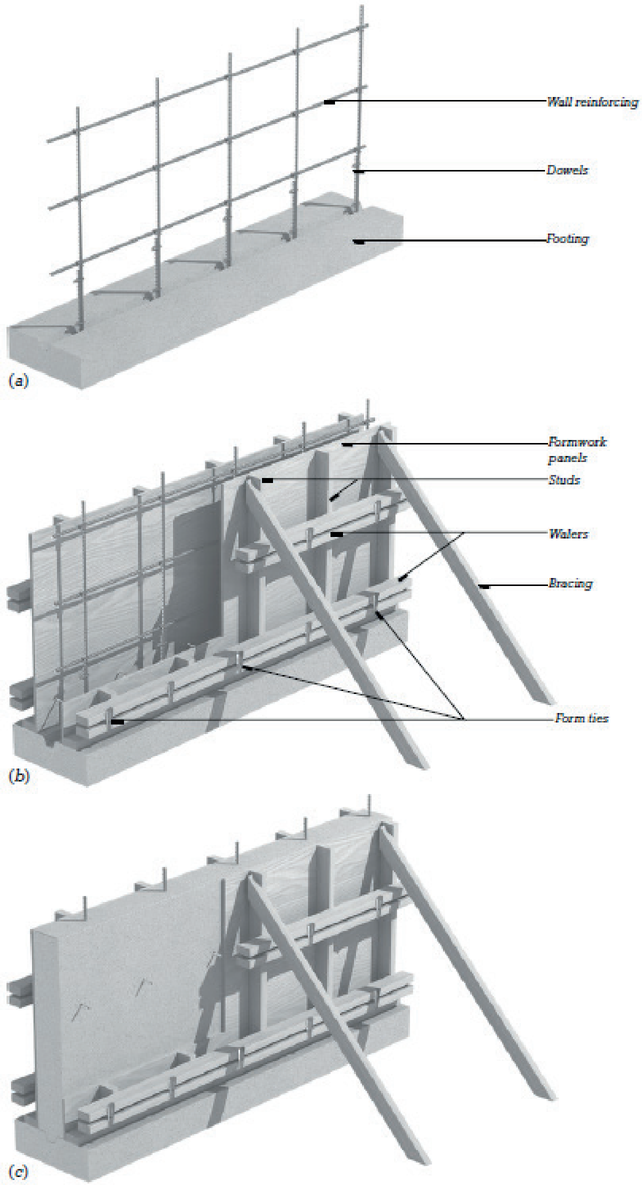


*Figure 1. Reinforced Concrete Wall Construction (Allen & Iano, 2019, p. 540)*

There are three main cost components of reinforced concrete frame constructions from less to more as cost of the concrete, the cost of the steel rebars, and the cost of the formwork. Usually, the cost of formwork accounts for half of the total cost of construction. Therefore, the cost can be decreased by the use of standardized and simple formworks (Allen & Iano, 2019).

The formwork is necessary to shape and support the concrete until it cures since it is placed as a formless blur that lacks physical strength. It can be considered as an entire building temporarily erected and demolished to deliver the second concrete permanent structure. The typical materials used for formwork panels are wood, metal, and plastic. The formwork is set as a negative form of the intended concrete. A form-release compound such as oil, wax, and plastic preventing the concrete from adhering to the formwork is applied to formwork surfaces that encounter concrete. Formwork must be able to withstand the weight and pressure of wet concrete without bending, which frequently necessitates the use of temporary supports. The formwork aids in the retention of the hydrational water of concrete during curing. The formwork is pulled away from concrete surfaces cleanly after curing. Concrete and formwork should not be damaged during this process. The formwork is typically used repeatedly as construction progresses (Allen & Iano, 2019).

Since concrete doesn't have useful tensile strength, reinforcement is applied to support it. Therefore, the fundamental concept of reinforcement is the placement of reinforcing steel where the structural member experiences tensile forces since concrete resists compression forces. In other words, while concrete resists compression, steel reinforcement resists tension in the structure. The calculations of the structural engineer reveal the placement, amount, and size of steel reinforcement bars called rebars to be used in the structure (Allen & Iano, 2019).

Concrete pouring and curing are completed after the reinforcement process. Concrete can be cast into a wide range of forms owing to its liquidity. The casting process enables strong connections and structural continuity between building elements (Macdonald, 2018). Site-cast concrete frames are likely to shorten at the rate of half a millimeter for every meter due to continuous compressive stress caused by dead loads. Although this is assumed to be the case after 28 days for practical reasons, it takes a long period for concrete to acquire its full design strength (Allen & Iano, 2019).

### 1.3. ADDITIVE MANUFACTURING

Creating 3D objects by layering techniques (Labonnote, Rønnquist, Manum, & Rüther, 2016; Mathur, 2016), additive manufacturing is a promising field for the construction industry (El-Sayegh, Romdhane, & Manjikian, 2020).

Additive manufacturing is a technology enabling the creation of three-dimensional models by layering materials on top of each other (Labonnote et al., 2016; Mathur, 2016). 3D Printers with varying sizes and purposes are used to create these models (Kietzmann, Pitt, & Berthon, 2015; Mathur, 2016). Therefore, AM is an expanding field simplifying the process of production to the creation of a 3D model to achieve a finished product (Delgado Camacho et al., 2018). In this sense, AM can be considered as a hot glue gun controlled by a computer. Elements are added to each other layer by layer based on the information provided (Kietzmann et al., 2015). This ability of AM to produce parts from digital files enables time and cost saving for prototypes (El-Sayegh et al., 2020). There are different terminologies used to refer to additive manufacturing such as 3D Printing, Desktop Manufacturing, Rapid Prototyping, Automated Fabrication, and Layered Fabrication (Mathur, 2016).

The history of AM starts with stereolithography which is developed by Charles Hull in 1984 (Mathur, 2016). Stereolithography constitutes the base of contemporary

AM applications (Kietzmann et al., 2015). It is a method for creating three-dimensional objects from digital image data (Labonnote et al., 2016; Mathur, 2016).

As the name suggests, AM provides additive processes for fabrication which is different from prevalent manufacturing techniques being formative and subtractive processes (Delgado Camacho et al., 2018; Kietzmann et al., 2015). While formative processes require mold for production, subtractive processes produce waste to achieve production (Delgado Camacho et al., 2018). In the course of manufacturing history, subtractive processes have frequently dominated (Mathur, 2016). Most contemporary manufacturing applications include some form of subtractive techniques such as drilling, cutting, mining, turning, filling, and grinding (Kietzmann et al., 2015). The AM technology provides the potential to eliminate the disadvantages of conventional manufacturing processes. The difference between subtractive manufacturing and additive manufacturing is given in Figure 2.

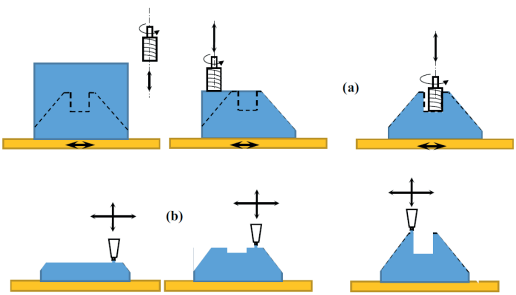


*Figure 2. Schematic Representation of Subtractive Manufacturing (a) and Additive Manufacturing (b) (El-Sayegh et al., 2020, p. 34)*

AM has three sequential phases that are design, printing, and post-production (Kietzmann et al., 2015). The design phase is composed of the creation of a CAD file and its conversion machine language format (Mathur, 2016). The printing phase consists of the conversion of 3D design into 2D layers which will be printed and constructed in an additive manner. The last phase is not applicable for all AM applications since some 3D printers deburr, sand, polish, seal, and paint the object. However, postproduction might be necessary for some AM applications to finish the final object (Kietzmann et al., 2015). The workflow of the 3D printing process can be seen in Figure 3.

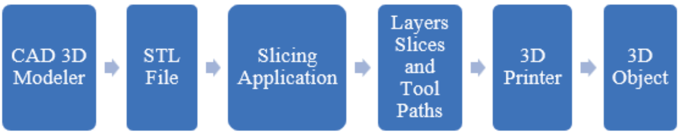


*Figure 3. Workflow of 3D Printing Process (Hager, Golonka, & Putanowicz, 2016, p. 296)*

### 1.3.1. ADDITIVE MANUFACTURING TECHNOLOGIES IN CONSTRUCTION

AM is an important driver towards the digitalization of the construction industry (El-Sayegh et al., 2020) Several factors drive the industry towards automation such as reducing construction time on-site, diminishing construction costs, downsizing labor for safety reasons, and increasing design flexibility (Lim et al., 2011). AM can be considered an alternative method and automated process for construction offering onsite and offsite fabrication (El-Sayegh et al., 2020; Mathur, 2016; Oesterreich & Teuteberg, 2016). Although the tracings of AM go back to the 1980s, its applications in the construction industry are relatively recent (Mathur, 2016). In the late 1990s, the construction industry started to experiment with AM through proof-of-concept applications (Lim et al., 2011; Pegna, 1997). AM in the construction industry is at the formative stage with many potentials (Mathur, 2016; Oesterreich & Teuteberg, 2016). Its potential is expected to be exploited soon (Dallasega, Rauch, & Linder, 2018) along with its widespread application (Oesterreich & Teuteberg, 2016).

3D printers can create models by gathering commands from CAD files (Mathur, 2016). BIM software can be utilized to obtain CAD file which is converted to machine language format such as STL (El-Sayegh et al., 2020). Therefore, the creation of the digital file including the necessary data for the 3D printer is the first step (Mathur, 2016).

Structural and mechanical properties of concrete should be included in the BIM model for AM applications in construction projects (Davtalab, Kazemian, & Khoshnevis, 2018). The use of BIM increases productivity, quality, and efficiency while reducing lead time and cost (Arayici, Egbu, & Coates, 2012). Integration of AM and BIM provides a systematic approach for the analysis of printing method, strength, and appearance (Wu, Wang, & Wang, 2016). Additionally, while conflicts in design are reduced, the cost is estimated faster and more precisely (Maskuriy, Selamat, Maresova, Krejcar, & Olalekan, 2019).

According to the classification provided by Gibson et al. (2021), AM systems are divided into five categories that are powder-based systems, solid sheet systems, photopolymer-based systems, and extruded material systems. While material jetting technology and binder jetting technology among powder-based systems are suitable for construction applications due to selective binder activation, selective paste intrusion, and d-shape techniques, cement-based technology among extruded material systems are suitable for construction applications due to concrete printing and contour crafting techniques. (Ingaglio, Fox, Naito, & Bocchini, 2019; Lim et al., 2011; Shakor, Sanjayan, Nazari, & Nejadi, 2017). Figure 4 demonstrates AM systems, the technologies used in each system, and the techniques applied to each technology. Among the techniques used in construction applications d-shape, concrete printing, and contour crafting are more common.

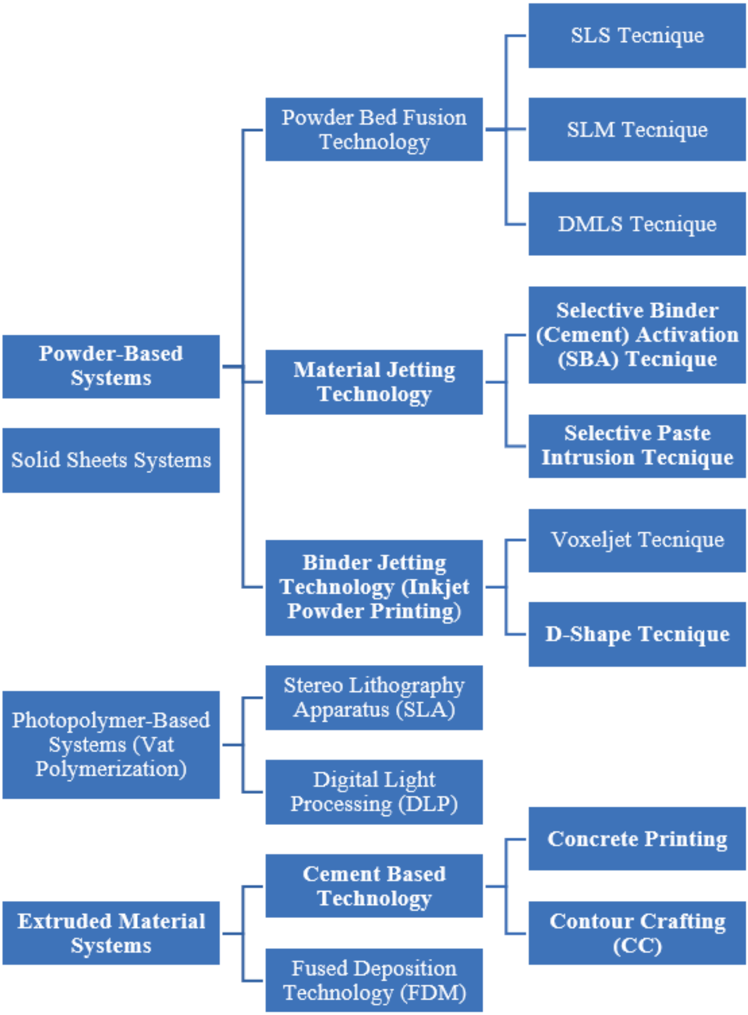


*Figure 4. Overview of AM systems, Technologies, and Techniques (El-Sayegh et al., 2020; Ingaglio et al., 2019; Lim et al., 2011; Mathur, 2016; Shakor et al., 2017)*

The D-shape technique is developed by Dini in 2005 (El-Sayegh et al., 2020). The material used in the D-shape technique is powder. A binder such as resin is used to harden the powder (Lim et al., 2011; Lowke et al., 2018; Shakor et al., 2017). The typical processes of the D-shape technique are layering the powder material to the desired thickness, depositing the binder to the areas that need to be solidified, and taking out the printed material of the powder bed (Gosselin et al., 2016; Lim et al., 2011; Xu, Ding, & Love, 2017).

High-performance concrete which allows more geometric control is used in the concrete printing technique (Gosselin et al., 2016; Lim et al., 2011). Selective solidification (SLA) printers are used to create a solid object out of the liquid where energy is applied to the liquid to solidify it (Horvath, 2014).

Contour crafting is the first AM technique used for onsite construction (Davtalab et al., 2018). This technique is developed by Khoshnevis (Behrokh Khoshnevis, Hwang, Yao, & Yeh, 2006). The gantry system is used to extrude concrete. As concrete is extruded, trowels connected to a nozzle smoothen the surface (Gosselin et al., 2016). Higher surface quality, increased fabrication speed, and a wider range of material availability are among the benefits of this technique (Davtalab et al., 2018), unavailability of horizontal extrusion, the complexity of the technique, and the lack of necessary mechanical properties are the limitations of the technique (Ingaglio et al., 2019).

