الجمهورية الجزائرية الديمقراطية الشعبية وزارة التـعليم العالي والبحث العلمي

وزارة التـعليم العالي والبحث العلمي

Democratic and Popular Republic of Algeria

Ministry of Higher Education and Scientific Research

University 8th May 1945 of Guelma Faculty of Science and Technology

Department of Architecture

Course Handout

New Information and Communication Technologies (NICT) in Urban and Architectural Projects

Level: Third-Year Bachelor's Degree

Specialty: Operational Project Management (*Conduite Opérationnelle de Projet – COP*)

Prepared by:
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Domain: Architecture and City Professions

Branch: City Professions

Specialty: Operational Project Management

Level: Bachelor's Degree (License)

Semester: 05

Teaching Unit: UET 1

Course Title: New Information and Communication Technologies (NICT) in Urban and Architectural Projects

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Weighting: 100%

Coefficient: 1

Credits: 1

Instructor: Dr. Sofiane BENSEHLA

Academic Rank: Assistant Professor (Class B)

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Course Objective

The objective of this course is to provide students with both conceptual and practical knowledge of New Information and Communication Technologies (NICT) applied to architectural and urban project management. Through this course, students will explore advanced tools and systems such as Decision Support Systems (SIAD), Computer-Aided Publishing (PAO), Geographic Information Systems (GIS), Building Information Modelling (BIM), and City Information Modelling (CIM). The course aims to equip future project managers with the ability to analyse, visualize, simulate, and communicate urban and architectural data effectively throughout the entire project lifecycle, from feasibility studies to design, implementation, and final presentation. Emphasis will also be placed on collaboration, data integration, and digital communication to support informed decision-making and professional reporting.

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Foreword

In an era of digital change, the incorporation of New Information and Communication Technologies (NICT) has become essential in the profession of architecture and urban planning. This course will look at how NICT technologies, such as design and modelling software, decision support systems, and digital publication, may help urban and architectural projects be more creative, efficient, and sustainable.

By presenting both fundamental principles and existed applications, the course equips future architects, urban planners, and project managers with the knowledge and data-driven mindset necessary for today's challenges. Whether through Building Information Modelling (BIM), Geographic Information Systems (GIS), or advanced visualization techniques, NICT opens new opportunities for collaboration, simulation, and communication throughout the project lifecycle.

This course aims to provide students with the theoretical foundations and make them understand the current cutting-edge techniques of design and planning in an increasingly interconnected world.

Lesson 1: Introduction to New Information and Communication Technologies (NICT) – Definitions, Components, and Applications

1. Introduction

In the digital age, New Information and Communication Technologies (NICT) have become essential tools for transforming the way we access, process, and share information across all fields of activity. Whether in education, business, governance, or urban and architectural project management, NICT plays a critical role in enhancing productivity, fostering innovation, and improving decision-making processes.

This lesson provides an overview of New Information and Communication Technologies (NICT), covering their definitions, main components, and tools such as cloud computing, internet networks, and search engines. It aims to give students a foundational understanding of digital technologies and how they function in modern information systems.

2. Definition of NICT

NICT abbreviated as New Information and communication technology has taken several definitions from several researchers and according different areas, starting from simpler definition according to the Oxford English Dictionary defining each concept of it separately,

- New: *"Not previously existing; now made or brought into existence for the first time."*
- Information: "*Knowledge communicated concerning some particular fact, subject, or event; that of which one is apprised or told; intelligence, news."*
- Communication: *"The transmission or exchange of information, knowledge, or ideas, by means of speech, writing, mechanical or electronic media, etc…"*
- Technology: *"The branch of knowledge dealing with the mechanical arts and applied sciences; the study of this."* (Oxford English Dictionary, s. d.)

Information and Communication Technology is defined by ISO (ISO, 2008) as "technology for gathering , storing, retrieving, processing, analysing and transmitting information" (Felice et Christoforos 2021). Furthermore, several references defined ICT according to its area of use, for example, In business, (Zhang, Aikman, et Sun 2008) define ICTs as "technologies used by people and organizations for their information processing and communication purposes", while in education, ICT is defined as a "continuum of skills and abilities" that encompasses the convergence of information technology (IT) and telecommunication technologies. In education, ICT refers to the use of digital tools and technologies to support teaching, learning, and administrative processes (Zuppo 2012).

Drawing a holistic definition of NICT, the following definition is given:
NICT (New Information and Communication Technology) refers to the integrated set of technologies, systems, and networks that enable the collection, processing, storage, transmission, and exchange of information in digital formats. It encompasses hardware (e.g., computers, servers, mobile devices), software (e.g., applications, databases, cloud computing), and communication infrastructures (e.g., internet, wireless networks, telecommunications). These technological components are continuously evolving, allowing NICT—with its new advancements—to be applied across multiple disciplines such as education, economy, social development, governance, and healthcare. Furthermore, NICT plays a transformative role in the digital era by fostering connectivity, innovation, and accessibility worldwide. By bridging geographical distances and facilitating global interaction, NICT has become a cornerstone of modern society.

3. ICT components

ICT encompasses a wide range of components that facilitate the management, processing and any operation using ICT, here are the key components of ICT:

Hardware: The physical devices used in ICT, including computers, servers, routers, smartphones, and other digital equipment.

Software; Programs and applications that run on hardware, including operating systems, productivity tools, and specialized ICT applications.

Network & Connectivity: Infrastructure that enables communication and data transfer, such as LAN (Local Area Network), WAN (Wide Area Network), and the internet.

Data Storage & Retrieval: Systems and technologies used to store and access digital information, including databases, cloud storage, and external drives.

Data Security & Privacy: Measures to protect digital data from unauthorized access, breaches, and cyber threats, including encryption and access control.

Internet & Web Technologies: Tools and protocols that support online services, including websites, browsers, email, and cloud computing.

ICT Policies & Regulations: Laws and guidelines that regulate ICT usage, such as GDPR (data protection), cybersecurity laws, and digital rights frameworks.

Human & Organizational Resources: The people (IT professionals, users) and structures (training, management) that support and optimize ICT operations.

4. Cloud computing and edge computing

Cloud computing refers to the delivery of computing services over the internet, including servers, storage, databases, software, and analytics like Google Drive. It enables on-demand access to a shared pool of resources, promoting scalability, flexibility, and cost-efficiency (Sissodia et al. 2025). Edge computing, on the other hand, involves processing data closer to the source, reducing latency and bandwidth constraints. It is particularly useful for real-time applications and IoT devices like Amazon Alexa for smart home control (Siripuram 2024) (figure1).

The evolution from cloud to edge computing has been driven by the need for faster processing, reduced latency, and improved security. Edge computing addresses the limitations of cloud computing by decentralizing data processing, making it ideal for applications requiring immediate responses, such as autonomous vehicles and smart cities (Liu et al. 2019)

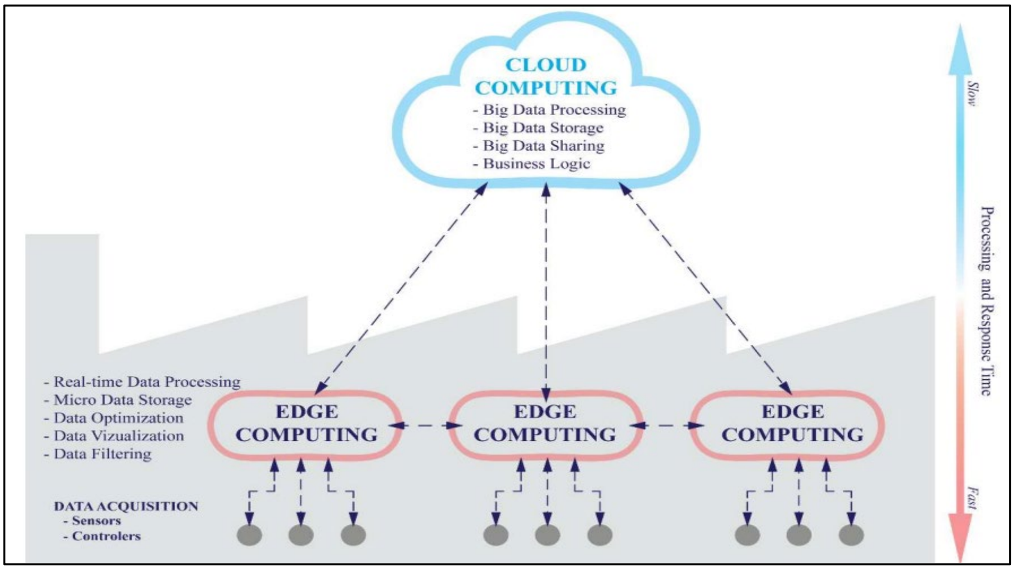

Figure 1. Edge Computing and Cloud Computing (Bajic et al. 2019).

5. Internet search engine and Metasearch engine

Internet

The Internet is a global network of interconnected computers and devices that communicate using standardized protocols. It enables the sharing of information, resources, and services across vast distances, connecting billions of users worldwide. Data is transmitted between devices through cables, fibre optics, satellites, and wireless technologies, ensuring seamless connectivity (Baltra et al. 2023) .

At this field it is essential to know the difference between internet, extranet, ad intranet.

The Internet is a global network that connects millions of private, public, academic, business, and government networks, facilitating a vast array of information exchange. In contrast, intranets and extranets serve more specialized functions within organizations, focusing on internal and external communication, respectively (Watson 1999).

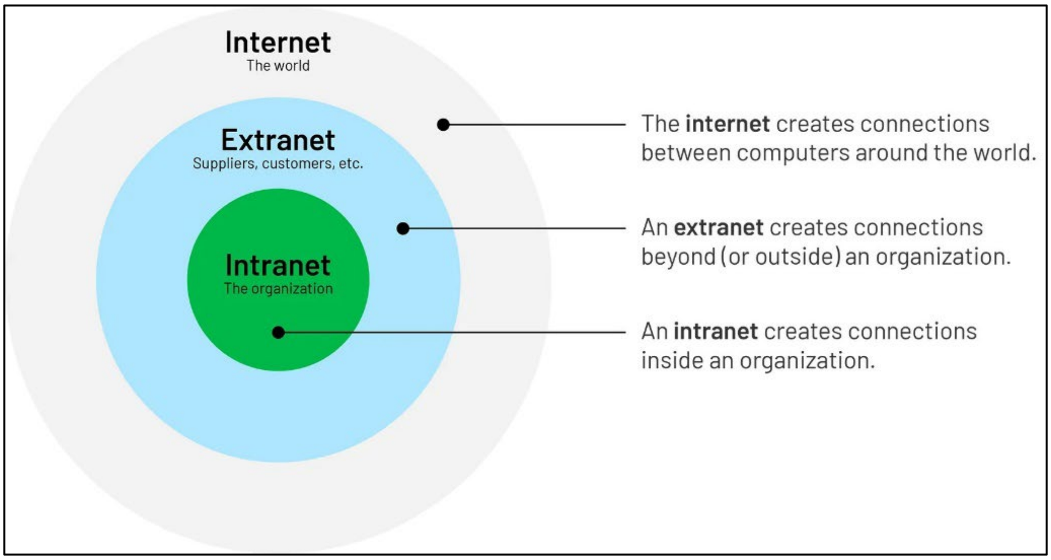

Figure 2. Difference between Internet, Extranet, and Intranet (Alcero 2022).

5.1. Internet search engine

A web application that allows users to find resources based on a query in the form of words. Resources can include web pages, images, videos, and more. Examples of search engines include Google and Bing.

5.2. Metasearch engine

A metasearch engine is a search tool that gathers results from multiple general search engines, processes them, and presents a combined and structured list of search results to the user. Unlike traditional search engines, it does not maintain its own database but relies on external search engines to retrieve information. Examples: DuckDuckGo, Dogpile, and Carrot2.

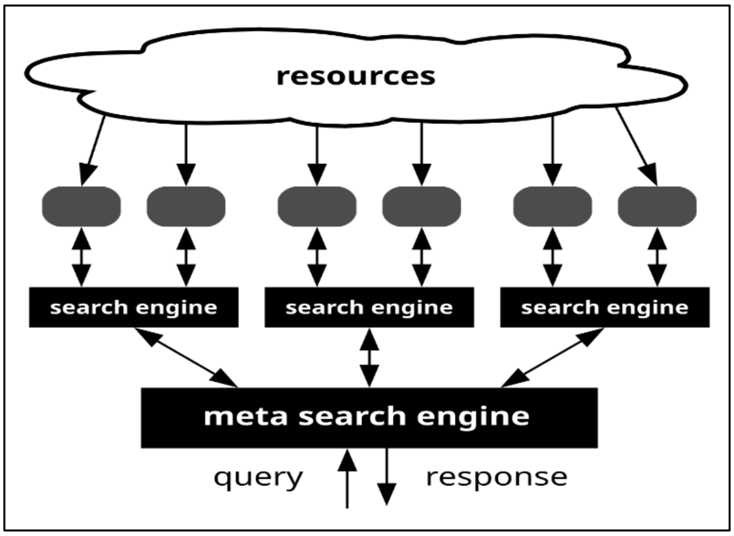

Figure 3. Metasearch engine and search engine (Wikiwand 2024).

6. Conclusion

New Information and Communication Technologies (NICT) represent a vital foundation for today's digital world. From basic components like hardware and software to advanced systems such as cloud and edge computing, these technologies enable efficient data processing, communication, and information access. Understanding NICT and its tools, including internet search engines and networks, is essential for navigating and leveraging the digital landscape effectively in any professional field.

