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Smart Technologies: An Overview

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ABSTRACT

Smart technology refers to the integration of computing and telecommunication technology into other technologies that did not previously have such capabilities. Smart technologies are systems, tools, or instruments which are capable of thinking, learning, and adapting to the situation. They are designed to collect and process data through the integration of sensors, software, and Internet connectivity, leading to more informed decision-making processes. The most common area where a person comes in touch with smart technology is in the home or through wearables. Today, it seems that everyone has a smartwatch and smartphone, and lives in a smart home that is in a smart city. Businesses in many industries – manufacturing, real estate, mobility, agriculture, retail, service, and other sectors – are using smart devices for a wide variety of objectives and tasks such as tracking and managing inventory. From smartphones to smart homes, smart technology is essential in today's fast-paced lifestyle. This paper explores the various ways smart technology improves efficiency, enhances comfort, and connects the world.

KEYWORDS: *smart technologies, smart devices, smart cities, smart homes, smart phone, wearable devices.*

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INTRODUCTION

Technology is an integral component to any business. It has become a vital part of our daily lives, influencing how we work, communicate, learn, and live. Today, technology has witnessed a remarkable evolution to become a need rather than an option. Our lives seem to revolve around technological innovations and advancements. The uses of technology in our daily lives enhance convenience, productivity, and connectivity in our daily routines. Technology has permeated our lives immensely. From the time you get up in the morning to the time you go back to sleep at night, you are simply interacting with other technology or the other. Everything that people do, starting from the start of the day to the end involves some or the other kind of technology. In addition, technology does the following [1]:

- It bridges gaps and strengthens global connectivity
- It brings shopping to your home
- It allows knowledge at your fingertips
- It eases communication and social interactions
- It helps in remove working
- It brings your bank to your home

The term "SMART" originally derived from the acronym "self-monitoring, analysis and reporting technology," but it has since evolved to encompass a broader range of intelligence and advanced functionality. Today, smart technology is applied across various domains, including smart homes, smart cities, and smart health. Smart or intelligent technologies represent a significant evolution in how technology interacts with users and environments, operating with degrees of autonomy that traditional devices cannot match. While conventional technologies follow predetermined instructions without adaptation, smart devices constantly gather environmental data, communicate with networks, and make autonomous decisions based on changing conditions. Smart technologies can learn from experiences, anticipate needs, and respond to changing environments without human intervention. They have the ability to learn, adapt, and interact.

WHAT IS SMART TECHNOLOGY?

Smart technology refers to devices, systems, and applications that utilize artificial intelligence, Internet connectivity, and sensors to collect data, make decisions, and perform automated tasks. What makes a technology "smart" is its ability to communicate and work with other networked technologies. Sometimes "smart" or "intelligent" simply refers to the fact that these devices can be programmed to perform certain tasks, like a coffeemaker starting to brew your favorite cup of coffee at 7 o'clock in the morning. Smart technology is embedded in devices, systems, and places capable of interacting with human and other device activity through advanced technologies. They are embedded in smart homes, smart cities, smart mobility, wearable devices, and smart factories.

Smart technology systems typically consist of four main components [2]: (1) sensors that collect environmental data, (2) processors that analyze this information, (3) actuators that execute physical actions based on decisions, and (4) connectivity features that enable communication with other devices, networks, or cloud services. These components work together to enable the autonomous and adaptive behaviors that define smart technology. AI is a core component that enables the "smartness" in smart technology. While basic smart devices might operate on simple if-then programming, more advanced smart technologies use artificial intelligence and machine learning algorithms to analyze patterns, predict outcomes, and improve performance over time.