Gantry systems and articulated robot systems are mostly utilized delivery methods in AM (El-Sayegh et al., 2020). The gantry system uses the cartesian coordinate system, which allows the printer's nozzle to move along three axes that are x, y, and z (Labonnote et al., 2016). Transportation, installation, and size are the limitations of gantry systems. Additionally, sharp corners are unable to be obtained by 3D printing concrete (El-Sayegh et al., 2020). An articulated robot system includes a robotic arm taking up less space compared to a gantry system. It can be attached to a portable platform, enabling onsite application (Delgado Camacho et al., 2018). Nonetheless, its workspace is limited compared to that of the gantry system. Extrusion of material out of a nozzle is applied in contour crafting, concrete printing, and d-shape techniques (El-Sayegh et al., 2020).

### 1.3.2. ADDITIVE MANUFACTURING APPLICATIONS IN CONSTRUCTION

In the past few years, there have been some 3D-printed buildings of some companies such as Winsun, 3D Printuset, CyBe, ApisCor, and COBOD (El-Sayegh et al., 2020).

The Chinese company Winsun was one of the first to enter the construction industry using 3D printing (El-Sayegh et al., 2020). The first project is 3D printing ten houses using a continuous 3D printer. Printing is completed off-site, and the building is assembled on-site (Hager et al., 2016). Similarly, their other projects such as the six-story apartment building, 1100 $m^2$ mansion, and office in Dubai are printed off-site and assembled on-site (Dubai Future Foundation - Dubai 3D printing strategy, 2018 as cited in El-Sayegh et al., 2020; Winsun – Future of Construction, 2016). The office in Dubai took 17 days to be constructed having 50 to 80% less labor cost and 30 to 60% less waste generation than conventional methods (El-Sayegh et al., 2020).  It is an example of offsite fabrication whose parts are printed in China and installed in Dubai (El-Sayegh et al., 2020). The Danish company 3D Printhuset constructed a 3D printed building in Copenhagen which demonstrates geometrical freedom that can be created with AM technology ("World Leader in 3D Construction Printing | COBOD International," n.d.). The Russian company ApisCor printed a 40 $m^2$ building onsite in 24 hours ("Apis Cor | Construction with Robotic Precision," n.d.). The total cost of this project accounts for 10,134 dollars (Maskuriy et al., 2019). The Dutch company, CyBe has an 80 $m^2$ 3D printed house, bridge, and laboratory in different countries (El-Sayegh et al., 2020). The German company, COBOD suggests gantry-based modular 3D printers which can print two-story buildings of 12 x 27 x 9 meters onsite (Barnett & Gosselin, 2015). The World's Advanced Saving Project is a 3D printer company that constructed a 3D printed pavilion with the use of earth materials such as straw, raw soil, lime, and rice husk. The building costs 900 Euros (El-Sayegh et al., 2020).

### 1.3.3. ADDITIVE MANUFACTURING ADVANTAGES

AM technology provides cost-related, time-related, labor-related, design and quality-related, and sustainability-related advantages which can make it a potential alternative construction method to conventional ones.

AM diminishes the cost of construction (Conner et al., 2014; Mathur, 2016). This cost is composed of the cost of materials, transportation of materials, and storing of materials (Hager et al., 2016; Maskuriy et al., 2019). Zero waste of materials reduces costs (Mathur, 2016). As construction work is mainly completed by machines, the required labor is diminished (Mathur, 2016). Therefore, the cost of labor is reduced due to the decrease in laborers (El-Sayegh et al., 2020). It reduces the insurance cost of construction companies (Mathur, 2016).

18 laborers, seven laborers for installment, ten laborers for MEP, and one laborer for monitoring the 3D Printer were utilized in the 3D printed office project in Dubai which result in a 60% reduction in labor cost compared to traditional buildings ("Winsun – Future of Construction," n.d.) Additionally, since laborers are affected by weather conditions on the construction site, work stoppages occur in conventional construction methods which increases costs (Mathur, 2016). Furthermore, indirect costs are reduced as a result of faster construction (El-Sayegh et al., 2020). While 35 to 60% of the cost of a concrete structure arises from formwork (Delgado Camacho et al., 2018), the elimination of formwork reduces costs significantly (El-Sayegh et al., 2020).

As a result of optimized site work and decreased remedial works, construction cost is reduced by AM (Wu et al., 2016). The CC method which is used for onsite printing is four times less expensive than conventional construction methods. (Mathur, 2016). The cost of printing a 200 $m^2$ building with CC accounts for approximately 5000 dollars (Wu, Zhao, Baller, & Wang, 2018).

AM diminishes construction time (Mathur, 2016). Construction speed with AM is faster than that of conventional methods (Hager et al., 2016; Maskuriy et al., 2019). Owing to printing on demand, the supply chain shrinks, and the lead time of materials is eliminated (Conner et al., 2014; Dallasega et al., 2018; Delgado Camacho et al., 2018). While construction of a structural wall takes 100 hours with conventional methods, it takes 65 hours with AM techniques (Buswell, Soar, Gibb, & Thorpe, 2007; Wu et al., 2016). Additionally, a 400 $m^2$ building composed of two stories is printed in 45 days by AM which would take 6-7 months to construct with conventional methods (Dallasega et al., 2018). Khoshnevis (2003) states that the CC technique enables the construction of the building on site in hours rather than months. Printing of a 200 $m^2$ two-story building takes less than two days.

AM improves labor safety on a construction site (Mathur, 2016). Automation and mechanization of the construction process bring about a reduction of accidents onsite as exposure of onsite laborer are reduced and the hazardous tasks are completed by the printers (Delgado Camacho et al., 2018; Hager et al., 2016). Laborers play a supportive role instead of active roles (Perkins & Skitmore, 2015). Additionally, construction productivity is increased (Chen, García de Soto, & Adey, 2018) since the CC machine can work until the task is finished (Mathur, 2016). While a 230 $m^2$ house can be constructed in 19 hours with 4 laborers with CC, which with conventional construction can last months (Mathur, 2016)

AM enables freedom in geometry (Wu et al., 2016). Complex geometries can be designed freely which gives design flexibility (Mathur, 2016). The forms that are difficult and expensive to be constructed with conventional methods can be printed as easily and cheaply as printing a regular form (El-Sayegh et al., 2020). Therefore, functionality outweighs constructability concerns (Delgado Camacho et al., 2018).

The gap between customizability and mass production can be bridged by the use of AM (Mathur, 2016; Wu et al., 2016). Utility conduits can be incorporated directly into the structure according to the data on the digital file (Mathur, 2016). The trowel system of CC enables the surface finish to be painted easily (Mathur, 2016). Automated reinforcement, automated tiling, and automated plumbing can further be integrated into the process (Mathur, 2016).

This technology has the potential to reduce the carbon footprint of construction (Kietzmann et al., 2015; Mathur, 2016). The use of recycled and low-impact materials as printing materials enhances the sustainability of 3D-printed buildings (El-Sayegh et al., 2020). Construction of single-family housing generates 3-7 tons of waste. Material waste is reduced to almost zero with 3D printing techniques (Berok Khoshnevis, 2003). Precise measurement of materials prior to construction is possible with additive manufacturing (Mathur, 2016). Therefore, AM is an eco-friendlier method than conventional methods due to the elimination of waste (El-Sayegh et al., 2020; Kothman & Faber, 2016). It is estimated that AM reduces construction waste by 30-60% (Labonnote et al., 2016).

Consequently, the benefits of applications such as additive manufacturing from the management perspective are time savings and on-time deliveries, cost savings and on-budget deliveries, enhanced quality, enhanced collaboration and communication, improved safety, improved customer relations, improved sustainability, and improved reputation of industry (Maskuriy et al., 2019; Oesterreich & Teuteberg, 2016).

### 1.3.4. ADDITIVE MANUFACTURING CHALLENGES

El-Sayegh et al. (2020) categorized the challenges of AM technology in the construction industry into 7 groups as challenges related to material, printer, software, design, management, regulations and liability, and stakeholders. Material-related challenges are related to pumpability, printability, buildability, and open time (Delgado Camacho et al., 2018; El-Sayegh et al., 2020). Printer-related challenges include scalability, directional dependency, and geometric limitations. Software-related challenges consist of cybersecurity, interoperability, and compatibility of the digital model with printing. Design-related challenges comprise the exclusion of building services, structural integrity problems, and the necessity of new design principles. In this sense, reinforcement is a challenge of additive manufacturing in large-scale construction applications. Two solutions to this problem are the manual addition of steel rebars between layers before or during printing (Paul, van Zijl, Tan, & Gibson, 2018), and the use of fiber-reinforced concrete (Paul et al., 2018). While the former includes printing a hollow structure which allows the installation of rebars manually with infilled concrete to connect the steel reinforcement to the printed structure (Paul et al., 2018; Wangler et al., 2016), the latter automates the construction process completely, therefore, time and labor cost decrease. A study revealed that fiber-reinforced concrete can meet the needs of structural applications due to its favorable characteristics (Yoo & Yoon, 2016). Fibers that reinforce concrete can be glass, carbon, steel, and plastics. Marthur (2016) mentions that fiber Reinforced Plastics (FRP) can be used in CC to provide additional strength to the construction. Single or dual nozzles on a gantry can be utilized to deposit them. Management-related challenges contain challenges regarding cost estimation, site set-up, and scheduling. Regulations and liability-related challenges are lack of codes regulations and liability issues. Lastly, stakeholder-related challenges include skepticism towards the technology, less demand for labor, and new skills required for labor (El-Sayegh et al., 2020; Maskuriy et al., 2019).

## 1.4. CONCLUSION

The building system is an important part of construction projects which affects the project objectives and project complexity directly. The building system is the composition of building elements forming a whole. Therefore, it includes units, processes, and applications of construction (Hasol, 1979; Türkçü, 1975, as cited in Kızıldeli, 2002). The prevalently used building systems can be considered into two categories which are dry process building systems and wet process building systems. While wooden, steel, and prefabricated systems are dry process building systems, masonry, and reinforced concrete systems are wet process building systems. Reinforced concrete frame structures are the most prevalently used building systems. The application of reinforced concrete frames is a slow and expensive process necessitating four main activities to be undertaken. These are the erection of formwork, placement of steel reinforcement, concrete pouring and curing, and removal of formwork (Allen & Iano, 2019).

AM is an important driver toward the digitalization of the construction industry and a promising technology for construction applications (El-Sayegh et al., 2020). It has three sequential phases which are design, printing, and post-production (Kietzmann et al., 2015). Several factors make AM advantageous for construction applications such as reducing construction time on-site, diminishing construction costs, downsizing labor for safety reasons, and increasing design flexibility (Lim et al., 2011). Since these factors are important to project objectives affecting the project complexity, AM is a potential building system via 3D printed buildings that can eliminate the disadvantages of conventional manufacturing processes. In other words, cost-related, time-related, labor-related, design and quality-related, and sustainability-related advantages can make AM an alternative construction method in addition to conventional ones. Although it has some challenges due to its applications in the construction industry being recent, its concurrent developments hold promises to mitigate those challenges related to material, printer, software, design, management, regulation, and stakeholders.

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# Chapter 2

## A COMPARATIVE EVALUATION OF THE INFLUENCE OF ARCHITECTURAL FOUNDERS ON CONTEMPORARY URBAN PLANNING AND DESIGN

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## 1.0 Introduction

Architecture, planning, and design play crucial roles in shaping the built environment and have a profound impact on society, culture, and the quality of life (Crysler, 2003; Alfaya, et al., 2020). Throughout history, visionary architects and designers have emerged as pioneers, introducing innovative concepts, design principles, and groundbreaking projects that have left a lasting legacy. Understanding the influence of these architectural pioneers on contemporary urban planning and design is essential for comprehending the evolution and current practices in the field. The historical context reveals that architectural pioneers, such as Frank Lloyd Wright, Le Corbusier, and Ludwig Mies van der Rohe, among others, introduced radical ideas that challenged conventional norms and sparked significant transformations in architectural theory and practice (Crysler, 2003; National Research Council. 2002). These pioneers pushed the boundaries of creativity, form, and functionality, leaving an indelible mark on the built environment (Katzschner, et. al., 2016; Levine, 2016).

Contemporary urban planning and design practices face unique challenges in the 21st century, including rapid urbanization, sustainability concerns, technological advancements, and the need for inclusive and resilient cities. Examining the influence of architectural pioneers on contemporary practices, provides valuable insights into the adaptation, continuity, and relevance of their ideas in addressing these challenges.

By undertaking a comparative analysis, this research aims to explore the direct and indirect impacts of architectural pioneers on contemporary urban planning and design (Newman, 1998; National Research Council. 2002; Alfaya, et al., 2020). It seeks to identify how historical concepts, principles, and projects have been integrated, modified, or rejected in favor of new approaches. Furthermore, the study aims to evaluate the effectiveness and significance of incorporating pioneer ideas in contemporary designs, considering the specific cultural, social, and environmental contexts.

The findings of this research hold several potential implications for urban planners, architects, policymakers, and stakeholders involved in shaping the built environment. Understanding the historical roots of contemporary practices allows for a critical evaluation of current approaches and offers insights into alternative strategies and design philosophies. The research may inform decision-making processes by identifying successful integration strategies and lessons learned from historical precedents. Additionally, it can foster a deeper appreciation for architectural heritage, enabling the preservation and revitalization of pioneering projects that continue to inspire and inform modern design. Overall, this research fills a significant gap in the understanding of the interplay between architectural pioneers and contemporary urban planning and design. By examining the historical influences and assessing their relevance in the present, it contributes to the ongoing discourse on how to create sustainable, livable, and innovative cities for the future.

## 2.0 Research Objectives

The under-listed research objectives and questions will guide the study in exploring the influence of architectural pioneers on contemporary urban planning and design practices, as well as in providing valuable insights and recommendations for future projects in the field. Research Objectives include :

(i) Investigate the historical contributions and contemporary influence of architectural pioneers in urban planning and design, including their innovative concepts and approaches.

(ii) Explore the adaptation and evolution of pioneer concepts in response to current societal, environmental, and technological trends, assessing their continuity and relevance in contemporary urban planning and design practices.

(iii) Examine the effectiveness and significance of incorporating pioneer ideas in contemporary urban planning and design, and provide recommendations for integrating historical concepts and principles into future projects, aiming to enhance the quality and sustainability of urban environments.

## 3.0 Methods

Data Collection was based on the followings:

(i) Literature Review: Conduct an extensive review of relevant literature, including scholarly articles, books, research papers, and case studies, to gather comprehensive information on architectural pioneers, their design principles, and their influence on urban planning and design. This will establish a theoretical foundation for the study and identify key concepts and theories to be explored.