Lesson 2: Architectural and Urban Projects: Concepts, Scales, and Interventions

1. Introduction

This lesson introduces the fundamental distinctions between architectural and urban projects. It explores their definitions, the various types of urban interventions, and the different spatial scales involved in shaping the built environment, from a single plot to vast megalopolises.

2. Definition of Architectural project

An architectural project encompasses the design, planning, and execution of buildings, parts of buildings, or small urban spaces, integrating functionality, aesthetics, and materials. It is led by architects and professionals to ensure structural and design quality (Law Insider, s. d.).

An architectural project may involve the construction of a new building, a part of a building, or the renovation and rehabilitation of existing structures.

3. Definition of Urban project

An urban project is a planned initiative focused on shaping, improving, or transforming cities, neighbourhoods, and public spaces. It integrates urban planning, architecture, transportation, sustainability, and infrastructure to create functional, liveable, and environmentally friendly urban environments. Urban projects are often continuous processes that require collaboration between urban planners, landscape architects, transportation engineers, and other experts, alongside architects.

Urban projects provide various modes of intervention to address challenges in cities, particularly in city centres. These interventions include:

- Urban Renovation: Upgrading or modernizing existing urban areas while preserving their character.
- Urban Planning: Designing and organizing land use, transportation, and infrastructure for sustainable urban growth.
- Urban Redevelopment: Transforming underutilized or deteriorated areas into new functional urban spaces.
- Urban Restructuring: Reconfiguring the urban fabric by modifying layouts, infrastructure, or zoning.

- Urban Rehabilitation: Restoring and improving old buildings and public spaces while maintaining their original identity.
- Urban Renewal: A comprehensive approach that combines redevelopment, rehabilitation, and modernization to revitalize urban areas.

4. Difference Between Architectural and Urban Projects

From a general perspective, a project is defined by its scale and type of intervention, which determines whether it is an architectural or urban project. However, in many cases, urban projects encompass architectural projects, as they often include the development or renovation of buildings within a broader urban framework. For example, a city centre revitalization project (urban scale) may involve the restoration of historical buildings (architectural scale). This interconnection highlights the complementary nature of both fields in shaping sustainable and functional urban environments (Elshater 2017).

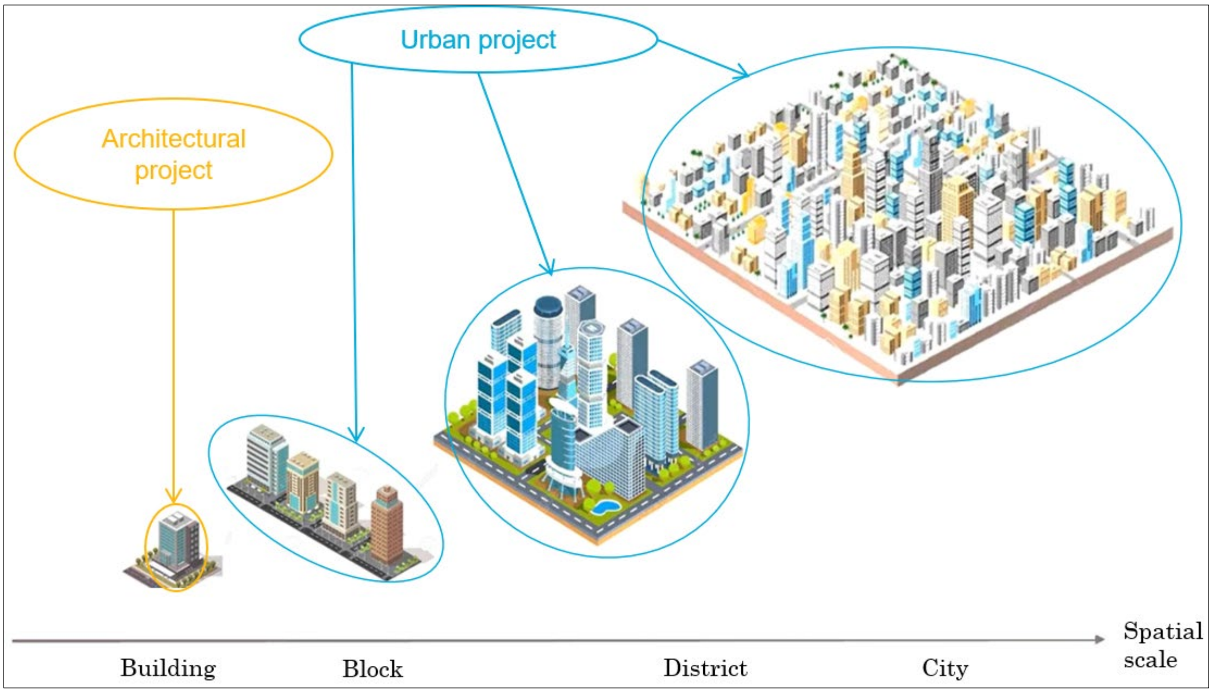

Figure 4. Spatial scale from building to city (Author).

5. The spatial scales of the city:

In urban and architectural studies, the city is analysed at different spatial scales, each representing a specific level of intervention and planning (Université de Nice 2024; Abeer Elshater 2017). The key scales of the city include:

- Plot (Parcelle): A small piece of land with a defined property unit.

- Block (Îlot): A group of buildings or undeveloped plots surrounded by streets within the public urban network.
- Parcelling (Parcellaire): A collection of multiple blocks, forming a structured urban subdivision.
- Neighbourhood (Quartier): An administrative division of a city, often defined by specific functions or identities, such as residential or commercial areas.
- City (Ville): Defined by administrative boundaries, encompassing diverse districts and urban functions under a unified governance system.
- Metropolis (Métropole): A large, influential city, often a capital or economic hub, characterized by major infrastructure, high population density, and significant economic activity.
- Megalopolis (Mégapole): A vast urban region formed by the merging of multiple metropolitan areas, creating a highly dense and interconnected urban network. Example: The Boston–Washington corridor (USA) or the Tokyo–Osaka megalopolis (Japan).

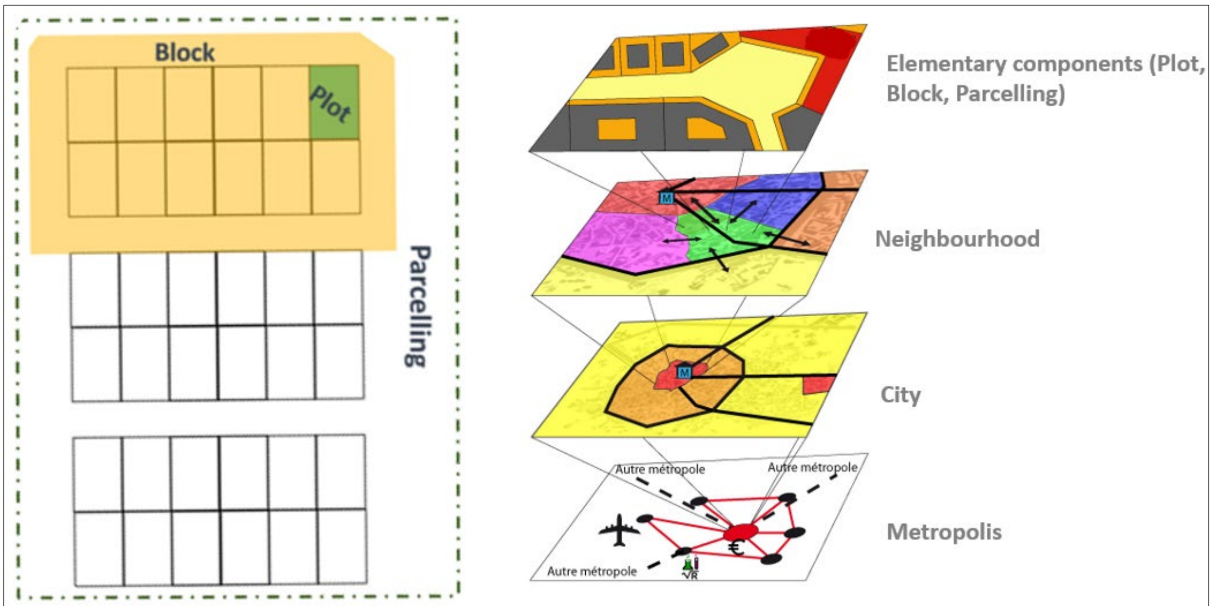

Figure 5. Diagram of urban scales (Université de Nice 2024).

6. Conclusion

Architectural and urban projects are intrinsically linked yet distinct in scope, scale, and purpose. While architectural projects focus on the design and execution of individual buildings or components, urban projects engage with broader systems of public space, infrastructure, and community needs. By understanding the hierarchy of spatial scales and the different forms of urban intervention, students can better appreciate the strategic thinking and coordination required in project development and execution across both domains. Moreover, understanding these spatial scales represents a crucial step in identifying which technologies can be applied or are most suitable for implementation at each level of intervention, whether it involves detailed architectural modelling or large-scale urban simulation and data management.

Lesson 3: How ICT Reshapes Architectural Design and Project Delivery

1. Introduction

The integration of ICT in architecture has revolutionized design, construction, and management. From CAD to BIM, digital tools enhance precision, collaboration, and efficiency. Emerging technologies like IoT, AI, and digital twins now enable smarter, data-driven decisions. These advancements address industry challenges in sustainability, cost, and quality. This lesson explores ICT's transformative role, from foundational tools to cutting-edge innovations. Its impact reshapes how buildings are conceived, built, and operated.

2. The Evolution of Architectural Design: From 2D Drafting to 3D Modelling

In the past, architects primarily worked in 2D, relying on hand-drawn sketches and technical drawings such as floor plans, elevations, and sections. To visualize their designs in three dimensions, they created separate perspective drawings and renderings manually.

The introduction of Computer-Aided Design (CAD) revolutionized architectural workflows. The first personal computer was developed in 1973, and by 1982, Autodesk launched AutoCAD, which became a cornerstone tool for architects. This software allowed for precise and efficient creation of 2D technical drawings, significantly improving accuracy and productivity.

In recent years, the industry has shifted toward 3D modelling and visualization. Advanced software such as SketchUp, Blender, 3ds Max, Rhino, and Revit enables architects to create detailed 3D models, allowing for photorealistic renderings, animations, and virtual walkthroughs. This evolution enhances communication with clients and stakeholders, providing a clearer understanding of design intent. Additionally, Building Information Modelling (BIM) has transformed collaboration and project management by integrating data-rich 3D models into the design and construction process, streamlining efficiency and decision-making.

This transition from 2D drafting to 3D modelling and BIM, driven by Information and communication technological (ICT) advancements, marks a significant development in architectural design, enhancing both creativity and technical precision in the industry.

3. Computer-Aided Design (CAD) (in French; La Conception Assistée par Ordinateur (CAO))

Represents the modelling and design of precise 2D and 3D virtual models for products, primarily used in engineering, architecture, and manufacturing. It enables professionals to visualize, simulate, and optimize designs before physical production. Key software includes AutoCAD, SolidWorks, and Revit. CAD streamlines prototyping, testing, and development processes, making it essential for efficient and accurate product design (ESAIL 2024).

4. Computer-Aided Drafting (CAD) (In French; Le Dessin Assisté par Ordinateur (DAO))

focuses on creating precise 2D technical drawings, widely used in architecture, engineering, and cartography. It emphasizes accuracy for project implementation and utilizes software like AutoCAD, DraftSight, BricsCAD, and LibreCAD (Bateche, s. d.).

5. Computer-Aided Manufacturing (CAM) (in French; Fabrication assistée par ordinateur FAO)

Is defined as the efficient use of computer technology in managing, controlling, and automating the manufacturing process. It focuses on using computer software to control machinery and automate production. CAM translates CAD designs into machine instructions to manufacture physical parts. Software programs like AutoCAD CAM and Mastercam are widely used in CAM processes (Bateche, s. d.).

6. Digital mock-up (maquette numérique) (DMU)

A Digital Mock-Up (DMU) is a complete, virtual three-dimensional representation of a product, system, or structure used in engineering, manufacturing, and design. It is created to simulate, analyze, and validate the product's shape and functionality, aiming to replace physical prototypes by providing consistent, up-to-date virtual models that reduce production costs and time while enhancing design accuracy (Riascos et al. 2015).

After further developments in 3D representation within the built environment, a digital mock-up emerged that encompasses everything from design and construction to the management, operation, and maintenance of the building. This model integrates all detailed project information, which led to the creation and evolution of **Building Information Modelling (BIM).**

7. BIM (BUILDING INFORMATION MODELLING)

According to Autodesk, a leader in 3D design and engineering software for architecture, BIM (Building Information Modelling) is a collaborative process that uses intelligent 3D models to plan, design, construct, and manage buildings more efficiently. These cloud-based models integrate data from all disciplines, creating a digital prototype (or digital mock-up) for the entire building lifecycle (Autodesk 2024).

Figure 6. Digital mock-up for BIM (Autodesk 2024).

7.1. The Three Meanings of BIM

BIM represents not merely a technological upgrade to conventional project delivery methods, but rather a fundamental transformation in workflow paradigms. While interpretations of BIM vary across the industry, the concept is universally recognized to encompass three distinct meanings (Liu et al. 2019):

7.1.1 BIM (Building Information Modelling)

- The *technology and process* of creating, sharing, and analyzing digital models of buildings.
- Uses intelligent 3D modelling for design, construction, and collaboration.

7.1.2 BIM (Building Information Models)

The *digital outputs*—the actual 3D models and data-rich prototypes of a building or infrastructure.

- Acts as a virtual representation of physical and functional characteristics.

