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Internet of Things (IoT) as a Tool in Architecture for The Concept of Sustainability in Egypt

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Abstract

The Internet of Things "IoT" concept is increasingly being observed in modern workplaces and buildings to intentionally increase the efficiency and effectiveness of how a building is used by organizations and managers. "IoT" applications in Architecture enhance spaces by transforming spaces and pursuing sustainability. This paper describes the emergence of IoT Technology in space impacting the built environment. IoT offers a valuable enabling technology that bridges the gap between physical things and software components and is seen as an essential tool to increase the efficiency of building automation systems and transform the dynamics of building management. The study hypothesizes that the concept of "Internet of Things" application in buildings will realize energy saving ideas. The work follows a theoretical analytical methodology. The theoretical part addresses the main definitions, advantages, and presents a review on IoT applications. The analytical part focuses on case studies by which examples from different parts were chosen highlighting emergence of IoT strategies in buildings, aiming to emphasis on lessons learned from analysis of presented case studies. Followed by a case study from Egypt (Administrative Buildings in Beverly Hills Compound, Elsheikh Zayed), where a survey was implemented. An analytical study was conducted to explore the applicability of potentials of IoT to sustainable concepts in architecture. The results confirm that the application of IoT to buildings is a source of positive benefits for buildings. The research concluded by recommending using IoT technology, as understanding its advantages and disadvantages will be of great benefit towards sustainability.

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Keywords: IoT; Sustainability Concept; Energy Saving; Architecture; Egypt.

1. INTRODUCTION

The age of ubiquitous computing has arrived due to the evolution of Internet technology and wired sensor networks. "The Internet of Things (IoT) consists of physical things communicating with each other, extending machine-to-machine and human-computer communication to things [1]. Connected objects should make life easier by mission automation and automatic decision making. The devices should work instantly and not necessitate people to constitute and attempt to make them work [2].

According to cisco, the internet of things market will nurture speedily and will reach 50 billion devices linked to the internet by 2020. IoT incorporates digital technologies with a powerful prospective to become more widespread in different areas of life [3]. Nowadays, emerging technologies keep penetrating the world. Due to ubiquitous digitization, the places we live, work, and study in have transformed completely due abundant wireless acquaintances, and expansions in technologies and smart devices.

Among the utmost efficient disrupting technologies are artificial intelligence (AI), Virtual / augmented/mixed reality (VR, AR, MR), Internet of Things (IoT), Cloud Computing, e-services (e-trading, e-banking-learning, and e-health), block chain technologies, etc. These tools with the correlated data analysis, can be used to enhance the quality of life by augmenting social and economic implementation. Following these inclinations, smart cities, buildings, homes, and smart schools are not just a conception but already a reality.

The Internet of Things is the concept where everyday objects are wirelessly connected into an interactive network [4]. It's a complex idea of Internet networking that allows everyday objects to associate to the Internet or each other to send and receive data and present specialized utilities over the network [5].

Buildings are becoming more and more human-centric and less engineering, construction and technology. Employee demand for more technology in the workplace is constantly growing. Building owners, developers, and facility managers are responding by emphasizing common spaces, flexible and adaptable facilities. Creating a

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smarter workplace that engages residents, understands how they use facilities in new ways, and incorporates sustainable practices is becoming increasingly important [5].

The use of these technologies is believed to improve the working environment, develop the services provided to communities, and improve quality of life. Under the guidance of the Supreme Universities Council, Egyptian universities have begun proposing the establishment of Artificial Intelligence and Internet of Things departments to prepare Egyptian students to study artificial intelligence and advance their scientific knowledge [3].

The significance of this study is to examine the implication of applicability of emergence of IoT technologies in the field of Architecture, as a means towards sustainability. The methodology employed follows systematic approach to achieve research goal. Through literature review and analysis of Global case studies, the research pursues to realize the benefits of IoT technologies in Egypt. A survey was implemented for administrative buildings in Egypt as applied example of realizing the connection of IoT and sustainability.

The research Addresses the following questions:

- Definition of the Internet of Things, characteristics, and areas of application.
- The need to benefit from the technology of the Internet of things in various fields.
- Areas for using the Internet of Things to develop the services and activities of administrative buildings.
- Challenges facing the use of the Internet of Things.

1.1. Aim of research

To maximize benefits for most people with minimal costs and impacts and to realize potentials of internet of things to maintain sustainability concept in architecture.

Research objectives:

- identify concept and strategies of IoT and its applications in Buildings.
- investigate advantages through lessons learned from case studies.
- discuss the implications of IoT approach in Architecture “Administrative buildings as an example” and make.
- recommendations to integrating IoT technologies in Buildings.
- Improve people quality of life through application of IoT strategies in Buildings.

1.2. Research Methodology

Theoretical Analytical study and Application:

The first part dealt with definitions, the advantages and challenges of Internet of Things technology and its applications in Architecture, as well as the concept of sustainability and its importance. Then, the second part dealt with the analysis of models for Architectural spaces applied to the Internet of Things. The applied part, dealt with an area in Egypt for one of the new urban communities (Beverly Hills, Sheikh Zayed) - Administrative Buildings - for the possibility of applying the idea of Internet of Things technology towards achieving the concept of Sustainability. A survey was conducted for the opinions of the beneficiaries, the users, and residents, by designing a questionnaire form (see Fig. 1).

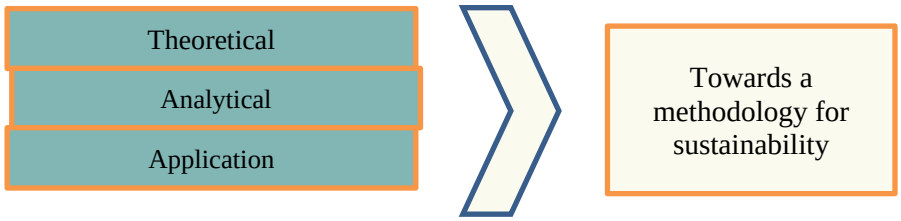


Fig. 1. Research methodology and steps of study (Author).

