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Development of Digitalization Road Map for Healthcare Facility Management

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ABSTRACT Effective Healthcare Facility Management (HFM) remain a crucial concern for high quality built healthcare sectors, both in the public and private areas. The anticipated resource efficiencies, complex systems, and maintenance are all driving up demand for efficiency and flexibility. However, it has been almost impossible with limited human and machinery resources to cope with the healthcare sector's demands. The added value of Digitization will assist organizations overcoming the limited resources issue to deal with the increasing healthcare demands. Based on an extensive literature review, the aim of this paper is to suggest innovative digital and facility management methods that improve the healthcare sector experience. The same literature has been used to extract significant variables to build a causal loop diagram (CLD) that assists in better understanding the interrelationship between those variables within healthcare systems. Furthermore, to prepare for the technology adoption, the paper conducted a cross-sectional survey to forecast the acceptance level in 550 participants from Qatar's healthcare sector. It also discusses applying the most innovative healthcare artificial intelligence techniques through an organized digital transformation process to guarantee delivering the healthcare services efficiently while optimizing resources and costs.

INDEX TERMS Digitalization, digital transformation, digitization, automation in healthcare, wearable sensors, healthcare robotics, facility management, information management, COVID-19, pandemic.

I. INTRODUCTION

The Digital transformation (DT) combines information, storage, communication, and networking technologies to transform services by replacing manual processes with digital processes or replacing older digital technology with newer digital technology. One of the key sectors in which DT has existed has been healthcare (HC), which applies to all facilities that medical professionals offer to protect people's physical and mental well-being. The digital revolution in healthcare opens up new market possibilities and yields new business models to solve medical practice, value development, and other aging populations. Both scholars and practitioners recognized the growing importance of DT in this industry [45]. The COVID-19 pandemic has changed these conventional interactions, allowing us to continue our scientific exchanges with the medical community through remote and interactive engagements. COVID-19 has served as a catalyst, motivating every organization to aggressively seek new ways to develop and participate in the digital world. Companies increasingly look at a comprehensive 360-degree strategy for multi-channel interaction, with well-planned, personalized content across specific platforms and impact analysis centered on data analytic. Figure 1 illustrates integrated central care management shown in an abstract way that combines the integration, connectivity, and engagement to achieve the digital transformation successfully. The digital environment evolves by enabling 24/7 virtual care service, real-time support, one-to-many solutions, simplifying data visualization, and other features. Digital technologies have been shown to expand the industry's partnerships with physicians and promote patient care. These platforms are not only convenient and user-friendly, but they also allow healthcare providers to make themselves accessible remotely via webinars, hot-lines, and even live video interactions [46]. Various academic articles discuss the various benefits, methods, and technologies of digitization in the healthcare sector. However, to the best of the authors' knowledge, few have attempted to

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combine these technologies in order to propose a digitization roadmap for the state of Qatar based on the level of readiness among healthcare workers and the general public. This study contributes to the body of knowledge by reviewing the most recent literature on healthcare facility management methods and caregiving technologies, as well as conducting a cross-sectional survey with healthcare professionals and general endusers to predict the level of acceptance for those methods and technologies This has been done using a 5-points likert scale in order to quantitatively analyze the results. Understanding how healthcare users and experts perceive those technologies and methods is critical not only for national and strategic planners to facilitate and prioritize the digitization process, but also for facility management experts, healthcare users, and staff to better understand which technologies and methods face formidable obstacles.

A. RESEARCH OBJECTIVES AND CONTRIBUTIONS

The current advancement of digital transformation between various industries prompted this study. This study will benefit both healthcare providers and potential researchers by investigating healthcare employees' and the general public's perceptions and attitudes toward the digitization of healthcare services and the implementation of artificial intelligence technologies in its institutions. The following are the research's major contributions:

1) We survey in details the current healthcare technological solutions to enhance the healthcare service performance, quality and safety.
2) We develop a causal loop diagram to examine the effect of adopting and using new technologies in healthcare industry targeting various aspects such as patient sat isfaction, work efficiency, healthcare worker workload and etc.
3) We analyze healthcare employees and common people' perceptions and attitudes toward the digitizing the healthcare services and the implementation of artificial intelligence technologies in its institutions.
4) We present a digitalization roadmap of the healthcare facilities services and technologies especially after the COVID-19 pandemic, in order to enhance the health care efficiency against time, budget and resources