(ii) Selection of Architectural Pioneers and Contemporary Case Studies: Identify and select a representative sample of architectural pioneers who have made significant contributions to the field of urban planning and design. Consider their influence, historical context, and availability of relevant documentation. Also, select contemporary case studies that demonstrate the integration or adaptation of pioneer ideas in current urban planning and design projects.

(iii) Comparative Analysis: Apply a comparative analysis approach to examine the influence of architectural pioneers on contemporary urban planning and design practices. Compare and contrast the design principles, concepts, and projects of the selected pioneers with those of the contemporary case studies. Identify similarities, differences, adaptations, and evolutions in design approaches and assess the impact of pioneer ideas on modern practices.

(iv) Evaluation and Assessment: Evaluate the effectiveness and significance of incorporating pioneer ideas in contemporary urban planning and design. Assess the outcomes, challenges, and opportunities associated with the integration of historical concepts and principles.

## 4.0 The Historical Architectural Founders

Architectural founders not only left a lasting impact on their respective eras, but also shaped the course of architectural history with their innovative ideas, design principles, and iconic projects. Their work continues to inspire and influence contemporary urban planning and design practices. These selected pioneer architects each had a distinctive vision and contributed to the evolution of architectural styles and principles. Their innovative ideas, groundbreaking projects, and philosophies continue to shape the field of architecture and inspire contemporary urban planning and design. Below are three influential historical architectural pioneers:

(i) Frank Lloyd Wright (1867-1959): Frank Lloyd Wright was an American architect known for his innovative designs and his philosophy of organic architecture. He emphasized a harmonious integration of buildings with their natural surroundings. Wright's work showcased distinctive features such as open floor plans, the use of natural materials, and the incorporation of geometric forms inspired by nature. His notable projects include Fallingwater, a residence built over a waterfall, and the Solomon R. Guggenheim Museum in New York City, with its iconic spiral design. Wright's work significantly impacted modern architectural practices and emphasized the importance of a close relationship between architecture and the environment.

(ii) Le Corbusier (1887-1965): Le Corbusier, born Charles-Édouard Jeanneret, was a Swiss-French architect, urban planner, and designer. He played a crucial role in the development of modern architecture during the early 20th century. Le Corbusier's design philosophy centered around functionalism and efficiency in architecture. He advocated for the use of new materials like reinforced concrete and pioneered the concept of "The Five Points of a New Architecture," which included the use of pilotis (supporting columns), free plan, ribbon windows, a free façade, and a roof garden (Zhang, 2023). Some of his notable works include Villa Savoye, a modernist residence that exemplifies these principles, and the Unité d'Habitation, a housing complex designed to provide improved living conditions for urban populations. Le Corbusier's ideas profoundly influenced the development of modern urban planning and architecture.

(iii) Ludwig Mies van der Rohe (1886-1969): Ludwig Mies van der Rohe was a German-American architect and one of the pioneers of the International Style of architecture (Zhang, 2023). His architectural approach focused on simplicity, transparency, and the use of industrial materials. Mies van der Rohe famously coined the phrase "less is more," advocating for clean lines and minimal ornamentation. He embraced steel and glass construction, creating open and light-filled spaces. Notable examples of his work include the Barcelona Pavilion, a highly influential modernist structure, and the Seagram Building in New York City, renowned for its sleek design and innovative use of glass and bronze. Mies van der Rohe's minimalist and elegant designs left a lasting impact on contemporary architecture.

### 4.1 Contemporary Urban Planning and Design: Overview of current approaches and trends

These current approaches and trends reflect the evolving priorities and challenges in architecture, planning, and design. They demonstrate a shift towards sustainable practices, technological advancements, user-centric design, and a holistic approach that considers social, environmental, and cultural factors. Embracing these trends allows for the creation of innovative and impactful spaces that respond to the needs and aspirations of contemporary society. An overview of current approaches and trends, in architecture, planning, and design is discussed below:

- ❖ Sustainable Design: Sustainability has become a crucial consideration in contemporary architecture and design. There is a growing emphasis on integrating eco-friendly practices, such as energy-efficient building systems, the use of renewable materials, passive design strategies, and the incorporation of green spaces. The sustainable design aims to minimize the environmental impact of buildings and create healthier, more efficient spaces.
- ❖ Adaptive Reuse: Adaptive reuse is gaining popularity as a sustainable approach. Instead of demolishing old structures, architects, and designers are repurposing existing buildings for new functions. This trend not only preserves the architectural heritage but also reduces waste and promotes more sustainable use of resources.
- ❖ Smart Technology Integration: The integration of smart technology in buildings is transforming the way we interact with our environments. From smart homes and buildings with automated systems for lighting, temperature control, and security to the use of advanced sensors and data analysis for optimizing energy consumption, technology is revolutionizing the functionality and efficiency of spaces.
- ❖ Biophilic Design: Biophilic design emphasizes the connection between humans and nature by incorporating natural elements into built environments. This trend focuses on integrating natural light, greenery, natural materials, and views of nature to enhance well-being, productivity, and overall occupant experience. Biophilic design aims to create environments that promote health, happiness, and a sense of connection with the natural world.

- ❖ Flexible and Multi-functional Spaces: Contemporary architecture and design are increasingly embracing the concept of flexible and multi-functional spaces. This trend recognizes the need for adaptable environments that can accommodate diverse activities and changing needs. Designers are creating spaces that can easily transform and adapt to different functions, allowing for versatility and maximizing the efficient use of space.
- ❖ Community-Centered Design: There is a growing focus on community-centered design, where architects and planners actively involve local communities in the design process. This approach ensures that designs meet the specific needs, cultural context, and aspirations of the people who will use and inhabit the spaces. The community-centered design fosters a sense of ownership, inclusivity, and sustainability in the built environment.
- ❖ Parametric Design and Digital Fabrication: Parametric design and digital fabrication techniques are revolutionizing the way architects and designers create complex forms and structures. These approaches use advanced computer algorithms and technologies to generate and fabricate intricate designs with precision and efficiency. This trend allows for the creation of unique, innovative, and highly customized architectural solutions.
- ❖ Resilience and Disaster-Responsive Design: With the increasing frequency of natural disasters and climate change impacts, resilient design has gained importance. Architects and planners are incorporating strategies to enhance the resilience of buildings and communities, including flood-resistant designs, energy self-sufficiency, and adaptable structures that can withstand extreme weather events.

### 4. 2 Identification of key challenges and considerations

By considering the key challenges and embracing responsible design practices, architects and designers can contribute to the creation of sustainable, inclusive, and ethical built environments that enhance the quality of life for individuals and communities. The identification of key challenges and considerations in the field of architecture, planning, and design includes the following:

- ❖ Climate Change and Sustainability: Addressing climate change and promoting sustainability are among the primary challenges in the field. Architects and designers need to prioritize energy-efficient design, utilize renewable materials, integrate green technologies, and implement strategies for reducing carbon emissions. Balancing the need for comfort and functionality with environmental responsibility is crucial.
- ❖ Urbanization and Population Growth: Rapid urbanization and population growth pose significant challenges in terms of urban planning and design. Creating livable and sustainable cities requires careful consideration of infrastructure development, efficient transportation systems, affordable housing, access to amenities, and preservation of green spaces. Designers must find innovative solutions to accommodate increasing urban populations while maintaining quality of life.
- ❖ Aging Infrastructure and Urban Decay: Many cities face the challenge of aging infrastructure and urban decay. Rehabilitating and repurposing existing structures, addressing urban blight, and revitalizing neglected areas are crucial considerations. Designers must balance the preservation of cultural heritage with the need for modernization and functional urban spaces.

- Social Equity and Inclusivity: Promoting social equity and inclusivity in design is essential. Architects and planners must consider the needs of diverse populations, including people with disabilities, elderly individuals, and marginalized communities. Creating accessible spaces, affordable housing options and inclusive public environments is crucial for fostering a sense of belonging and social cohesion.
- Resilience and Disaster Preparedness: Designing for resilience in the face of natural disasters, such as floods, earthquakes, and hurricanes, is a significant challenge. Architects and planners must integrate resilient design principles and develop strategies for disaster preparedness and recovery. This includes resilient building materials, adaptive infrastructure, and community-based planning to mitigate the impacts of climate-related events.
- Technological Advancements and Integration: Keeping pace with rapid technological advancements and effectively integrating them into design processes is a challenge. Architects and designers need to embrace emerging technologies such as Building Information Modeling (BIM), parametric design, virtual reality, and digital fabrication. Utilizing these technologies can enhance design efficiency, visualization, and construction processes.
- Cultural Sensitivity and Context: Designing within cultural contexts and respecting local traditions and values is a critical consideration. Balancing the integration of contemporary design approaches with cultural sensitivity is essential to ensure that designs resonate with local communities and respect their identity and heritage.
- Ethical and Responsible Design: Architects and

designers have a responsibility to consider the ethical implications of their work. This involves addressing issues such as social justice, human rights, environmental impact, and cultural sensitivity. Designers must strive to create spaces that promote equity, inclusivity, and social well-being while minimizing negative environmental consequences.

- Collaborative and Participatory Design: Engaging stakeholders and fostering collaborative and participatory design processes is crucial. Architects and designers should involve end-users, communities, and other relevant parties in decision-making processes. This participatory approach ensures that the design reflects the needs, aspirations, and values of the people who will use and inhabit the spaces.
- Building Codes and Regulations: Navigating building codes, regulations, and legal requirements present an ongoing challenge in the field. Architects and designers must stay updated with evolving codes and regulations to ensure compliance and safety. It is essential to balance design innovation with adherence to local, regional, and national building standards.
- Economic Constraints and Cost-Effective Design: Designing within economic constraints and creating cost-effective solutions is a significant consideration. Architects and designers must balance aesthetic aspirations with practicality and budget limitations. Finding creative and innovative ways to optimize resources, reduce construction costs, and maximize long-term value is essential.
- Ethical and Responsible Design: Architects and designers have a responsibility to prioritize ethical considerations in their work. This includes ensuring the safety and well-being of building occupants,

adhering to building codes and regulations, promoting social and environmental justice, and avoiding exploitative practices. Designers must also consider the lifecycle impacts of their designs, including the sourcing of materials, construction processes, and long-term maintenance.

- ❖ Cultural Preservation and Adaptive Reuse: Preserving cultural heritage and historical buildings while adapting them to contemporary needs is a delicate challenge. Designers must find ways to balance preservation with adaptive reuse, respecting the original character and significance of structures while making them functional and relevant for present-day use. This requires a deep understanding of cultural values and historical contexts.
- ❖ Data Privacy and Security: With the increasing integration of technology in buildings and cities, data privacy and security have become crucial considerations. Architects and designers need to ensure that smart systems and technologies implemented in designs prioritize the protection of user data and privacy rights. Implementing robust security measures and adhering to ethical standards in data collection and usage is essential.
- ❖ Health and Well-being: Designing for the health and well-being of occupants is a growing priority. Considerations such as access to natural light, indoor air quality, acoustic comfort, ergonomic design, and biophilic elements can significantly impact the physical and mental well-being of building users. Designers must incorporate evidence-based strategies to promote health and create environments that support well-being.
- ❖ Collaboration and Interdisciplinary Approach: Addressing the complex challenges in architecture,

planning, and design requires collaboration and an interdisciplinary approach. Designers must work closely with engineers, urban planners, sociologists, environmental experts, and other professionals to develop holistic and sustainable solutions. Embracing diverse perspectives and integrating different disciplines can lead to more innovative and inclusive designs.

- ❖ Ethical Supply Chain and Material Selection: Architects and designers need to consider the environmental and social impacts of their material choices and supply chains. Selecting sustainable, responsibly sourced materials and promoting fair labor practices are essential. Designers should prioritize materials with low carbon footprints, high recyclability, and durability, as well as support local economies and communities in the sourcing process.
- ❖ Post-Occupancy Evaluation and Continuous Improvement: Designers should prioritize post-occupancy evaluation to assess the performance and user satisfaction of their designs. This feedback helps identify areas for improvement and informs future design decisions. Continuous learning, research, and development are essential to ensure that designs evolve to meet changing needs and advancements in the field.

## 5.0 Analysis of their design principles and innovative concepts

Collectively, the design principles and innovative concepts of Frank Lloyd Wright, Le Corbusier, and Ludwig Mies van der Rohe challenged conventional norms, expanded the possibilities of architectural expression, and greatly influenced the development of modern architecture and urban planning. Their visionary ideas and groundbreaking projects continue to inspire and shape the field, leaving a lasting legacy that remains relevant in contemporary design practices (Gold, 2007). These influential architectural projects by Frank Lloyd Wright, Le Corbusier, and Ludwig Mies van der Rohe demonstrate their design philosophies, innovative concepts, and their lasting impact on the field of architecture. These projects showcase their visionary ideas, pushing the boundaries of architectural design and leaving a lasting legacy in the history of modern architecture. An examination of influential architectural projects, the design principles, and the innovative concepts by the selected pioneer architects: Frank Lloyd Wright, Le Corbusier, and Ludwig Mies van der Rohe is discussed below in the Table 1

### 5.1. Evaluation of the factors shaping contemporary urban planning and design practices

Some factors collectively shape contemporary urban planning and design practices, influencing the development of cities that are sustainable, inclusive, resilient, and responsive to the needs and aspirations of their residents. By considering these factors, urban planners and designers can create vibrant, livable, and thriving urban environments. An evaluation of the factors shaping contemporary urban planning and design practices includes the following:

- ❖ Sustainable Development and Environmental Considerations: Sustainable development has become a central factor influencing contemporary urban planning and design practices. There is a growing emphasis on creating environmentally friendly cities that prioritize resource efficiency, green spaces, renewable energy, and reduced carbon emissions. Urban planners and designers integrate sustainable principles to mitigate the environmental impact of urbanization and promote resilience to climate change.
- ❖ Population Growth and Urbanization: The rapid growth of urban populations presents a significant

challenge for contemporary urban planning and design. The need for adequate housing, efficient transportation systems, infrastructure development, and access to basic amenities requires careful consideration. Urban planners and designers strive to create compact, walkable cities that promote a high quality of life, social equity, and inclusivity.

- Smart Cities and Technology Integration: The rise of technology has greatly influenced contemporary urban planning and design practices. The concept of smart cities involves integrating digital technologies, data analytics, and connectivity to improve urban services, enhance efficiency, and provide a better quality of life for residents. Urban planners and designers incorporate technologies such as smart grids, intelligent transportation systems, and data-driven decision-making to optimize urban environments.
- Social Equity and Inclusivity: Contemporary urban planning and design practices prioritize social equity and inclusivity. Planners and designers strive to create cities that address social inequalities, promote affordable housing, facilitate access to amenities, and enhance public spaces (Alfaya, et al., 2020).
- Design considerations: include universal accessibility, mixed-income neighborhoods, and the creation of inclusive public realms that accommodate diverse populations.