7.1.3 BIM (Building Information Management)

- The *management of data* across a building's lifecycle (design, construction, operation).
- Ensures information is accessible, updated, and usable for decision-making.

Together, these three aspects make BIM a powerful tool for modern construction and facility management.

7.2. BIM process

BIM applications span the entire lifecycle of a facility, starting from the initial project programming through design, preconstruction, construction, and post-construction (operations and maintenance) phases, until demolition, renovation or rehabilitation (Liu et al. 2019).

The main BIM process consists of the following four stages:

Planning

Informs project planning by combining reality capture and real-world data to generate contextual models of existing built and natural environments.

Design

Conceptual studies, analysis, detailing, and documentation are completed. The preconstruction process begins using BIM data to inform scheduling and logistics.

Construction

Fabrication begins using BIM specifications. Project construction logistics are shared with trades and contractors to ensure optimal scheduling and efficiency.

Operations

BIM data is applied to the operation and maintenance of completed assets. This data can later be used for cost-effective renovations or efficient deconstruction.

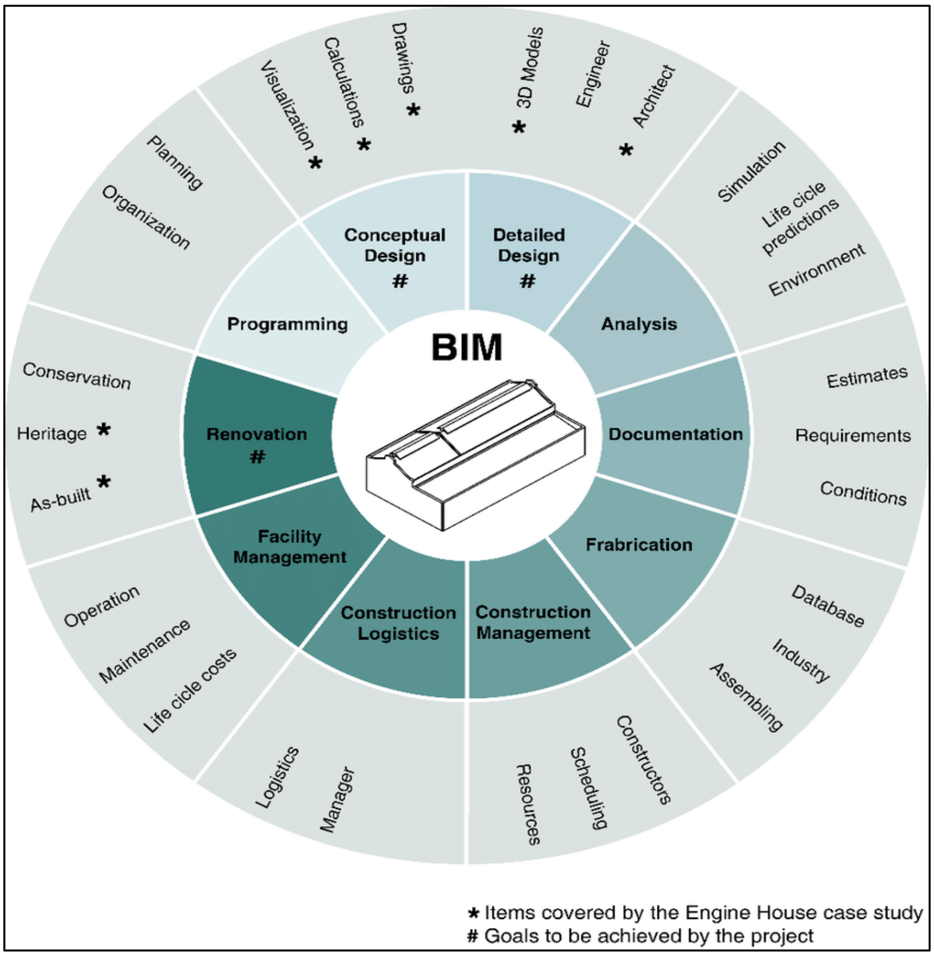

Figure 7. Diagram of a Building Information Modelling (BIM) work process (Gustavo 2020).

7.3. BIM dimensions

In the field of BIM, additional types of information are integrated into the digital model to enhance analysis and improve construction project management efficiency. These extensions, known as BIM dimensions, go beyond 3D geometry, incorporating time, cost, sustainability, and facility management data (BibLus 2024).

The key dimensions of BIM are presented in figure x

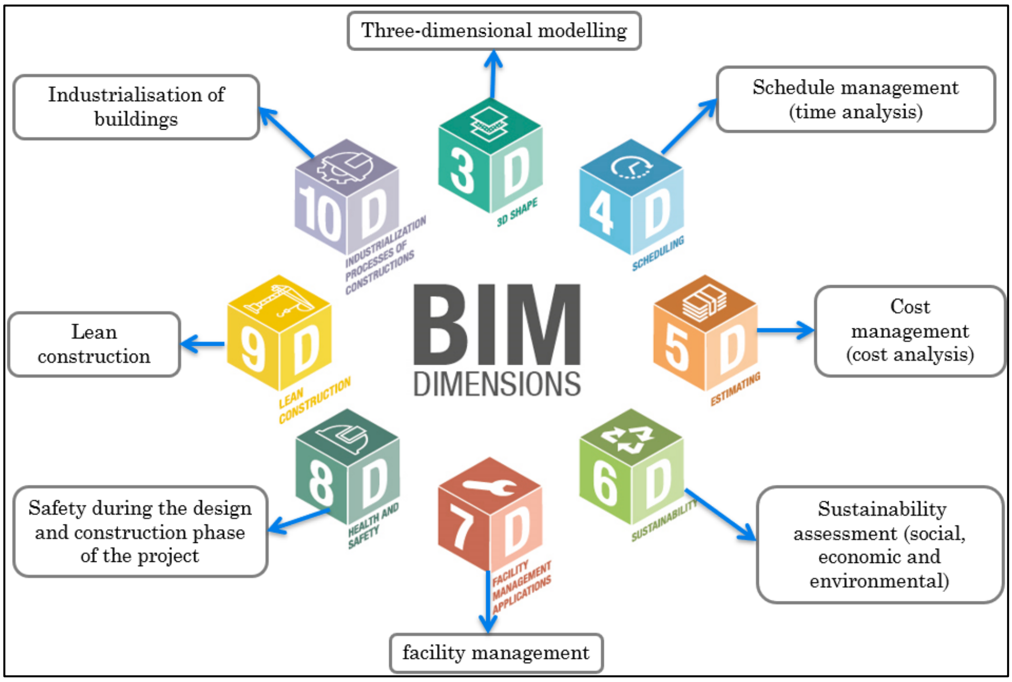

Figure 8. BIM dimensions (Marwah 2023).

7.4. Levels of collaboration (maturity) BIM

BIM Maturity Level of Collaboration refers to the degree of effective integration of Building Information Modelling (BIM) procedures, tools, and standards used in a project or company. Throughout the course of a building or infrastructure asset, it is a measurement of how successfully teams cooperate, exchange information, and make use of digital workflows.

In BIM collaboration, four main levels of maturity can be recognized:

Level 0

At this level, there is no collaboration or model sharing. The work is carried out using traditional 2D CAD drafting, along with paper-based or simple electronic documents.

Level 1

This level involves partial collaboration among project stakeholders. Both 2D and 3D CAD tools are used, primarily for conceptual work. However, models are not yet fully shared or integrated.

Level 2

Collaboration exists at this stage. Each participant works on their own discipline-specific model, and these models are shared using standardized formats (such as IFC) and then combined into a federated model for coordination and clash detection.

Level 3
This level represents complete collaboration through an integrated digital model. All stakeholders work simultaneously on the same model in real time, using a cloud-based collaborative platform. This level supports the entire lifecycle of the building, from design to operation.

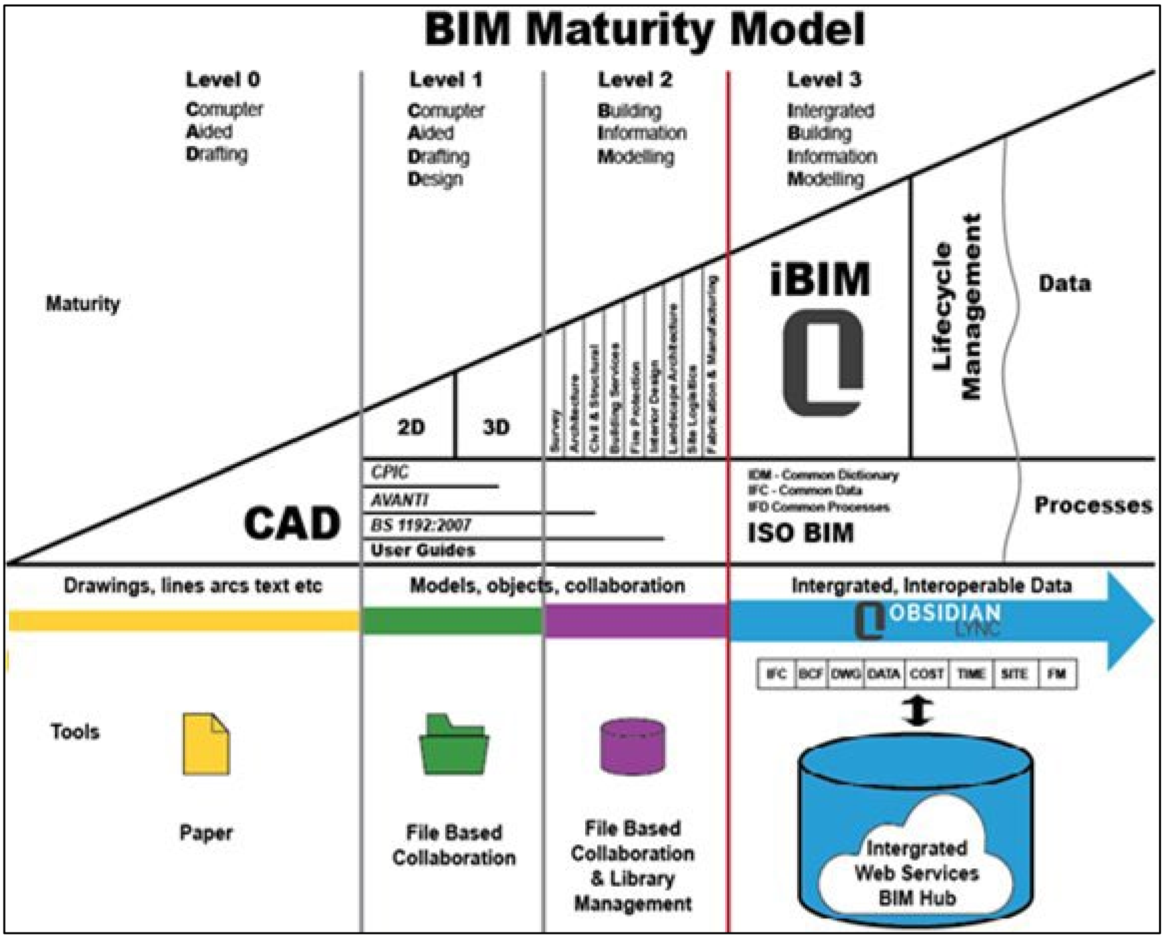

Figure 9. BIM Maturity Level (Kristýna et Vladimir 2017).

7.5. Level of development

In the realm of BIM, the acronym LOD, denoting Level of Detail or Level of Development, refers to the accuracy, clarity, and dependability of a BIM model during different phases of a project. As the Level of Detail (LOD) increases, the model's precision and complexity enhance correspondingly. The LOD framework defines the expected content of the BIM model throughout the project lifecycle. As the project evolves—from an early conceptual design to a fully detailed construction model—the LOD increases accordingly, incorporating more precise geometry and enriched data.

LOD is composed of two complementary dimensions:

- LOG (Level of Geometry): Refers to the visual and geometric representation of model elements.
- LOI (Level of Information): Refers to the non-graphical data and attributes attached to the model elements.

The following points summary the LOD in the BIM (Autodesk 2025)

- **LOD 100 – Conceptual Model**: Represents basic shape and size without detailed information; conveys the overall design intent.
- **LOD 200 – Schematic Design**: Includes approximate quantities, sizes, shapes, and locations to analyze spatial relationships and early designs.
- **LOD 300 – Detailed Design**: Provides accurate geometry, dimensions, and object components; used for construction documentation and coordination.
- **LOD 350 – Construction Documentation**: Contains detailed assemblies and fabrication/construction data; supports execution planning.
- **LOD 400 – Fabrication and Assembly**: Fully detailed model with specific connections and assemblies, ready for manufacturing and on-site assembly.
- **LOD 500 – Facility Management**: Reflects the as-built conditions with information on installed and operational components for maintenance and facility management.

7.6. BIM Professions

BIM management requires a dedicated team structure, divided according to the responsibilities of each profession involved in designing and constructing a building within the BIM process. Rather than being the responsibility of a single person, BIM management is typically composed of a BIM Manager, one or more BIM Coordinators, and one or more BIM Modelers.