Smart technology is based on integrating hardware with sophisticated software to develop systems and devices that can operate autonomously and adapt based on their usage. Here are the essential enabling components of smart technology [3]:

1. *Connectivity:* The majority of smart devices are Internet-connected and are a part of what is called the Internet of things (IoT). They are connected because they need to communicate, send, and receive data.
2. *Sensors:* Smart devices come with sensors that collect data from their surroundings. Sensors capture real-time data from equipment, machinery, and production processes.
3. *Data Processing:* The captured sensor data is processed on the device or sent to a centralized server or cloud for analysis. It processes this data, which allows the device to make informed decisions.
4. *Machine Learning and AI*: A number of smart devices have machine learning algorithms and artificial intelligence that can adapt to data over time. They learn, enabling them to adapt to your habits and improve your functionality. For example, a smart fridge could learn the kinds of groceries you regularly store and suggest recipes based on what is available at that time.
5. *Automation and Control*: After the data is processed and decisions are made, intelligent devices often automatically regulate operations without human involvement. For instance, smart lights can be scheduled to turn on or off, depending on the time of day or the presence of people in the room.
6. *User Interface*: Smart devices have interface that you can interact with use the services of smart devices. User interfaces in smart technology are designed to enhance user experience through easy-to-use and intuitive designs. These interfaces can customize experiences based on individual preferences, offering a personalized touch. Interactive displays and dynamic software help connect your most valuable resource – your people. For example, an interface allows you to control your car through physical buttons, touchscreen panels, mobile apps, or even voice commands.

EXAMPLES OF SMART DEVICES

At some point in 2008 or 2009, the number of things connected to the Internet came to exceed the world's human population. Since then, the IoT has become a vast network of connected objects collecting and analyzing huge amounts of data and autonomously performing tasks. According to predictions, the number of IoT connected devices will grow dramatically to 75 billion in 2025 and a staggering 125 billion by 2030. At that point, there will be almost 15 things connected to the Internet for each human on earth.

Smart technology relies on smart devices that are equipped with one or several sensors that provide data that they use to analyze and infer from, drawing conclusions from preprogrammed rules, confer with other smart devices, and act accordingly. A device qualifies as "smart" when it combines sensors for data collection, processing capabilities for analysis, connectivity for communication with other devices or networks, and some degree of autonomous decision-making. Some smart devices are also capable of learning by using experience to improve performance, anticipating, thinking and reasoning about what to do next. These cooperating devices can check system status and any change of environmental

parameters such as temperature, acceleration, radiation like light intensity, humidity, motion like heartbeat, pressure, etc. Examples are smart security cameras, smart bulbs, and smartphones. Other examples include the following:

- *Smart Wearable Devices:* The market for wearable electronics is quickly evolving beyond health care, fitness and wellness into infotainment, and commercial and industrial applications. Wearable electronics consists of several areas: sensors, actuators, electronics, and power supply or generation. They include smart watches, fitness trackers, smart garments, smart medical attachments, data gloves, etc. as illustrated in Figure 1 [2],
- *Smart Contact Lenses:* These are already in development. They will enable various point-of-care monitoring and wireless biomedical sensing, which may detect in real time the pathogen, bacteria, glucose, and infectious keratitis present in tear fluid.
- *Smart Thermostats*: Automatically adjust heating and cooling for optimal comfort and energy efficiency. A smart thermostat measures the temperature of a room and then applies heating and cooling accordingly. For example, a thermostat that adapts to your schedule and is programmable through an app or through the voice-activated Alexa. Figure 2 shows a smart thermostat [4].
- *Smart Washing Machine:* This device is capable of connecting to the Internet to access other capabilities. You may even be able to control it remotely using a mobile phone. Additionally, the smart washing machine in your home may be capable of communicating with other appliances so that they coordinate or alternate their activities for various benefits. For example, the washing machine starts a cycle 1 hour prior; or the washing machine settings let the television know of your clothing materials and detergents, so that relevant content of interest is added to your queue.
- *Smart Phone:* This is perhaps the greatest innovation of the last thirty years. These handheld devices have completely transformed the way that our world communicates, shrinking our once endless land and seascape into a global playground. Not to mention, they are great for browsing Instagram, Facebook, or Pinterest. What is crazy is the kids of the future will never know life without one! Soon enough, you will be able to control almost everything in your home with a touch of a button from your smartphone. You will be able to adjust the thermostat from work, check if you have left the lights on while you're away, and even lock your door from the driveway. Figure 3 shows a smart phone [4].
- *Smart Doorbells:* Similar to smart thermostats, smart doorbells have become commonplace in homes and businesses. Gone are the days of simple buttons that ring a chime and the hopes that someone heard it and are even home. Smart doorbells allow the end user to be notified through their smartphones any time someone presses the button. And not only do they know when someone pushed the button, but they can see and talk to them. In addition, smart doorbells often allow the ability to view the camera in it real-time.
- *Smart Television:* Smart TV's are essentially a hybrid of television and computer/Internet technology. So, in addition to spending hours channel surfing, you can stream content "on demand," you can go down the YouTube rabbit trail, or you can binge on the latest Netflix offering.

