IOT Within the Saudi Healthcare Industry During Covid-19

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Abstract. Internet of things (IoT) has improved quality of life and made life easier, more effective, and more productive. With the rapid spread of COVID-19, a need has emerged for technologies that enable countries and their healthcare sectors to confront the pandemic, reduce its spread and infection rate, and find a way to detect it as soon as possible. This research investigated the current status of adopting IOT technology within the Saudi healthcare sector during the COVID-19 pandemic. The research benefited from previous research that suggested solutions to leverage IOT technology to confront COVID-19. Structured interviews with experts from the field were conducted to collect the information for this research. The results indicated that all research participants are taking a clear initiative to adopt IOT technology and have taken some initial steps. It was observed that IOT technology was implemented in closed systems and not shared over the internet or outside a cloud. Privacy and security concerns were raised as major obstacles facing IOT adoption, in addition to strict standards imposed by the Ministry of Health (MOH). Moreover, the results show that COVID-19 can be seen as an enabler to promote IOT adoption. Moreover, participants highlighted many benefits of adopting IOT technology for example: improve advance patient care, provide real-time monitor and real-time data, provide proactive action, and homecare. Participants also emphasized the challenges of IOT adoption: poor infrastructure, shortage of staff and poor experience. Participants also highlighted IOT that awareness workshops can help in effective IOT adoption. This research should serve as a good starting point for further research on a greater scale.

Keywords: IOT adoption, internet of things, Saudi healthcare, COVID-19, Coronavirus, fight coronavirus, Saudi Arabia.

1   Introduction

Information technology has been rapidly developing in recent times and has revolutionized the way we go about our lives. A major contributor to this revolution is the so-called Internet of Things (IoT). IoT has improved quality of life and made life easier, more effective, and more productive. IoT is defined as a network of connected

objects or "things" that collect and send information from their software and sensors to central servers, all with a lower level of human involvement [1].

IoT is widely known for its impact on the personal level, as can be seen in the development of smart homes, smart lighting management systems, and smart parking, all of which can be easily controlled through remote devices. Fortunately, healthcare is also one sector that gets the most benefit out of IoT. The healthcare sector uses the IoT to monitor patient symptoms through sensors, to manage patient health, and to predict diseases. IoT can help with central patient care, which will lead to greater patient satisfaction. Moreover, IoT technology makes tracking staff, patients, and equipment much easier, faster, and more effective. Although the healthcare sector knows and trusts the IoT and its capabilities, there is a lot to be done before leveraging IOT to its full potential [2].

Currently, the coronavirus (COVID-19) pandemic is having a great impact on the world economy and on healthcare in particular [3]. Moreover, global public healthcare is also affected and there is a significant burden on their financial position and lives of patients and healthcare workers. With the rapid spread of COVID-19, a need has emerged for technologies that enable countries and their healthcare sectors to confront the pandemic, reduce its spread and infection rate, and find a way to detect it as soon as possible. Moreover, reaching patients is considered to be the second major issue after vaccine development; this is what the IoT can provide to the healthcare sector, in addition to other tools such as artificial intelligence, data analytics, and drones.

Smart wearable devices that use IoT technology can enable patients to track their own health and help healthcare providers deliver immediate care when needed [4]. These devices can also monitor and record symptoms and then analyze them to predict disease.

Many countries, such as China and Saudi Arabia, have implemented the IoT in their health sectors and leveraged its benefits to fight COVID-19. China has invested significantly in the IoT, especially in the healthcare sector. It uses IoT in conjunction with other technologies like robots, drones, and artificial intelligence (AI) to monitor patients wearing IoT-enabled devices to record any changes on the body. The Chinese health sector also use IoT technology to track infected people and make sure they are in quarantine. Saudi Arabia, with their promising Vision 2030, is also steadily moving forward to adopt new technologies in their healthcare sector. They know the power of the IoT and have started to adapt it into their health care.