II. LITERATURE REVIEW

A. IMPORTANCE OF FACILITY MANAGEMENT IN HEALTHCARE

Qatar is a rapidly growing country that is expected to be one of the developed countries by the coming few years. Hence, the Qatari government pays close attention to many important aspects; healthcare is one of them. As per Qatar News Agency (QNA) [1], the Qatari government allocated QAR 16.7bn ($ 4.52bn) to the health sector, representing 10.3% of its total annual budget for 2021. Part of this budget will be spent on important healthcare and facilities expansion projects like Hamad Medical Corporation facilities and the establishment of new health centers. As Qatar will host the FIFA World Cup 2022, this spending is expected to increase by approximately 2.2% every year until 2022, according to the regional investment bank Alpen Capital [2], due to the expected increment in population size. Due to the Pandemic of COVID-19, the resources were directed to the treatment, prevention measures of the infected cases, and the operation and maintenance of the current hospital's facilities to cope with the sudden increased healthcare demand. This halted several expansion projects and increased the daily processes and operations' waiting time. Over the world, the COVID19 pandemic has been put the global healthcare systems and facilities under intense pressure [3]. Even the supplies stockpiles of healthcare protective equipment have been depleted due to the spreading fear and the closure of the borders in many countries, which delayed the transfer of essential medical equipment to the healthcare staff around the world [4], [5]. It is a fact that COVID-19 is a highly contagious disease, and this brings attention to the importance of facility management services in healthcare clinics and hospitals [6]. Because this pandemic revealed how appropriate and innovative facility management services could play a vital role in controlling the situation by creating an antivirus-built- environment. In contrast, poor healthcare facility management can worsen it and aid in the virus transmission to the staff and visitors, and other hospital users [7], [8]. Therefore, this pandemic can be looked at as a reason to redesign the system of facility management in the healthcare sector, innovatively, with the aid of artificial intelligence to create efficient operational, maintenance, and facility management processes [9]. For instance, crowded hospitals by clinical and non-clinical staff are one of the major issues in the current situation due to the high transmittance ability of the virus, whether by the direct contact between the individuals or through the common surfaces such as handrails, doors, and windows handle [10], [14]. Hence, creating an automated, flexible work scheduling system and facilitating the work- from-home to optimize FM staff's physical presence in the healthcare can reduce the total number of internal staff inside the building [16]. On the other hand, Amos *et al.* (2020) suggested that continuously updated training for the FM staff who work in the healthcare sector about the new diseases and infections prevention will integrate the power of the FM knowledge with the medical science, which in summary will contribute in providing fast responses for any future pandemics [11]. These training programs for numerous staff worldwide can be somehow substituted by an integrated digital system that provides the latest updated information and instructions about diseases and viruses. This goes hand in hand with another suggestion for Amos *et al.* (2020b) that the healthcare administration's strategic role should be enhanced [18]. Creating such synergy would play a crucial role in improving healthcare performance by forming common goals, shared values and making the operational and tactical plans of FM be aligned with the vision of the healthcare institutes. Some areas in the hospitals are classified as high- risk areas for disease transmission.

The innovative facility management in collecting the waste materials in such areas as potentially beneficial in preventing disease spread and saving public health [13]. Nonetheless, applying this measure requires governments' investments to establish innovative and automated waste collection systems that benefit the healthcare sector and the whole community [12]. Further- more, the pandemic is a big motivation to change the services' design to-ward digitization and artificial intelligence. In China, 75,465 COVID-19 cases were analyzed, and 78-85 % got the viral transmittance through contaminated surfaces [15]. Therefore, removing the need for physically touching the facility services while using them can be a solution. This can be achieved through adding artificial intelligence to healthcare facilities like using facial recognition, voice orders, mobile apps to call lifts or open doors instead of using hands in addition to particular recognition, touch-less fingerprint and vein-based authentication, and the use of biometric characteristics for disease detection [9] and [17]. And of course, this does not revoke the importance of managing regular cleaning and disinfecting services, especially for the frequently contacted surfaces. The viruses, especially COVID-19, can remain bio-active and transmittable on surfaces for weeks at room temperature [19], [20]. Despite its promise to enable hospitals and clinics to coordinate patient care and streamline everyday activities efficiently, healthcare employees and common people have mixed attitudes and perceptions toward the implementation of AI technologies [47]. Sarwar et al [48] investigated the perspectives of AI implementation in clinical practice by distributing a questionnaire on 487 pathologist in 54 different countries. Their findings revealed approximately 75% of respondent have interest in implementing AI as a diagnostic tool. At the same time, 80% of the respondents predicted the implementation of AI technology in the healthcare field during the coming years. Oh et al [49] distributed an online questionnaire on 669 participants to investigate the level of awareness among doctors about the AI and assess their attitudes toward its applications. The results showed that most physicians believe that their roles will not be replaced by AI and that the AI will have supportive role for their work and hence that have had a positive attitudes toward it. Despite the potential for using a complex systems approach, few healthcare-focused studies have focused on the causal loop diagram and feedback mechanisms. Feedback loops are the links in complex systems that demonstrate self-organization [51], [52]. Complex system behavior is determined by the cumulative influence of positive (reinforcing) and negative (balancing) feedback processes [53], [54], [55]. Baugh *et al.* (2018)[56], for example, created a causal loop diagram to visualize the factors that affect the Health Promotion policy and practice and to recognize specific leverage points of improving Health Promotion policy. Moreover, Sahin *et al.* (2020) [57] designed a preliminary causal loop diagram (CLD) of the COVID-19 pandemic to demonstrate the COVID-19 pandemic's complexity across health–socio–economic–environmental boundaries and to investigate its influence on socio-economic systems.