APPLICATIONS OF SMART TECHNOLOGIES

As shown in Figure 4 [3], several types of smart technologies are used to solve and address very different needs in daily life, industries, education, health, and government, etc. Common applications of smart technologies include the following [2,3,5]:

- *Smart Home*: The term "smart home" refers to a house with interconnected systems and devices such as heating and cooling, appliances, electronics, security, and lighting. A smart house also features home automation that facilitates the control of these systems with minimal human intervention. Smart home technology provides homeowners with security, comfort, energy efficiency, and convenience. Smart home technologies broadly fall into one of 3 categories: security, convenience and entertainment. They include many aspects of home monitoring and control: access control (smart locks); fire, gas and water leak detection; temperature monitoring; convenience and improved energy efficiency through lighting control, heating and air conditioning control; automated meter reading; and automated entertainment control. A great example of smart home technology are thermostats like Google's Nest, which an electronic, programmable, and self-learning Wi-Fi-enabled thermostat that optimizes heating and cooling of homes and businesses to conserve energy. Figure 5 shows a representation of smart home [6].

- *Smart City:* This idea of smart cities is slowly but surely coming into reality as many countries around the globe are adopting this idea and coming up with their own model of smart cities. At the core of smart city lies the sensors and actuators embedded in the smart devices that sense the environment for facilitating effective decision making. The core entities of a smart city consists of smart infrastructure, smart governance, smart policies, smart transportation, smart healthcare, smart agriculture, smart education, smart economy, smart environment, smart industry, smart energy, and smart feedback mechanisms that helps to truly realize the concept of a smart city ecosystem. Figure 6 shows the enabling technologies in a smart city [7].
- *Smart Factory:* A commonly accepted definition of a smart factory is a flexible system that can self-optimize performance across a broad network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes. Smart factory systems allow for direct communication between the product (work piece) and the production system. The basic smart technologies enabling a smart factory are not that different from a smart home – sensors, actuators, computer processing, algorithms and connectivity. Modern factories are highly complex systems with sophisticated processes and requirements. The smart factory represents a leap forward from more traditional automation to a fully connected and flexible system. The benefits are greater asset efficiency, lower cost, better quality, and enhanced safety and sustainability. Figure 7 shows different types of smart factory technology [8]. Smart manufacturing is the future of smart factories. Smart manufacturing integrates advanced technologies such as the Internet of things (IoT), automation, and artificial intelligence (AI) into existing workflows, enabling organizations to optimize performance throughout the manufacturing lifecycle. Figure 8 is a typical example of smart manufacturing [8].
- *Smart Logistics:* Smart logistics can be defined as the effective use of data for structuring traffic management and navigating traffic for optimal use of traffic system and logistics management. It can be applied to public traffic networks like managing inner-city or highway traffic. Most commonly though, it refers to solutions that improve efficient commercial transport and warehousing, and the facilitation of connectivity between different logistics networks.
- *Smart Education:* Smart education aims to enhance the process of students learning by integrating technology into the classroom. We use tools like smart boards and interactive screens to make the lessons more engaging. Lessons on online learning platforms are tailored according to students' performance. Virtual and augmented reality assisted in laying out tough topics in a fun and simple method. These tools aid in better learning outcomes. Figure 9 shows how smart technology is used in a classroom [9].
- *Smart Agriculture:* Smart agriculture, tools that help farmers grow crops better Soil sensors test ground moisture levels. Drones hovering above fields to check on crops' health. Automated watering systems measure data from the weather station and only water your plants as necessary. These smart tools can conserve water, boost crop yields, and reduce farm work.
- *Smart Campus:* A smart campus is connected and digital, one that operates efficiently and leverages technology to do more. At the same time, it empowers a cutting-edge academic environment, and its wealth of available infrastructure operation data can be used to create living labs for practice-oriented research and teaching and developing needed workforce skills and experience. Every day, we are learning how the power of digitalization is bringing vast amounts of data together and leveraging automation and insights to create the ideal campus environment, a truly smart campus.
- *Smart Cooking:* If you are frustrated because your cooking skills are lackluster, there might still be hope for you. Smart kitchen appliances will enable you to control the cooking process so that you would not have to wing it anymore. They might not help you become the world's greatest chef, but they will certainly improve the food you serve your family.
- *Smart Waste Management:* This would eliminate the need for large dumpsters outside apartment buildings or trash cans crowding city streets. Installing smart sensors on waste containers means trash collectors would not waste gas and time rounding neighborhoods where there is not any trash — they would instead only empty the cans that are nearing full. Perhaps by this time there will be an electric garbage truck collecting your trash.
- *Smart Car:* Not to be confused with the (tiny) vehicle of the same name, smart car technology has progressed rather slowly. Yes, many current