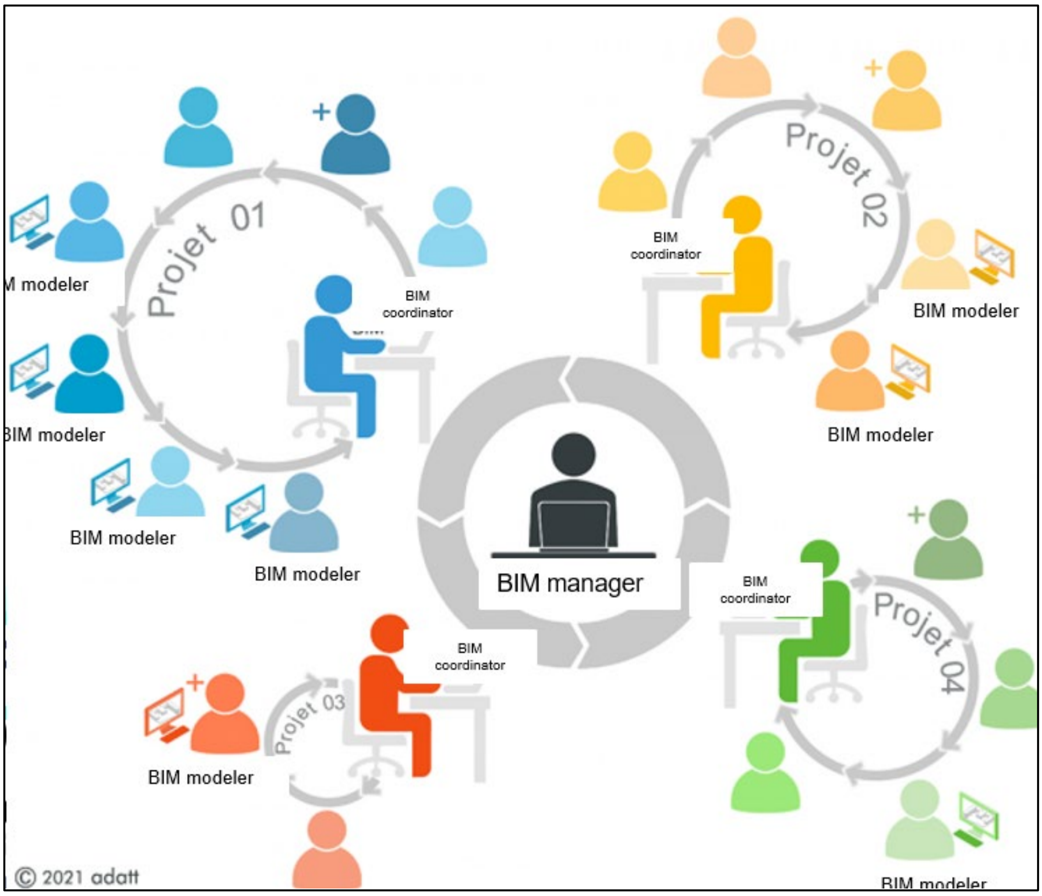

Figure 10. BIM team (« BIM Manager - Adatt » 2022).

7.6.1 BIM Manager

Often considered the lead digital modeler, the BIM Manager is responsible for implementing, managing, and coordinating the BIM process—a collaborative engineering workflow based on a shared model used by the various stakeholders of a construction or civil engineering project.

The main objectives are to enhance project management and monitoring, facilitate informed decision-making, and ensure control over costs, technical challenges, regulations, and environmental constraints.

Throughout the project, the BIM Manager:

- Oversees the optimization of the BIM process,
- Coordinates and manages teams,
- Leads meetings,
- Prepares reports and technical summaries.

7.6.2 BIM Coordinator

Also known as the Model Manager, the BIM Coordinator is responsible for supervising the BIM Modelers within their organization. They ensure the accuracy and quality of the models produced and manage their exchange with external stakeholders.

As the BIM point of contact for a specific construction package, the coordinator:

- Manages and coordinates the digital models handled by the company,
- Guides modelling practices to align with the **project's BIM Execution Plan (BEP)**,
- Verifies compliance and consistency in modelling and parameterization.

7.6.3 BIM Modeler

Also referred to as BIM Technician or BIM Designer, the BIM Modeler creates the 3D elements that form the digital building model.

With similar technical expertise as traditional 2D designers, BIM Modelers are also capable of:

- Integrating the digital data required at each phase of the project,
- Ensuring the consistency of deliverables extracted from the model, such as bills of quantities, plans, and schematic diagrams.

8. Technologies Used in BIM

In recent years, significant technological advancements have led to the development of various BIM tools and technologies, enhancing efficiency across a building's lifecycle.

8.1. Parametric modelling

Parametric modelling is a design approach that uses parameters and constraints to create 3D models of objects or structures. This method involves defining rules and relationships that govern the model's geometry and behaviour. When parameters are modified, the software automatically adjusts the design accordingly. Widely used in architecture, engineering, and product design, parametric modelling enables efficient design iterations and simplifies updates, making it easier to explore different design options.

8.2. Interoperability

Interoperability refers to the ability of different BIM applications to communicate and exchange data effectively. This allows users to work across platforms without needing deep knowledge of each software's specific characteristics. Open BIM standards aim to enhance performance and design quality by promoting interoperability. These non-proprietary protocols, such as Industry Foundation Classes (IFC), COBie (Construction Operations Building Information Exchange), ifcXML, and BIM Collaboration Format (BCF), facilitate collaboration among software applications and stakeholders in the construction industry through standardized data formats (Eastman 2011).

8.3. Open BIM and Closed BIM

These concepts revolve around the choice of software and data formats used in project development. Open BIM involves exchanging digital models through standardized formats like IFC, enabling interoperability among project participants who may use different software. In contrast, Closed BIM relies on proprietary formats from specific software vendors, requiring all participants to use the same platform.

8.4. Cloud-Based BIM Technology

Cloud and mobile technologies enhance the efficiency of standalone BIM tools by enabling project teams to collaborate through continuous information flow. Cloud computing platforms allow for advanced analysis, leading to cost-effective computational applications and communication systems. Connected BIM offers several advantages, including a unified platform that supports architecture, engineering, and construction professionals in managing multidisciplinary models within a common data environment (CDE).

8.4.1 Digital Twin

A digital twin in BIM is a digital replica of a physical building or infrastructure. This virtual model includes not only 3D geometry but also comprehensive data about the structure, such as architectural, structural, mechanical, electrical, and plumbing (MEP) details, material specifications, and real-time sensor data. Digital twins provide a dynamic representation that can be used for monitoring, analysis, and optimization throughout a building's lifecycle (Tran Duong et Sanjeev 2023).

8.5. BIM Tools and Software

BIM software can be categorized into **three main usage groups**, depending on the user's role in the building lifecycle:

8.5.1 Software for Building Owners and Managers

This category focuses on monitoring design development, managing costs and schedules, and overseeing the facility throughout its lifecycle. It also allows owners to compare planned models with actual construction and maintain control over data access.

Examples: *Autodesk BIM 360 Ops, ArchiFM, Planon*

8.5.2 Software for Engineers and Architects

These tools support visual design, structural modelling, and system simulations. They help professionals evaluate energy performance, mechanical systems, and acoustics, allowing for accurate, data-driven design decisions from the early stages.

Examples: *Revit, ArchiCAD, Rhino + Grasshopper, SketchUp, IES VE, DesignBuilder*

8.5.3 Software for Construction Managers

Designed for project execution, this software helps manage scheduling, cost estimation, clash detection, and logistics. It improves coordination on-site and ensures smoother, more efficient construction processes.

Examples: *Navisworks, Synchro, Primavera P6, Buildertrend, CostOS*

8.6. Virtual Reality and Augmented Reality

Virtual Reality (VR) and Augmented Reality (AR) are two advanced technologies that play a significant role in the BIM (Building Information Modelling) process.

Virtual Reality (VR) uses computer simulations to immerse users in an interactive environment, allowing them to experience and explore virtual worlds as if they were real. This technique is commonly used in architecture and construction to evaluate both the outside and interior designs of buildings. It allows designers, clients, and stakeholders to virtually walk around and interact with a place prior to construction, which aids in the identification of design challenges and improves decision-making. VR provides a more intuitive knowledge of size, spatial connections, and user experience, making it an effective tool for design validation and presentation.

Augmented Reality (AR) improves real-world views by displaying digital information, which is often accessed via mobile devices or PCs. In architecture and construction, AR is utilised for maintenance by providing technicians and facility managers with real-time, interactive overlays of building systems, equipment, or infrastructure. AR facilitates troubleshooting, improves accuracy, and reduces downtime during maintenance or repairs by visualising essential data, such as schematics, manuals, or sensor readings, right on the actual asset.

8.7. Robotics and Drones

In the BIM process, robots and drones play critical roles in improving construction, surveying, and other associated processes. These technologies are transforming the industry via increased efficiency, precision, and safety.
Drones have gained popularity in construction because to their speed, accuracy, and cost-effectiveness. They are used for quick site surveys, 3D mapping, volume measurements, and real-time progress tracking. Drones can enable safe access to difficult-to-reach regions such as bridges, large buildings, and distant sites, ensuring reliable data gathering while minimising worker danger. Furthermore, drones are useful for analysing staff productivity and following building progress.

Robotics, such as those used in masonry or 3D concrete printing, are also revolutionising the building sector. These robots can do repetitive or risky tasks, increasing efficiency, accuracy, and safety on the jobsite. Robots employed in 3D concrete printing, for example, can produce complex construction components fast and precisely, saving manual labour and material waste.

Advanced instruments, such as the Leica RTC360 camera, are also useful in the BIM process. These cameras can do extensive 3D scanning of urban surroundings, which is very important for reconstruction and rehabilitation operations. They provide accurate modelling and analysis for restoration or retrofitting work by collecting exact data from existing buildings.

9. Smart building

An intelligent building is one that uses technology to enable efficient and economical use of resources, while creating a safe and comfortable environment for occupants. Intelligent buildings can use a wide range of existing technologies, and are designed or retrofitted to allow for the integration of future technological developments.

This process begins at the design stage, using virtual buildings modelled through BIM.

9.1. Smart building components

A smart building uses a network of intelligent sensors and automated systems to manage key functions like energy generation, metering, HVAC, lighting, and security. These systems are coordinated through a building automation system that controls smart appliances, sensors, and actuators to improve the comfort and well-being of occupants. Examples include smart thermostats, lighting, refrigerators, smoke detectors, video cameras, air conditioners, and window/door sensors.

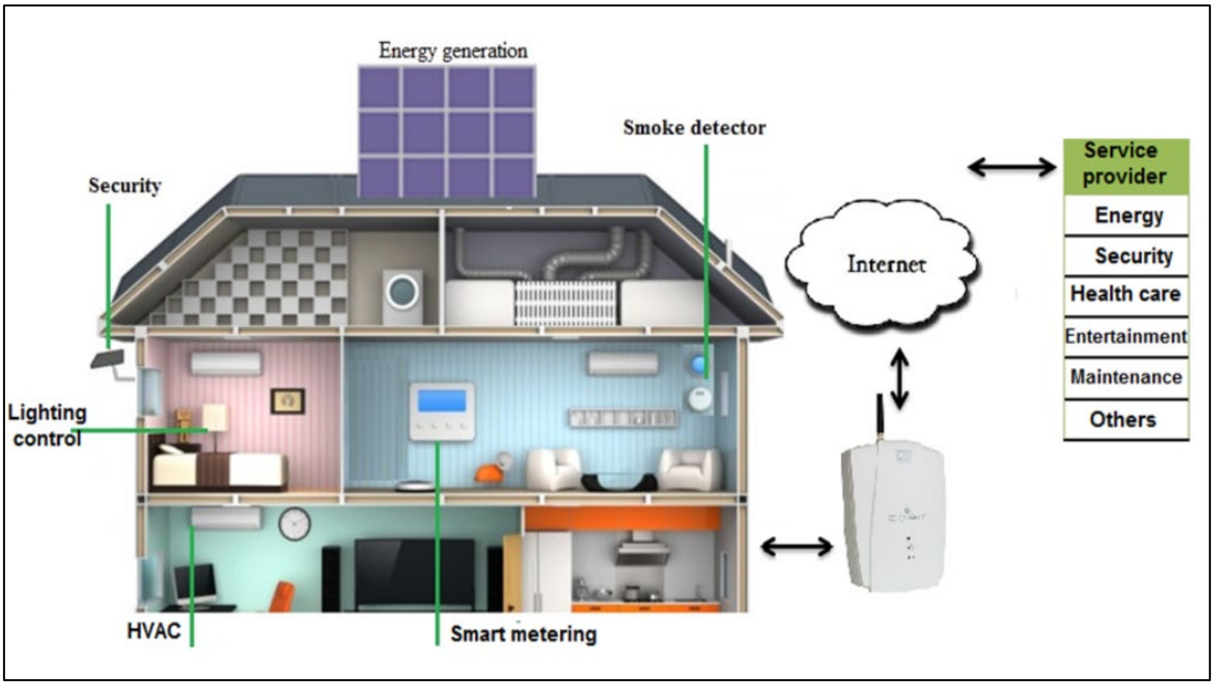

Figure 11. Smart appliances, sensors, and actuators in a smart residential building (Qolomany et al. 2019).

At the core of smart buildings, four main technological components can be recognized:

9.1.1 Internet of Things (IoT)

IoT stands for the Internet of Things and is closely linked to the concept of smart environments. More precisely, it forms the foundation of a smart building. IoT refers to a network of physical devices connected via the internet—whether wirelessly or through cables—whose purpose is to communicate with other devices, actuators, and sensors. These devices collect data from the building and enable real-time responsiveness and automation.

9.1.2 Connectivity

Connectivity is what enables real-time data exchange between devices. Communication among all smart systems is made possible through internet-based technologies. Wi-Fi, cellular networks, and other communication protocols act as the digital glue that connects all components within a smart building, ensuring seamless interaction and data transfer.