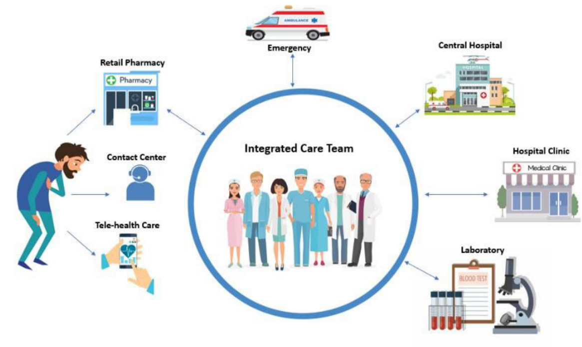

FIGURE 1. Integrated centric care management.

B. COMPARATIVE HEALTHCARE SOLUTIONS

The COVID-19 pandemic has challenged healthcare structures worldwide and left no one in suspicion that the COVID19 pandemic is putting massive stress on health systems worldwide, spotlight the sub-optimal flexibility of even those ranked as high-performing. This makes us reevaluate the measure to which we are applying the proper metrics in assessing health schemes that might have screened how unprepared some countries were in this case of a pandemic. Moreover, shutting down traditional care (e.g., inperson appointments) requires the fast deployment of virtual health care solutions to avoid health organizations' failure. However, tensive research has tried to draw essential models on strengthening pandemic preparation. But few have studied the impact of the fragmented systems for health on efficiently moderating the pressure by evaluating the healthcare system's ability to stand against COVID-19 from learning the lessons from other countries on arranging varied preferences and purposes in strengthening health systems. Engineers have expertly collaborated with researchers and clinicians to recognize, limit spread, and contribute to novel solutions. In this section, various frameworks are proposed and categorized according to their technological type of structure:

1) SURVEILLANCE SYSTEMS

COVID-19 diagnosis, as well as prevention and monitoring steps, will benefit from digital technologies. Quer *et al.* (2021) developed a wearable sensor connected with a smartphone application that collects activity body data, self-assessment symptoms, and diagnostic testing results for COVID-19 detection [29]. Furthermore, Hua and Shaw (2020) proposed a health barcode system to track the positive COVID-19 cases in China; the application alerts the users of having proximity to a positive tested person [30]. In Hong Kong, a symptom surveillance application called the Biovitals platform is designed for asymptomatic individuals with COVID-19 disease. The quarantined patients will have a wearable biosensor on their arms to monitor common vital signs [26]. Similarly, The COVID Alert application is explained by Allan *et al.* (2020) and implemented in Canada to support stop the spread of COVID-19. A positive person for COVID-19 gets a one-time-key from their health provider

TABLE 1. Summary of innovative healthcare solutions.

Type	Use Case	Use Technology	Reference	Year
Surveillance Systems	COVID-19 Detection	Wearable Sensors	[29]	2021
	Healthcare barcode system	Application connected with location	[30]	2020
	Quarantined patient health tracking	Bio-vital platform	[26]	2020
	COVID-19 Alert Application	Location	[28]	2020
Telemedicine Systems	E-consult platform	Real-time messaging	[25]	2020
	mHealth platform	Blockchain technology	[31]	2021
	Remote patient monitoring system	Blockchain technology	[32]	2021
	Smart Healthcare System	IOTA technology	[51]	2019
	Smart Care System	Medical Sensors Connected via Internet.	[21]	2020
	Medical platform	Smart ubiquitous computation devices.	[21]	2020
	Tele-robotic Surgery System	Wire/wireless transmission of transactions	[21]	2020
	Medical platform	Web-based platform	[22]	2020
Diagnostic Support System	Hyperlipidemia disease diagnoses	Deep Learning	[33]	2019
	Pneumonia area detection	Deep Learning	[34]	2020
	COVID-19 X-ray images detection	Machine Learning	[35]	2021
	COVID-19 X-ray images detection	Deep Learning	[36]	2020
	Chronic Lymphocytic Leukemia Detection	Machine Learning	[23-24]	2019-2020
Clinical Decision-making tools	Health Status Decision Making	Machine Learning	[37]	2018
	Predict diabetes	Deep Learning	[38]	2020
	COVID-19 detection	Machine Learning	[39]	2020
Drones Systems	Deliver medical Supplies during COVID-19	Drones	[27]	2020
	Sanitize Areas	Drones	[40]	2020
	Track areas during lockdown	Drones	[41]	2020
	Network mobile drone cameras	Drones	[42]	2020
Robots Systems	Nurse Robot	Robot	[43]	2020
	Robot-assisted Surgery	Robot	[44]	2020

to access the application. After entering the key, COVID Alert Application will inform other people who communicated close with that positive person for at least 15 minutes and guide them on the next steps based on their nearest public healthcare provider location [28].