2. INTERNET OF THINGS

- **The definition:**

A term that has arisen meaning the new creation of the Internet that allows accepting amongst interrelated strategies (via Internet Protocol), and these devices include tools, sensors, numerous artificial intelligence instruments, and others. This goes afar the traditional definition of people communicating with computers and smartphones over a single global network and throughout the well-known conventional Internet protocol. What characterises the Internet of Things is that it allows the person to be free from the place, connotation that the person can control the tools without the need to be in a specific place to deal with a specific device. [6 ,7]

- **What are the things:**

The understanding between the devices takes place directly, and the human being is one of the terminals of communication, just like the other terminals. Things here mean any device or terminal that can be identified on the Internet. To enable new-fangled procedures of communication amongst people and things and amid the things

themselves. The Internet of Things is an established concept of the Internet so that all things in our lives have the capability to join to the Internet or to each other to send and gather data to achieve exact utilities across the network, and by connecting several different things via sensor modes, and ordered through the Internet [8] .Where things can interrelate with each other on one hand and with humans on the other, permitting many new applications in the medical fields, industrial, economic, educational, sports, and even at the level of the daily life of the individual. The basis of the topic be contingent on the scenario of the interaction of things via the Internet to provide the best services for humans. [9]

According to [10], to encounter the effects of IoT, the need for using green IoT which deliberated a future technological enrichment of IoT interconnected to technology and green economy, which aims to attain advances in environmental and human wellbeing. The goals of the Green IoT include energy efficient, decrease greenhouse effect, lessen energy consumption and CO2 emission, electronic waste management and apportioning of surrounding environment to benefit in generating power supply. [11, 12]

IoT technologies has brought various useful benefits to society and improved the quality of life in general, addresses some key facts about IoT technologies associated to the quick development of IoT: increased use of raw materials, more acceptable price ranges of electronic devices, long-term environmental impacts, increased e-waste and consequential social impacts. Less work and restrictions. [13 ,14]

- **The Internet of Things and the Internet of Everything:**

The Internet of Things is one of the components of the transition to the Internet of Everything, and to achieve the dream of the Internet of Everything, here is a list of the technologies that it offers and its integration with the Internet of Things: Mobility, Big data, The new generation of Internet addresses. [15]

- **Elements of IoT:**

The following diagram Fig. 2 presents the four elements of internet of things that include: users, data, processes and Things.

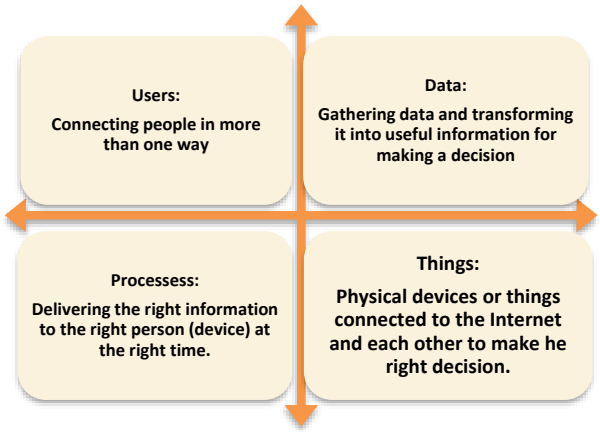


Fig. 2. Four elements of IoT.

- **Aspects to consider:**

- Invest in quality infrastructure and tools, to ensure a reliable and secure network architecture to support the IoT.
- Adopt a policy of containment, provide a work environment in which workers feel that they are part of the change, and pave the way for individuals' creativity to support this technological change and not fear or reject it.
- Develop effective data management policies: support and extract useful data to deliver the right information to the right time to the right people.

2.1. IoT Applications [16]

Benefits of the Internet of Things "Fig. 3":

The Internet of Things allows for effective and simple control of objects from afar. Different items can communicate with each other utilizing the Internet Protocol in a more developed form.

Examples of Applications of IoT:

- Transportation: assist with traffic monitoring and improving road safety.
- Surveillance: give real-time environmental observations by deployed sensors.
- Wearables: used in the entertainment industries, fitness, and health monitoring.
- Smart environment: enhance environmental utilization efficiency.

- Safety: can be used in residential, commercial, and public settings.
- Utilities: allow for remote monitoring and management of customer water consumption.
- Industrial internet: business analytics, maintenance, and industrial automation.

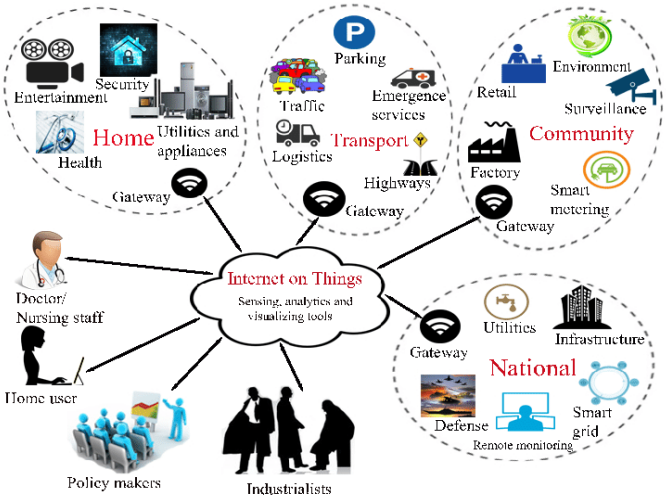


Fig. 3. IoT Applications.

IBMS allows the building to increase its resource consumption in response to tenant usage. HVAC is intelligently and automatically managed. The installation of an energy management system allows for smooth and efficient building operations, as well as an environmentally friendly property. [17]

2.2. The influence of the Internet of Things on Buildings[18]

An energy efficient, occupant-optimized	**Building management systems**
Smart buildings can be achieved by adopting a more holistic approach to building control and processing of all building data, including all systems and sensors.	Facilities managers can automate and manage many variables of building operations. Collected data is stored and analyzed over time.

2.2.1. Moving to the Internet of Things [19]

Integration of information technology and operation technology for factories and various facilities.

Operational engineering is expressed as the automated infrastructure for industrial control in a particular organization and incorporates strategies, sensors, and software to power and overseer manufacturing and production procedures.

This leads to improved productivity, reduced costs, reduced risks, improved performance, and provides flexibility and effectiveness for various industries and institutions. This is the first step regarding automation and the alteration to the digital world [20, 21].

There are several Advantages as Simplify manufacturing, Smart work environment, Ensure security from the start of the production process to its completion

2.2.2. Types of communication in the Internet of Things:

There are 3 types of pf communication in IoT (Fig. 4)

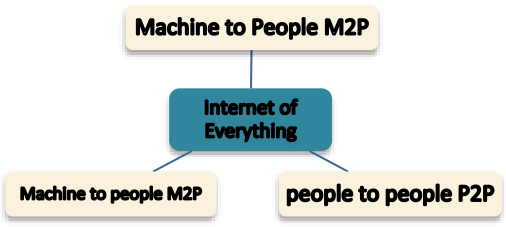


Fig. 4 Internet of Everything Operations facilitate the connection of users with electronic devices, objects and information in the easiest way [22]

2.3. IoT Applications and challenges in Architecture "Fig. 5. &Fig. 6"

Fig. 5. illustrates fundamental characteristics of the IoT.

Fig. 6. Internet of Things - Smart Environments and Smart Spaces Creation.

3. CASE STUDY FOR IOT APPLICATION; RESHAPE THE CITY EXPERIENCE [23]

Three areas where advances in IoT technology are already starting to shape the cities of tomorrow, and how residents are benefitting from (and participating in) [24]. (Table 1).