**Table 1.** *Summary of the examination of influential architectural projects, the design principles, and the innovative concepts of the selected pioneer architects: Frank Lloyd Wright, Le Corbusier, and Ludwig Mies van der Rohe*

| Selected Pioneer Architects | Design Principles | Case Study One | Case Study Two |
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| (1) **Frank Lloyd Wright:** | **(1) Organic Architecture**: Wright believed in harmoniously integrating buildings with their natural surroundings, emphasizing a close relationship between architecture and the environment. He incorporated natural materials, open floor plans, and organic forms inspired by nature into his designs.<br>**(2) Unity of Design**: Wright aimed for a holistic approach, where all elements of a building, from the structure to the furniture and fixtures, were designed to work together as a cohesive unit.<br>**(3) Spatial Flow:** Wright prioritized creating spaces that flowed seamlessly from one to another, often employing open floor plans, interconnected rooms, and visual connections between indoor and outdoor spaces.<br>**Innovative Concepts:**<br>Prairie Style: Wright developed the Prairie Style, characterized by low-pitched roofs, overhanging eaves, horizontal lines, and integration with the surrounding landscape. This concept aimed to create a sense of harmony between architecture and nature.<br>**Broadacre City**: Wright proposed a visionary concept known as Broadacre City, envisioning a decentralized urban environment with individual homes on large plots of land, connected by efficient transportation systems. This idea challenged traditional notions of urban planning and highlighted the importance of personal space and connection to nature | **Fallingwater**:<br>Fallingwater, located in Pennsylvania, USA, is considered one of Wright's most iconic projects. Built over a waterfall, it seamlessly integrates with the surrounding natural environment. Its cantilevered design, use of stone and organic materials and incorporation of the waterfall into the house's structure exemplify Wright's philosophy of organic architecture. | **Solomon R. Guggenheim Museum**: The Guggenheim Museum in New York City is an architectural masterpiece that revolutionized museum design. Its spiraling ramp, open central atrium, and continuous flow of space-challenged traditional museum layouts. The design encourages visitors to experience art dynamically and unconventionally, reflecting Wright's vision of a holistic architectural experience. |

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| (2) **Le Corbusier:** | **(1) Functionalism**: Le Corbusier believed that architecture should prioritize functionality and efficiency. He aimed to design buildings that fulfilled the needs of their inhabitants, with careful consideration of spatial arrangements and circulation.<br>**(2) Modular Systems**: Le Corbusier developed modular systems, such as the Modulor, based on human proportions. These systems aimed to create standardized units for designing spaces and structures that were adaptable, flexible, and harmonious with human scale.<br>**(3) Pilotis and Free Plan**: Le Corbusier introduced the use of pilotis (supporting columns) to elevate buildings, freeing up the ground level for circulation and creating an open and flexible space. The free plan concept allowed for the flexible arrangement of interior spaces without the constraint of load-bearing walls.<br>**Innovative Concepts:**<br>(1) The Five Points of a New Architecture: Le Corbusier's concept outlined the principles of his architectural language, including pilotis, free plan, ribbon windows, a free façade, and a roof garden (Gray, 2021). These ideas aimed to maximize light, air, and space while creating functional and aesthetically pleasing buildings.<br>(2) Radiant City: Le Corbusier proposed the idea of the Radiant City, a utopian vision of a vertically organized urban environment with tall residential towers surrounded by green spaces. This concept aimed to address urban congestion and provide better living conditions for urban populations. | **Villa Savoye**:<br>Villa Savoye, located in Poissy, France, is an iconic example of Le Corbusier's design principles. The building features an open floor plan, ribbon windows, a roof garden, and pilotis, all representing his Five Points of a New Architecture. Villa Savoye exemplifies the modernist movement and became a manifesto for functionalist design. | **Chandigarh Capitol Complex**:<br>The Capitol Complex in Chandigarh, India, showcases Le Corbusier's urban planning principles. It comprises several buildings, including the High Court, Legislative Assembly, and Secretariat. The complex's layout emphasizes open spaces, symmetry, and monumental scale, reflecting Le Corbusier's vision of a modern, functional, and socially inclusive city. |

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| (3) **Ludwig Mies van der Rohe:** | (1) Minimalism: Mies van der Rohe embraced minimalism, advocating for simplicity, clean lines, and a focus on essential elements. He believed that architecture should be stripped down to its fundamental elements, rejecting unnecessary ornamentation.<br>(2) Transparency: Mies van der Rohe used large expanses of glass in his designs to create transparency and a sense of connection between indoor and outdoor spaces. This approach aimed to bring natural light into the building and create a visual continuity with the surroundings.<br>(3) Structural Expression: Mies van der Rohe celebrated the structural elements of buildings, showcasing them rather than concealing them. He utilized steel and glass construction, emphasizing the expression of the building's structural system.<br>**Innovative Concepts:**<br>(1) Open Plan: Mies van der Rohe championed open floor plans, eliminating unnecessary walls and partitions to create flexible and fluid spaces that could adapt to various functions.<br>(2)"Less is More": Mies van der Rohe popularized the phrase "less is more," which became a fundamental principle of modern architecture. This concept advocated for simplicity, elegance, and the elimination of unnecessary elements, emphasizing the importance of essential elements and clean design.<br>(3) Steel-and-Glass Construction: Mies van der Rohe's innovative use of steel and glass construction techniques revolutionized the possibilities of architectural design. He employed large, uninterrupted expanses of glass supported by steel frames, creating a sense of openness, transparency, and lightness in his buildings.<br>(4) Floating Roofs: Mies van der Rohe often employed flat roofs that appeared to float above the building's structure, giving a sense of weightlessness and horizontality. This design choice contributed to the overall minimalist aesthetic of his architecture.<br>(5) Universal Space: Mies van der Rohe aimed to create spaces that were universally accessible and adaptable to different functions and users. His designs embraced flexibility, allowing for various configurations and use over time. | **Barcelona Pavilion**:<br>(i) The Barcelona Pavilion, originally designed for the 1929 International Exposition in Barcelona, Spain. It is a groundbreaking work of modernist architecture. Its minimalistic design features open spaces, a flowing plan, and the innovative use of materials like glass, steel, and marble. Is an architectural masterpiece that features an open-plan layout, minimal structural elements, and the use of luxurious materials such as marble, chrome, and glass.<br>(ii) The Pavilion showcases Mies van der Rohe's concept of minimalist design and spatial fluidity, with the building's transparency blurring the distinction between interior and exterior spaces. The pavilion embodies Mies van der Rohe's design philosophy of simplicity, elegance, and harmony between indoor and outdoor spaces. | **Seagram Building**:<br>(i) Situated in New York City, the Seagram Building is a prime example of Mies van der Rohe's modernist approach. It is a sleek and minimalist skyscraper with a bronze exterior and large glass windows.<br>(ii) The building's verticality, clean lines, and use of high-quality materials exemplify Mies van der Rohe's focus on elegance and structural expression. The Seagram Building has had a significant influence on the design of corporate skyscrapers worldwide. |

- Health and Well-being: The focus on health and well-being has become integral to contemporary urban planning and design. Planners and designers recognize the impact of the built environment on physical and mental health. They promote walkable neighborhoods, access to green spaces, active transportation options, and the integration of health facilities. Designing for healthy lifestyles and enhancing public health outcomes are key considerations.
- Cultural Heritage and Identity: Preserving cultural heritage and identity is an important factor shaping contemporary urban planning and design practices. Planners and designers strive to incorporate local culture, history, and architectural heritage into urban developments. They promote the adaptive reuse of existing structures, the revitalization of historic neighborhoods, and the integration of cultural spaces to foster a sense of place and community identity.
- Participatory Planning and Citizen Engagement: Contemporary urban planning and design practices encourage citizen engagement and participatory processes. Planners and designers involve local communities in decision-making, ensuring that their voices are heard, and their needs and aspirations are considered. Participatory planning fosters a sense of ownership, empowerment, and social cohesion, leading to more inclusive and responsive urban environments.
- Resilience and Disaster Preparedness: The increasing frequency of natural disasters and climate change impacts has led to a focus on resilience in urban planning and design. Planners and designers integrate strategies to enhance the resilience of cities, including flood-resistant infrastructure, climate-responsive

design, and disaster preparedness measures. Creating cities that can withstand and adapt to environmental challenges is a key consideration.

- ❖ Economic Development and Innovation: Economic development and innovation play a vital role in shaping contemporary urban planning and design practices. Planners and designers seek to create urban environments that attract investments, foster entrepreneurship, and support job creation. They promote mixed-use developments, creative industries, and innovation districts to stimulate economic growth and improve the overall quality of life (Sukhwani, et. al., 2020).
- ❖ Governance and Policy Frameworks: The governance and policy frameworks within which urban planning and design take place greatly influence contemporary practices. Effective policies and regulations that promote sustainability, social equity, and participatory decision-making are essential. Planners and designers collaborate with policymakers, stakeholders, and community organizations to develop integrated approaches and ensure alignment with broader development goals.

### 5.2. Comparative Study Analysis

By recognizing and incorporating pioneer concepts and ideas into contemporary practices, architects, planners, and designers can draw from a rich legacy of innovative thinking and apply them to address current challenges and shape the future of the built environment. Identification of pioneer concepts and ideas relevant to contemporary practices in architecture, planning, and design are discussed below:

- ❖ Functionalism: Functionalism, pioneered by architects such as Le Corbusier and Walter Gropius, emphasized the prioritization of functionality and efficiency in design. This concept remains relevant in contemporary practices, with a focus on creating spaces that serve their intended purpose effectively while considering user needs and optimizing spatial layouts.

- Bauhaus Principles: The Bauhaus movement, led by Walter Gropius, promoted the integration of art, craft, and technology in design. Its emphasis on simplicity, minimalism, and the use of industrial materials continues to influence contemporary practices. The Bauhaus principles of form following function, experimentation, and interdisciplinary collaboration are still valued today.
- Organic Architecture: Organic architecture, popularized by Frank Lloyd Wright, advocates for a harmonious integration with the natural environment. This concept emphasizes the use of natural materials, incorporation of natural light, and designs that respond to the site's context. The idea of sustainability and a connection with nature is relevant to contemporary practices, with an increased focus on eco-friendly design and biophilic principles.
- Contextualism: Contextualism, as exemplified by architects like Louis Kahn, promotes designs that respond to the cultural, historical, and physical context of their surroundings. Considering the site's characteristics, local traditions, and social fabric is crucial in contemporary practices, ensuring that buildings and urban developments integrate harmoniously with their surroundings.
- User-Centered Design: Pioneered by architects such as Christopher Alexander and his concept of "A Pattern Language," user-centered design prioritizes the needs, preferences, and experiences of the people

who will inhabit and use the spaces. This concept remains relevant in contemporary practices, with an emphasis on creating inclusive, accessible, and human-centric designs that enhance user well-being and satisfaction.

- Sustainable Design: Architectural pioneers like Buckminster Fuller and his geodesic dome and Richard Buckminster and his concept of “Spaceship Earth” advocated for sustainable design practices. Their innovative ideas about resource efficiency, renewable energy, and ecological considerations laid the foundation for contemporary sustainable design practices. Today, sustainable design is a fundamental principle in response to environmental challenges and the need for long-term sustainability.
- Parametric Design: The concept of parametric design, popularized by architects like Zaha Hadid, involves using computational tools and algorithms to generate complex and innovative forms. The parametric design allows for the creation of highly customized, adaptable, and visually striking designs. This concept continues to influence contemporary practices, particularly in the fields of digital fabrication and advanced architectural modeling.
- Adaptive Reuse: The idea of adaptive reuse, championed by pioneers like Bernard Rudofsky and Jane Jacobs, promotes repurposing existing buildings and structures rather than demolishing them. This concept encourages sustainability, the preservation of cultural heritage, and the revitalization of urban areas. In contemporary practices, adaptive reuse is gaining prominence as a responsible approach to design that minimizes waste and conserves resources.
- Participatory Design: Pioneered by architects like

John F. C. Turner, participatory design involves involving users and communities in the design process. This concept emphasizes collaboration, inclusivity, and empowering local communities to have a say in shaping their built environment. The participatory design remains relevant in contemporary practices, with an increased emphasis on engaging stakeholders, fostering social equity, and co-creating solutions that reflect local needs and aspirations.

❖ High-Tech Architecture: High-tech architecture, associated with architects like Norman Foster and Richard Rogers, embraces technological advancements and their integration into the design. This concept emphasizes the use of innovative materials, structural systems, and advanced building technologies. The concept of high-tech architecture continues to influence contemporary practices, particularly in the application of sustainable technologies, smart building systems, and digital fabrication techniques.

### 5.3 The comparative study of pioneer projects and their contemporary counterparts in the field of architecture, planning, and design:

By comparing these pioneer projects with their contemporary counterparts, we can observe the evolution of architectural ideas and concepts over time. Table 2 depicted the contemporary projects pay homage to the pioneering designs while incorporating new technologies, sustainable practices, and a fresh perspective on how architecture can respond to the needs and aspirations of the present.

### 5.4 Assessment of the influence of architectural pioneers on modern urban planning and design

Architectural pioneers have had a profound influence on modern urban planning and design, shaping the way cities is conceived, organized, and experienced (Dhamo, 2021). Their innovative ideas, design principles, and philosophies continue to inspire and influence contemporary approaches. By integrating their visionary concepts with evolving societal needs, contemporary urban planners and designers can create sustainable, inclusive, and vibrant cities for the future. Their innovative ideas and concepts continue to resonate in contemporary practices, leaving a lasting impact on the built environment.

Table3 presented some key aspects highlighting their influence.