This paper emphasizes the positive impact of the IoT in the healthcare sector and discusses the current situation in the healthcare sector of Saudi Arabia, especially during the coronavirus pandemic. Moreover, it can serve as a starting point to inform Saudi healthcare leader about the current status of IOT in healthcare and how IOT will help them to confront the current pandemic or any potential future crisis. Furthermore, it can serve as a foundation for future studies in addition to encourage and motivate healthcare leaders to fully adopt IOT technology in Saudi healthcare.

2   IoT Technology: Overview

Before discussing the research on the IoT, it would be helpful to discuss the architecture of IoT.

2.1   **The Layers of IoT in Healthcare and Its Components**

   IoT technology is built on three layers. First, the physical or perception layer is where the devices and sensors are located. Second, the network layer is where the routers and gateways are used. Third, the application layer is where the cloud and servers are located. According to [1], the architecture of IoT in health care has six layers: perception, transport, processing, application, business, and network. The perception layer concerns objects and sensors that are available in the environment. It determines whether there is a smart object in the area and senses those objects in some "physical parameters" for information such as motion, temperature, and location. The transport layer transfers sensor data from the perception layer to the processing layer and reverse through RFID, Wi-Fi, and Bluetooth. The processing layer, or middleware layer, stores a large amount of information and analyses it. The application layer delivers the user an application-oriented service which IoT has different application on such as a smart home and smart health. The business layer manages all IoT systems, such as user privacy.
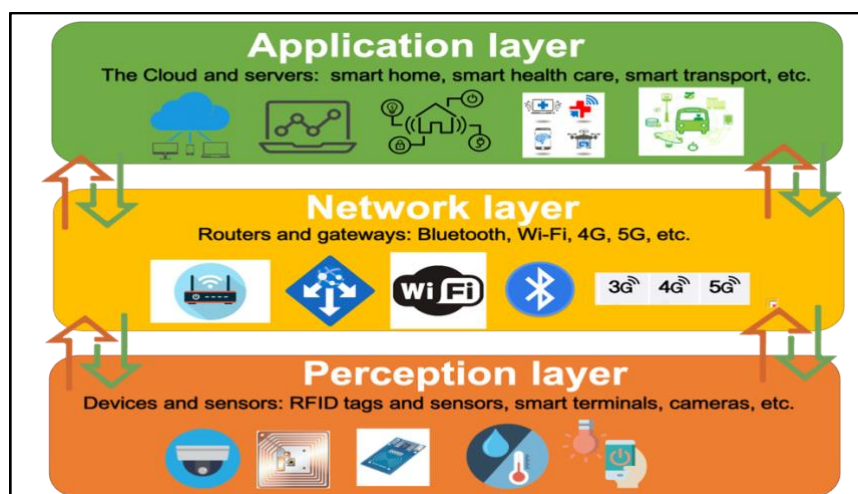

Fig. 1. IOT Layers

   [1] also explain the following five components of IoT in health care: 1) the sensor collects information; 2) the collected information goes through a smart network; 3) this collected information is saved in the cloud; 4) the information is investigated and analyzed using big data analysis to select the right choice; and 5) the clarified information is sent to a smart medical clinic, which takes appropriate actions toward

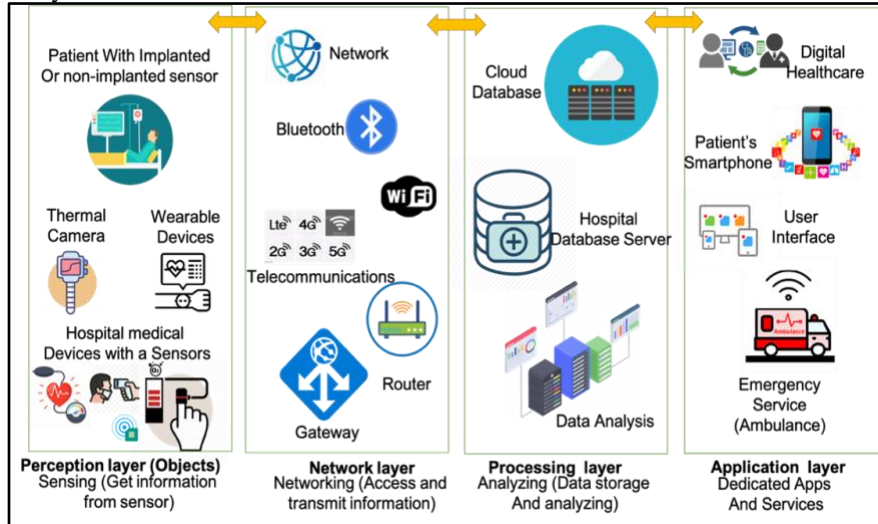diagnosis and treatment. This cycle then returns to step one to sustain the circularity of the system.