2) TELEMEDICINE SYSTEM

Telemedicine is a practical, powerful way to triage and provide timely, quality healthcare services. During this public health emergency setting, telehealth plays a crucial role in managing the access and continuity of care for patients, supporting co-workers on the front line, optimizing inperson services, and minimizing infectious transmission of COVID19 coronavirus. The Mayo Clinic Center for Connected Care in the US has implemented a scalable organizational platform for telemedicine delivery called eConsult. The platform will react in real-time by letting the patients send files (e.g., images and text). The physician evaluates the patient transaction and triages patients based on necessity and urgency [25]. In comparison, Albahri *et al.* (2021) used a different approach by proposing a framework called mHealth to offer healthcare services in a decentralized architecture for all emergence stages of patients with cardiovascular disease through blockchain technology for decision-making [31]. Using blockchain technology in such a case will improve hospital connectivity between physicians and patients by maintaining a continuous and tamper-proof update of all records across different hospitals for patient history data. In the same context, Alaa *et al.* (2021) proposed a remote patient monitoring system design for efficient detection of critical medical cases by integrating the system with edge computing and blockchain technologies to optimize medical data records exchanging between various entities [32]. Likewise, in Canada's Smart Care system, in which the patient has several medical sensors at home attached to their body connected via the Internet with the hospital. The system transmits the patient's data to the hospital, and the physician will make a consultation and advise further patient remotely [21]. Like South Korea, the medical doctors with patients access their medical records via the Internet and medical communication network infrastructures daily while utilizing the Smart Ubiquitous Computational Devices [21]. A new system called the Tele-Robotic Surgery system is implemented in Washington. The platform lets surgical procedures be carried across large distances while utilizing wired and wireless transmission subject to proper Quality-of-Service provision for the patient's reliability and safety undergoing telesurgery [21]. Further, Downey *et al.* (2020) explained the application is being used in the UK through the patient to visit clinical appointments with healthcare physicians from The Royal Wolverhampton network of clinicians while managing their consultation appointments and prescriptions [22].

3) DIAGNOSTIC SUPPORT SYSTEMS

Artificial intelligence as a tool for disease diagnosis has become a recent research hotspot. A conventional deeplearning algorithm is used in the conventional framework diagnostic technique to classify features from which a doctor manually selects diagnostic report features. Zhang *et al.* (2021) proposed an automated diagnostic program that measures human physiological parameters to diagnose hyperlipidemia. The deep learning (DL) method is used to build the proposed framework [33]. In contrast, Poplavskiy *et al.* developed a DL computational approach focused on singleshot detectors, squeeze-and-extinction deep neural networks, augmentations, and multi-task learning for pneumonia area detection [34]. As explained in [35], using machine-learningbased methods to distinguish COVID-19 and normal chest X-ray images positively affects diagnosis. The experiment showed that using DL methods to classify chest X-ray images to identify COVID-19 has many promises. The accuracy score for the classification performance was 94.7 percent. Farooq *et al.* (2020) proposed another study on distinguishing COVID19 cases from other flu and pneumonia cases. The authors provided an accurate DL architecture as well as an opensource and open-access dataset. On the COVID-19 dataset, this model achieved 96.23 percent ac-curacy (on all classes) and can assist in the early screening of COVID19 positive cases, reducing the burden on healthcare systems [36]. Also, the machine learning (ML) technique was implemented in Denmark to classify patients with chronic lymphocytic leukemia (CLL) who were at risk of infection due to immune dysfunction [23], [24].

4) CLINICAL DECISION-MAKING TOOLS

Structural structures are often exposed to harsh situations, which can lead to system deterioration over time. Their health status and institutional requirements are critical for decision-making management. ML approaches have gained popularity due to their advantages in extracting information from statistical representations of cases and enabling decision-making. To strengthen systemic situation assessment decision-making, the authors of [37] used a DL approach. This method may be helpful in learning more about complex systems that are subject to uncertainty. A technique was used to extract statistical descriptions from various structural data to determine the systemic state and health status of decision-making. DL has greater systemic diagnostic accuracy than supervised shallow learning, according to the results. In today's world, diabetes affects nearly everyone. A vital component of diabetes is the glucose factor in the blood. Diabetes is caused by blood glucose levels fluctuating. The authors discussed the importance of using ML and DL to predict diabetes [38]. A study was developed to predict diabetes disease using different ML approaches with an accuracy rate is 93.2 percent. To aid the decision-learning model, Wiley *et al.* (2020) proposed a predictive ML technique for COVID-19. The system will identify high-risk people in early-stage identification and allocate required services (e.g., ICU beds) and some necessary treatments before permanent clinical harm occurs [39].