9.1.3 Artificial Intelligence (AI) Solutions

AI acts as the "brain" of the smart building. With AI-powered algorithms, raw data collected from IoT devices is processed and translated into meaningful insights. AI filters and interprets large volumes of structured and unstructured data to generate useful outputs. For example, AI can alert occupants if room temperature or humidity exceeds comfort levels, notify maintenance needs, or signal when parking spaces are unavailable.

9.1.4 Control Centre

The control centre is the interface where data is monitored and managed. It is typically a centralized software platform with a user-friendly dashboard, accessible from computers or mobile devices. This centre allows users to supervise building systems, make adjustments, and respond to alerts in real time, ensuring efficient building operation.

9.2. Example of Smart building: The Edge building

The Edge is an office building constructed in 2014 in Amsterdam, The Netherlands. Designed by PLP Architecture and built by a company specializing in large-scale projects, the building spans 40,000 m² and houses the international service firm Deloitte. It serves as a showcase of Deloitte's global transition towards the "digital era."

The building integrates the Internet of Things (IoT) as its foundational principle, using smart technologies to enhance efficiency and functionality. Although The Edge did not follow the traditional Building Information Modelling (BIM) process during its construction, it benefits from many of BIM's advantages through the incorporation of advanced smart technologies. These technologies enable seamless connectivity and operation, bringing the building closer to a true smart building.

The Edge is considered the smartest and greenest building in the world, combining cutting-edge technology with sustainable design. A custom smartphone app connects users to the building's intelligence, managing personal preferences, workspaces, lighting, temperature, and parking in real time. This app provides users with a highly efficient and personalized experience (Aftab, Ron, et Michael 2019).

With a Desktop Sharing System, 2,500 employees share 1,000 desks, fostering collaboration through shared spaces and spontaneous interactions. The design optimizes the work environment for comfort and productivity.

From a maintenance perspective, all building systems—lighting, elevators, HVAC, even coffee machines—are centrally monitored. Real-time data from thousands of sensors improve maintenance efficiency, reduce costs, and align with BIM methodology, which is mandatory for public projects in the Netherlands since 2012.

Environmentally, The Edge is a net-positive energy building, utilizing geothermal energy and the largest solar panel system in Europe. It consumes 70% less energy than typical office buildings and achieved a record BREEAM sustainability score of 98.4%.

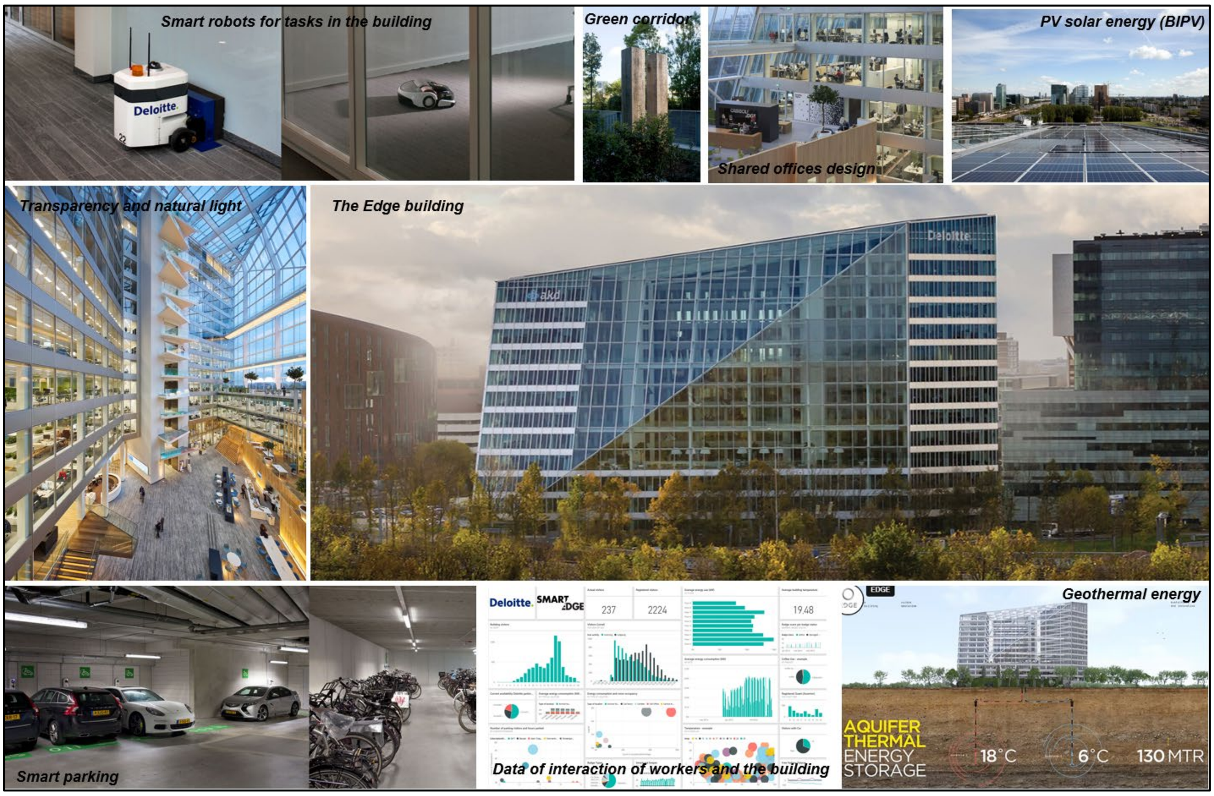

Figure 12. The edge building and Its concepts (Author and (« The Edge » 2024)).

For a comprehensive visual overview of The Edge building, you can watch the following video: https://swissroc.ch/fr/the-edge-le-batiment-le-plus-intelligent-du-monde/

https://www.smartautomationmag.com/index.php/videos/smart-buildings-the-edge-building

10. Conclusion

ICT has redefined architecture, bridging design and technology for smarter outcomes. BIM, IoT, and AI optimize workflows, reduce errors, and improve sustainability. As digital tools evolve, they promise greater efficiency and innovation in the AEC sector. The future lies in integrated systems like digital twins and smart buildings. Embracing these technologies is key to resilient, adaptive architecture.

Lesson 4: Smart Cities and Their Technological Systems

1. Introduction

Cities have long been the centre of human civilization, driving economic, social, and cultural progress. As technological advancements have rapidly progressed, urban areas have evolved, transforming traditional cities into smart cities. The integration of Information and Communication Technologies (ICTs) and the Internet of Things (IoT) into urban planning, management, and services is reshaping cities into more efficient, sustainable, and participatory environments. Smart cities leverage these technologies to improve quality of life, address challenges like urban growth, and promote ecological sustainability.

2. Historical presentation

Historically, cities have always been at the heart of economic, social and cultural activity. Over the centuries, they have constantly evolved under the influence of many factors, not least technological progress. Over the last two centuries, urban planning has undergone profound changes in terms of design, planning and management, guided by the development of information and communication technologies (ICTs).

The rapid development of these technologies has enabled the gradual transformation of traditional cities into smart cities. By digitising urban functions such as mobility, energy, public services, the environment and governance, ICTs promote more efficient, sustainable and participative management of urban space.

In this way, the smart city is emerging as an innovative response to contemporary challenges: urban growth, ecological transition, improving quality of life and optimising resources.

3. Definition of smart city

A smart city is an urban area that leverages Information and Communication Technologies (ICT), sensors, and Artificial Intelligence (AI) to enhance operational efficiency, optimize public services, and improve citizens' quality of life. Its development begins with a digital infrastructure that evolves over time through advanced technologies.

According to (Yin et al. 2015) a comprehensive smart city framework should consider four key perspectives:

- Technical Infrastructure – Reliable ICT, IoT sensors, and connectivity.

- Application Domain – Smart solutions in transport, energy, healthcare, etc.
- System Integration – Seamless interaction between different urban systems.
- Data Processing – Real-time analytics and AI-driven decision-making.

At its core, a smart city transforms traditional urban spaces through data-driven governance, sustainability, and citizen engagement.

The evolution towards a smart city often begins with the development of a digital city, which over time integrates advanced technological solutions to become more connected, sustainable and resilient.

IBM one of the world's largest technology companies, specializes in hardware, software, cloud computing, data analytics, and tech innovation defines "*A smart city is an urban area where technology and data collection help improve quality of life as well as the sustainability and efficiency of city operations. Smart city technologies used by local governments include information and communication technologies (ICT) and the* internet of things *(IoT).*"(Alice et Alexandra 2023)

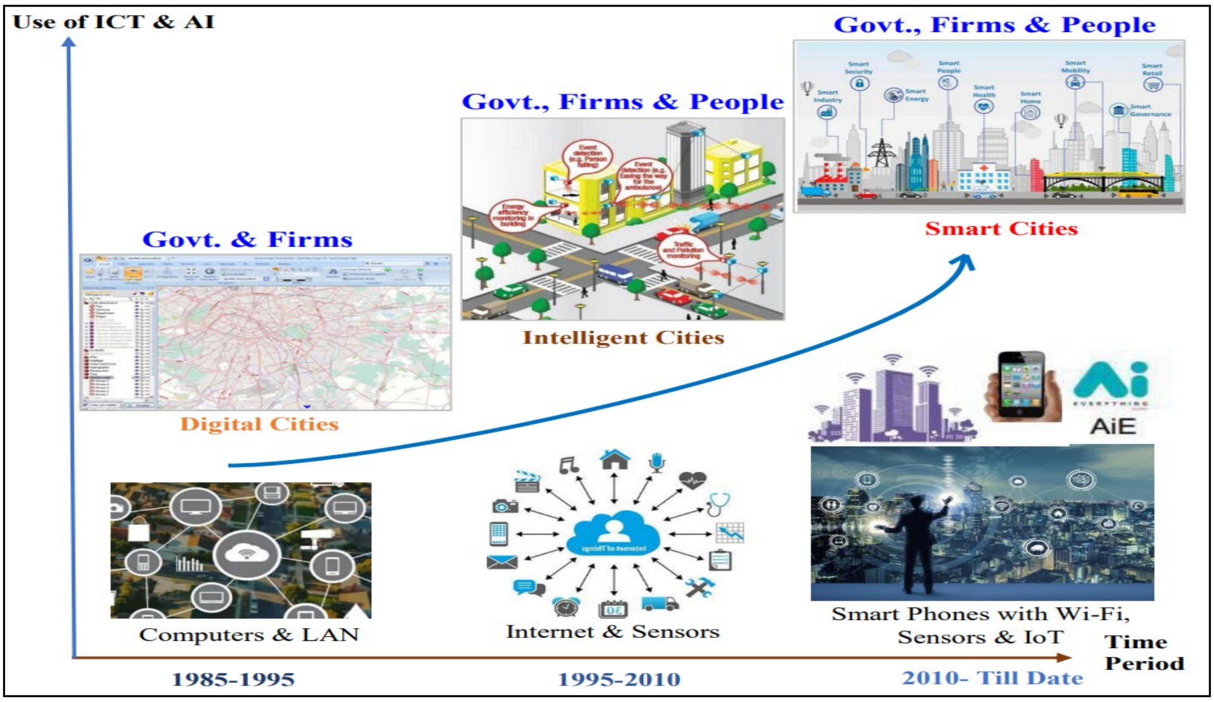

Figure 13. The development from digital cities to smart cities (Das 2020).

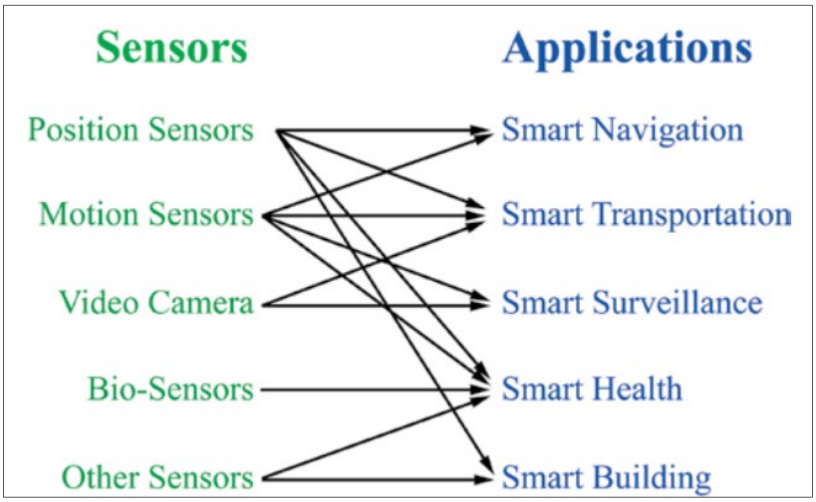

Figure 14. Sensors & Related ICT Services in the Heart of Smart Cities (Das 2020).

4. Smart city objective

The main objective of a smart city is to optimize urban functions and promote economic growth while improving the quality of life for citizens through smart technologies and data analysis. The true value lies in how this technology is used, rather than the amount of technology available.

The main objectives of a smart city can be summarized in the following four points:

Technological Advancements: Integration of AI and IoT improves urban systems like traffic and waste management, increasing efficiency and reducing costs.

Urban Sustainability: Use of renewable energy, smart grids, and green infrastructure reduces carbon emissions and enhances environmental resilience.

Social Inclusivity: Policies supporting affordable housing, accessible transportation, and citizen engagement promote equity and community well-being.

Economic Growth: Digital infrastructure and smart technologies attract investment, support innovation, and create jobs, boosting local and national economies.