*Table 2. Summary of the comparative study of pioneer projects and their contemporary counterparts in the field of architecture, planning, and design*

| **Selected Frontline Architects & Their contemporary counterparts** | **Innovative Design Strategies and Analysis** |
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| (1) Villa Savoye by Le Corbusier (1929-1931) & Contemporary Counterpart: Casa Malaparte by Adalberto Libera (1937-1942) | (i) **Villa Savoye**: Designed by Le Corbusier, is a modernist masterpiece that exemplifies the principles of the International Style. It features an open floor plan, ribbon windows, and a rooftop garden. Casa Malaparte, designed by Adalberto Libera, shares similarities with Villa Savoye in terms of its modernist design and integration with the natural surroundings. Both projects showcase the innovative use of geometric forms, functional layouts, and the concept of the "machine for living."<br>**Pioneer Project**: Fallingwater by Frank Lloyd Wright (1935-1939)<br>**Counterpart:** Contemporary Counterpart: The Pierre by Olson Kundig Architects (2016).<br>(ii.) Fallingwater, a residential masterpiece by Frank Lloyd Wright, is renowned for its integration with nature, cantilevered balconies, and its relationship with a waterfall. The Pierre, designed by Olson Kundig Architects, draws inspiration from Fallingwater in terms of its site-specific design and connection with the surrounding landscape. Both projects emphasize the seamless integration of architecture with nature and demonstrate the importance of creating harmonious relationships between built and natural environments.<br>**Pioneer Project**: Seagram Building by Ludwig Mies van der Rohe (1954-1958) Contemporary<br>**Counterpart**: The Hearst Tower by Foster + Partners (2006).<br>The Seagram Building, designed by Mies van der Rohe, is an iconic example of the International Style, with its bronze-clad facade, minimalistic design, and functional elegance. The Hearst Tower, designed by Foster + Partners, pays homage to the Seagram Building in terms of its sleek, modernist aesthetic and use of sustainable design principles. Both projects emphasize the use of high-quality materials, timeless design, and the integration of architecture and technology. |
| (2) **Pioneer Project**: Fallingwater by Frank Lloyd Wright Fallingwater, designed by Frank Lloyd Wright in the 1930s, is an iconic example of organic architecture | It seamlessly integrates with its natural surroundings, utilizing cantilevered platforms and terraces that seemingly float over a waterfall. Fallingwater exemplifies Wright's principles of harmony between humans and nature.<br>**Contemporary Counterpart**: The Edge by PLP Architecture The Edge, located in Amsterdam, is a sustainable office building that embodies contemporary design principles. Like Fallingwater, it embraces its surroundings and incorporates green technologies. The Edge utilizes smart building systems, including sensors for optimizing energy consumption and providing a healthy working environment.<br>**Comparative Analysis**: Both Fallingwater and The Edge prioritize sustainability and their relationship with the natural environment. While Fallingwater showcases organic forms and a close connection to the site, The Edge employs advanced technologies for energy efficiency and user comfort. |
| (3) **Pioneer Project**: Barcelona Pavilion by Ludwig Mies van der Rohe The Barcelona Pavilion, | **Pioneer Project**: Seagram Building by Ludwig Mies van der Rohe The Seagram Building, designed by Mies van der Rohe in the 1950s, is an exemplary modernist skyscraper. It features a bronze-clad facade, a minimalist aesthetic, and an open plaza that fosters a sense of public space within the urban context (Alfaya, et al., 2020). The building became a model for corporate architecture.<br>**Contemporary Counterpart:** One World Trade Center by Skidmore, Owings & Merrill (SOM) One World Trade Center, built on the site of the original Twin Towers in New York City, represents contemporary high-rise architecture. It combines sustainable design strategies with symbolic significance. The tower features energy-efficient systems, a robust structural design, and a public observatory that engages with the surrounding urban fabric.<br>**Comparative Analysis**: Both the Seagram Building and One World Trade Center embody iconic architectural expressions of their time. While the Seagram Building focuses on simplicity and materiality, One World Trade Center addresses resilience, sustainability, and the commemoration of a significant historical event. |

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| (4) **Villa Savoye** by Le Corbusier, Villa Savoye, designed by Le Corbusier in the 1920s | a) **Pioneer Project**: Villa Savoye by Le Corbusier, Villa Savoye, designed by Le Corbusier in the 1920s, is a landmark of modernist architecture. It embodies the five points of architecture: pilotis (elevated ground floor), free plan, free facade, ribbon windows, and roof terrace. The design emphasizes functional living spaces, open floor plans, and a strong visual connection with the surrounding landscape.<br>**Contemporary Counterpart**: The Glass House by Philip Johnson The Glass House, designed by Philip Johnson in the 1940s, is an influential example of modernist architecture. It features floor-to-ceiling glass walls, an open plan, and a minimalist aesthetic. The design blurs the boundaries between interior and exterior spaces, immersing occupants in nature.<br>**Comparative Analysis**: Both Villa Savoye and The Glass House explore the concepts of transparency, simplicity, and the integration of architecture with nature. While Villa Savoye showcases the principles of Le Corbusier's modernism, The Glass House reflects Philip Johnson's interpretation of the modernist movement.<br>**Pioneer Project**: Barcelona Pavilion by Ludwig Mies van der Rohe The Barcelona Pavilion, designed by Mies van der Rohe for the 1929 International Exposition in Barcelona, is an architectural masterpiece. It features an open plan, the use of luxurious materials, and a flowing spatial arrangement. The Pavilion exemplifies Mies van der Rohe's "less is more" philosophy.<br>**Contemporary Counterpart**: Serpentine Gallery Pavilion by Various Architects The Serpentine Gallery Pavilion, an annual architectural commission in London's Kensington Gardens, represents contemporary experimental architecture. Each year, a different architect is selected to create a temporary pavilion that pushes the boundaries of design. The pavilions explore innovative materials, forms, and interactive experiences.<br>**Comparative Analysis**: Both the Barcelona Pavilion and the Serpentine Gallery Pavilion showcase architectural experimentation and the exploration of spatial qualities. While the Barcelona Pavilion embodies timeless elegance and simplicity, the Serpentine Gallery Pavilion represents the ever-changing and forward-thinking nature of contemporary architecture. |
| (5) **Pioneer Project**: Sydney Opera House by Jørn Utzon (1957-1973) & Contemporary Counterpart: Harbin Opera House by MAD Architects (2015). | **The Sydney Opera House**: Designed by Jørn Utzon, is an architectural icon renowned for its expressive sail-like forms and innovative engineering. The Harbin Opera House, designed by MAD Architects, draws inspiration from the Sydney Opera House in terms of its sculptural design, fluid curves, and integration with the natural landscape. Both projects showcase the transformative power of architecture in creating iconic cultural landmarks. |
| (6) **Pioneer Project**: Habitat 67 by Moshe Safdie (1967) & Contemporary Counterpart: | **Habitat 67: D**esigned by Moshe Safdie, is a visionary housing complex that reimagines urban living through its modular, stacked structure and interconnected terraces. The Interlace, designed by OMA/Ole Scheeren, echoes the spirit of Habitat 67 with its innovative approach to housing design. It features a series of stacked, cascading residential blocks that create communal spaces and promote social interaction. Both projects challenge traditional notions of housing and demonstrate alternative approaches to urban living. |

*Table 3. Summary of the Assessment of the influence of architectural pioneers on modern urban planning and design*

| | Selected Principles | The Influence of their Principles on Modern Urban Planning and Designs |
|---|---|---|
| | Design Principles and Aesthetics: | Architectural pioneers introduced new design principles and aesthetics that departed from traditional approaches. Concepts such as functionalism, minimalism, and the integration of art and technology brought a fresh perspective to urban planning and design. These ideas continue to inspire contemporary practices, emphasizing clean lines, simplicity, and a focus on functionality. |
| | Human-Centric Approach: | Pioneers like Le Corbusier and Frank Lloyd Wright emphasized the importance of designing spaces that prioritize human needs and experiences. Their ideas promoted user-centered design, considering factors such as comfort, accessibility, and well-being. This human-centric approach remains integral to modern urban planning and design, with a focus on creating inclusive, livable environments that enhance the quality of life. |
| | Integration with Nature: | Architectural pioneers recognized the significance of harmonious integration with the natural environment. Concepts like organic architecture and biophilic design promoted a strong connection between buildings, landscapes, and ecosystems. Contemporary practices embrace these ideas, emphasizing sustainable design, green infrastructure, and the creation of urban spaces that foster a sense of well-being and ecological balance. |
| | Spatial Planning and Zoning: | Pioneers like Ebenezer Howard and his concept of the garden city and Le Corbusier's Radiant City proposed innovative spatial planning strategies. Their ideas emphasized the separation of functions, efficient land use, and the integration of open spaces within urban environments. These concepts have influenced contemporary urban planning, contributing to the development of mixed-use zoning, pedestrian-friendly neighborhoods, and the preservation of green areas. |
| | Adaptive Reuse and Preservation: | Architectural pioneers demonstrated the value of adaptive reuse and preservation of historic buildings. Their ideas emphasized the cultural and architectural heritage of cities, promoting the revitalization of existing structures rather than solely focusing on new developments. Modern urban planning and design embrace these concepts, with a greater emphasis on sustainable practices, heritage conservation, and the integration of old and new elements within urban contexts. |
| | Community Engagement and Participatory Design: | Pioneers like Jane Jacobs emphasized the importance of community engagement and participatory design in shaping cities. Their ideas highlighted the need for inclusive decision-making processes, involving residents and stakeholders in urban planning initiatives. Contemporary practices prioritize community engagement, promoting collaborative approaches, participatory workshops, and dialogue with local communities to ensure that urban spaces reflect their aspirations and values. |

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| | | Sustainability and Environmental Considerations | Many architectural pioneers were early advocates for sustainable design principles. They recognized the importance of resource efficiency, passive design strategies, and renewable energy systems. Their ideas have significantly influenced contemporary urban planning and design, with a strong emphasis on sustainable practices, energy-efficient buildings, green infrastructure, and the integration of renewable technologies. |
| | | Innovation and Technological Integration: | Architectural pioneers were often at the forefront of technological advancements, incorporating new materials, structural systems, and construction techniques into their designs. Their ideas continue to drive innovation in contemporary urban planning and design, with the integration of digital technologies, smart city solutions, and advanced building systems for improved efficiency, connectivity, and user experience (Vainio, 2011). |

## 6.0 Case Studies: Selection of specific cities or urban projects for in-depth analysis

Selecting these specific cities or urban projects for in-depth analysis, researchers can delve into the unique characteristics, challenges, and successes of each case, offering valuable lessons for urban planning, design strategies, and sustainable development. A selection of specific cities or urban projects for in-depth analysis includes the following:

(i) Barcelona, Spain - Eixample District: The Eixample district in Barcelona is renowned for its urban planning and architectural significance. Designed by Ildefons Cerdà in the 19th century, it features a grid pattern with chamfered corners, wide avenues, and ample green spaces. The district's innovative urban layout, mixed land uses, and integration of public amenities make it an interesting case study for analyzing the impact of urban planning on community livability, social interactions, and urban mobility (Mackay, 1985; Sanaan Bensi, & Marullo, 2018).

(ii) Curitiba, Brazil - Bus Rapid Transit (BRT) System: Curitiba's BRT system is a pioneering example of sustainable urban transportation. Developed in the 1970s, it features dedicated bus lanes, integrated stations, and efficient scheduling. The system's success in reducing traffic congestion, improving public transport accessibility, and promoting sustainable mobility makes it an intriguing project to analyze for its influence on contemporary urban transportation planning and design.

(iii) Masdar City, Abu Dhabi, United Arab Emirates: Masdar City is a groundbreaking sustainable urban development project aiming to be a carbon-neutral and zero-waste city. It incorporates renewable energy technologies, smart grid systems, and sustainable building practices. Analyzing the planning and design strategies of Masdar City provides insights into the challenges and opportunities associated with creating sustainable cities, as well as the integration of advanced technologies in urban development.

(iv) Medellín, Colombia - Urban Renewal Projects: Medellín has undergone remarkable urban transformations through various urban renewal initiatives. Projects like the Metrocable system, public escalators in Comuna 13, and the Parques del Río project have revitalized marginalized areas, improved accessibility, and enhanced public spaces. Examining these projects offers insights into the inclusive urban development, social integration, and the role of infrastructure investments in transforming urban communities.

(v) Songdo International Business District, Incheon, South Korea: Songdo International Business District is a planned smart city designed with sustainable principles and advanced technologies. It incorporates features like smart buildings, intelligent transportation systems, and a pneumatic waste disposal system. Analyzing the development and implementation of Songdo provides valuable lessons on the integration of smart technologies, sustainable design, and the creation of a futuristic urban environment.

(vi) Portland, Oregon, USA - Urban Growth Boundary: Portland's Urban Growth Boundary (UGB) is a notable example of land use planning and growth management. The UGB sets a clear boundary for urban expansion, preserving rural areas, protecting natural resources, and promoting compact, walkable neighborhoods. Examining the effectiveness of Portland's UGB in managing urban growth, promoting sustainable development, and preserving a high quality of life offers insights into sustainable land use practices and regional planning.

(vii) The High Line, New York City, USA: The High Line is an elevated linear park created on a historic freight rail line in Manhattan. It has become a symbol of successful adaptive reuse and urban regeneration. Analyzing the planning, design, and socio-economic impact of The High Line provides insights into the revitalization of post-industrial urban spaces, the integration of public parks in dense urban areas, and the role of community engagement in shaping successful urban projects.

### 6.1. An Examination of how various concepts have been applied or adapted in selected cases

Diverse concepts have been applied or adapted to suit specific contexts, addressing the unique challenges and opportunities of each project discussed below. The successful implementation of these concepts demonstrates their enduring relevance and influence in shaping contemporary urban planning and design practices, highlighting the value of learning from historical precedents and innovative ideas in creating sustainable, inclusive, and vibrant cities. An examination of how pioneer concepts have been applied or adapted in the selected cases are presented in Table 4.

### 6.2 Evaluation of the impact and effectiveness of incorporating pioneer ideas in contemporary designs

Incorporating pioneer ideas in contemporary designs has had a significant impact on the built environment, shaping the functionality, aesthetics, and sustainability of urban spaces. Evaluating the effectiveness of this incorporation involves considering various aspects:

(i) Design Innovation: The integration of pioneer ideas has sparked design innovation, pushing the boundaries of creativity and challenging conventional norms. By incorporating pioneering concepts such as organic architecture, human-centric design, and integration with nature, contemporary designs have evolved to prioritize user experience, environmental sensitivity, and visual appeal. This has led to the creation of more engaging, sustainable, and visually striking architectural and urban designs.

(ii) Sustainable Development: Pioneer ideas often championed sustainable development principles. Concepts like passive design strategies, energy efficiency, and the use of renewable materials have been incorporated into contemporary designs, resulting in reduced energy consumption, lower carbon footprints, and healthier built environments. Evaluating the impact of these sustainability-focused concepts in contemporary designs can reveal their effectiveness in mitigating environmental impact and promoting long-term resource efficiency.

(iii) User Experience and Well-being: Pioneer's ideas emphasized the importance of human experience and well-being in design. Concepts such as biophilic design, community engagement, and human-scale planning have influenced contemporary designs, creating spaces that foster a sense of connection, social interaction, and overall well-being. Evaluating the impact of these ideas on user satisfaction, comfort, and community cohesion, provides insights into their effectiveness in enhancing the quality of life in urban environments.

(iv) Adaptability and Flexibility: Pioneering concepts often emphasized adaptability and flexibility in design. As contemporary urban environments face evolving challenges, such as rapid urbanization, technological advancements, and changing demographics, the incorporation of flexible design principles allows for the adaptation of spaces to meet diverse needs over time. Evaluating the effectiveness of pioneer ideas in promoting adaptability and flexibility can shed light on the ability of contemporary designs to respond to changing circumstances and maintain relevance.