5) DRONES SYSTEMS

Drones that deliver medical supplies are becoming a more integrated part of modern human society, particularly as 5G and the Internet of Things (IoT) become more prevalent. Drone-based distribution aspects can be used to access a wide variety of medical facilities. Drones deliver COVID supplies in North Carolina. For an utterly no-contact experience, the drones will drop Personal Protective Equipment and other supplies via parachute. They also want to use drones to distribute medical supplements, drugs, and vaccines without exposing people to COVID or requiring them to wait long periods [27]. The South Delhi Municipal Corporation (SMDC) in India used a similar drone to sanitize COVID-19 hotspots by spraying a sanitizer over the region [40]. Delhi has been put under lockdown to prevent the spread of the virus, with no public transportation, such as private buses, taxis, and autorickshaws permitted on the roads. During the full lockdown in Delhi, police use drones to track different areas [41]. In Unmanned Aerial Vehicles (UAVs), networked mobile drones integrated with cameras are used to combat COVID19 in enhancing emergency responses, health surveillance, and detecting infectious and respiratory conditions, including monitoring body temperatures, heartbeats, and respiratory rates [42].

6) ROBOTS SYSTEMS

Robots are becoming more noticeable in the health industry. Nowadays, users are faced with multiple benefits involving both human and robot interactions. A set of experimental researches were implemented. Abutaleb *et al.* (2020) developed a Nurse Robot (NR) system that acts as a programmable diagnostic device with a multi-function manipulator designed to help patients recover better. This paper's main contribution is to deliver a multi-functional robotic system that works on reading vital human signs. The system will be executed using the Arduino platform to handle multiple sensors for the vital readings. The output is used for the robot to interact with the patients based on the input data. The speaker will be the way of interaction between robot and patient. Simultaneously, using infrared (IR) sensors to facilitate the robot to read the human availability. IR is applied to identify if the patient near the robot, using IR light beams and Near-Field Communication (NFC) method to read the hospital's patient ID as his identity [43]. Nevertheless, kimmig *et al.* (2020) created robot-assisted surgery (RAS) to help patients who urgently need complex-oncological-surgery for gynecological cancer avoid hospitalization to make areas for COVID-19 patients. RAS potentially decreases infection with the surgical section's body fluids and operational gasses and the number of directly unprotected medical staff [44]. A summary of Innovative healthcare solutions is shown in Table 1.

III. METHODOLOGY

A cross-sectional analysis study has been carried out, with qualitative and quantitative phases. The first phase entails a thorough review of the literature on innovative health-care technologies and facility management practices. This includes searching academic papers for critical, innovative healthcare ideas and determining FM necessary measures after the COVID-19 pandemic. The second phase of this research constituted a semi-structured interview with healthcare and facility management professionals, to attain more knowledge about the gathered technological ideas and facility management methods. The causal loop diagram (CLD)

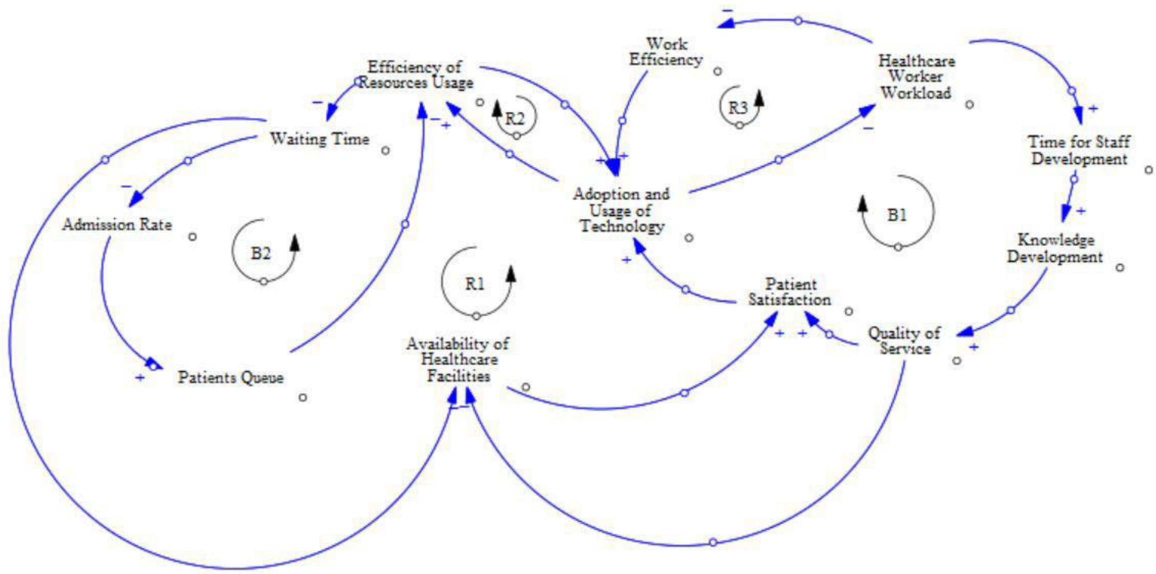

FIGURE 2. Causal loop diagram.