Fig. 2. IOT layers in healthcare

3 Literature Review

3.1 IoT in the Healthcare Sector

The governments, organizations, and initiatives of nations have all recognized the importance of IoT and its positive impact. The healthcare sector specifically has clearly benefited from the power of IoT, because IoT offers the best, most effective, and most efficient way to manage their health operations [5].

According to [3], about 76% of healthcare organizations trust the IoT and its capability to transform the healthcare industry. A report from Arab Health states that the global internet-of-medical-things (IoMT) market was worth US$41.2 billion in 2017 and is expected to increase to US$158.1 billion by 2022 [6] and to US$188 billion by 2024 [3].

IoT plays an important role in the healthcare sector by helping to manage its operations and prevent chronic disease. It helps monitor and track patients' health and sends alerts to healthcare provider that unusual changes happened by using radio-frequency identification (RFID) tags and Real-time locating system (RTLS) technology [2]. According to [7], older people (60 or older) are the patients that can benefit most from IoT. They benefit by using IoT-enabled devices like health trackers (e.g., a bracelet), glucometers, and skin sensors to monitor their blood pressure, blood sugar level, and heart rate. This can help save lives by recommending specific safety actions or by notifying healthcare providers and the patient's guardian of any unusual changes. In addition, [7] suggests using smart shirts that have numerous sensors that monitor the patient's vital signs and inform healthcare providers about the patient's

condition in case of an emergency and even locate him or her via GPS. According to [1], IoT can be used in medical information management to detect and prevent falls, which are considered a serious problem for older people. Finally, [8] offers a fall-detecting system that is based on IoT and big data modelling, which uses machine-learning (ML) techniques based on a decision tree.

3.2 **Impact of IoT on the Healthcare Sector During the COVID-19 Pandemic**

From the studies discussed above, we can say that IoT can effectively help minimize the spread of the coronavirus. COVID-19 has changed the world and pushed countries to adopt new technology and search for "practical and cost-effective solutions" to manage the pandemic and reduce its negative impacts on the economy and on people's lives [9]. The healthcare sector has faced the following key critical issues: patient overload, safety of healthcare workers, and healthcare resource shortage. Moreover, [9] states that most of these problems occurred because of not effectively reaching the patient; however, IoT technology can improve patient tracking. IoT technology can ensure that all infected patients are quarantined and tracked using an internet-based network, and it can monitor and capture real-time data and information from infected patients. Moreover, [9] emphasizes that by successfully implementing IoT, there will be critical merits of IoT for the COVID-19 pandemic. It will reduce the "chance of mistakes, deliver superior treatment, lower expenses, effective control, and enhance patient diagnosis." This technology can be used to monitor not only infected patients but also older people and people with a high risk of developing severe complications from the disease [3].

Another suggested use for IoT technology in fighting COVID-19 is air cleaning systems. In [10], Terrence DeFranco said that one solution for managing and reducing COVID-19 infection is to use IoT technology to clean the air indoors and make sure the environment is free from viruses. Applying a program that manages indoor air quality will create a healthy environment and reduce infection. This can be done with an indoor virus detection sensor that controls contaminants and ensures the environment is getting enough ventilation [10].