(v) Cultural and Contextual Relevance: Incorporating pioneer ideas requires careful consideration of cultural and contextual relevance. Evaluating the impact of these ideas in contemporary designs involves assessing how they are adapted and applied to specific cultural, social, and environmental contexts. Effective incorporation respects local traditions, responds to regional challenges, and addresses the unique needs of communities, resulting in designs that resonate with the local context and contribute positively to the cultural fabric of the place.

(vi) Economic Viability: The incorporation of pioneer ideas in contemporary designs must also be evaluated in terms of economic viability. While innovative concepts may enhance the functionality and sustainability of designs, they should also be financially feasible and economically viable. Evaluating the cost-effectiveness, long-term maintenance requirements, and economic benefits of incorporating pioneer ideas provide insights into their practicality and effectiveness in contemporary designs.

### 6.3. Factors Influencing Continuity and Adaptation

#### 6.3.1 Analysis of societal, environmental, and technological factors influencing design evolution

The interplay of societal, environmental, technological, economic, regulatory, and cultural factors shapes the evolution of design practices. Designers must consider these influences to create solutions that respond to the needs and aspirations of society while addressing pressing environmental concerns and leveraging technological advancements. Understanding and analyzing these factors enables designers to anticipate future trends, develop innovative design approaches, and create built environments that are responsive, sustainable, and culturally relevant. Analysis of societal, environmental, and technological factors influencing design evolution include the following:

(i) Societal Factors: Society plays a crucial role in shaping design evolution. Changing social values, cultural norms, and user preferences influence the way designs are conceptualized and implemented. Factors such as demographic shifts, urbanization, globalization, and evolving lifestyle impact design choices. For example, the increasing focus on inclusivity and accessibility has led to designs that cater to diverse user needs. Social factors also drive the demand for sustainable and environmentally conscious designs, as society becomes more aware of the importance of ecological responsibility.

(ii) Environmental Factors: Environmental considerations are increasingly influencing design evolution. With growing concerns about climate change, resource depletion, and environmental degradation, designers are incorporating sustainability principles into their work. Environmental factors drive the adoption of eco-friendly materials, energy-efficient technologies, and strategies that minimize waste and carbon footprints. Designers are also incorporating nature-based solutions, such as green roofs, rainwater harvesting systems, and passive design strategies, to mitigate the environmental impact of buildings and urban spaces.

(iii) Technological Factors: Technological advancements have a profound impact on design evolution. New technologies provide designers with innovative tools, materials, and construction techniques that expand the realm of possibilities. Digital design tools, Building Information Modeling (BIM), virtual reality, and 3D printing enable more efficient and accurate design processes. Additionally, smart technologies, the Internet of Things (IoT), and data-driven systems have led to the emergence of intelligent buildings and cities, influencing the way designs are conceptualized and experienced.

(iv) Economic Factors: Economic factors significantly influence design evolution. Market dynamics, construction costs, material availability, and financial considerations play a vital role in shaping design choices. Economic factors impact the feasibility and viability of design concepts, influencing decisions regarding materials, construction methods, and project budgets. Additionally, economic factors also drive trends in design aesthetics, as market demands and consumer preferences influence design styles and features.

(v) Regulatory and Policy Factors: Regulatory frameworks and policies have a significant influence on design evolution. Building codes, zoning regulations, sustainability certifications, and government incentives shape the design process and outcomes. Regulations and policies related to energy efficiency, accessibility, environmental standards, and safety impact the way designs are developed and implemented. Designers need to stay abreast of evolving regulations and adapt their practices to meet legal requirements and industry standards.

(vi) Cultural and Historical Influences: Cultural and historical factors have a lasting impact on design evolution. Local traditions, architectural heritage, and cultural values influence the design language and aesthetic preferences of a place. Designers often draw inspiration from the local context and cultural symbolism to create designs that resonate with the community. Historical architectural styles and landmarks can serve as references or sources of inspiration, leading to design approaches that blend modernity with cultural continuity.

## 7.0. Conclusion and Recommendations

### 7.1 Conclusions:

The research on contemporary studies in architecture, planning, and design has yielded several significant findings and key insights. Here is a summary of the main findings and insights:

(i) Pioneer Architects and Concepts: The examination of historical architectural pioneers revealed their significant contributions to shaping the field of architecture. Pioneers such as Frank Lloyd Wright, Le Corbusier, and Zaha Hadid introduced innovative design principles and concepts that challenged traditional norms. Their ideas, including organic architecture, the concept of the "machine for living," and parametric design, continue to inspire and influence contemporary practices.

(ii) Design Principles and Innovative Concepts: The analysis of pioneer architects' design principles and innovative concepts highlighted their emphasis on functionality, integration with nature, and experimentation with form. Concepts like harmony between the built environment and natural surroundings, sustainable design strategies, and the use of cutting-edge technologies were key features in their works. These principles have paved the way for contemporary designers to explore new possibilities and push the boundaries of design.

(iii) Influential Architectural Projects: The examination of influential architectural projects demonstrated the lasting impact of pioneer concepts on modern urban planning and design. Projects such as Fallingwater by Frank Lloyd Wright, Villa Savoye by Le Corbusier, and the Guangzhou Opera House by Zaha Hadid showcased the application of innovative ideas and the integration of contextual factors. These projects have become iconic symbols of architectural excellence and continue to inspire designers worldwide.

(iv) Contemporary Approaches and Trends: The overview of current approaches and trends revealed a growing focus on sustainability, technology integration, and cultural considerations in design practices. Contemporary designers are increasingly adopting sustainable design principles, leveraging advanced technologies for design and construction, and prioritizing cultural sensitivity in their works. This shift reflects a broader recognition of the need for environmentally responsible, technologically advanced, and culturally relevant designs.

*Table 4. Summary of the examination of how pioneer concepts have been applied or adapted in the selected cases*

| Selected Case-studies | Applications of the Concept | Case-Studies figures |
|---|---|---|
| **(i) Barcelona, Spain-Eixample District:** | The Eixample district in Barcelona, demonstrates the application of pioneer concepts in urban planning. The Eixample district not only is the most iconic in Barcelona, but it's also the most diverse in terms of things to do in Barcelona. Most of the famous Gaudí buildings like Sagrada Familia or Casa Batlló are located in this district (Sanaan Bensi, & Marullo, 2018). Inspired by the principles of the Garden City movement and the vision of Ildefons Cerdà, the district emphasizes the integration of green spaces, accessibility to amenities, and the use of a grid pattern with chamfered corners to promote better ventilation and sunlight penetration (Levine, 2016; Gebrian, 2022). These pioneer concepts of green urbanism, mixed land uses, and pedestrian-friendly design have been adapted and applied in the Eixample District, creating a vibrant, livable urban environment. |  Figure 1. Source. https://barcelonando.com/eixample/) |
| **(ii) Curitiba, Brazil - Bus Rapid Transit (BRT) System:** | Curitiba's BRT system (Figure 2) showcases the application of pioneer concepts in urban transportation (Lindau, et. al., 2010). Influenced by the ideas of Jaime Lerner, the city implemented a dedicated bus lane system, integrated stations, and efficient scheduling, inspired by the principles of high-capacity, high-frequency public transport systems. These concepts, initially pioneered by Curitiba, have been widely adopted and adapted in various cities worldwide, shaping modern urban transportation systems and influencing sustainable mobility planning (Irina 2017). |  Figure 2. Bus rapid transit (BRT) system in Curitiba, Brazil. Source: Irina. (2017). |
| **(iii) Masdar City, Abu Dhabi, United Arab Emirates:** | Masdar City (Figure 3) exemplifies the application of pioneer concepts in sustainable urban development. Inspired by principles of ecological urbanism, and renewable energy integration, Masdar City has implemented sustainable building practices, smart grid systems, and advanced energy technologies (Lau, 2012; Federico Cugurullo (2013). These pioneer concepts have been applied to create a carbon-neutral and zero-waste city, setting a benchmark for sustainable urban development and influencing contemporary eco-friendly projects globally. |  Figure 3. Masdar City, Abu Dhabi, United Arab Emirates. **Source:** Lau, (2012) |

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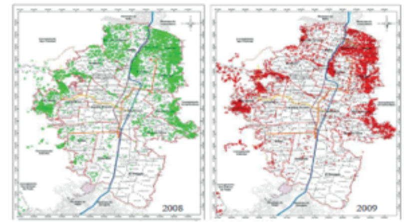
| **(iv) Medellín, Colombia - Urban Renewal** Projects: | Medellín's urban renewal projects (Figure 4) demonstrate the adaptation of pioneer concepts in community-focused development. Inspired by the principles of social urbanism, and participatory design, the city implemented transformative projects like the Metrocable system and public escalators in Comuna 13. These projects, prioritize social inclusion, connectivity, and the improvement of public spaces, showcasing the application of pioneer concepts of community engagement and participatory planning in urban regeneration efforts (Paula Restrepo Cadavid 2011; de Tomás Medina, 2018; Alfaya, et al., 2020). |   Figure 4. Medellin, Colombia- Urban Renewal Projects: Medellin Solidaria 2008 and 2009 Cohorts. **Source**. Medellin (Colombia) Paula Restrepo Cadavid (2011) |
| **(v) Songdo International Business District, Incheon, South Korea:** | Songdo International Business District (Figures 5) incorporates pioneer concepts in smart city development. Drawing inspiration from the principles of sustainable urbanism and advanced technology integration, Songdo City applies smart building systems, intelligent transportation networks, and sustainable infrastructure. These concepts have been adapted to create an interconnected, technologically advanced urban environment that promotes energy efficiency, resource management, and high quality of life (Rugkhapan & Murray, 2019). |  Figure 5. The International Business District (IBD) in Songdo, South Korea . **Source:** https://www.businessinsider.com/songdo-south-korea-design-2017-11 |

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|---|---|---|
| **(vi) Portland, Oregon, USA -Urban Growth Boundary:** | Portland's Urban Growth Boundary (UGB) (Figure 6) exemplifies the adaptation of pioneer concepts in managing urban growth (Adler, 2022). Influenced by the principles of compact city development and sustainable land use planning, the UGB sets a clear boundary to contain urban sprawl, preserve natural areas, and promote a mix of land uses. Portland's experience with the UGB has informed similar land use strategies in other cities, demonstrating how pioneer concepts of growth management and sustainable land use can be adapted to local contexts. |  Figure 6. Portland, Urban Growth Boundary. Oregon, USA. **Source:** Adler, 2022 |
| **(vii) The High Line, New York City, USA:** | The High Line (Figure 7) showcases the application of pioneer concepts in adaptive reuse and urban regeneration. Drawing inspiration from the principles of repurposing existing infrastructure and creating vibrant public spaces (Lang, & Rothenberg, 2017; Loughran, 2014). The High Line transformed an abandoned railway into an elevated linear park. This adaptive reuse approach has influenced numerous projects worldwide, promoting the conversion of obsolete infrastructure into valuable urban assets and fostering community engagement in shaping urban environments. |  **Figure 7**. Portland, Oregon, USA. **Source.** Loughran, (2014) |

### 7.2. Implications for future urban planning and design practices

This research on contemporary studies in architecture, planning, and design has several implications for future urban planning and design practices. These implications provide guidance and directions for shaping the future of the built environment. Here are the key implications:

(i) Embracing Sustainability: The research highlights the importance of integrating sustainability into future urban planning and design practices. The imperative to create environmentally responsible, resource-efficient, and resilient cities is evident. Future designers must prioritize sustainable design principles, including energy efficiency, renewable energy integration, green infrastructure, and sustainable transportation. This shift towards sustainability will contribute to mitigating climate change, improving air and water quality, and creating healthier, more livable cities.

(ii) Leveraging Technological Advancements: The research underscores the significance of embracing technological advancements in urban planning and design. Future designers should leverage digital tools, building information modeling (BIM), computational design, and data-driven systems to enhance the efficiency, accuracy, and innovation of their work. Additionally, smart technologies and the Internet of Things (IoT) can be integrated to create intelligent, responsive urban environments that optimize resource utilization, enhance connectivity, and improve the quality of life for residents.

(iii) Promoting Cultural Sensitivity and Identity: The research emphasizes the importance of cultural sensitivity and identity in future urban planning and design practices. Designers should actively engage with local communities, stakeholders, and cultural experts to understand and incorporate the unique cultural characteristics, heritage, and aspirations of a place. By respecting and promoting cultural identity, future designs can create spaces that foster a sense of belonging, social cohesion, and pride among residents.

(iv) Adaptive and Resilient Design: The research underscores the need for future urban planning and design practices to prioritize adaptive and resilient design solutions. Given the uncertainties and challenges posed by climate change, rapid urbanization, and socio-economic shifts, designers must develop strategies that allow for flexibility, adaptability, and resilience. Future designs should anticipate and respond to changing conditions, promote disaster resilience, and provide spaces that can evolve and accommodate future needs.

(v) Education and Knowledge Exchange: The research highlights the importance of continuous education and knowledge exchange in shaping future urban planning and design practices. Design professionals should stay updated with the latest research, emerging technologies, and best practices in the field. Furthermore, knowledge exchange platforms, conferences, and collaborative networks should be fostered to facilitate the sharing of experiences, lessons learned, and innovative ideas.

### 7.3. Suggestions for further research and exploration

This research on contemporary studies in architecture, planning, and design opens up avenues for further research and exploration. Building upon the existing knowledge, future studies can delve deeper into specific aspects and areas to expand our understanding and inform future practices. These research suggestions provide directions for further exploration and advancement in the field of architecture, planning, and design. This includes the investigating the potential of emerging technologies such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) in urban planning and design. Research the applications of these technologies in design visualization, simulation, data analysis, and user engagement.

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# Chapter 3

## ECO-DESIGN: AN APPROACH TO DESIGN PRODUCTS BY USING ECO-FRIENDLY OR REUSABLE MATERIALS

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## Introduction

In an era characterized by growing environmental concerns, the furniture industry is experiencing a notable shift towards sustainability. Eco-design furniture, also known as eco-friendly or sustainable furniture, has emerged as a viable solution to reduce environmental impact without compromising style or comfort. This article explores the concept of eco-design furniture, its benefits, and its significance in the quest for a greener and more sustainable future. The aspects of furniture on the environment depends on the material used in production. Wood, metals, and plastic are common raw materials used in furniture manufacturing. Concepts such as "eco-design," "green design," "environmental design," and "sustainable design" have emerged as responses to the urgent need for finding alternative approaches that minimize harm to the environment. These concepts aim to reduce negative environmental impacts and promote responsible practices.. From sourcing and manufacturing to use and disposal, eco-design furniture aims to reduce energy consumption, waste generation, and the depletion of natural resources. It prioritizes sustainable materials, innovative manufacturing techniques, and recyclability. By adopting environmentally friendly materials, reducing waste, and prioritizing durability, eco-design furniture offers an appealing alternative to conventional furniture. Its benefits extend beyond aesthetics, positively impacting the environment, human health, and future generations. As the demand for sustainable solutions continues to rise, eco-design furniture is poised to play a vital role in shaping a more sustainable and mindful world. The aim of eco-design is to protect the environment by increasing the lifecycle of a product. It can be done by redesigning or recycling the product. Eco-design has been studied in the past for a couple of years and it has been accepted successfully in the product development process of industries. Environmental pollution is increasing day by day in industrialized countries. Therefore, it is important to save the environment by using eco-friendly or reusable materials. The environmental aspects of furniture depend upon the type of furniture. Wood, metals and plastic are commonly used materials in the manufacturing of furniture. The material should be selected according to its recyclable and reusable characteristics.