has been designed in this study using VENSIM software to conceptually model dynamic systems holistically, illustrating how variables interact. (i.e., Adoption and usage of technology, Efficiency of Resources Usage, Waiting time, Availability of Healthcare Facilities, Patient Satisfaction, etc.). The fundamental feedback structures of the system, as well as high- and low-leverage intervention locations and natural constraints that can help us develop more realistic expectations for healthcare digital transformation, are depicted in this diagram. This, in addition to the literature review and semi-structured interviews, enabled us to formulate the questionnaire structure properly. The quantitative analysis focused on distributing a questionnaire to randomly selected end-users and professionals in the healthcare and facility management fields to determine the extent to which the summarized methods and technologies were accepted from their perspectives. With a response rate of 87.5%, 550 completed responses were returned using a 5-point Likert-type scale (1 = Very Low, 2 = Low, 3 = Moderate, 4 = high, 5 = Very High). Of those respondents, 76.5% were from the healthcare and facility management profession, while 23.4% of them were end-users for the healthcare facilities. The results were analyzed using SPSS software to conduct a comparative analysis using Mean, Median, Standard Error of Mean, Variance, Standard Deviation, T Value and P Value. Additionally, the nonparametric Kruskal-Wallis statistical test has been employed to test for the null hypothesis that the variable's distribution is the same for each category (medical staff or common people). Those results have been used to make recommendations to decision makers in the healthcare industry.

IV. ANALYSIS AND DISCUSSION OF RESULTS

A. HEALTHCARE CLD ANALYSIS AND DISCUSSION

A CLD is developed to understand the logic of adopting such technologies on the quality of healthcare service. As shown from Figure 2, there are total of five loops that is presented in Table 3. The logic of loops is described as follows:

1) The first loop (B1), more adopting technologies, it causes a decrease in healthcare worker workload This decrease of workload, causes a fall in knowledge development, quality of service and patient satisfaction; therefore, as a result using of technologies will be less.
2) The second loop (B2), an increase in using new technologies cause and increase in efficiency of resources usage. This rise in efficiency, causes a decrease in total of waiting time. The fall in waiting time will cause a rise in admission rate and number of patients in queue; this increase will cause a decrease in efficiency of resources usage.
3) The third loop (R1), as in previous loop, an increase in using technologies causes a rise in efficiency of resources usage which causes a fall in waiting time, this leads to an increase in availability of healthcare facilities. As a result, gain satisfaction from patient this will encourage to adopt and use more technologies.
4) The fourth loop (R2), as in R1 loop, an increase in using technologies causes a rise in efficiency of resources usage which causes back an increase need of adopting new technologies.
5) The fifth loop (R3), as in B1 loop, more adopting technologies, it causes a decrease in healthcare worker workload, this decrease leads to a rise in work efficiency which requires at end to increase the need of adopting new technologies.

As clearly seen from CLD discussion, adopting new technologies and use of them in healthcare industry, will have a major effect on work efficiency, performance and resource availability and patient satisfaction.

TABLE 2. Comparative analysis for common people group.

Technology	N	Mean	Median	Std. Error of Mean	Variance	Std. Deviation
P_WearableSensor	415	4.0819	5	0.06238	1.636	1.27898
P_DiagnosesRespiratory	415	4.0964	5	0.05781	1.387	1.17763
P_DiagnosesLeukemia	415	4.5518	5	0.05256	1.146	1.07073
P_PredicitDiabetes	415	4.5398	5	0.05259	1.148	1.07125
P_Drones2Deliver	415	4.3357	5	0.06129	1.555	1.24711
P_Drones2Sanitize	415	4.4193	5	0.05805	1.399	1.18265
P_Robots4Collection	415	4.5277	5	0.05294	1.163	1.07837
P_NurseRobot	415	3.7205	5	0.07566	2.376	1.54136
P_AssistanceRobot	415	3.0337	3	0.07883	2.579	1.60579
P_BookingSatisfaction	415	2.6554	3	0.05809	1.400	1.18334
P_WaitingSatisfaction	415	2.3373	2	0.06192	1.591	1.26144
P_ConflictInfo	415	3.5494	4	0.07647	2.427	1.55785
P_OnlineAppointment	415	3.8289	5	0.07176	2.137	1.46196