5. Technologies and smart systems for smart City

At the all its scales and infrastructures, the smart city accounted for numerous technologies and smart systems,

5.1. Geospatial technologies

Geospatial technologies in smart cities are tools that gather, analyse, and visualise location-based data to help with urban planning, management, and decision-making. Geographic

Information Systems (GIS), Global Positioning Systems (GPS), and remote sensing are among the technologies that assist municipal officials in understanding spatial linkages and trends throughout the urban environment. Geospatial technologies are critical in fields such as traffic management, environmental monitoring, land use planning, and emergency response because they provide precise and real-time information on the location and movement of people, vehicles, infrastructure, and natural resources. In the context of smart cities, they allow more effective service delivery, enhance data-driven governance, and help to create sustainable and well-organised urban landscapes.

5.2. Artificial intelligence

Artificial Intelligence (AI) refers to the simulation of human intelligence processes by machines, particularly computer systems. In general, AI systems function by ingesting large amounts of labelled training data, analysing the data to identify patterns, correlations, and solutions, and using these models to make predictions about future states.

Artificial intelligence (AI) for Smart Cities is the use of intelligent algorithms and data-driven technology to improve the efficiency, sustainability, and liveability of urban areas. AI provides real-time analysis of data from a variety of sources, including IoT sensors, cameras, and linked devices, to improve services such as traffic management, energy consumption, garbage collection, public safety, and city planning.

5.3. Internet of Things (IoT) and sensors

The Internet of Things (IoT) in the context of a smart city refers to a network of interconnected physical objects, sensors, and systems that interact and share data via the internet. These devices capture, transmit, and analyse data in real time, allowing for better control of urban services and resources including traffic, trash, energy, water, and public safety. IoT integration enables cities to increase operational efficiency, reduce costs, improve inhabitants' quality of life, and promote sustainability by optimising resource utilisation. Smart traffic lights, smart electricity and water meters, and environmental monitoring systems are some examples of IoT applications in smart cities.

5.4. Blockchain and Cybersecurity

Cybersecurity in smart cities is the securing of digital systems, networks, and data utilised in urban services from cyber threats such as hacking, data theft, and system assaults. It guarantees that smart city technology such as networked traffic lights, energy systems, and public services run smoothly, securely, and without interruption.

Blockchain in smart cities is a decentralised and secure digital technology that records and verifies transactions or data transfers across systems. Because blockchain information cannot be readily manipulated, it contributes to increased trust, transparency, and security in services such as digital identification, smart contracts, supply chain management, and public records.

5.5. Smart urban system

A Smart Urban System is a network of digital technology, infrastructure, and services that collaborate to improve municipal operations. Data from sensors, IoT devices, and communication networks are used to monitor and optimise urban services, including transportation (smart traffic, public transit), energy (smart grids, renewable energy), water and waste management, public safety and health, and environment monitoring. These systems make real-time decisions to improve efficiency, lower expenses, promote sustainability, and improve inhabitants' quality of life.

5.6. Citizen Engagement and Governance Platforms

Citizen Engagement and Governance Platforms are digital tools and platforms that allow citizens to communicate with local officials, make decisions, and contribute to the growth of their community. These platforms enable online voting or surveys on urban projects; reporting concerns such as broken lighting or garbage problems; accessing public data and city services; and participating in community debates or planning.
Smart cities use these platforms to promote openness, inclusivity, and collaborative governance, ensuring that residents have an active role in creating municipal policies and solutions.

6. Smart city characteristics

A smart city is defined by six interconnected characteristics that aim to improve urban living through innovation, technology, and inclusive governance (Bee smart city 2024).

- Smart Government focuses on enhancing interactions between municipalities and citizens through transparency, digital services, and collaborative tools like co-creation and crowdsourcing.
- Smart Economy aims to create a dynamic, sustainable, and competitive local economy by attracting talent, fostering innovation, and supporting start-ups through digital transformation and strategic development.

- Smart Environment involves sustainable urban planning and the use of technology to manage natural and built environments efficiently—reducing pollution, waste, and emissions while improving resilience and energy use.
- Smart Living seeks to enhance quality of life for all demographics through better housing, healthcare (eHealth), safety, social inclusion, and accessible technology (like IoT and smart buildings).
- Smart Mobility targets efficient, eco-friendly urban transportation by promoting multi-modal transport systems, electric and shared vehicles, and infrastructure that supports smooth mobility for all citizens.
- Smart People emphasize education, digital inclusion, and civic engagement. It supports lifelong learning, creativity, open-mindedness, and public participation as foundations for innovation and prosperity in the city.

7. Conclusion

Smart cities represent the future of urban development, blending technology and sustainability. ICT, IoT, and AI optimize resources, services, and quality of life. From geospatial tools to citizen platforms, innovation fosters inclusive, resilient communities. The journey from traditional to smart cities is a global priority. Embracing these changes ensures greener, more efficient urban spaces.

Lesson 5: The Role of Geographic Information Systems in Urban Development

1. Introduction

Geographic Information Systems (GIS) play a vital role in the development and management of smart cities by enabling the effective use of spatial data. This lesson defines GIS and explains its key characteristics, emphasizing its role in urban planning, resource management, and real-time decision-making. GIS is a powerful tool for capturing, analyzing, and visualizing geospatial data, helping urban planners, engineers, and policymakers make informed choices. As cities continue to grow and evolve, GIS becomes indispensable for understanding complex spatial relationships, optimizing urban systems, and driving the development of smart cities.

2. Geographical information system

A Geographic Information System is an IT tool for capturing, storing, querying, analysing and displaying geospatial data. Geo-spatial data describes both the location and the attributes of spatial features. For example, to describe a road, we refer to its location (i.e. where it is) and its attributes (e.g. length, name, speed limit and direction). In the context of smart cities, GIS helps planners, engineers, and decision-makers visualize and understand complex spatial relationships by layering different types of data, such as transportation networks, land use, population distribution, or environmental conditions on digital maps. This allows for better planning, resource management, and real-time problem-solving (Esri France 2024).

3. Geographical references

Geographic information can either contain an explicit geographic reference (such as latitude and longitude or a grid of national coordinates) or an implicit geographic reference (such as an address, postcode, or road name). Geocoding is an automatic process used to convert implicit references into explicit ones, allowing objects and events to be precisely located on the Earth for analysis.

4. GIS components

Geographic Information Systems are made up of six components;

- Hardware

  The physical devices used to run GIS software and store data, such as computers, servers, GPS units, drones, and mobile devices.

- Software

The programs and applications that process and analyse geospatial data. Popular GIS software includes ArcGIS, QGIS, and GRASS GIS.

- Data

The core of any GIS system—this includes spatial data (location-based data like coordinates, maps) and attribute data (descriptive information like names, population, or speed limits).

- Users

Skilled users and analysts who operate the GIS, interpret results, and make decisions. This includes GIS specialists, urban planners, engineers, and decision-makers.

- Methods (Procedures)

The workflows, models, and analytical techniques used to collect, manage, and analyze the data effectively. These ensure accuracy, consistency, and relevance of GIS outputs.

- Network (in smart cities)

Connectivity tools that enable data sharing and communication between GIS systems, especially in cloud-based or web GIS environments.

5. Uses and Applications of Geographic Information Systems (GIS)

The uses of GIS and its applications span multiple fields and support a wide range of situations. Below are the main areas where GIS plays a significant role

- **Mapping and Visualization**

GIS enables the creation of detailed, dynamic maps and visual representations to understand spatial relationships, patterns, and geographic contexts. This function is crucial for identifying trends and communicating complex data effectively.

- **Data Management**

GIS systems are used to collect, organize, and maintain accurate geographic data related to assets, infrastructure, and natural resources. This supports informed planning and efficient resource allocation across various sectors.

- **Field Mobility and Data Collection**

Mobile GIS tools allow field personnel to gather data in real-time and access geographic information on-site. This enhances the accuracy of data collection and supports timely decision-making in dynamic environments.

- **Monitoring and Supervision**

GIS facilitates real-time monitoring of infrastructure, environmental changes, and urban systems through integration with sensor networks and IoT devices. This capability is essential for resource supervision, maintenance, and emergency response.

- **Spatial Analysis**

One of the core strengths of GIS lies in its analytical functions. It allows for the exploration, measurement, and prediction of spatial trends, helping users to model scenarios, assess risks, and optimize planning strategies.

- **Design and Planning**

GIS supports the evaluation of alternative development scenarios and assists in identifying optimal solutions. It plays a significant role in urban design, environmental planning, transportation networks, and infrastructure development.

- **Decision Support**

By integrating and analysing diverse data sources, GIS provides a comprehensive understanding of spatial phenomena. This supports evidence-based decision-making in public administration, environmental management, and business operations.

- **Public Engagement and Communication**

GIS tools are increasingly used to engage citizens and stakeholders by making geographic information accessible and interactive. These platforms facilitate transparency, collaboration, and community participation in urban governance.

- **Data Sharing and Collaboration**

Modern GIS platforms support cloud-based data sharing, allowing various stakeholders—government agencies, researchers, businesses—to collaborate effectively. This improves coordination and fosters innovation across sectors.

6. Geographic Data Models in GIS

Geographic Information Systems (GIS) use two distinct types of geographic models: the vector model and the raster model.

6.1. Raster Data

Raster data, also known as gridded data, represents the Earth's surface as a matrix of equally sized cells (or pixels), where each cell holds a value corresponding to a specific attribute such as color, temperature, elevation, or land cover. This type of data is particularly suited for representing continuous phenomena and is commonly used in remote sensing and environmental analysis. Raster data can be acquired through various means, including scanning, satellite imaging, or aerial photography, and may require processing to be used effectively in GIS.

6.2. Vector Data

Vector data represents geographic features on the Earth's surface using three basic geometric shapes: **points**, **lines**, and **polygons (surfaces)**. This data model is ideal for depicting discrete objects with defined boundaries, such as roads, buildings, or land parcels. Each geometric object is linked to attribute data that provides additional information about the feature it represents.

- **Point:** The simplest vector geometry, a point is used to represent precise locations of small features. At large scales, it can denote individual objects like trees, fire hydrants, or waste bins. At smaller scales, such as a 1:1,000,000 road map, a point might represent an entire city or regional capital.

- **Line:** A line (or polyline) represents linear features such as roads, rivers, pipelines, or networks for communication, energy, water, and sewage. Lines can also represent abstract or conceptual paths, such as the axis of a road or the flow of information or financial transactions.

- **Polygon (Surface):** A polygon represents areas with defined boundaries. It may depict real-world geographic entities such as lakes, forests, or urban zones, or more abstract administrative areas like municipalities or zoning districts.

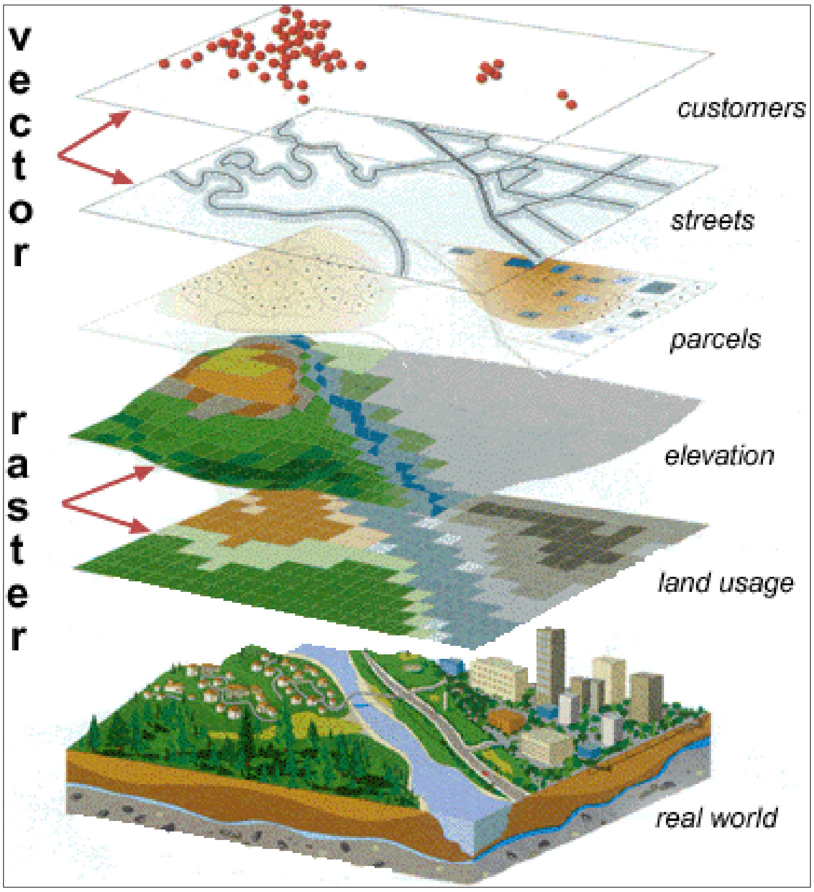

Figure 15. Raster and vector data for GIS (Eyes in the Sky 2010).

7. Data Acquisition Modes in GIS

In a Geographic Information System (GIS), data acquisition refers to the procedures by which spatial and attribute data are gathered and entered into the system. GIS analysis' accuracy and reliability are heavily influenced by data quality and source. GIS data may be gathered in a variety of ways, the main modes include:

- **Direct Data Collection (Primary Data)**

Field-based techniques using tools like GPS, theodolites, or mobile survey apps allow real-time collection of accurate geospatial data. These methods are essential for up-to-date and localized studies.

- **Topographic Surveys (Theodolite Measurements)**

A theodolite is an optical instrument used to measure horizontal and vertical angles. It is used in triangulation to determine accurate positions of physical features and boundaries from a fixed point.