TABLE .1 AREAS OF PROGRESSES IN IOT TECHNOLOGY

1- Computer vision	2- Edge Computing	3- Data Analysis
Raw video is captured as data by cameras and other visual sensors and then processed into valuable and actionable information.	Edge computing processes and analyzes data directly at the source where it was collected.	Sensors, cameras, radio frequency identification (RFID), and Bluetooth devices are constantly passing information that turns into data. People are constantly sharing their activities, and data is becoming a vibrant part of cities. An example "fig. 7"
- stand up to improve service quality - Improving public safety - Reducing traffic congestion, - A new level of efficiency. Example: Monitor nearby parking lots. Or monitor the flow of pedestrian and vehicle traffic to optimize traffic and crosswalk signals. public security	As people occupy or occupy parts of the building, sensors record their activity and edge computing can be used to adjust lighting and climate control.	 Fig. 7. Known as "City in the Box," South Korea's Songdo city was built from the ground up as a smart city. attaches RFID tags to all vehicles to measure and adjust traffic patterns. Fiber optic cables run through every corner of the city.

This technology can be used to decrease production costs by growing automation between its devices, beginning from the human factor [12].

Benefits include Deliver more efficient and diverse real-time presentations. It is based on collecting data in real time from users too.

To adopt IoT technology within an institution:

-Changes in prospective product marketing and publicizing strategy in proof and equitable phase

-How people distinguish new products, associate competitors, and transformation buying patterns

- Consumers in the Internet world can totally change the company's policy by articulating their opinions about products on the Internet to evade losses and advance production rapidly and efficiently.

3.1. IoT and Sustainability concept in Architecture

In this part, International Case studies will be presented, that achieve sustainability using the Internet of things, followed by an evaluation model to identify common strengths, as a basis for developing a methodology for the possibility of its application in Egypt.

- Sustainability concept

The concept of sustainability in architecture is a general term for environmentally friendly design performs in the building sector. It is the process of eco-designing buildings, taking into relation the reduced consumption of energy, materials and resources while lessening the influence of construction and use on the environment while adjusting for harmony with the environment. The concept of sustainability in architecture is the conservation of the ecological, economic, and social systems that make up the urban environment, the congruent use of resources and the compatibility with the present and future requirements of mankind. A process that comprises the technical direction of development. [25, 26]

- General principles of sustainability

1. Conservation of energy and water
2. The life cycle of the building
3. Structural design
4. Sustainable urban design

Sustainable Architecture incorporates Urban and site design, landscape, transportation system, building architecture form, indoor environment and interior spaces design, waste management, building materials, energy consumption, water ecosystem, air quality.

It is predictable that people spend 80 to 90% of their time indoors. As a result, the health, happiness, and productivity of people can be greatly manipulated. Buildings are the principal source of today's high levels of energy consumption and carbon productions; on average, the construction segment accounts for 30 to 40% of demand in numerous countries; in countries like the United Arab Emirates, where problematic climatic conditions result in high air conditioning loads, this value exceeds 60% [27].

TABLE. 2 A COMPARISON OF THE USE OF THE INTERNET OF THINGS IN THE FIELD OF SALES MANAGEMENT [AUTHOR AFTER 19]

	Before	**IOE (Internet of Everything)**
Customer experience	Unidentified mass marketing, unified purchaser service	Real time, micro-targeting, place and contextual proposals, customer service
Innovation	Fixed retailing resolutions based on perception about past sites and intuition about customer desires	Adaptive selling assessments established on prophetic analytics related to customer behavioral data (e.g. sales, trends)
Employee efficiency	Arrangement and employment of store staff based on regulated information	Active optimization of store staff grounded on in-store customer passage arrangements and performance.
Asset operation	Ineffective usage of energy in stores (e.g. lighting, cooling)	Customizable energy consumption in stores based on customer traffic and functioning needs.
Supply chain	Regulated product range and numerous out-of-stock occasions, depending based on accessible shelf space.	“unlimited” assortment of products available(e.g. endless aisle) by extending in-store record through online and mobile shopping

The following diagram “Fig. 8” shows pillars of IoT system.

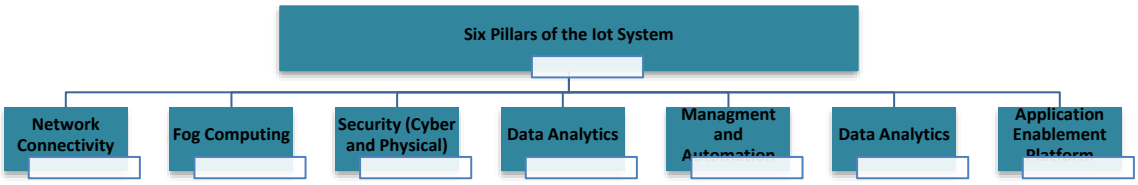


Fig.8 Pillars of IoT system.

3.2. Challenges of application of IoT

- Convert all types of protocols for specific companies to IIP protocols.
- To realize the concept of interoperability.
- allowing all kinds of applications and devices to work together in a unified environment.

4. 4.CASE STUDIES OF IOT APPLICATIONS IN ARCHITECTURE

Sample were selected that included 4 architectural projects, taking into account the functional discrepancy between the projects. The projects are:

1- The edge, Amsterdam
2- Siemens City, Vienna Austria
3- Capital Tower, Singapore
4- IBM Watson IoT Munich, Germany

The analysis of the models depends on the description of the building, ideas of Internet of Things technology, sustainability, challenges, and proposed solutions.

1-Energy Efficiency for Deloitte offices, Amsterdam, The edge[28] (Table .3.)
Smart structure from Schneider Electric

TABLE.3 THE EDGE, AMSTERDAM

The edge in Amsterdam, designed by London-based PLP Architecture	
Description	- Incorporates a variety of smart technology and adjustable work areas “fig. 9 and 10”. -Implements environmental-control facilities; bring the outside world in the office. [29] - LED-connected luminaires continuously monitor occupancy, movement, light intensity, humidity, and temperature within the facility. - Each employee can access a smartphone app to find a parking space, adjust the temperature and lighting, and track their progress in the building's gym.