B. QUESTIONNAIRE ANALYSIS AND DISCUSSION

In this study, a questionnaire were distributed among healthcare and FM profession and endusers for the healthcare facilities. The first technology is the wearable sensors that send real-time signals to the healthcare providers if their patients' health is at risk by exceeding certain biomarkers. As shown in Table 2 and Table 4, the mean of acceptance is 4.0819 in common people and at a higher mean of 4.3675 in the medical staff group, as shown in Figure 3. This difference can be justified mainly by the fact that the medical staff is more aware of the consequences of having late admission to the hospital in case of emergencies, like stroke, for example. According to an emergency doctor at a local medical corporation, ''sensor technology for vital sign monitoring will be a major breakthrough for various healthcare services. A nurse at the same medical corporation has agreed with that opinion about a considerable need for continuous, precise, and long-term monitoring of human vital signs technology without the need for walk-in appointments at hospitals. The second technology is the diagnosis of respiratory infections automatically using X-ray technology. As shown in Tables 2 and 4, there is a high acceptance in common people with a mean of 4.0964 and a higher mean of 4.3846 in the medical staff group. This technology will save the hospitalization costs due to respiratory viral transmission, and this is the reason the medical staff has less rejection rate compared to the common people.

The same acceptance pattern goes with the technology of nursing robots, diabetes early diagnosis, robots to collect waste materials, the drones to sanitize the hospitals and deliver medical supplies to rural areas or quarantined patients, as seen in Figure 3. Furthermore, a senior internal medicine consultant has shown an agreement in using smart diagnosis systems to help doctors reach faster and accurate diagnoses. He commented that this would be a great benefit to utilize these technologies in their favor to the patient and the physician. On the other hand, using robots as surgery assistance has had conflicting opinions with a mean of 3.1966 of medical staff and 3.0337 amongst common people, as shown in Tables 2 and 4. This instable attitude toward the use of artificial intelligence in medical surgeries can be attributed to the novelty of the AI in the medical surgeries and not having enough time to gain trust, as illustrated in Figure 3 and Tables 2 and 4. Using robots in surgeries requires much smaller incisions, less blood being lost, a quicker post operation recovery which means a shorter stay at the hospital, which also means lower cost due to the reduced number of staff required during and after surgery. Nevertheless, we interviewed two of the rejecters for this idea, a physician assistant at a Qatari local medical corporation. He commented that only the human could make a proper instant decision in some situations during the surgery that can save the patient's life. Hence, we cannot risk introducing new technology to save time or money at the expense of a patient's life or wellbeing. a supervisor in customer services at the same medical corporation has agreed with his opinion about rejecting the idea of using robots in healthcare for two reasons: 1. Depending on robots will introduce a lack in human experience and skills 2. Because robots rely on programming, they lack the common sense and reasoning ability of humans. On the other hand, a dentist at a local dental clinic advised that he does not object to using the robotic technology in minor oral operations. Nonetheless, when it comes to major oral and maxillofacial surgeries, there is still a lack of trust in the AI to be capable of doing human work from the perspective of making proper urgent decisions during the operation. According to the current appointments, the system seems to have big frustration from the perspective of patients. The level of satisfaction has been measured and yielded a mean of 2.3373, indicating a low satisfactory level. On the other hand, the online appointment system, which provides a real-time platform to meet the doctor using video or voice calls, has gotten a mean of 3.8289 out of 5, which is an indicator that this technology reverses the disappointment caused by long waiting times to meet the doctors as shown in Table 2 and Table 4. Regarding this context, an opinion received from a patient mentioned despite significant advancements in healthcare services in recent years, the patient wait time and repeated appointments for vital sign checks are still problems that need to be addressed.

One of the solutions is to think innovatively about facility management. Facility management is an essential part of any services firm's success, and hospitals are one of them.