models include such features as: voice activated climate control, touch screen GPS, park assist, and backing cameras. Truthfully, we are all still waiting for the electric/self-driving Google or Apple car, both of which may or may not be very far off.

- *Smart Transportation:* The art and science of moving from one place to another is an inherent part of our lives — not just today but throughout history. From chariots and horses to carriages, automobiles, steam trains and spacecraft — being on the move is a part of being human. With the emergence of intelligent transportation systems and the Internet of things (IoT), the world is entering the next stage of movement — smart transportation. Smart transportation includes systems that make travelling seamless and safe. GPS apps provide live traffic information and display the ideal routes. Now, electric vehicles and self-driving cars. Many also use mobile applications to check bus or train schedules and arrange ride-sharing services. These tools save time and cut down on pollution. Smart transportation is being implemented today in several cities with their successes and failures being used to improve systems in new locations. Figure 10 shows smart transportation [10].
- *Smart Port:* The shipping industry has been notorious for its resistance to change and its conservative approach when met with emerging technologies foreign to the regular practices of shipping operations. A smart port is a modern and technologically advanced port that leverages innovative technologies and data-driven solutions to enhance its operational efficiency, safety, and sustainability.

BENEFITS

Smart technology offers numerous benefits including enhanced efficiency through automation, improved resource management and energy savings, greater convenience and time savings, personalized experiences based on user behavior, remote monitoring and control capabilities, improved safety and security features, and data-driven insights that enable better decision-making in various contexts. Smart technologies have made contemporary living much more energy-efficient, safe, and environmentally friendly. Other benefits of smart technology include the following [3]:

- *Automation:* Automation features increase productivity by automating routine tasks, thereby reducing the need for manual intervention. Smart technology represents a more advanced form of automation with greater flexibility and intelligence. It is based on integrating hardware with sophisticated software to develop systems and devices that can operate autonomously and adapt based on their usage. Smart technologies, devices, systems, or platforms automate processes by using sensors, Internet connectivity, artificial intelligence, and data analytics to improve efficiency and offer intelligent feedback. Combining sensors, connectivity and artificial intelligence (AI), these technologies aim to automate tasks, enable and enhance automation, and allow for more efficient workflows. From automatically turning on lights to helping cities manage traffic, smart technologies make lives easier, safer, and smarter.
- *Convenience:* Smart devices learn how you use them and can anticipate what you need to do without you doing anything. It is transforming businesses and simplifying daily life. Smart home technology can make your life so much easier. For instance, preprogramming your HVAC system means you would not have to get up in the middle of the night to raise the thermostat — your home will remain at the ideal temperature on a 24/7 basis. You can also set up smartphone alerts to notify you of everything from a water leak to a possible break-in. You can even see who's ringing your doorbell when you are in an upstairs bedroom.
- *Accessibility:* The ability to control who enters your home is another of the many benefits of smart home technology. If you are expecting a package delivery while you are at work, you can use your smartphone to see when the driver arrives and unlock the door remotely to let him or her inside. No more worries about leaving packages on the porch until you get home! If your kids forget their house key, you can let them inside with just a few taps on your mobile device.
- *Sustainability:* Most of us are concerned about protecting the environment. A smart home's excellent energy efficiency results in less energy consumption, meaning you will live in a more eco-friendly house. The technology is also compatible with renewable energy products such as solar panels and geothermal heat pumps. As concerns about the environment grow, smart technology is being used by both companies and homes to reduce energy use. One instance is how it can switch the lights off or change the heating in a room by itself and by doing so saves you a lot of energy and money.
- *Increased Security:* Security is a crucial benefit of smart technology, providing advanced features to