**1. Environmental Impact**

In recent years, there has been significant advancement in the scientific understanding of the relationship between human activity and environmental integrity. Researchers have come to recognize that human activities have shaped and influenced ecosystems to a considerable extent, challenging the perception that nature is primitive or pristine (Janzen, 1998; Vitousek et al., 1997). In the 1980s, the primary focus of environmental policy was on reducing local or regional environmental degradation caused by specific pollutants and hazardous wastes.

However, as time progressed, the understanding of environmental issues expanded, leading to a recognition of the global nature of many environmental challenges. To address these complex and broad-ranging environmental problems, there is a need for a European or global economic-environmental model that possesses certain properties. The model should account for multiple countries and regions, reflecting the interconnectedness of environmental issues and their global impact. It should consider the diverse economic and environmental conditions across different countries. model should have a detailed breakdown of sectors within each country, allowing for a comprehensive analysis of the environmental implications of various economic activities. This disaggregation enables a more accurate assessment of material use and productivity patterns. The model should consider trade flows between countries and account for the specific product groups involved in these exchanges. This allows for an examination of how trade affects environmental impacts and resource use in different sectors. The model should incorporate an understanding of how socio-economic factors drive environmental change and how environmental factors, in turn, influence socio-economic development. This endogenous explanation helps capture the dynamic relationship between the economy and the environment. The model should possess the capability to simulate different policy alternatives and assess their potential environmental outcomes. It should utilize a forecasting approach to project the implications of these policies over time, enabling policymakers to make informed decisions. These properties contribute to the development of an integrated sustainability scenario, where economic and environmental factors are considered together to guide policy formulation and decision-making. By employing such a model, policymakers can better understand the complex interactions between the economy and the environment, and design effective strategies to address environmental challenges at a global scale.

The concept of human-dominated ecosystems acknowledges the profound impact that human activities have had on the environment. This includes activities such as agriculture, urbanization, deforestation, pollution, and climate change. These human-driven changes have altered landscapes, biodiversity, and ecosystem functioning on a global scale. Chemical production, losses of energy and materials, and the amount of waste have been considered as the most important environmental impacts of furniture, although also the concern of the emissions of chemical substances from the material during its utilization is raising (UEA, 2005; Besch, 2005; Parikka and Nissinen, 2005a).

The furniture industry is responsible for producing products by using several types of synthetic materials which can only increase the negative impact on the environment. It produces pollution during the manufacturing period as well as at the end of the furniture's life. Plastics and synthetics are non-disposable, mostly made from fossil fuels, such as oil and their extraction can destroy entire ecosystems. Furniture production relies on the extraction of raw materials, such as wood, metals, plastics, and textiles.

Furniture manufacturing involves energy-intensive processes, including cutting, shaping, assembling, and finishing. The use of fossil fuels for energy, emissions of greenhouse gases, and the generation of solid waste and wastewater contribute to air and water pollution, as well as climate change. The lifespan of furniture can vary depending on its quality, durability, and user behavior. Short-lived or poorly made furniture often ends up in landfills, contributing to waste accumulation. Disposal of furniture can be challenging as it may contain materials that are difficult to recycle or that release toxic substances when incinerated. Some furniture manufacturing processes involve the use of chemicals, such as adhesives, paints, and finishes. Improper handling or disposal of these chemicals can lead to water and soil contamination. Unfortunately, the use of some of these materials during the furniture manufacturing phase (paints, lacquers, varnishes, inks, colors, adhesives and adhesives) generates mainly dangerous greenhouse gases. By using these raw materials, the furniture industry contributes to the pollution of our planet. The amount of waste we produce is nearly related to our utilization and production patterns.

Around 80% of a product's environmental impact can be deceased with better design. It is in designers hand to produce products with a sustainable results for the future by designing products that has long lives and fulfill the needs of the user (Cooper, 2000). According to TÜİK Turkish statical institute, a total of 104.8 million tons of waste, 30.9 million tons of hazardous waste, was generated in manufacturing industry workplaces, mining enterprises, thermal power plants, organized industrial zones (OIZ), health institutions and households within the scope of the research. The total amount of waste increased by 10.5% compared to 2018 (21:39,15may 2023).

The environmental aspects of furniture are diverse and vary depending on the materials used in manufacturing. The use of wood in furniture raises concerns related to deforestation and habitat destruction. Unsustainable logging practices can lead to the loss of biodiversity and contribute to climate change. To mitigate these impacts, it is important to promote responsible forestry practices, such as certification systems like the Forest Stewardship Council (FSC), which ensures that wood is sourced from sustainably managed forests. Additionally, using reclaimed or recycled wood can help reduce the demand for new timber. Metals, such as steel and aluminum, are commonly used in furniture frames, legs, and hardware.

The environmental impacts associated with metal extraction and processing include energy consumption, greenhouse gas emissions, and water pollution. To address these issues, it is important to encourage recycling and the use of recycled metals in furniture manufacturing.

Additionally, choosing metals that have been produced using environmentally friendly practices, such as low-carbon or recycled content metals, can help minimize the environmental footprint. Plastics are prevalent in various furniture components, including upholstery, coatings, and structural elements. The production of plastics involves the extraction of fossil fuels and energy-intensive manufacturing processes. Improper disposal of plastic furniture can contribute to plastic pollution, which has adverse effects on ecosystems. To address these concerns, furniture manufacturers can opt for alternative materials, such as bio-based or recycled plastics. Additionally, designing furniture for longevity and recyclability can help reduce waste and minimize environmental impacts.

The energy used in manufacturing processes, such as cutting, shaping, and finishing furniture, can contribute to greenhouse gas emissions. Employing energy-efficient technologies and practices can help reduce energy consumption and associated environmental impacts. Furniture production often involves the use of adhesives, paints, varnishes, and other chemical finishes. It is essential to choose low VOC (Volatile Organic Compound) or VOC-free options to minimize indoor air pollution and harmful emissions. Packaging and transportation: The packaging materials and transportation methods used to deliver furniture can have environmental implications. Optimal packaging design that minimizes waste and efficient logistics to reduce transportation-related emissions are important considerations. To promote sustainable furniture manufacturing, various approaches can be adopted, including using environmentally friendly materials, implementing eco-design principles, embracing circular economy practices (e.g., recycling and reusing furniture), and prioritizing responsible sourcing and production methods.

The economic situation of each country is generated by the emphasis on continuous economic growth, which is very often associated with an increasingly high consumption of already limited natural resources. This is related to the lack of synthesis between the exhaustibility and renewability of raw materials, which recently has been the source of many environmental and social problems. Sustainable development, as an idea practiced for many years, encounters numerous economic, political and cultural barriers, which i.e., lead to crossing the limits of tolerance of nature.

The trend of sustainable product development is shifting from reduce, reuse and recycle to include recovery, redesign and remanufacture, and leading to the implementation of multiple generation life-cycle products The emphasis on continuous economic growth often leads to increased consumption of limited natural resources, which can result in environmental and social problems. Many natural resources are finite and can be depleted through excessive consumption.

Additionally, some resources have limited renewability, meaning their regeneration rate is slower than their extraction rate. The unsustainable extraction and use of resources can lead to environmental degradation and social inequities. Balancing the use of exhaustible resources with the promotion of renewable and sustainable alternatives is crucial for long-term environmental and economic stability. Sustainable development: Sustainable development aims to harmonize economic growth with environmental protection and social well-being.

However, implementing sustainable development practices faces various barriers, including economic, political, and cultural factors. Economic systems often prioritize short-term gains over long-term sustainability, political challenges arise due to competing interests, and cultural values and consumption patterns may not align with sustainable practices. Overcoming these barriers requires collaborative efforts from governments, businesses, civil society, and individuals.

The concept of sustainable product development is evolving beyond the traditional "reduce, reuse, recycle" approach. It now encompasses concepts such as recovery, redesign, and remanufacture. This shift highlights the importance of circular economy principles, where products are designed to have multiple life cycles through recycling, refurbishment, and remanufacturing. By extending the life cycle of products, we can reduce resource consumption, waste generation, and environmental impacts. These challenges require a comprehensive approach that integrates sustainable practices into economic systems, promotes responsible consumption and production, and encourages innovation in product design and manufacturing. It also requires collaboration between stakeholders, including governments, businesses, consumers, and civil society organizations, to drive systemic change towards a more sustainable and inclusive future.

## 2. Waste Material

Waste is commonly defined as any material by-product of human and industrial activity that is discarded or no longer utilized in its original form or purpose. It is typically considered to have limited or no residual value in its current stat (Serpell and Alarcon, 1995). Production chemicals, energy and material losses, and waste generation are indeed significant factors to consider. Here's a further elaboration on these aspects: The use of various chemicals in furniture manufacturing, such as adhesives, paints, coatings, and flame retardants, can have adverse environmental impacts. These chemicals may contain volatile organic compounds (VOCs) or hazardous substances that can contribute to air and water pollution during production. Proper handling, substitution with safer alternatives, and implementing strict chemical management practices can help mitigate these impacts.

Furniture production processes can result in energy and material losses, which contribute to resource depletion and environmental degradation. For example, inefficient manufacturing techniques, improper material selection, and suboptimal production planning can lead to excessive energy consumption and material waste. Adopting energy-efficient technologies, optimizing material use through design and production improvements, and implementing waste reduction strategies can minimize these losses.

Furniture waste is a significant concern, and its volume is closely linked to consumption and production patterns. This waste includes discarded furniture at the end of its lifecycle, as well as manufacturing scrap and offcuts. Improper disposal of furniture waste can contribute to landfill burden, release harmful substances into the environment, and hinder resource recovery. Implementing waste management strategies like recycling, refurbishment, and designing for disassembly can help reduce waste and extend the lifespan of furniture. In addition to these factors, the emissions of chemical substances from furniture materials during utilization (e.g., off-gassing of VOCs from upholstery or finishes) are also of concern. These emissions can contribute to indoor air pollution, potentially impacting human health.

Choosing low-emission materials, opting for environmentally friendly finishes, and ensuring proper ventilation can help mitigate these effects. It is important to address these environmental impacts through various strategies, including adopting sustainable production practices, promoting circular economy principles (such as recycling and reuse), encouraging responsible material sourcing, and promoting conscious consumption patterns. By considering the entire life cycle of furniture, from raw material extraction to disposal, and implementing environmentally conscious choices at each stage, it is possible to minimize the environmental footprint of the furniture industry. The environmental aspects of furniture can vary depending on the nature of the furniture and the materials used in its manufacturing. Wood, metals, and plastics are commonly employed as raw materials in the furniture industry, and each material has its own environmental considerations (EU, 2007).

1997, the glass recycling efforts in the United Kingdom were commendable, with the glass industry successfully recycling 425,000 tons of glass (Coventry, 1999). However, the recycling rate in Hong Kong remains relatively low at 1% compared to other countries. For example, the recycling rates in the USA, Japan, and Germany are 20%, 78%, and 85% respectively. Glass holds great potential for reuse in various applications within the construction industry, particularly in the context of windows. When proper care is taken during the demolition phase, glass window units can be directly reused without the need for additional processing or manufacturing (Coventry, 1999).

The global market for ferrous metal recycling is highly developed, making it the most profitable and recyclable material available. Ferrous metals, such as steel, have well-established demands and wide-ranging applications, which contribute to their acceptance and utilization on various sites. Ideally, steel should be directly reused whenever possible. If direct reuse is not feasible, it can be melted down to produce new steel through the recycling process. In the Netherlands, more than 80% of scrap arising from ferrous metals is recycled, and almost 100% of the material can be claimed as recyclable. The steel industry in the country reports that approximately 100% of steel reinforcement is made from recycled scrap, while 25% of steel sections are manufactured using recycled scrap materials. This showcases the high rate of recycling and the ability to repeatedly recycle scrap steel (Coventry, 1999).

Furniture waste constitutes a substantial portion of municipal solid waste in many countries. As consumerism and disposable culture prevail, furniture turnover rates have increased, leading to a significant increase in furniture waste generation. Improper disposal of furniture waste often results in it being sent to landfills. Many furniture items are made of materials that decompose slowly or not at all, such as wood treated with preservatives, synthetic materials, and metal components. While some furniture components, such as metal frames, can be recycled, others, like upholstered parts or composite materials, are more difficult to recycle effectively. By promoting recycling, reuse, and responsible consumption, the furniture industry can contribute to reducing furniture waste and moving towards a more circular economy. Environmental sustainability is a driver for new products and markets based on new environmentally friendly technologies.

On the other hand, sustainability goals also motivate life extension of existing systems (EFFRA 2013). The challenge for eco-product developers is to fulfill a need or to provide a benefit to the customer/user at the lowest environmental/economic "cost". Environmental knowledge must be implemented into basic product development otherwise environmental demands will not be properly addressed (Cooper,1999).

Eco-design and environmentally related knowledge is also in a company's internal business interest for use as guidance and a method to develop smarter, more effective product system solutions. Environmental sustainability acts as a catalyst for innovation and the development of new products and markets. As society becomes more aware of environmental issues, there is a growing demand for eco-friendly technologies and solutions. This creates opportunities for businesses to introduce environmentally friendly products and tap into emerging sustainable markets. By aligning with sustainability goals, companies can attract environmentally conscious consumers and gain a competitive edge. Sustainability goals also motivate the life extension of existing systems. By extending the lifespan of products, resources are conserved, and waste generation is minimized. This can be achieved through strategies like refurbishment, remanufacturing, and retrofitting, which allow products to be used for a longer period, reducing the need for new production and disposal.

The challenge for eco-product developers is to meet customer needs or provide benefits while minimizing environmental and economic costs. This involves integrating environmental knowledge and considerations into the core product development process. By incorporating sustainability principles from the early stages, such as material selection, energy efficiency, and end-of-life planning, environmental demands can be effectively addressed. Eco-design and environmentally related knowledge are also beneficial for companies internally. They serve as a guide and method for developing smarter and more effective product solutions. By considering environmental factors, companies can optimize resource use, reduce waste, and improve the overall efficiency of their product systems. This can lead to cost savings, enhanced reputation, and improved customer satisfaction. Integrating environmental knowledge and eco-design principles into product development is not only crucial for meeting sustainability objectives but also for staying competitive in a rapidly evolving market. By prioritizing environmental considerations, companies can drive innovation, create value for customers, and contribute to a more sustainable future.