In [11], the authors propose a home hospitalization system based on the IoT, cloud computing, and fog computing. This proposed system allows the patient to receive treatment and recover in their own home without going to the hospital and possibly getting infected with COVID-19. This home system will primarily benefit patients with chronic disease, especially older people. Moreover, this system will solve problems of resource shortages and overcrowding that hospitals have suffered during the pandemic. The system will monitor the patient's health and the room's environment during the home hospitalization period so healthcare providers can monitor patients remotely.

On the other hand, [12] suggests that implementing a centralized IoT system for diagnosing COVID-19 patients will be more effective if it is done by the government. The authors emphasize that integrating telemedicine benefits (e.g., accessing patient health records through software and with a communication channel between

healthcare provider and patient) with their proposed IoT system will improve the system and make it suitable not just for the COVID-19 crisis, but for future situations.

According to [13], they proposed an IOT architecture with the use of smart sensors to measure and record body temperature that will identify infected individuals and maximize social distancing. Moreover, this IOT system is connected to a cloud computing and uses data analysis to make effective decisions based on real-time data.

Furthermore, [14] proposed a monitoring system that gathers real-time symptoms data from wearable sensors to identify potential coronavirus cases. This will be done via eight machine learning algorithms implemented within IoT infrastructure that tracks both potential and conformed cases in addition to the outcome of treatment of recovered patients. The goal of this system solution is to minimize mortality rates by early detection, tracking recovered cases and a better understanding of the nature of the disease. The result shows that five of these eight algorithms have received an accuracy of more than 90%.

Another system design proposed by [15] has the ability to detect and monitor coronavirus cases by IOT based smart glasses. The glasses will send a notification to the officer if system identify a suspected case among the masses of people based on the captured body temperature by thermal cameras. Moreover, the system can use face identification on suspected carriers of the virus who have high body temperature. The information of the visited location of the suspected cases via Google Location History (GLS) will be used to provide " reliable data on detection process". This system will help decrease screening time with minimum human interaction and as a result reduce the chance of the virus spreading.

During this pandemic, many countries have leveraged the use of the IoT in their healthcare sector. In China, Wuhan was the first city to identify a coronavirus outbreak. With its incredible Wuhan Wuchang Smart Field Hospital, China gives a great example on how to apply IoT technology in health care. This hospital uses several smart devices, such as bracelets, to monitor patients and record vital information like blood pressure, blood sugar level, blood oxygen saturation, and heart rate. If there is any sign of infection, the medical provider will be informed [16]. China also launched an app called the Close Contact Detector, which notifies people if they are near someone who is confirmed to have or is suspected of having the virus [9].

Hong Kong is using electronic tracker wristbands to track citizens and notify authorities when an individual, particularly one who recently arrived from an international destination, is not following compulsory home quarantine orders [17]. The passengers are given a bracelet to wear which has a unique QR code to track their movement. They then download an app called StayHomeSafe and scan the QR code, and once they reach their apartment, they should move around only to calibrate the device. The app uses geofencing, which is a location-based technology that uses RFID, GPS, Wi-Fi, or cellular data to create a virtual perimeter for an app. Russia, Poland, Singapore, and South Korea have all launched apps similar to the StayHomeSafe app used in Hong Kong [18].

With the Saudi Arabi promising vision 2030, there will be noticeable improvement in healthcare electronic services including IOT application. There are many

Telehealth application and e-services in Saudi healthcare that helps in managing patient information, deliver advanced care remotely and effectively, and increase treatment outcomes. As [19] explain, Telemedicine (SEHA App) used to deliver care at a distance and enable patient to manage their healthcare journey. An appointment app called Mawid, which is a central appointment system that patients can use to manage their appointments. Moreover, recently, The Ministry of Health (MOH) lunch Tabaud App to help in fighting and contain COVID-19 pandemic. MOH comes with strategy to use those Mobile applications, in addition to Tawakklna and Tetamman, to contain and mitigating the risk of the disease [19].