- **Remote Sensing (Aerial Photography and Satellite Imagery)**
    - **Aerial Photos** involve capturing a set of overlapping images to create a complete view of an area, which helps identify **coordinates and elevation (altimetry)**.
    - **Satellite Imagery** provides extensive raster data for land use, vegetation, and environmental monitoring.
    - **Radar Imagery** captures surface characteristics by interpreting wave reflections, useful even in cloudy or nighttime conditions.

- **Global Positioning System (GPS)**

GPS (Global positioning system) devices use satellite signals to determine accurate geographic locations. Modern GPS tools can achieve centimetre-level accuracy, making them valuable for land surveys, infrastructure mapping, and mobile data collection.

- **Digitisation (for Vector Data)**

Digitisation involves tracing features from paper maps or scanned documents into digital vector format (points, lines, polygons). It preserves spatial geometry and allows editing. Preprocessing may be required if the source is cluttered.

- **Scanning (for Raster Data)**

Scanned maps convert physical documents into raster images. When georeferenced, they can be used for spatial analysis. This method is fast and cost-effective but may introduce distortions from the original material.

- **Importing Existing Digital Data**

GIS software allows importing of pre-existing datasets in formats such as shapefiles, GeoJSON, DXF, or CSV. These may come from government agencies, scientific repositories, or open-source platforms.

- **Standard Data Exchange Formats**

For interoperability and long-term use, GIS supports standard formats (e.g., GML, KML), which facilitate data sharing between systems and institutions.

- **Crowdsourced Data / Volunteered Geographic Information (VGI)**

Community-driven data collection via platforms like OpenStreetMap allows users to contribute geospatial information. It is cost-effective and widely used in humanitarian and urban contexts, though it may require verification.

8. GIS Software

Geographic Information System (GIS) software includes digital tools and platforms for capturing, storing, managing, analysing, and visualising geographic data. These software tools enable users to construct maps, do spatial analysis, maintain geographic records, and make decisions in a variety of sectors, including urban planning, environmental monitoring, transportation, public health, and others.

Common Examples of GIS Software:

- ArcGIS (by Esri): A comprehensive, widely-used commercial GIS platform for mapping and spatial analysis.
- QGIS (Quantum GIS): An open-source alternative to ArcGIS, offering powerful tools and extensibility through plugins.
- GRASS GIS: An open-source tool for geospatial data management and analysis, used in academia and research.
- MapInfo Professional: A commercial GIS application used for business and location intelligence.
- Google Earth Engine: A cloud-based platform for planetary-scale geospatial analysis.
- AutoCAD Map 3D: A GIS-based extension of AutoCAD used primarily in engineering and infrastructure projects.

- GeoServer: An open-source server for sharing and editing geospatial data.

9. Conclusion

In conclusion, Geographic Information Systems (GIS) are at the heart of smart city development, offering valuable insights into the dynamic and interconnected systems that make up urban environments. By leveraging GIS technologies, cities can enhance their planning processes, improve resource management, and engage citizens in the governance of urban spaces. As the demand for sustainable and resilient urban environments increases, GIS will continue to play a critical role in shaping the cities of the future. Understanding the principles and applications of GIS is essential for anyone involved in the design, management, and governance of urban areas, particularly in the context of smart city initiatives.

Lesson 6: City Information Modelling (CIM) and Its Role in Smart Cities

1. Introduction

This lesson defines City Information Modelling (CIM) and explores its characteristics, highlighting its importance in modern urban planning. CIM integrates various technologies and data sources to support the planning, design, and management of urban environments. It enables enhanced decision-making and contributes to the development of smart cities by providing a comprehensive digital framework for urban systems.

2. City information model (CIM)

City Information Modelling (CIM) is a digital framework in urban planning that functions similarly to Building Information Modelling (BIM) in construction. It is a computerised knowledge model that integrates processes, policies, and technologies to support the planning, design, and management of urban environments. CIM represents a 3D evolution of Geographic Information Systems (GIS), enriched with multi-scale visualisations, tools for drawing and describing 3D elements, and the ability to model their interrelationships within the urban context (Dantas, Sousa, et Melo 2019; Al-Sayed 2015).

CIM combines large-scale geospatial data (GIS), detailed architectural and infrastructural data (BIM), and real-time inputs from the Internet of Things (IoT) to create a holistic, data-rich model of the city. This model enables simulation, analysis, and coordination across various urban systems, making CIM a key component of smart city strategies, urban sustainability, and informed decision-making.

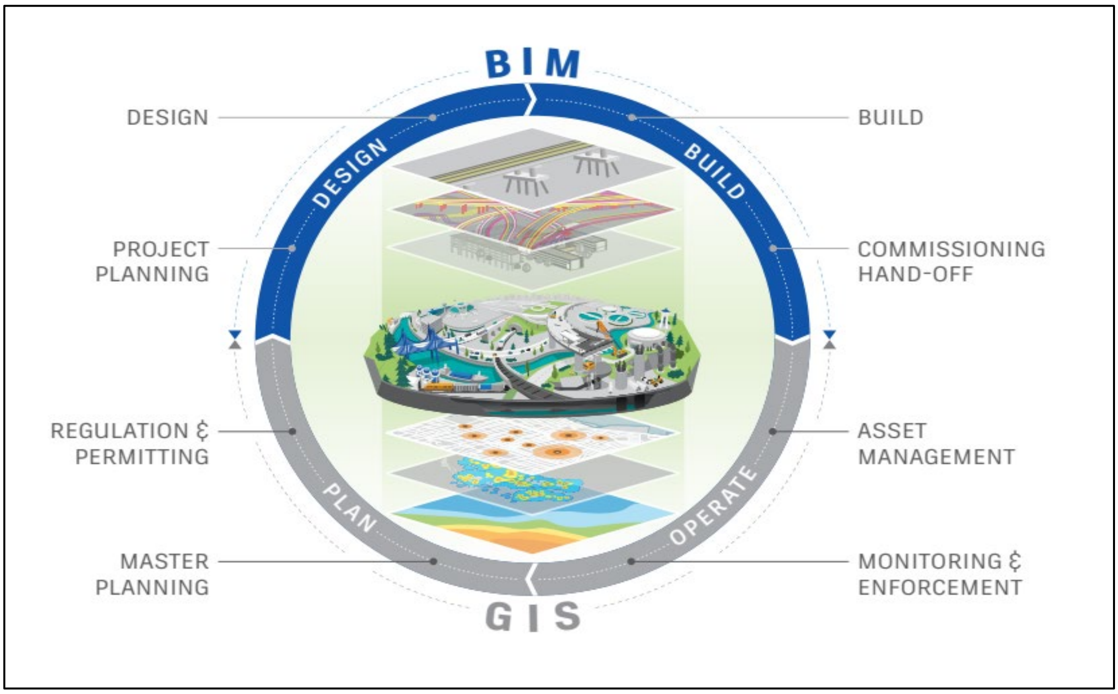

Figure 16. Combination of BIM and GIS for CIM production (Patel 2022).

City Information Modelling (CIM) and Urban Digital Twins (UDT) are emerging technologies that play a key role in advancing smart city development. These systems support a wide range of functions, including data integration, urban analysis, design, simulation, and modelling. By fostering collaboration among various stakeholders, they contribute to building cities that are more sustainable, inclusive, healthy, prosperous, and participatory. Relying on open standards and comprehensive multiscale, multitemporal databases, CIM and UDT enable the integration of diverse data sources to capture and represent the full complexity of urban systems, features, and dynamics.

In the context of cities and urban environments, Big Data serves as a powerful tool for understanding, managing, and enhancing urban life. It enables the real-time collection of information from various sources such as traffic systems, GPS, surveillance cameras, and more. The integration of Big Data within City Information Modelling (CIM) addresses the challenges of analysing and processing vast and complex datasets in the urban context.

Big Data is typically stored and managed using advanced digital infrastructure, often referred to as urban data platforms or cloud-based data ecosystems.

Moreover, since CIM aims to support the operation of the entire city, Big Data provides flexible and scalable models for evaluating and analysing key urban themes—such as population dynamics, transportation networks, industrial activities, and public services. (iec 2021).

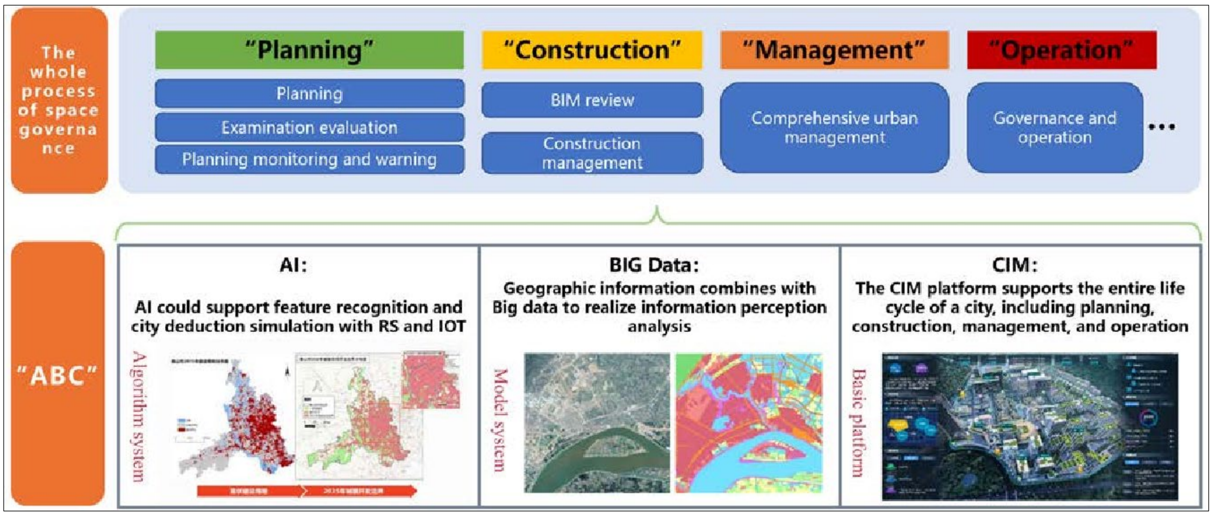

Figure 17. CIM technologies (iec 2021).

3. City Information Modelling (CIM) Tools

City Information Modelling (CIM) technologies are advanced digital platforms for modelling, analysing, and managing three-dimensional urban settings. They integrate geospatial data, develop information models, and provide real-time urban data. These tools facilitate long-term urban planning, smart infrastructure management, and stakeholder collaboration.

Common CIM Tools and Platforms:

- Esri CityEngine: A powerful tool for 3D modelling of urban environments, supporting procedural modelling and integration with GIS data.
- Autodesk InfraWorks: Used for infrastructure planning and design, allowing the visualization of large-scale city projects in 3D with real-world context.
- Bentley OpenCities Planner: A collaborative platform for planning and communicating urban developments through cloud-based 3D models.
- UrbanSim: A simulation platform designed to support urban planning decisions by modelling the impacts of policy on urban development.
- SketchUp (with plugins): While primarily a 3D design tool, SketchUp can be adapted for city modelling through plugins and extensions for geolocation and GIS data integration.
- FZK Viewer / 3DCityDB: Used for managing and visualizing 3D city models in CityGML format, often applied in digital twin and smart city initiatives.
- Unreal Engine / Unity (with GIS/BIM plugins): Game engines increasingly used to create real-time, immersive urban visualizations integrated with geospatial and architectural data.

Figure 18. Bentley Opencities Planner 3D visualisation (« Bentley Opencities Planner » 2025).

4. Interoperability in CIM

Similarly to BIM interoperability, in the context of City Information Modelling (CIM), interoperability refers to the ability of different digital systems, software platforms, data formats, and stakeholders to seamlessly exchange, interpret, and utilize urban data throughout the entire lifecycle of a city's planning, development, and management processes. In urban models, two major open standards that support this interoperability are CityGML and Industry Foundation Classes (IFC).

5. Conclusion

City Information Modelling (CIM) represents a transformative approach in urban planning, offering a comprehensive and dynamic tool for managing complex urban systems. By combining geospatial data, 3D models, and real-time inputs, CIM enables smarter, more sustainable cities. Its ability to support simulations, urban analysis, and collaborative decision-making enhances the capacity of urban planners, engineers, and policymakers to design cities that are more sustainable, inclusive, and resilient. With its growing importance in the development of smart cities, the integration of CIM with other technologies like Big Data and IoT is paving the way for more responsive and efficient urban environments.

Lesson 7: Introduction to Interactive Decision Support Systems (IDSS)in Architecture and Urban Planning

1. Introduction

This lesson introduces Interactive Decision Support Systems (IDSS) and highlights their essential characteristics. SIAD systems play a crucial role in assisting decision-makers in complex, multi-faceted environments, such as architecture and urban planning.

2. Introduction to Definition of Decision Support Systems (IDSS)

The concept of Interactive Decision Support Systems (IDSS), abbreviated in French as *Système Interactif d'Aide à la Décision* **(SIAD)**, has its origins in the work of the Anglo-Saxon school, particularly in the pioneering research of Scott Morton in 1971. The aim of these systems is to support decision-makers in their decision-making process, particularly in complex or poorly structured contexts.

SIADs are based on an interaction between human intuition and computer processing power, combining analytical models, visualisation and interactivity. According to Keen and Scott Morton (1978), ADIS are intended to assist - not replace - human judgement, by improving the quality of decisions rather than just their operational effectiveness (Zaraté 2005).