protect data and devices. It continuously monitors for potential security threats in real-time, enabling quick responses and enhancing overall safety. Devices such as security cameras and smart locks do more than warn you of potential dangers. They can also take steps to help keep you safe, such as automatically locking a door. Technology is not only going to make our lives more accessible than ever before; it will also have the potential to make our homes a lot safer too. Surveillance equipment will become more and more accessible, enabling homeowners to monitor their homes from anywhere.

- *Increased Comfort:* Smart home technology also increases comfort and convenience by automating processes and making your life easier. You can control temperature, lights, security, and other home features with a button or voice command. Home automation systems can use geo-fencing to detect when residents are close to home and automatically turn on lights, adjust the temperature, and unlock the front door. This provides a seamless experience for homeowners, eliminating the need to adjust settings manually upon arrival.
- *Efficiency:* Efficiency is maximized through resource optimization, which reduces waste and lowers operational costs. Smart technology automates various tasks, saving time for users and businesses alike. Its ability to easily scale to meet growing demands without increasing complexity further underscores its efficiency. Smart devices gather data to determine how to improve. They study patterns to optimize systems, assisting you in avoiding both waking up on the wrong side of the bed and getting to work late.
- *Cost-effectiveness:* Most homeowners experience a relatively quick return on their investment in smart technology. Some homeowner's insurance providers now offer discounts when transitioning to a smart home due to the added safety benefits. And when the time comes to put your house on the market, you may be able to sell it at a higher price — more buyers will seek a home equipped with this state-of-the-art technology. Smart devices consume less energy (reducing energy bills) and automate repetitive tasks (giving back time you would otherwise lose). Automation leads to significant cost savings by lowering labor costs and minimizing errors. Additionally, smart technology promotes reliable operations and maintains high-quality standards. Because smart transportation makes better use of the resources available, it can cut down costs thanks to preventative maintenance, lower energy consumption, and fewer resources used towards accidents. Cost savings can also be gained by riders when inexpensive public transit is efficient enough to compete with private vehicle ownership.
- *Connectivity:* The integration and connectivity of multiple devices and systems enable seamless communication, which significantly improves overall efficiency. Users can also monitor and control their devices from anywhere using smartphones, tablets and computers, which provides convenience, flexibility and greater control.
- *Time and Energy Saving*: Smart technology saves you time and energy in different ways. You can control devices with a single touch or voice command, so you do not have to spend time figuring out buttons or searching through menus. You can also preset scenes so that your home is ready for bedtime, waking up, or entertaining guests automatically. For example, you can dim the lights and close the blinds at night, turn on the music and set the thermostat to a comfortable temperature before leaving for work in the morning, or have all the lights turned off and shades closed when you go on vacation.
- *Data Processing:* Smart technology processes data as it is collected, providing immediate insights and enabling swift, informed decision-making. This technology is capable of managing and analyzing large volumes of data, enhancing operational capabilities. Moreover, its data processing capabilities enable predictive analytics, which helps organizations foresee potential issues before they occur, optimizing maintenance schedules and improving operational efficiency.

CHALLENGES

Potential downsides of smart technology include privacy concerns due to extensive data collection, security vulnerabilities that could lead to unauthorized access, dependency on Internet connectivity and power, compatibility issues between devices from different manufacturers, complexity in setup and troubleshooting, and potential job displacement in sectors where smart automation replaces human workers. Smart cities require sensors — a lot of sensors — and those sensors all require power. Other challenges include the following [10]:

- *Security*: The security of smart technology varies widely depending on the manufacturer, device type, and implemented safeguards. Many smart

devices still have security vulnerabilities including weak default passwords, unencrypted communications, infrequent security updates, and data privacy issues. One can improve security by regularly updating firmware, using strong passwords, enabling two-factor authentication when available, and isolating smart home networks from sensitive personal devices.