4 Methodology

4.1 Methodological approach and data collection

The goal of this research is to investigate and gain a better understanding of the current status of IOT adoption in Riyadh, Saudi Arabia, and if coronavirus pandemic affects its adoption. A qualitative research design was adopted. To gather the qualitative data, this research conducted structured interviews due to the limited time, the shortage of experts in the field, and the limited adoption of IOT technology in the Saudi healthcare sector. The interviews were conducted through phone, Microsoft Teams, or Zoom and lasted approximately 30 minutes each. It has eight open-ended questions and was answered by five participants. The participants were selected as they have the most expertise in the field and have knowledge of IOT adoption in Saudi Arabia's healthcare sector. The participants' roles and work locations are shown in Table 1.

   Five out of the six participants that met the criteria were interviewed. The other participant refused to publish or use the information he provided.

Table 1. Participant role and working place

Participant	Role	Working place
Participant 1	Director of healthcare technology development.	King Abdulaziz Medical City NGHA.
Participant 2	Group Chief Information Technology Officer.	Saudi German Hospital Group - BAB Medical Education Company Limited.
Participant 3	Director of e-Services and e-Channels.	Dr. Sulaiman AL Habib Medical Group.
Participant 4	Integration Services Manager.	King Faisal Specialist Hospital and Research

		Center.	
Participant 5	- Executive Vice President. - Asst. Professor.	- Taibah Valley company. - Taibah university.	

4.2 **Data analysis**

Thematic analysis was performed to analyze the qualitative data. During the interview, notes were taken, and the interviews were recorded in case of any missing notes that were not captured. To analyze the data, different steps were taken. First, the notes and data from the interview records were transcribed into a document. Second, the data were coded by highlighting similarities and differences between the data (text). Third, themes were generated by identifying patterns among created codes and then reviewing them. Finally, themes were defined and named for brevity and clarity. Moreover, the level of IOT adoption and the degree of obstacles hindering IOT adoption was measured on scale of one to five as shown in table 2.

5 Result

After analyzing the data, eight themes were identified: (1) adoption of IOT technology in the Saudi healthcare sector, (2) obstacles to the application of IOT technology, (3) supported IOT technology devices, (4) effect of the COVID-19 pandemic on IOT application, (5) desired benefits of IOT adoption, (6) challenges faced when trying to adopt IOT technology, (7) raising leadership and end-user awareness of the power of IOT technology, and (8) criteria for measuring the success of adopting IOT technology.

1. Adoption of IOT technology in the Saudi healthcare sector

All participants agreed that Saudi Arabia's healthcare sector is moving forward to adopt IOT technology and has initiated steps in this action. Four of the participants discussed that they use IOT technology within closed systems and store data in local datacenters. They do not share information through the Internet and to an external cloud. Participant (P1) said, "No, we don't have full adoption of IOT technology. We don't have a device that collects data by sensors for example, and then feeding bigdata database or cloud over the Internet. However, we have solutions over a closed system (semi-IOT technology) that do some certain function, but not sharing the data to an open platform." On the other hand, P3 said that they are using IOT technology in their hospital, and they have started using smart wearable devices such as the Apple Watch, which is integrated with their applications to collect patients' vital signs and stores them directly within their electronic health records (EHR). He added that they have a new department that mainly focuses on emerging technology such as IOT, AI, and deep learning.

P4 highlighted that some critical departments such as cardiovascular diseases are required to collect some parameters when a patient is discharged from the hospital, so

they give them a device to collect those vital signs. After that, there are two options: the device company either transmits the data to the hospital through a secure channel or stores the data within the device, and when the patient comes back to the hospital, they upload the patient's data to the hospital system. The adoption results are summarized in Table 2.