3. Definition of Decision Support Systems (IDSS)

Decision Support Systems (IDSS) are interactive information technology solutions that help decision-makers make informed decisions. They allow for the analysis of complicated data, the simulation of many situations, and the comparison of alternatives in order to pick the best appropriate solutions based on set objectives.

4. IDSS components

An Interactive Decision Support System (IDSS) is made up of several interdependent components that work together to help decision-makers solve complex problems. The main components are:

4.1. Data Management Subsystem

Collects, stores, and retrieves relevant data.

4.2. Model Management Subsystem

Processes data using analytical models for simulations and predictions.

4.3. Knowledge Engine (Expert Systems & Reasoning)

Integrates domain-specific rules and expertise for decision logic.

4.4. User Interface (UI)

Enables users to interact with the system intuitively.

4.5. User/Decision-Maker

The architect, urban planner, or policymaker who interprets IDSS outputs.

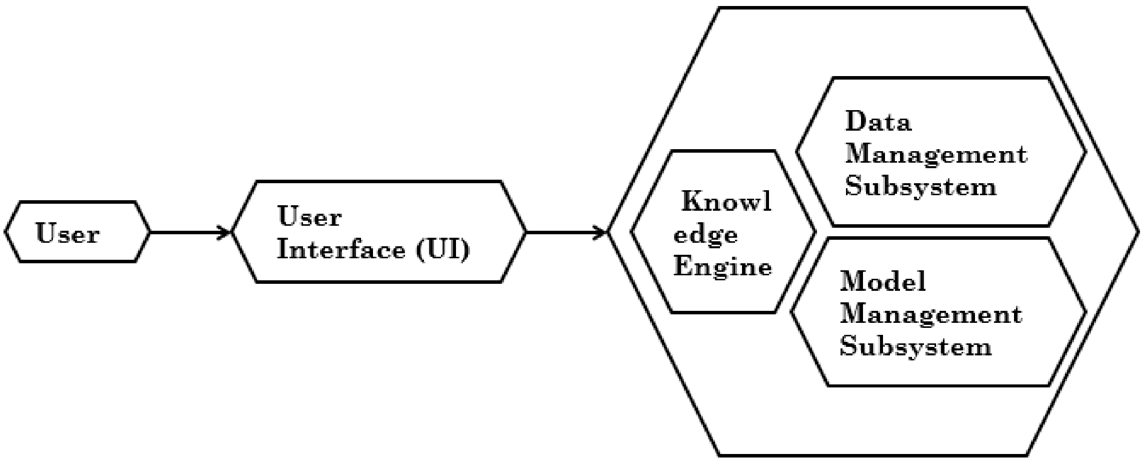

Figure 19. Les composantes d'un SIAD (Auteur).

5. Objectives of an Interactive Decision Support System (IDSS)

IDSS (Interactive Decision Support Systems) enables the achievement of several key objectives during its implementation. Below are the most important ones:

1. Support Complex Decision-Making

Assist decision-makers in analyzing complex, multi-criteria problems—technical, environmental, economic, and social—with greater clarity and structured reasoning.

2. Facilitate Data Integration and Analysis

Combine and process heterogeneous data sources (e.g., spatial, financial, demographic, regulatory) to generate meaningful insights for informed decision-making.

3. Improve Transparency and Justification

Enable traceable and explainable decisions by making evaluation criteria and methods visible, understandable, and reproducible.

4. Simulate Scenarios and Forecast Outcomes

Model various design or planning scenarios and assess their potential impacts prior to implementation (e.g., traffic flow, land use, energy performance).

5. Enhance Collaboration Among Stakeholders

Provide a shared digital platform where architects, urban planners, engineers, and policymakers can collaborate and exchange insights effectively.

6. Optimize Resource Allocation

Help in the efficient allocation of resources—such as budget, time, and land—based on prioritized needs and existing constraints.

7. Reduce Uncertainty and Risk

Identify potential risks and assess the robustness of decisions under various assumptions and conditions.

8. Support Strategic and Tactical Planning

Contribute to both long-term strategic visioning (e.g., urban master plans) and short-term operational decision-making (e.g., site layout, project phasing).

6. Role of IDSS in architecture and urban planning

Decision Support Systems (SIAD) play an important part in modern architecture and urban planning by allowing for data-driven, informed decision-making across the design and development processes. These systems use modern technology to assist experts analyse difficult circumstances, optimise designs, and evaluate probable results prior to execution. SIAD enables performance-based methods in architectural design by providing tools such as parametric modelling and building performance simulation, which allow architects to evaluate many design choices against criteria such as energy efficiency, daylighting, and structural integrity.

Urban planners employ SIAD's geographic information systems (GIS) and data analytics capabilities to evaluate land use trends, model transportation networks, and forecast urban expansion. The systems also contribute to sustainability initiatives by allowing for life cycle evaluations and environmental impact studies, which assist professionals in making environmentally responsible decisions. Beyond technical applications, SIAD alters stakeholder involvement with interactive 3D visualisations and virtual reality, making complicated ideas understandable to non-experts. As cities confront rising difficulties from climate change and increased urbanisation, these decision support systems become more important in producing resilient, efficient, and liveable urban settings.

7. IDSS Tools and Software for Architecture and Urban Projects

Interactive Decision Support Systems (IDSS) rely on specialized software and digital tools to analyse data, simulate scenarios, and optimize design and planning decisions. In architecture and urban planning, these tools integrate **geospatial analysis, parametric modelling, artificial intelligence (AI), and real-time visualization** to enhance efficiency, sustainability, and stakeholder collaboration. SIAD tools can be classified into two main categories based on scale and application:

- **Urban Planning Tools**:
    - **GIS platforms** (e.g., ArcGIS, QGIS) for spatial data analysis.
    - **Urban simulation tools** (e.g., CityEngine, AnyLogic) for scenario testing.
    - **Environmental modelling software** (e.g., ENVI-met, Climate Consultant) for sustainability assessments.
    - **Urban digital twins** (e.g., ESRI Urban, Virtual Singapore) for real-time monitoring.
- **Architectural Design Tools**:
    - **BIM platforms** (e.g., Revit, ArchiCAD) for 3D modelling and documentation.
    - **Parametric design tools** (e.g., Grasshopper, Dynamo) for algorithmic optimization.
    - **Energy analysis software** (e.g., Ladybug Tools, DesignBuilder) for performance evaluation.

- **AI-assisted design tools** (e.g., Spacemaker, Midjourney) for generative concepts.

These tools enable professionals to make data-driven decisions at both macro (urban) and micro (building) scales.

8. Conclusion

This lesson provides an overview of Interactive Decision Support Systems (IDSS), focusing on their role in enhancing decision-making processes in architecture and urban planning. IDSS systems combine human expertise with advanced computational models to support complex decisions, allowing decision-makers to evaluate various scenarios and alternatives. By integrating data, simulations, and visualizations, IDSS helps improve the quality and effectiveness of decisions, making it an essential tool in managing the challenges of modern urban environments.

Lesson8: Computer-Aided Publishing (CAP)

1. Introduction

This lesson introduces the concept of Computer-Aided Publishing (CAP), explores the main tools and software used in Desktop Publishing (DTP), and examines its applications in architecture and urban projects.

2. Definition of Computer-Aided Publishing (CAP)

Computer-Aided Publishing, often abbreviated as CAP or more commonly known as Desktop Publishing (DTP), referred to in French as *Publication Assistée par Ordinateur (PAO)*—is the process of using specialized software to design, format, and produce high-quality printed or digital documents.

Printed Documents: These can take various formats (e.g., books, brochures, posters) and may consist of multiple pages with complex layouts.

Digital Documents: Typically presented as single-page files (e.g., PDFs) or slide-based formats (e.g., presentations), often combining text, images, and interactive elements.

DTP enables precise control over typography, graphics, and layout, ensuring professional-quality outputs for both print and digital media.

3. General Tools and Software Used in Desktop Publishing (DTP)

Desktop Publishing (DTP) involves the use of specialized tools and software to design, layout, and produce professional-quality documents, primarily in digital formats. These tools are varied and continually evolving, with each new version offering enhanced features and support for multiple file formats to suit different applications. DTP is widely applied across numerous sectors, including education, architecture, industrial design, and corporate communications.

In recent years, the integration of artificial intelligence (AI) into DTP software has further optimized workflows—improving usability, automating layout tasks, and enhancing the overall quality and reliability of published materials.

Some of the common publishing and design software used in DTP are included in figure 20.

Figure 20. Common software's used in desktop publishing (Datapage 2017)

In Desktop Publishing (DTP), a range of physical tools supports the creation, layout, and production of professional documents. Input tools such as keyboards, mice, graphic tablets, scanners, and digital cameras enable users to enter and digitize text and visual content. During the composition phase, designers use colour guides, grid systems, typography charts, and precision measurement tools to ensure visual harmony, accuracy, and consistency. Finally, output tools like printers, plotters, cutting devices, and binding machines are essential for producing and finishing high-quality physical copies of the publication.

4. Using DTP in Architecture and Urban Projects

The use of Desktop Publishing (DTP) in architecture and urban projects is a crucial step in presenting final reports and deliverables in a professional and visually effective format. The process begins with the use of specialized software and applications tailored to these fields.

In architecture, commonly used tools include AutoCAD, Revit, SketchUp, Rhino, and ArchiCAD for producing 2D technical plans and 3D models. Applications such as Lumion, Twinmotion, and Render AI are then used for photorealistic rendering. Additionally, tools like Excel, Word, MS Project, Primavera, PowerPoint, and Adobe Acrobat are employed for generating quantitative analyses, budget reports, schedules, and descriptive documentation.

Once the design and analysis phases are completed, the final product is prepared using DTP tools to ensure high-quality printed or digital outputs for presentations, portfolios, or reports.

In the urban planning context, Geographic Information System (GIS) applications play a central role. Software like Google Earth, QGIS, and ArcGIS is widely used for mapping urban areas and analysing infrastructure. Tools from the architectural field, such as AutoCAD, Civil 3D, and SketchUp, are also applied to support urban design. The results are often published in the form of large-format printed maps or digital posters, accompanied by legends and appropriate scales.

To enhance visual presentation, Photoshop and Render AI are commonly used to improve the quality and clarity of architectural and urban visuals. These tools contribute to making the final presentation more readable, credible, and visually impactful.

For portfolio creation, platforms like Canva and Adobe InDesign are widely favoured due to their flexibility, professional templates, and ease of use (Figure21).

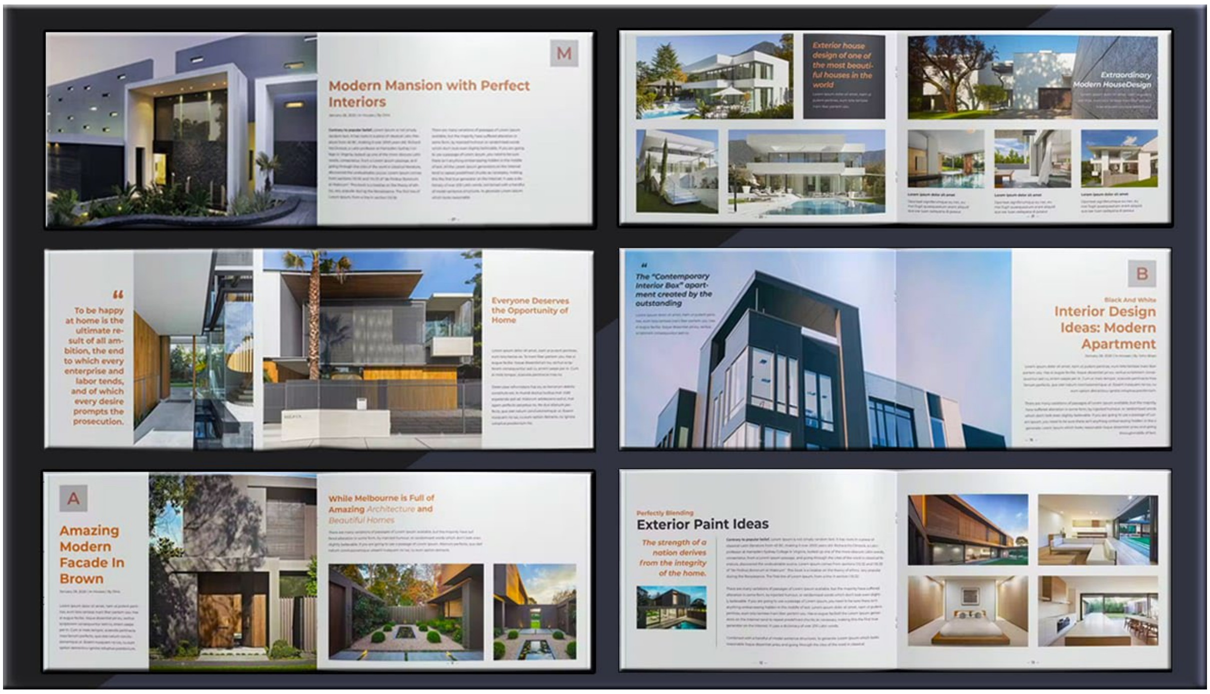

Figure 21. Architectural portfolio creteated using indesign (Stefano 2024)

5. Conclusion

To conclude, Computer-Aided Publishing (CAP) plays a vital role in enhancing the visual quality and professionalism of documents in both architectural and urban projects. By integrating design, layout, and presentation tools, CAP ensures clear and impactful communication. The use of specialized software allows for better organization and visualization of complex information. As digital tools continue to evolve, CAP remains essential for producing high-quality deliverables. Its application bridges the gap between technical content and effective visual storytelling.

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