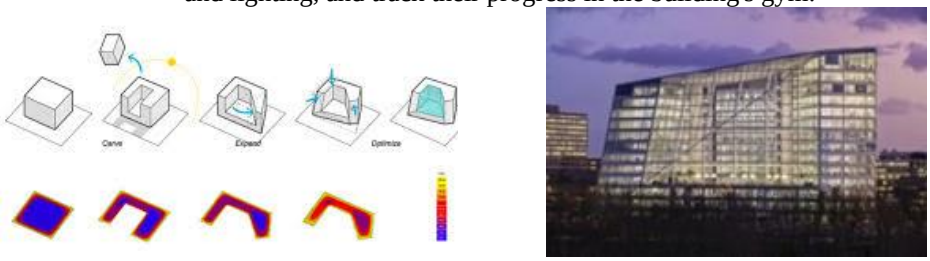


Fig. 9. The Edge Building Form

Fig. 10. Indoor spaces

IoT Concepts	- Philips created a light fixture that could communicate with the Internet. - The new panel includes incorporated motion, temperature, light, and air sensors, as well as LEDs driven by low-energy Ethernet cables. - The panels were put, each with IP address, for remote monitoring.
Sustainability	- Provides a completely new working environment, giving it the highest BREEAM, the world's leading assessor of sustainable construction. - Installed solar panels on the south façade and adjacent buildings to generate more energy than it consumes - Collect rainwater and use it to irrigate courtyards and gardens and flush toilets. - A 130-meter-deep aquifer thermal space system generates all the energy required aimed at heating and cooling. - Each user's waste is recorded and taxed by weight to encourage conservation. - Parts can be turned off when not in use to save energy.
Challenges	Building complicated technologies necessitated a more comprehensive approach to property management, as well as evaluate and act on massive amounts of big data generated by the building and its residents.
Solution	- building management continuously detect, monitor and analyze energy consumption trends and data, and make regular adjustments to ensure balanced use and comfortable building environment. - New waste and environmental policies have been introduced for all service contracts, work permits, bidding and procurement processes. - assigned an ecology officer to conduct frequent inspections and identify methods to improve the building's and immediate surrounds' natural environment.

2- Siemens: Vienna (Table.4.))

TABLE .4 SIEMENS, VIENNA

	Siemens City- Vienna Austria	**Smart city energy research:**
Description	- Building a smart city with internet of things - A living lab where future intelligent city ideas and technology are tested. -Using a series of steel-glass atriums to invigorate Siemens office buildings.	
IoT Concepts	- The new offices are a showcase for environmentally conscious design and energy-efficient building techniques. -The lighting, temperature, and ventilation are all controlled by the building management system, which has access to almost 10,000 sensors and offers energy-efficient lighting. When a sensor detects that all have left an area, the heating and lighting systems in the office are immediately turned off. The energy-efficiency will result in a 1,000-ton annual CO2 emissions reduction.	
Sustainability	- Meet the criteria of EU of green buildings - Energy efficient luminaires with optimum light distribution and lamps used. - Light put in the entrance area - Internal louvres direct light onto the ground, and the building's safety ensures a wide spread of light.	

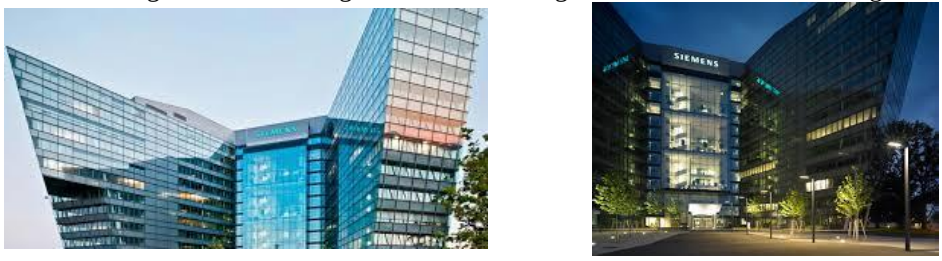


Fig. 11 Exterior form

Fig. 12. Indoor environment and green areas surrounding the building

	- The big glass roofs and free zones between the adjoining office wings provide for plenty of natural light, external and interior lighting included in the concept.
challenges	The electrical grid is a unique component. To establish a smart grid, many sorts of data from building automation systems must be collected and merged with present and forecast weather information. Calculating cost and efficiency entails determining how much data and monitoring hardware the system requires.
solution	Siemens has gathered a 3-part package that its components include technologies for: Power management in smart buildings, low-voltage, grid solutions.

3-Capital Tower, Singapore (Table .5.))

TABLE . 5. CAPITAL TOWER, SINGAPORE

	Capital Tower, Singapore
Description	- It is entirely assimilated with intelligent building management systems and has its peculiar wireless local area network (LAN). IBMS amongst IoT applications: from low-emissivity glass windows to adjustable air volume boxes for optimum indoor air quality, with the ambition of acquiring effective, sustainable and environmentally friendly properties. -Elevator lobbies and restrooms are equipped with motion sensors to save energy, and double-glazed windows diminish heat infiltration, minimizing energy utilization. To lessen water consumption, the building usages condensate from the ventilation system. -Double glazing reduces energy wastage in cooling the building.
	 
	Fig. 13. Architecture form
IoT Concepts	Solving the problem of pollution caused by parking spaces, that affects indoor air quality through consume fans are furnished with sensors that are connected to an intelligent building management system. They are only actuated in the parking garage whilst the carbon monoxide sensors register more than 1,000 parts/million, which outcomes in substantial energy savings while still conveying improved indoor air quality. [30]
Sustainability	Optimizing energy efficiency through the building - Incorporates an energy recovery wheel system in its air- conditioning system which allows for the recovery of cool air to maintain the chillers' efficiency. - motion detectors are installed at the lift lobby and toilets to conserve energy - double glazed glass windows help to decrease heat penetration and lessen energy consumption - in lowering water usage, the building harnesses water condensation from the air handling unit for use as top-up water for the cooling towers. - office and car park are fitted with carbon monoxide (CO) monitoring devices.
challenges	Energy savings
solutions	Sustainable solutions can be applied by new materials installed and monitoring pollution and co2 released.

4-Watson IoT Head Quarter, Munich, 2017 [31] (Table.6)

TABLE. 6 WATSON IOT, MUNICH

IBM Watson IoT Munich, Germany	**Universal Design Studio, Jan Architects**
Description	A technology company sell Internet innovations to international companies. It must work from a workspace and accurately display what Internet systems offer things. IBM has opened a live laboratory for its IoT technology. Watson IoT represents the latest smart office technology available, also providing a floor for future testing.