Table 2. Adoption results

Themes	Related Questions (Patterns)	Point-scale from (1 to 5) where: 1 Strongly disagree, 2 Disagree, 3 Nature, 4 Agree, and 5 Strongly agree				
		P1	**P2**	**P3**	**P4**	**P5**
1. Adoption of IOT technology in Saudi healthcare sector.	Does Saudi healthcare sector has initiated steps in IOT technology?	5	5	5	4	3
	Have full IOT adaption	1	1	5	4	1
	Use IOT technology within closed systems (Semi-IOT technology)	5	5	1	5	3
2. Obstacles that prevented the application of IOT technology.	Do you have any kind of obstacles that prevent you from adopting IOT technology?	5	2	1	5	3

2. Obstacles to the application of IOT technology

As showing in table 2, there are many obstacles that prevent Saudi healthcare from adopting IOT technology. Three participants agreed that privacy and security issues are the biggest obstacles they face. However, P2—who has experience in data security and privacy—argued that "any new technology comes out, people used to mention privacy and security as an issue." He added that "All technologies are supported with standards and controls that will make sure we use the technology correctly and protect our data in case if their integrity, availability, and confidentiality."

Two participants (P1 and P2) stated that they are not sure about the accuracy and safety of the devices that collect data. However, P4 disagreed and said that the accuracy of the devices depends on the manufacturers, and nowadays these

companies are more advanced and provide the market with excellent devices at different prices.

Four participants mentioned that there are no standards or regulations from the Ministry of Health (MOH) that guide the adoption of IOT technology in healthcare. Moreover, the MOH prevents sharing patient information over the Internet or storing it in the cloud. P3 mentioned that they don't have any obstacles.

3. Supported IOT technology devices

P1 referred to devices that patients can use to adjust the room temperature and lights and call the nurse. However, he emphasized that all those devices are linked to closed systems that perform certain functions. He also mentioned that on the hospital gates, they use thermal cameras that sense body temperature. In addition to a thermal camera, P2 added that they are using a smart analyzer in their laboratory. P3 said they used Apple Watches, Accu-Chek for testing blood glucose, smart refrigerators for medicines, and point of care (PoC) technology. Three participants mentioned that they are using bedside devices that are linked to their closed system. Moreover, P4 added that they are using Philips Patient Monitoring, Welch Allyn vital signs monitor, and MAQUET ventilators.

4. Effect of the COVID-19 pandemic on IOT application

P3 highlighted that COVID-19 did not affect their adoption of IOT technology. However, all other participants stressed that COVID-19 has had a positive impact on their hospitals' adoption of IOT technology, and it works as an enabler to promote IOT adoption. P1 said, "COVID-19 made everyone change their healthcare delivery. Hospitals want to minimize the exposure of their healthcare provider and patients to the virus, monitor infected patients inside and outside the hospital, and deliver the healthcare service to them. All of that can be done by applying IOT technology." P4 added that during the COVID-19 pandemic, there was a specific budget for handling the pandemic, and there was a high demand for devices that support IOT technology.

5. Desired benefits of IOT adoption

All participants agreed that IOT technology will improve patient care and increase patient engagement and satisfaction. Moreover, all of them discussed the benefit of IOT in terms of how it will help in home care especially for elder patients. They all pointed out that IOT technology will provide them with real-time monitoring and data which will help take proactive action before situations become critical. Three participants stressed that with real-time data, IOT technology will improve disease management.

Four participants believed that IOT technology will help reduce operating costs. P3 said, "Adopting IOT technology will reduce the usage of power like electricity. Moreover, with the real-time data, the health provider will deliver the service to the patient without unnecessary visits to the hospital which will save doctors time and hospital resources used in the reception."

Three participants agreed that IOT will improve data accuracy and reduce errors, mainly human errors. They also indicated that adopting IOT technology will provide them with massive amounts of data which will improve treatment outcomes and help in decision-making.

6. Challenges faced when trying to adopt IOT technology

Participants highlighted many challenges they faced when they trying to adopt IOT technology. Four participants stressed that patient privacy and security are the biggest challenges to IOT adoption. Moreover, they highlighted that that MOH standards and regulations prevent sharing patient information and saving it on the cloud, which will make full IOT adoption more difficult.

P3 noted that infrastructure is one of the big challenges faced by the Saudi healthcare sector. P1 and P2 agreed that many hospitals have poor healthcare infrastructures, but they did not face this problem in their hospitals. In addition, P1 mentioned that 5G technology can help solve many IOT challenges faced by the Saudi healthcare sector. P3 added that end users (doctors and nurses) are not technical oriented, and they need training and education programs to facilitate IOT application.