## 3. Eco-design

Eco-design furniture refers to furniture that is consciously designed with environmental considerations in mind, aiming to minimize its environmental impact throughout its entire life cycle. Eco-design principles are applied from the initial design stages, material selection, manufacturing processes, product use, and even end-of-life disposal. The world is now getting more aware of the need to 'go green' and maintain an eco-friendly lifestyle.

Eco-design is a systematic way to include environmental life cycle considerations in product design. The aim of Eco-design is to avoid and minimize environmental impacts of a product throughout its life cycle. Eco-design is a holistic approach that objects to integrating environmental considerations into the product development process. With the growing global concern for sustainability and the environmental impacts of industrial activities, eco-design has emerged as a crucial strategy for creating products that minimize their ecological footprint. It focuses on choosing sustainable and renewable materials, such as FSC-certified wood, bamboo, recycled plastics, reclaimed materials, or organic fabrics. It aims to reduce the use of non-renewable resources and minimize environmental damage caused by extraction or harvesting. Eco-design is a systematic approach that integrates environmental considerations into the product design process. Eco-design furniture aims to optimize the use of resources throughout its life cycle. This involves designing for efficient material utilization, minimizing waste during manufacturing processes, and considering the energy and water efficiency of production methods.

By reducing resource consumption and waste generation, eco-design furniture contributes to a more sustainable and circular economy. The goal of eco-design is to minimize or avoid environmental impacts throughout the entire life cycle of a product. It involves making conscious decisions at every stage, from material selection and manufacturing to product use and end-of-life disposal. Selection of substances, materials, and components: Eco-design involves choosing materials and components that have a lower environmental impact. This includes considering factors such as the resource intensity of materials, their toxicity, recyclability, and biodegradability.

Opting for renewable, recycled, or low-impact materials can reduce the environmental footprint of the product. Prolongation of product lifetime: Designing products to have a longer lifespan is an essential aspect of eco-design. This can be achieved through robust construction, repairability, and modularity. By creating products that are durable and repairable, we can reduce the need for frequent replacements, resulting in resource savings and reduced waste generation. Eco-design furniture emphasizes longevity and durability.

By creating furniture that is built to last, with sturdy construction and high-quality materials, the need for frequent replacements is reduced. This approach not only reduces resource consumption but also saves money for consumers in the long run.

It promotes repairability and disassembly. Designing furniture with easily replaceable parts and repair-friendly features encourages repair instead of disposal. This reduces waste and contributes to a more circular economy. Additionally, furniture designed for disassembly facilitates recycling and material recovery at the end of its life, minimizing environmental impacts. Additionally, eco-design furniture may incorporate modular or adaptable features that allow for flexibility and reconfiguration, extending its usability and relevance. Eco-design furniture also takes into account user needs and well-being. It ensures ergonomic design, comfort, and functionality while minimizing the use of harmful substances. For example, using non-toxic adhesives, paints, and finishes reduces indoor air pollution and promotes healthier living environments. Eco-design emphasizes the importance of designing products that consume less energy during their use phase. This can be achieved through energy-efficient components, smart controls, and optimizing energy consumption throughout the product's lifecycle. Energy-efficient products not only reduce environmental impacts but also provide cost savings for the users.

Eco-design promotes the development of products that are designed with end-of-life considerations in mind. Designing products for easy disassembly and separation of components facilitates recycling and resource recovery. Additionally, creating products that can be reused or repurposed after the initial use phase helps extend their life cycle and reduce waste generation.

By integrating these principles into the design process, eco-design seeks to minimize the environmental impact of products and promote sustainable consumption and production patterns. It recognizes that environmental considerations should be an integral part of product development from the very beginning, rather than an afterthought.

Ultimately, eco-designed products aim to meet consumer needs while minimizing resource consumption, waste generation, and environmental harm. Eco-design furniture aims to minimize energy consumption, waste generation, and emissions during the manufacturing phase. It involves implementing efficient production techniques, using eco-friendly technologies, and reducing or eliminating the use of harmful chemicals or solvents. This includes, e.g., the selection of substances, materials and components, prolongation of product lifetime and creation of products that consume less energy during their lifetime and are recyclable or reusable after the use phase (Kärnä, 2002).

It is a design approach that focuses on incorporating environmental sustainability principles into the creation of furniture. It aims to minimize the ecological impact of furniture production, use, and disposal by considering the entire lifecycle of the product. One key aspect of eco-design furniture is the emphasis on creating durable and long-lasting products. By using high-quality materials and craftsmanship, designers ensure that the furniture can withstand wear and tear over time. This extends the product's lifecycle and reduces the need for frequent replacements, which in turn reduces waste and resource consumption (EFFRA 2013).

In addition to durability, eco-design furniture also considers the environmental impact of the materials used. Designers prioritize using eco-friendly materials that are renewable, recyclable, or biodegradable. They may also explore innovative materials and technologies that have a reduced environmental footprint compared to traditional materials. Furthermore, eco-design furniture encourages the concept of life extension. Instead of disposing of furniture when it becomes outdated or worn out, efforts are made to extend its useful life. This can involve refurbishing, repairing, or repurposing furniture to give it a new lease on life.

By promoting life extension, the environmental impact associated with the disposal and production of new furniture is reduced. The responsibility of eco-design developers is to balance the needs and desires of customers/users with the goal of minimizing the environmental and economic impact of their products. They must consider environmental knowledge and apply it throughout the entire product development process to ensure that environmental demands are properly addressed (Cooper,1999).

To provide benefits to customers/users, eco-design developers need to ensure that their products meet or exceed customer expectations in terms of functionality, quality, and aesthetics. They must create products that are not only environmentally friendly but also deliver a positive user experience and value.

However, it is important to note that the concept of "cost" in eco-design extends beyond just economic factors. The cost also includes the environmental impact associated with the product's lifecycle, such as resource depletion, pollution, and waste generation.

Eco-design developers aim to minimize both the economic and environmental costs while maximizing the benefits for the customer/user. Absolutely, the development of eco-design has been supported by the creation of various information, strategies, and tools that assist designers in integrating environmental considerations into their design processes. These resources enable designers to analyze the environmental strengths and weaknesses of their products, prioritize improvement areas, support idea generation, and facilitate efficient collaboration with other design criteria (Tischner et al., 2000). Eco-design principles provide guidelines and strategies for designing products with environmental sustainability in mind. When applied to furniture design, these principles help minimize the ecological footprint of furniture and promote sustainable practices. Choosing materials that are environmentally friendly, renewable, and have a lower environmental impact. Considering the entire lifecycle of the product, from raw material extraction to manufacturing, transportation, use, and disposal. Aim to minimize environmental impacts at each stage and design for durability, repairability, and recyclability.

Designing furniture to be energy-efficient both during its use and manufacturing. Incorporate energy-saving features such as LED lighting, efficient appliances, and power-saving modes. Optimize manufacturing processes to reduce energy consumption and emissions.

Designing furniture that is aesthetically pleasing and functional to encourage its use and longevity. Combine sustainability with innovative and attractive designs that resonate with consumers.

By integrating these eco-design principles into furniture design processes, designers can create products that prioritize environmental sustainability, promote resource efficiency, and contribute to a more sustainable future. Eco-design furniture reflects a holistic approach that considers environmental, social, and economic aspects. It embodies sustainable practices, promotes responsible consumption and production, and strives for a more sustainable future. By choosing eco-design furniture, individuals and businesses can contribute to the preservation of natural resources, reduction of waste, and the creation of a more sustainable and aesthetically pleasing living and working environment.

## 4. Example of Eco-design furniture

### 1. Eco coffee table by the American manufacturer Orient Express Furniture

Introducing the exquisite eco coffee table from the magnificent Magnolia collection by Orient Express Furniture, an esteemed American manufacturer. This designer table showcases a captivating eco-inspired style, meticulously crafted using reclaimed teak wood. The table's unique and original design is sure to impress.

**Figure 1.** *Eco coffee table by Orient Express Furniture*
**Sourced:** *https://www.theclassyhome.com/Brand/Orient+Express*

## 2. Natural material furniture by Kalon

The enchanting Stump coffee table, meticulously crafted from a solid block of domestically sourced ash or maple trees harvested from the lush forests of Maine. This extraordinary piece exemplifies the delightful interplay between the inherent variations found in natural materials and the sleek precision of contemporary design.

**Figure2.** *Stump by Kalon*
**Sourced:** *https://kalonstudios.com/shop/stump-trunk/stump/*

**3. Piet Hein Eek**

Furniture and eco-designs are renowned for their utilization of humble materials, crafted in a traditional manner. They embody a profound commitment to sustainability and social responsibility throughout the furniture production process. While these designs embrace the use of recycled materials, their visual appeal extends beyond mere reusability. In fact, they achieve a remarkable paradox by transforming these materials into one-of-a-kind pieces that exude the essence of artistic masterpieces.

**Figure 3.** *Furniture made of wooden scraps. Design and pics by Piet Hein Eek*

**Sourced:***https://smartroombcn.com/ecodesign-and-furniture/*

**4. David Trubridge**

The New Zealand designer is renowned for their eco designs and furniture, which are crafted using locally sourced raw materials. Considered modern craftsmen, they possess a unique flair for experimenting with wood, pushing the boundaries of its potential. Their work beautifully embodies the trend of 'raw sophistication' or 'raw elegance.'

The Cloud lamps underwent a redesign process, transitioning from their original production in plastic to a more environmentally friendly material. The decision to discontinue the plastic version was prompted by its negative impact on the environment. Today, these lamps are thoughtfully crafted using bamboo, offering a prime example of the wisdom in rectifying past choices.

**Figure 4.** *Lamp made of bamboo, the improved object which was originally designed in plastic. Design and pics by David Trubridge*

**Sourced:***https://smartroombcn.com/ecodesign-and-furniture/*

**5. Campana Design**

The Brazilian studio of brothers Fernando and Humberto Campana is widely acclaimed for their exceptional work in eco-design and furniture. Their designs are deeply rooted in the culture and traditions of their country, drawing inspiration from the rich tapestry of Brazil's heritage. Notably, their creative process involves the innovative use of recycled materials, resulting in furniture pieces that reimagine and repurpose everyday objects.

**Figure 5.** *Lamps made of broken glass; shoes made from recycled plastic. Design and photos by Campana Brothers*

**Sourced:** *https://smartroombcn.com/ecodesign-and-furniture/*

### 6. Frank Ghery, "Rocking Chair

Frank Gehry, a renowned architect and designer, has collaborated with Herman Miller to create notable furniture pieces such as the "Rocking Chair" and the "Little Beaver Chair and Ottoman." Herman Miller, as a company, is dedicated to ecologically sound practices and has a range of products that exemplify eco-design techniques, including sustainability, material preservation, energy efficiency, recycling, and disassembly.

**Figure 6.** *Frank Ghery,"Rocking Chair*

**Sourced:***https://www.researchgate.net/publication/336263528_Ecological_Design_As_A_Result_Of_Environmental_Pollution_And_It%27s_Effects_On_Today%27s_Furniture*

### 7. Fels stool by OUT

Fels, a captivating sculptural stool designed by Berlin-based brand OUT, is a testament to sustainable practices and exquisite craftsmanship. Made from wood sourced through sustainable forestry, the materials used in creating Fels are carefully selected to maintain biodiversity and environmental productivity. The wood is forested in Germany and Austria, ensuring responsible harvesting practices.

**Figure 7.** *Fels stool by OUT*

**Sourced :** *https://www.dezeen.com/2022/05/18/furniture-designs-sustainable-materials-dezeen-showroom/*

### 8. Kelp Collection chair by Interesting Times Gang

The Kelp Collection chair by Swedish studio Interesting Times Gang is made from recycled fishing nets, which gives it a bright green color. The fishing nets are combined with recycled FSC-certified wood fibers to create the furniture's bio-composite material, which is 3D printed to create the chair's curving form. Interesting Times Gang designed the chair to bring awareness to the eradication of kelp forests due to unsustainable fishing practices and rising sea temperatures.

**Figure 8.** *Kelp Collection chair*

**Sourced :** *https://www.dezeen.com/2022/05/18/furniture-designs-sustainable-materials-dezeen-showroom/*

## 5. Material and Method

This study examined the researches on eco-design, and furniture produced from recycled and natural materials was examined in the world. Thesis, journal, book, newspaper and article studies published in this field were reviewed. A coffee table has been designed using concrete top and iron frame. The concrete used in this product has been recycled from a demolished building.

## 6. Conclusion

A coffee table has been designed using a concrete top and iron frame. The concrete used in this product has been recycled from a demolished building waste material. This product is easy to assemble. Concrete top with black matte metal frame, no extra decoration, minimalist lines. Modern and simple design, not only suitable for the living room, suitable for large and small spaces, versatile in different Spaces. This product has 4 rubber stoppers beneath each base to prevent scuffing and sliding.

**Figure 9.** *3D model of the coffee table*

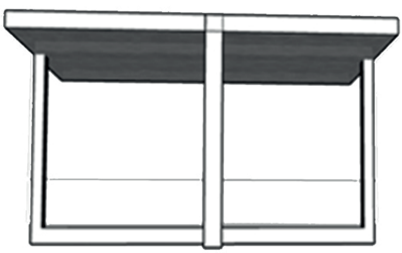

**Figure 10.** *3D model of the coffee table*

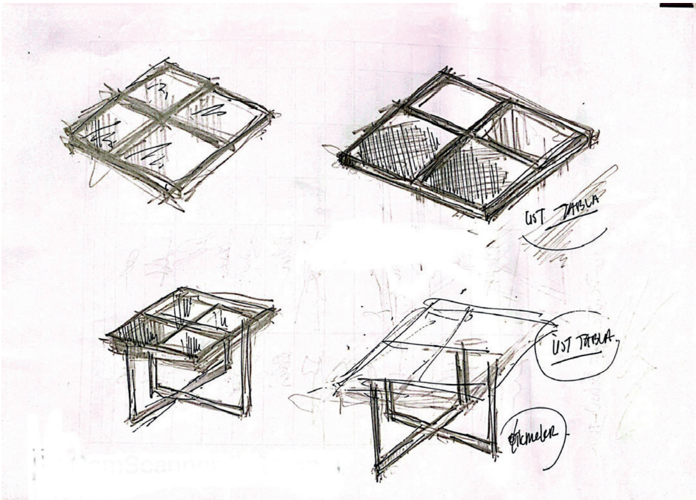


**Figure 11.** *Sketches of the coffee table*

By integrating eco-design principles into the furniture manufacturing process, the industry can significantly reduce its environmental impact while offering consumers sustainable and high-quality products. Eco-design furniture not only contributes to resource conservation and waste reduction but also provides aesthetically pleasing, functional, and healthy solutions for individuals and communities.

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