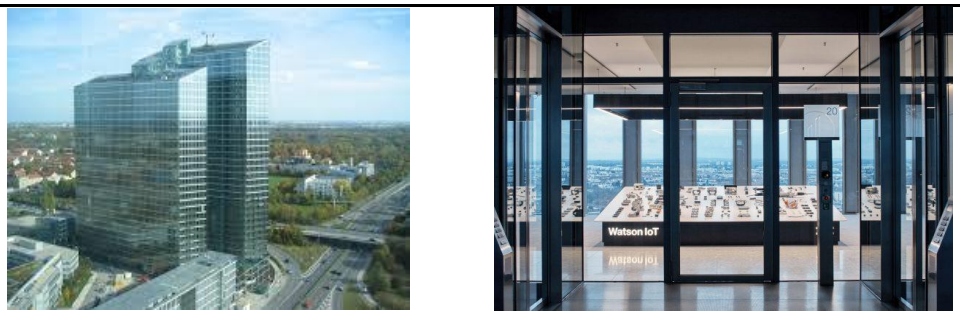


Fig. 14. IBM building

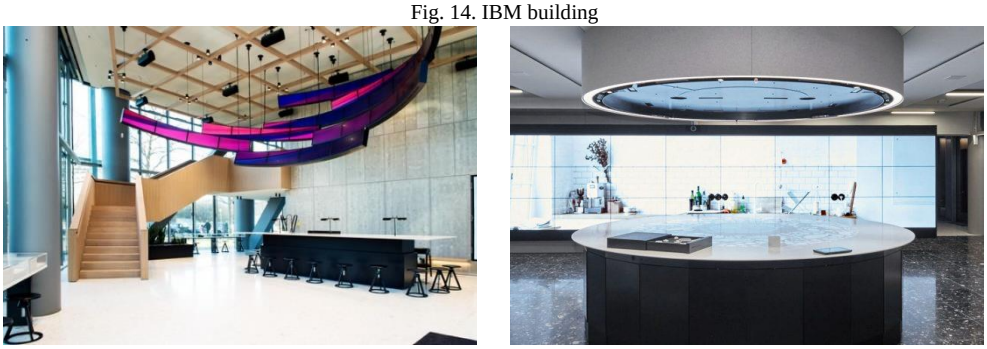


Fig. 15. These cameras and sensors are used by the mixed reality table to recognize things and play associated video clips.

IoT Concept	Building IoT with Watson IBM contributed $ 200 million, and Map Project Office constructed 25 stories of IBM with Siemens smart building technologies to complement Watson's IoT system. Employee workstations, technological labs (dubbed "collaborators"), and a display for IoT technology breakthroughs are all part of the 24,000-square-foot building.
Sustainability	The Watson IoT system in the building is designed for hot desking, with over 1,000 employees and customers using the facility. Each user has a digital ID, so the system knows who is in which seat and can adjust the heating and lighting to suit their inclinations.
Challenges	Applying smart applications and users' applicability to accommodate smart solutions. IBI's goal is to incorporate the products it sells, and it's well on its way. The customer-centric design of Universal Design Studio reflects the company's technology, but it also demonstrates how style, innovation, and functionality can coexist.
solutions	-Awareness and applying guide for users

4.1. Evaluation and Lessons learned from International Case studies presented (Author)

- Buildings achieved different applications of smart technologies.
- Innovations of ideas implemented towards lessen energy consumption and decrease carbon footprints that targets towards greener environment.
- Internet of Things helped Buildings towards better quality of life for users and Beneficiary.
- Establishment of such technologies need a strategy and financial support and continuous follow-up and maintenance to react in real-time.
- Achievement towards sustainability in the following: water conservation, application of solar panels helped in clean energy, less energy consumption by using sensors to turn off light and water and AC when not in use.

5. APPLICATION IN EGYPT

A suggested platform for applying IoT strategy in administrative buildings in Egypt to decrease cost and energy, aiming to sustainable approach.

5.1. 5.1. Case study in Egypt:

Egypt has been affected by global technological developments, especially in the areas of architecture and planning, as it has begun to formulate plans to implement several smart cities.

• Aiming for sustainability with Internet of Things technology:

Applied Research Steps: study the status of several buildings in Sheikh Zayed's Beverly Hills. The study relied on Conducting surveys to gather residents and users' opinions on the importance of technology implementation and discussion for the Internet of Things.

Extract the characteristics of closed urban communities and make them viable. Applying intelligent systems to services and various intelligent systems and applications that can be used in buildings and spaces and are suitable for gated communities.

- Beverly Hills Compound

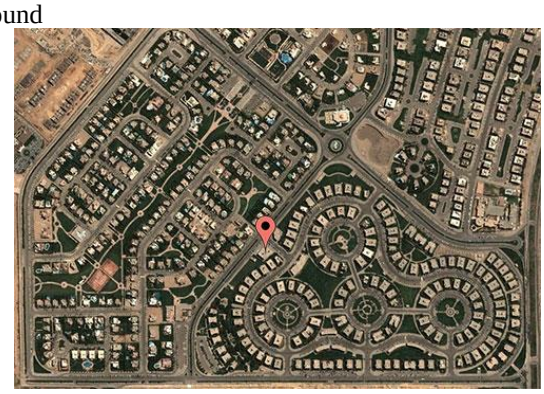


Fig. 16. Beverly Hills compound, El-sheikh Zayed [32]

Location:

One of SODIC West's projects, Beverly Hills, is near to the Cairo Alexandria Desert Route, five minutes from the Cairo Alex Toll Station and up the path from Smart Village. East of Square (Mall of Arabia).

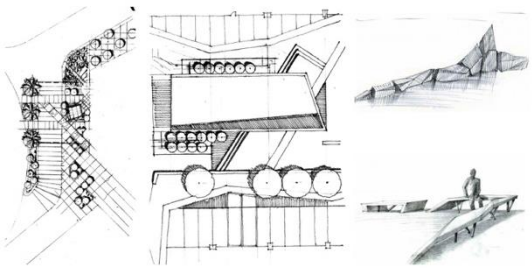
Facilities:

Beverly Hills was one of Sheikh Zayed City's first major residential developments and is located on Desert Road between Cairo and Alexandria. Beverly Hills has developed into a welcoming and active city west of Cairo, making it a desirable address.

Beverly Hills opened in 2001 and is home to approximately 3,000 homes, townhouses and apartments surrounded by extensive landscaping and gardens and wide roads. Beverly Hills brings together social, sports and commercial activities in one place. Social clubhouse and sports facilities, multipurpose courts, gymnasium and SPA. Beverly Hills has language schools, Beverly Hills German School (BHS), New Vision International School (NVIS) and Preschools for every learning needs. Medical facilities with experienced doctors and dental clinics with cutting-edge technology and high-quality materials. In addition to facilities and services such as pharmacies, cafes/restaurants, convenience stores, housekeeping services, showrooms, stationery, and other services

- The polygon SODIC Business Park Zayed

Study of Business Area, The Polygon “Fig. 17”



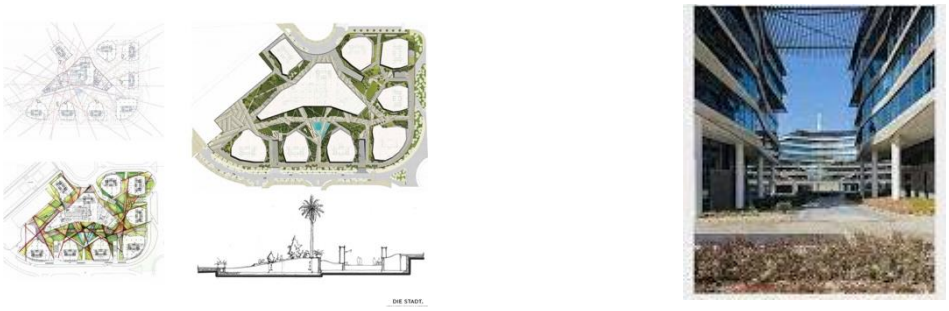


Fig. 17. [33] & [34]

The figure shows an example of a 'mixed-use community' called 'The Polygon' in business Park, an 11-building complex. The function is characterized by a modern façade with some irregular surfaces. There is enough green space between buildings. Shade is available to form a shaded corridor to access the plaza area square.