Three participants agreed that staff shortage and poor experience are two of the barriers they faced, as P4 said, "Lot of people knows the concept of the IOT and the broad idea behind it. However, less of them knows the details of IOT adoption and how much effort it will take to implement it effectively."

P4 expressed concerns about the availability and maintenance of the devices in the Saudi market. He said, "We don't have local manufacture in Saudi Arabia that provide the Saudi market with devices that support IOT technology. Which means that we have to buy spare parts from outside the country in case of devices' maintenance." He added that the companies raised their prices—especially after COVID-19—which may reduce the demand for such devices.

The main challenge P2 faced in their hospital is time. "We are moving forward in IOT application, but we need more time to fully implement it effectively in our hospital."

P5 highlighted that resistance to change—from both top management and end users—in medium to small size hospitals is one of the biggest challenges to Saudi healthcare's adoption of IOT technology.

7. Raising leadership and end-user awareness of the power of IOT technology

Four participants emphasized and highlighted the importance of education and awareness programs for end users and how they will help raise their awareness of the power of IOT technology and the added value it can potentially provide. They all agreed that they do not have problems with top management since they are the ones who guide and lead the hospital's digital transformation. As P4 said, "In our hospital, top management and healthcare provider are the ones who asked for more IOT solutions. They are aware of the added value that IOT can deliver and saw some of its potentiality. However, we have some concern about the patients."

All participants agreed and discussed how running demos help in raising leadership and end-user awareness of the power of IOT technology. As P2 said, "We can run a demo (proof of concept (POC)) help in raising leadership and end user awareness."

8. Criteria for measuring the success of adopting IOT technology

All participants agreed that decreased response time—which will improve customer service—will be one of the criteria for measuring the success of adopting IOT technology. They all discussed that optimizing and utilizing resources along with reducing operating costs will be considered as success factors. In light of the current

COVID-19 pandemic, they all agreed that infection control and minimizing patients' hospital stay will be considered as a criterion for success.

Three participants mentioned patient satisfaction as another criterion for evaluating progress. The other two participants argued that having accurate results in real-time and the validity of devices are two important requirements. P4 and P5 added that increasing productivity and reducing errors can be considered as critical criteria.

6   Discussion

Studies have shown the importance of IOT technology in the healthcare sector and how its application will enhance the effectiveness of hospital performance, improve the patient's health and care, and increase their satisfaction. With the current situation, solutions to overcome the COVID-19 pandemic and minimize its spread are crucial. Results indicate that COVID-19 works as an enabler to promote IOT adoption in the Saudi healthcare sector.

Results show that IOT technology is still a nascent phenomenon especially in the Saudi healthcare sector, and its adoption is still at an early stage. Moreover, there are some emerging IOT applications, but they are done in closed systems (semi-IOT technology). Thermal cameras, wearable devices, and other devices that use sensors to gather data such as body temperature, blood pressure, heart rate, and other body parameters are used in Saudi hospitals but not shared over the Internet or stored in an external cloud. The current Saudi Ministry of Health (MOH) regulations prevent sharing patient information through the Internet or storing it in the cloud because of concerns about data privacy and security. Electronic health records (EHR) are still not stored in a central datacenter for all Saudi hospitals. This is one of obstacles to widespread IOT adoption by Saudi hospitals.

A central datacenter for storing all EHRs and sharing information among hospitals and over the Internet is important to adopt IOT successfully within the Saudi healthcare sector. In addition, [12] suggested that having a centralized IOT system built by the government and integrates telemedicine benefits will improve the system and make it suitable not just for the COVID-19 crisis but also for future situations.

The infrastructures in Saudi healthcare sector are undergoing a huge improvement, especially in big hospitals. On the other hand, medium to small size hospitals are still facing some infrastructure challenges in addition to resistance to change and a shortage of expert staff. However, these challenges can be overcome by launching demos (proof of concept (POC)) and conducting education and training programs.