- *Privacy:* With the increasing deployment and use of smart technologies there is growing concern over privacy in general and hacking in particular. Can the data collected by smart devices be used against you? If a device can be remotely operated, can it be hacked and used without permission?
- *High Costs:* Cost is typically a major roadblock for organizations because initial implementation may require substantial financial investment, such as maintenance costs, upgrades, and workforce training. For many organizations, careful consideration of costs and return on investment (ROI) analysis is essential to ensure financial viability. Integrating a whole-house automation system into your property can be a substantial financial investment, with costs ranging from several thousand to tens of thousands of dollars. However, it is important to note that this type of advanced technology comes with a wide range of features and capabilities that can significantly improve your living experience. Despite its many advantages, the cost of installing expensive whole-house automation systems is often a barrier for many homeowners who may not have the financial means to afford it.
- *Transition from Legacy Processes*: Transitioning from legacy processes to modern digital systems can be difficult for manufacturers. This transition can require large up front costs in new equipment, technology, and downtime due to installations and employee training.
- *Changing Labor Demands:* According to studies, 76% of today's supply chain operations are being impacted by labor shortages. On top of this, labor costs for manufacturers have increased 20% since 2010. Rising labor costs coupled with unfilled positions are causing manufacturers to turn to advanced solutions, like automation, to help ease the effects of changing labor demands.
- *Cybersecurity:* In 2022, the manufacturing sector constituted 24.8% of all cybersecurity attacks within the industrial world. Cybersecurity threats can jeopardize data integrity, operations, and reputation.

CONCLUSION

Smart technology refers to devices and systems designed to operate in a more intelligent, efficient and interconnected manner. These technologies typically incorporate advanced capabilities such as artificial intelligence (AI), the Internet of things (IoT), automation, data management, processing and analytics, machine learning, and connectivity to the Internet or other networks. Smart technologies facilitate our lives at high levels where we can do numerous things with very little efforts like setting smart bulbs or ordering food with voice commands or set your home with a voice command.

It is becoming increasingly clear that smart home technology is the wave of the future. And the good news is that it is getting more affordable almost by the day. Smart technology has seen explosive growth in recent years. It should come as no surprise that a major driving force behind the use of smart technology is for this technology to use energy and natural resources more intelligently. More information on smart technologies is available from the books in [11-20].

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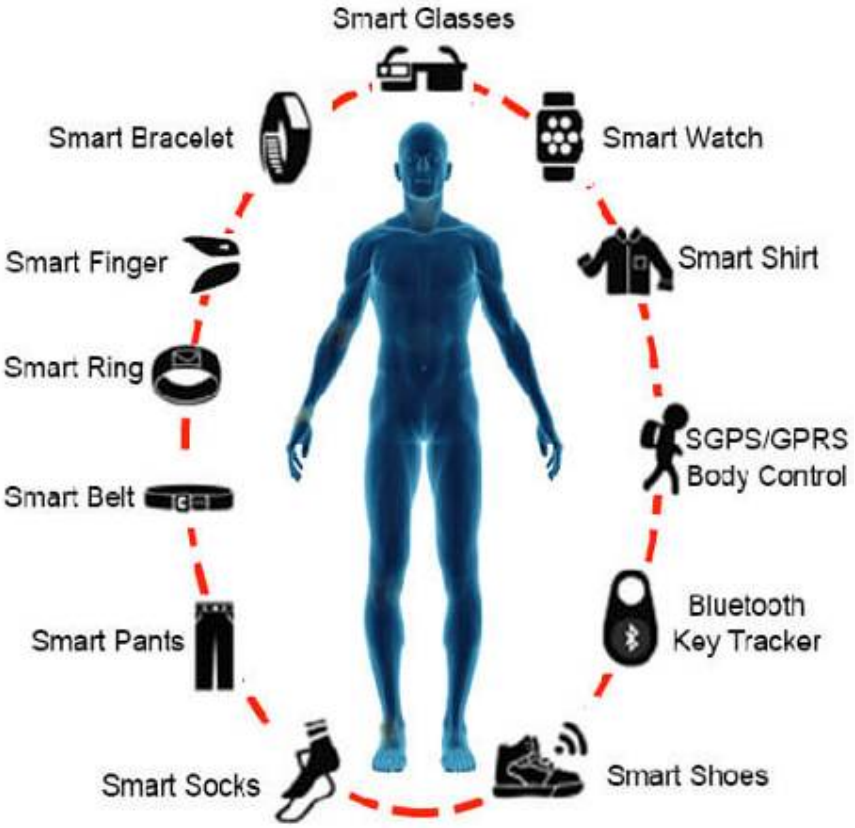