- Survey

This research is based on a survey of visitors to the area. The poll included (regional residents-users-workers). A questionnaire was developed to collect the views of the beneficiaries. Steps were explained and recorded the contents and items of the questionnaire. Questions included opinions on the use of smart technology in everyday life. How technology integration can improve quality of life. In addition to collecting suggestions and opinions. Findings to complete critical priority smart systems and applications that can be applied to achieve sustainability. The sample size was 350 people of different age groups include residents, workers, visitors and occupants (Fig. 18), results were summarized and providing a methodology of IoT implementation and activation applicable in Egypt to proposed case study.

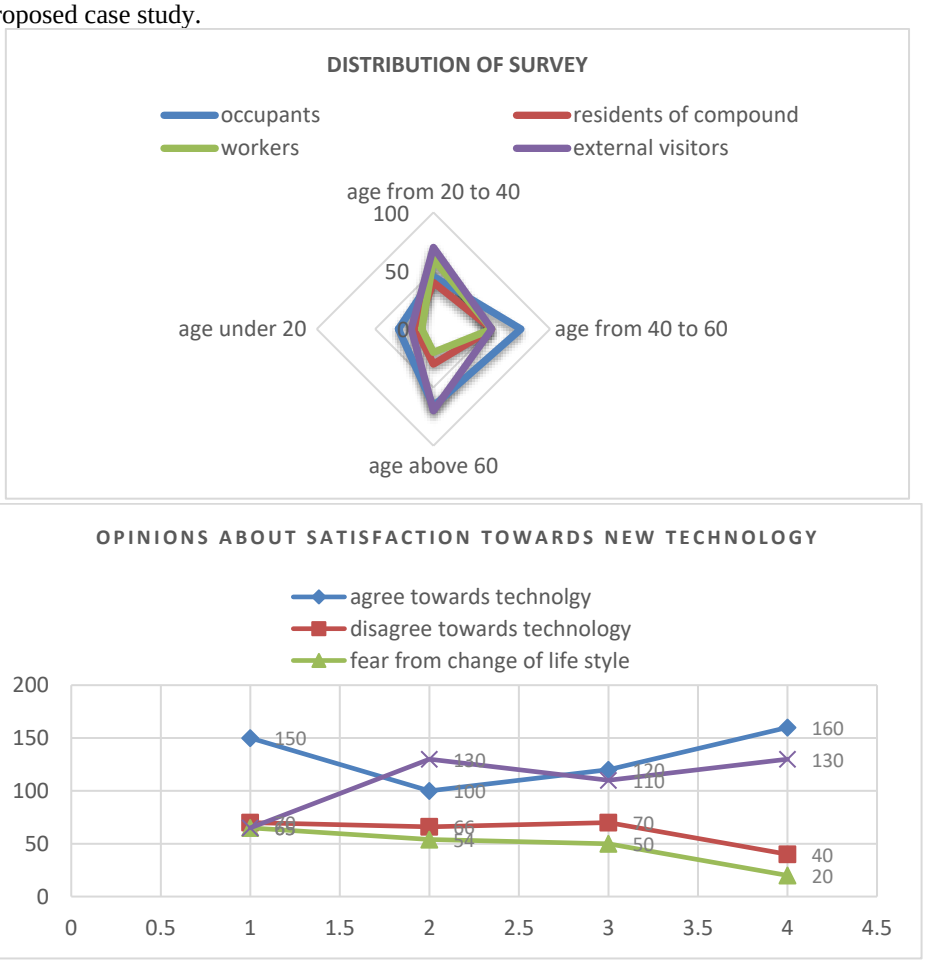


Fig. 18 Samples of survey results [Author]

- Results of survey:

Results show that agree of satisfaction was towards new technology as a new thinking for better and ease of problems in the past. Above 60 years old was a little bit discussing about change and ways of use but was eager to shortcut longer steps done in the past. Under 20 years old found it familiar to use different apps and easy way to click buttons and smart screens. Workers find it satisfactory in terms of better environment and new ways for modern workspaces. Residents was happy to get introduced to new technology as this community was seeking

better services. Specialists, architects and urban planners agree that such technologies should be implemented from the beginning and most of all towards environmental protection and saving for future generations, waste management and energy conservation were important, and users' satisfaction was of priority. The results confirm application of IoT technologies would help to satisfy users' needs and achieving sustainability concept.

6. SUGGESTED SOLUTIONS FOR APPLICABILITY OF IOT TO ACHIEVE SUSTAINABLE APPROACH (FIG. 19)

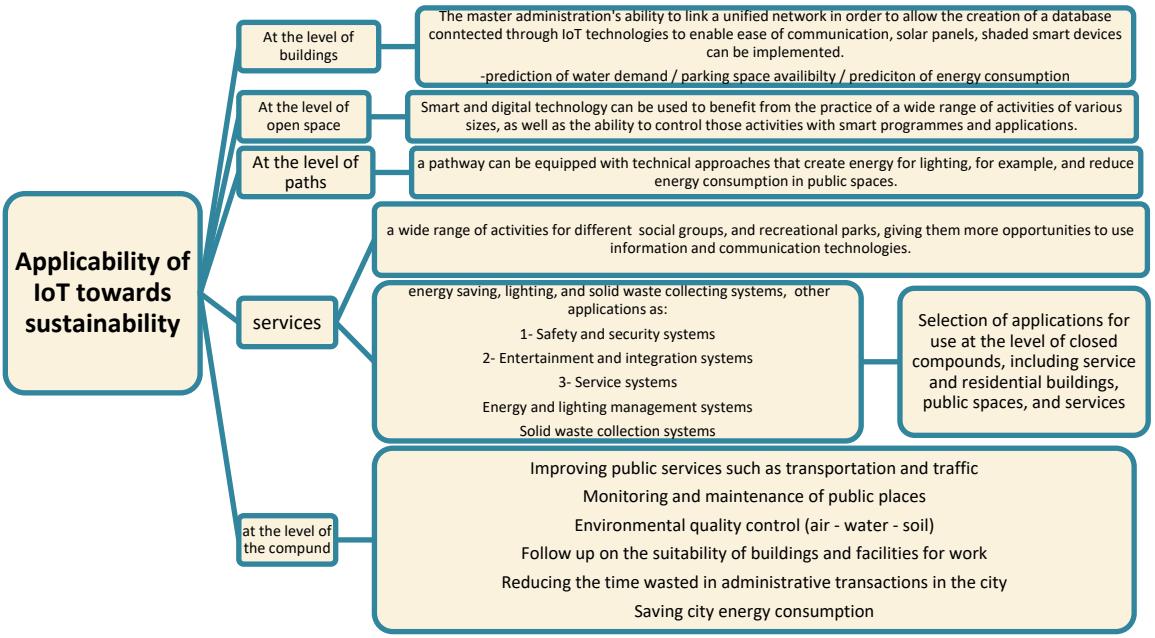


Fig. 19. Suggested solutions strategy [Author]