Using 5G will solve many other challenges in IOT application and boost its adoption. 5G mobile networks can significantly provide a lot of capabilities compared with previous networks to effectively adopt IOT in healthcare. It can enhance the reliability of wireless connections, provide real-time data transmission, real-time monitoring, long-distance coverage, and strong security. 5G can reduce latency, which is the time required for data to be transmitted from point to point, to less than 5 ms, which will enhance the efficiency of the network and enable the availability of

data in real-time. Moreover, it will provide a large bandwidth (more spectrum), which means faster throughput (faster transfer data) [20, 21].

7   Conclusion

This research investigated and obtained a better understanding of the current situation of IOT adoption in the Saudi Arabian healthcare sector in Riyadh and whether the COVID-19 pandemic affected its adoption. Moreover, this research was interested in finding the obstacles that prevent the Saudi healthcare sector from adopting IOT technology and the desired benefits from applying it. It also shed light on the usefulness of IOT in confronting COVID-19 and the proposed solutions to face it.

It can be concluded that IOT adoption within the Saudi Healthcare sector is still at infancy but there is clear initiative from Healthcare leaders to take advantage of the value it can provide. Therefore, this research should serve as a good starting point for further research on a greater scale. Because of limited time, the shortage of expert professionals in IOT adoption in Saudi healthcare, and access to these professionals, future research should cover a larger sample size of hospitals spreading across the country. Moreover, the Ministry of Health (MOH) should champion an IOT initiative and find solutions on how it can expedite IOT adoption across the Kingdom.

8   Managerial and Theoretical Implication

8.1   Managerial implication

Research proved that IOT can help in managing healthcare operations and reduce chronic disease. It also shows that implementing IOT properly in healthcare will minimize the chance of errors, provide excellent treatment, minimize operation cost, and improve patients care and diagnosis. Moreover, many critical problems like patient overload, safety of healthcare workers, and healthcare resource shortage can be solved by adopting IOT in healthcare. For example, IOT can help healthcare provider remotely monitor and track patient's health and make an alert if unusual changes happened. It also can reduce operation cost by managing hospital utility cost to use it only when needed.

The results indicate that IOT within Saudi Healthcare still in infancy but there is a clear initiative from healthcare leaders to take advantage of the value IOT can provide. The results also confirmed that there are some emerging IOT applications however, they are done in closed systems. The Ministry of Health (MOH) prevent sharing information over the internet or store it in outside cloud for security and privacy concern. Therefore, the ministry of health can use international standard and regulation to make sure patient's information are protected. They also may use a framework that is developed by the Communication and information technology Commission (CITC) which is called Internet of Things (IoT) regulatory framework to ensure patient's privacy and security.

The results show that medium to small hospitals in Saudi Arabia didn't adopt IOT because of insufficient infrastructure and resistance to change. Therefore, lunching a demo (proof of concept (POC)) and conducting education and training programs may raise the awareness of the importance of IOT to the hospitals and the value it can add.

Regarding security issues, using 5G mobile network can solve many challenges in IOT application and boost its adoption. It can enhance the reliability of wireless connections, provide real-time data transmission, real-time monitoring, long-distance coverage, and strong security.

This paper should serve as a starting point for more future studies about IOT in Saudi healthcare and cover a larger sample size including medium and small hospitals spreading across the country.

8.2 **Theoretical implication**

Based on the research [22], it can be said that covid-19 accelerate the adoption of digital technology in the healthcare sector. In contrast, this paper shows that COVID-19 can be seen as an enabler to promote IOT adoption in Saudi healthcare because IOT can help in effectively reaching the patient and deliver quality healthcare remotely without human interaction. Moreover, it is crucial to have a central datacenter for storing all EHRs and sharing information among hospitals and over the Internet to successfully adopt IOT in Saud healthcare. Research [12] suggested that having a centralized IOT system built by the government and integrates telemedicine benefits will improve the system and make it suitable not just for the COVID-19 crisis but also for future situations.

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