Figure 1 Different types of wearable technology [2].

Figure 2 A smart thermostat [4].

Figure 3 A smart phone [4].

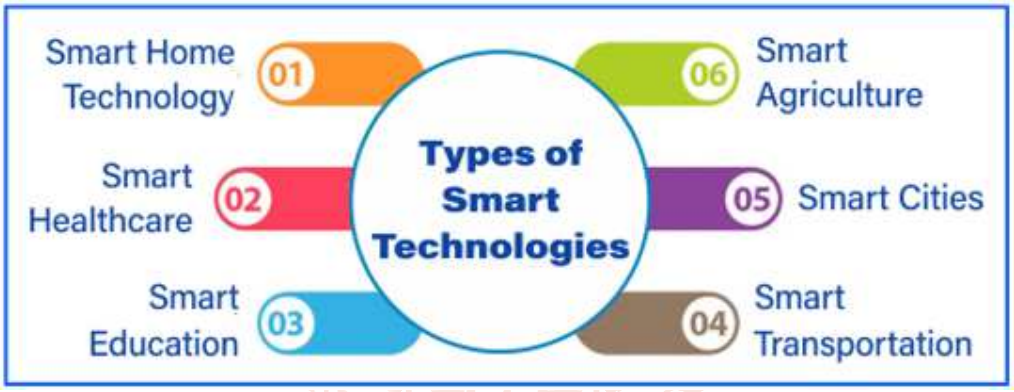

Figure 4 Types of smart technologies [3].

Figure 5 A representation of smart home [6].

Figure 6 Enabling technologies in a smart city [7].

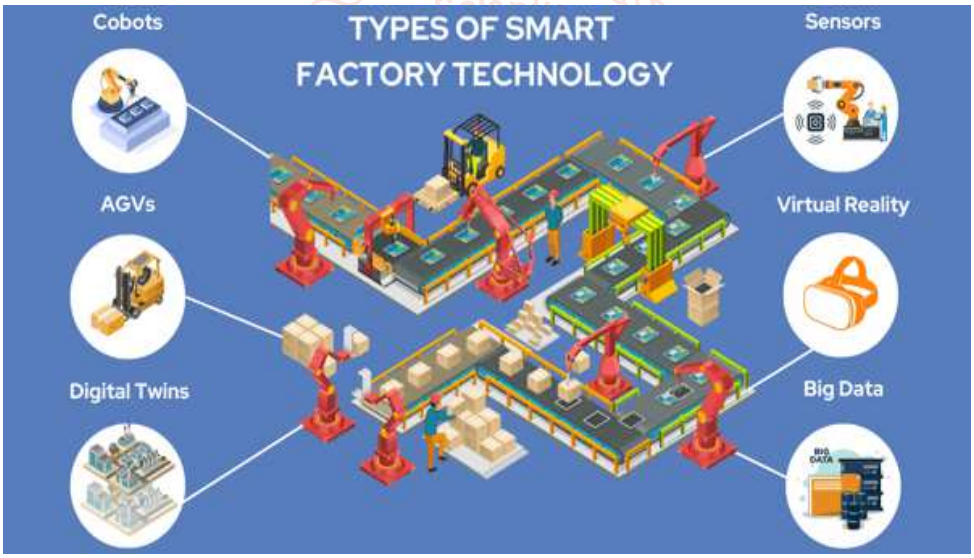

Figure 7 Different types of smart factory technology [8].

Figure 8 A typical example of smart manufacturing [8].

Figure 9 How smart technology is used in a classroom [9].

Figure 10 Smart transportation [10].