6.1. Proposed Application of IoT concepts on case study "the polygon" (Author)

- Buildings must be sustainable, easily adaptable to changing conditions and always reconfigurable.
- Buildings can power controls and save energy by tailoring the system. Upgrading components can save 5-15% energy. Smart buildings with adapted systems can achieve 30-50% building savings.
- IoT devices in the building can view and control parameters questionable to the health and sustainability of the occupants. Indicators of air quality and resource consumption. AI-driven analytics empower facility managers to monitor implementations and improve their ability to make real-time decisions.
- Applications of IoT technology include public electric transportation, low-cost energy storage, long-term storing, plastic recycling, LED lighting effectiveness, reachable solar energy, carbon dioxide apprehend and storage, lighting, electrical systems, plumbing, roof units including HVAC systems, including fire. Mechanical systems such as alarms, elevators, surveillance cameras, and security systems.
- Sensors can be placed throughout buildings to measure temperature, light, CO2, etc.
- Actions can be taken in real time to enable key operational insights.
- Building automation improves occupant comfort and effectiveness of building systems, reducing energy consumption and operating costs.

6.2. Advantages and Disadvantages (Table. 7)

TABLE. 7 ILLUSTRATES ADVANTAGES AND DISADVANTAGES OF TECHNOLOGICAL APPLICATION IN ARCHITECTURE[35]

Advantages	disadvantages	Advantages for occupants
maintain a high level without many management, streamline repetitive work, and lower employee costs	Increased network security raises the risk of cyber-attacks.	Improve occupant experience by providing a modern and intuitive work space.
Higher security and integration control, and a safer environment for inhabitants	Sensors perform tasks that would have been performed by employees, resulting in employment losses.	Comfort, apps that connect users to the building and adjust to their movements
Savings in operational costs and	Costly to implement	Flexibility and systems updated in response

utility bills allow for more efficient resource management and energy consumption regulation. Increases property value, green commercial buildings with energy efficiency a rise in the resale value People take longer to adapt to and grasp systems as they get more complicated.	People take longer to adapt to and grasp systems as they get more complicated. Vendor lock-ins	to society's greater digital improvements: lighting control - electrical energy regulation and monitoring - communication management -(heating, ventilation and air conditioning) (HVAC) water conservation and buildings For fire protection - Security automation - Attracting and retaining quality tenants - Efficiency and long-term profitability Pre-planned maintenance Security and protection, IoT equipped buildings.

Evaluation of sustainability concept of the proposed methodology of IoT strategy in Architecture (Author) (Table 8)

TABLE 8. ANALYSIS IN TERMS OF THE POSSIBILITY OF IOT STRATEGY

axes	The idea	The possibility of realizing the idea through the Internet of Things strategy
The location and the land	Reusing buildings and sites to protect the land, controlling pollution, activating recycling, increasing the density of vegetation cover around buildings, encouraging different forms of transportation	IoT could benefit in connections through Controlling pollution resulting from running water and lighting by sensing the amount used and can calculate the amount consumed, reducing heat islands - recycling - improving the internal quality of the building and providing it with shades that can be movable or in some parts that can be used in controlling the amount of sun entering the building that can act as energy saver.
Innovation and design	Understanding the local natural environment, the integrated design by linking all aspects related to the building, the use of natural daylighting, ventilation, building envelope and thermal insulation.	IoT can help in making Lighting system, that reduce the number of lighting devices used in the building, control the sun, develop effective strategies in usage patterns by users and occupants. use light panels to close and open openings and windows, anticipating towards pollution reduction
Energy management	Cooling and air conditioning systems, load management and control devices, office equipment control	IoT use advanced control using sensors, in addition to the use of natural lighting, periodic maintenance, reducing consumption and operating cost. Connections help in collecting data to identify areas need less or more consumptions patterns, three types of smart technologies need security systems: lighting, heating, ventilation and air conditioning. In case no one is present in the space, this technique can be used, the lights are turned on only when needed. Connected to sensors and software that allow it to monitor and optimize energy usage, the smart security system uses sensors and software to monitor the entrances and exits of the building, allowing to close it when no one is around. This allows energy to be saved.
Water management and treated water	Effective water management	IoT contribute in water management by applicability to Using low-flow equipment and controlling the quantities of water used that reduce consumption as needed only without wastage. The use of a thermostat to control the temperature by setting the temperature in advance, which contributes to saving energy and water Using a number of technologies such as automatic control and control by sensors or devices that deliver a previously specified amount of water to rationalize consumption. Use of devices connected to the Internet to identify any leakage and control consumption. The use of gray water for some applications such as irrigation, cooling, industrial

		purposes, toilets and fire extinguishing devices. Collecting rainwater Utilizing roofs to collect and store water.
Resource and waste management	Materials: The use of recycled materials or renewable materials in construction to reduce negative impacts on the environment, Reducing operational waste and recycling.	Conservation in many aspects include: Ceilings "protection, reduce weather fluctuations and reduce heat, use reflective surfaces and recyclable materials, use solar panels" - floors "use materials that are easy to clean and maintain, recyclable and low emission of harmful organic gases and use a minimum amount of glue, - walls" use moisture-resistant types
Indoor environment quality	Improving the internal environment and productivity	IoT can control and improve temperatures, maintaining cleanliness, using natural lighting, caring for indoor cultivation, noise control.

IoT and Sustainability: the link in between (Fig. 20)

Balance the high performance and energy efficiency of the building and balance the economic aspects of the building with the environment. By focusing on integrated design designed for a variety of industries, building envelope and interior design helps illuminate the building's surrounding and reduce pollution and noise while decreasing negative impacts on the building.

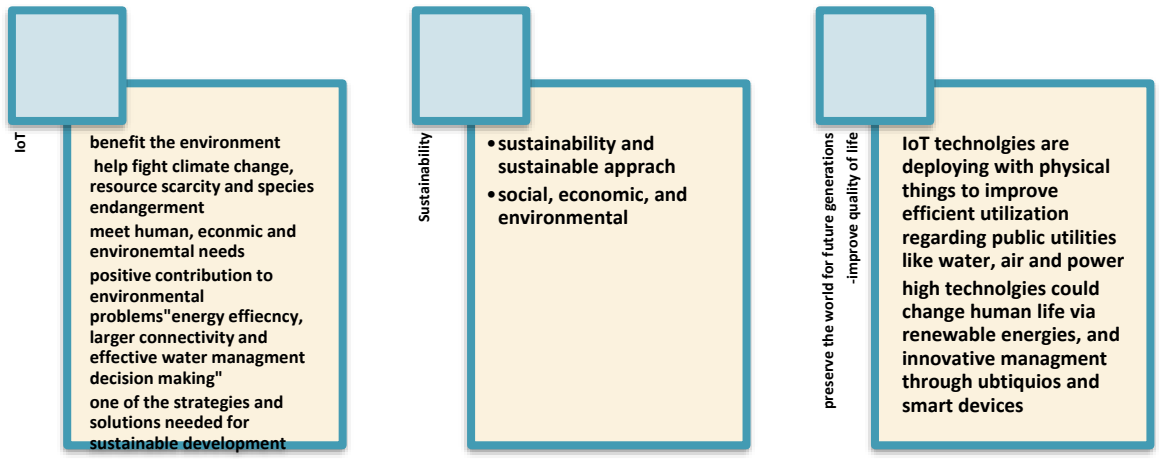


Fig. 20. IoT as a tool for sustainability concept in Architecture (Author after [36])

Inventive technologies work a key position in the concept of smart buildings, however research on privacy and ethics is leveraging IoT in a range of requirements and environments to make conventional buildings smart, proficient and safe. [36] IoT include several items shown in Fig. 21.

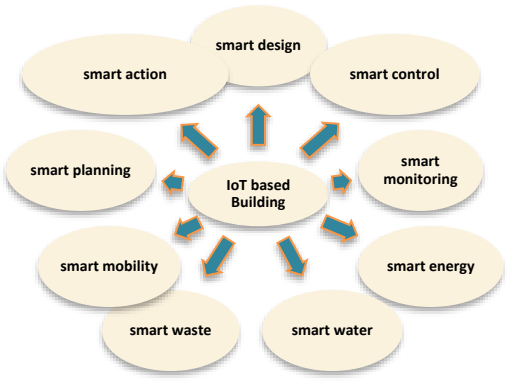


Fig. 21 Elements of IoT building [37]

IoT applications in buildings

It is critical to discourse technologies and policies to reduce pollution threats, transport left-over, resource consumption, energy consumption, and ensure public wellbeing, quality of life, environmental sustainability and cost control.[38] Fig. 22 depicts the role of IoT in administrative buildings.

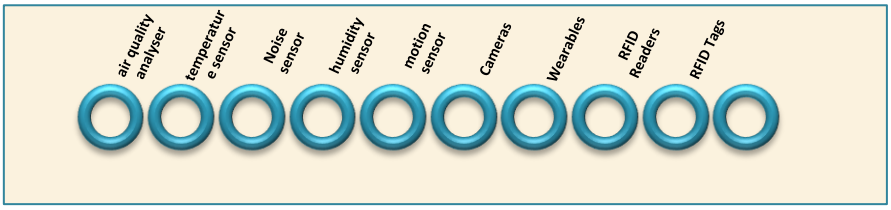


FIG 22. ROLE OF IOT IN ADMINISTRATIVE BUILDINGS

IoT can collect and provide huge quantities of data consuming innovative communication techniques that can be analyzed for intelligent decision making. The enormous data demands of IoT require storage volume, cloud computing, and high bandwidth for transfer to build IoT ubiquitous. Processing and transmitting this large amount of data consumes a lot of energy in IoT devices.[39]

IoT will play a major role in powering smart cities, impacting many of its applications in different ways In facilitating public alteration, decreasing traffic congestion, providing cost-effective community amenities, public safety, and health, lessening energy consumption, refining reconnaissance procedures, and diminishing pollution. IoT has identified its important place in the context of information and communication technology and social development.

7. RESULTS

- - Information and communication technology has become an essential tool in all fields of science, technology and environment. The rapid development of computer hardware and software has led to a requirement on applications for services and commercial activities, and a dependence on transportation. Implement intelligent solutions for using clean energy and develop governmental, economic and environmental systems.
- -The application of Internet of Things technology is considered more sustainable because it does not consume energy unnecessarily.
- - Make the most of available space and reduce costs.
- -Companies are introducing new technologies to the industry~ Internet of Things technology connects everything and makes it possible to control the environment with the click of a button.
- - Buildings are equipped with sensors and software, can collect and analyze data about occupants, surroundings and operations to be used to improve building performance, make it more comfortable for its occupants, and more sustainable.
- - Egypt is affected by technological progress as it has started planning and implementing smart city initiatives that rely on information technology.

8. CONCLUSION

- IoT has become a part of everyday life and has had a major impact on the development of architecture. The Internet of Things can be applied to buildings to automate routine tasks and needs in homes and businesses. This is an opportunity to dramatically improve living and working conditions, leading to lower manufacturing and energy use, lower costs, improved safety, increased personal productivity and quality of life.
- To implement IoT in Egypt, one should consider three factors: social expectations, economic factors, and government obligations. The smart city movement is related to the development and implementation of IoT technology.
- Challenges in applying IoT technology in Egypt may require research to overcome the problems that may arise from applying the technology in everyday life and data generation.

Main research findings are summarized as follows:

- With Internet of Things technology, buildings are no longer just Internet-connected buildings. Equipped with sensors and programs, it can collect data about its occupants, its surroundings, and its operation. All this data is analyzed to ensure the building is running at maximum efficiency and improves user experience.
- Factors such as building size, number of users and activity levels, level of automation, determining where connectivity is required, budget, security, energy management and time should be considered when choosing a building management system, users, their awareness, and age groups to embrace technology.
- Addressing buildings with Internet of Things technology requires consideration of security, efficiency, compatibility, scalability, and cost.
- Internet of things technology in buildings helped reduce costs and reduce energy consumption.
- Monitor and manage the use of energy, lighting and heating, ventilation and air conditioning to improve environmental sustainability.
- Improve workflow, improve customer experience and reduce lighting exposure.

Cost reduction strategies with IoT technology:

- Compatibility with devices that use the same operating system, or at least common protocols. This simplifies management and maintenance and reduces hardware and software licensing costs.
- Cities and buildings can become more sustainable and efficient by controlling energy production and consumption by reducing production during periods of low energy consumption.

9. RECOMMENDATIONS

- More research on the impact of human variables and long term studies on health issues on users..
- Investing in the Internet of Things across all industries.
- problems of interoperability, privacy and security should be discussed.

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