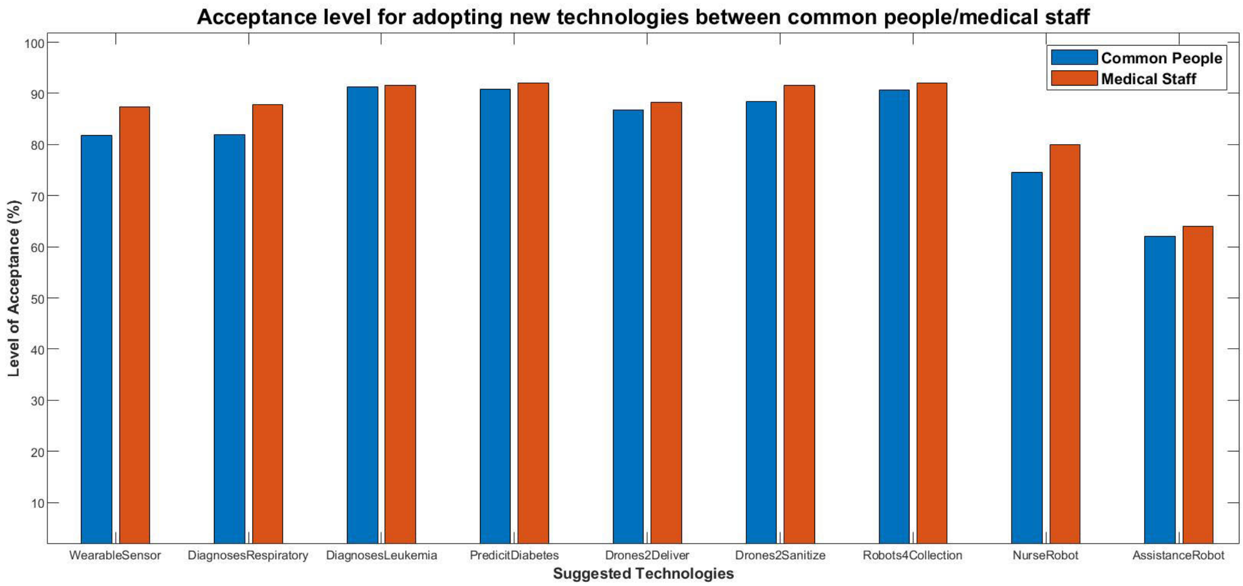

FIGURE 3. Acceptance level for adopting new technologies between common people/medical staff.

TABLE 3. Loops description.

Index	Description	Loop Type
B1	Adoption and usage of technology -> (-) healthcare workerload -> (+) Timer for Staff Development -> (+) Knowledge Development -> (+) Quality of Service -> (+) Patient Satisfaction -> (+) Adoption and usage of technology	Balancing Loop
B2	Efficiency of Resources Usage -> (-) Waiting Time -> (-) Admission Rate -> (+) Patients Queue -> (-) Efficiency of Resources Usage	Balancing Loop
R1	Adoption and usage of technology -> (+) Efficiency of Resources Usage -> (-) Waiting time -> (-) Availability of Healthcare Facilities ->(+) Patient Satisfaction -> (+) Adoption and Usage of Technology	Reinforcing Loop
R2	Adoption and usage of technology -> (+) Efficiency of Resources Usage -> (+) Adoption and Usage of Technology	Reinforcing Loop
R3	Adoption and usage of technology -> (-) Healthcare Worker Workload -> (-) Work Efficiency -> (+) Adoption and usgae of techbology	Reinforcing Loop

Optimizing the number of non-medical staff in the hospitals, facilitating the work-from-home for them, and providing remote access to control the facilities like AC, Lighting. etc., would mitigate the risk of viral transmission. Respondents have been asked to evaluate this suggestion, where five means they strongly agree, and one means disagreement, as shown in Figure 4. The responses varied between disagreement, neutral and the majority strongly agreed on this suggestion. A mean of 3.5556 in the responses has been observed. This indicates partial agreement on this idea. To elaborate further, we met a civil engineer who voted as neutral (3). He advised that facility management staff in a healthcare facility is essential, and their number is not that big compared to the other sections' staff. Hence, their presence will not impact the place, and their absence will not make that difference.

On the other hand, a senior mechanical engineer, voted for ''1/5'' because he said the facility management should always be there to ensure everyone's safety. He advised that instead of reducing the number of on-site staff, the best way to manage Mechanical and Electrical facilities during the covid-19 pandemic is by dividing manpower into different zones with minimum numbers to reduce the possibility of infection and to cover the areas to achieve proper maintenance for facilities. By dividing manpower into a large number of zones, we reduce the probability of contact between manpower. We can easily track any infected case depending on the zone assigned to each person. He also emphasized that safety precautions should be considered a priority.

Therefore, we should start by controlling the entrance of manpower to the site by taking their temperature and being aware of any signs of illness. Secondly, using face recognition technology for attendance. Moreover, supervisors should present a daily brief description of covid-19 and its circumstances to increase awareness for manpower. And finally, each supervisor should complete control of their assigned zones and con-firm that manpower is following safety precautions on-site and report any suspected case immediately to management. Besides, a civil facility engineer, who voted for ''5/5'' with a total agreement, advised that the best way to manage the medical facility team innovatively, especially during emergencies like the COVID-19 pandemic, is to categorize them by the age and their type of work. He explained that the elderly facility management staff should be working from home all the time for their safety, while other staff should be divided into weekly shifts on site while the work should be continuous from home. This will reduce the number of staff on-site, which reduces the infection transmissions. Moreover, a Quality Engineer at a facility and general services

TABLE 4. Comparative analysis for medical staff group.

Technology	N	Mean	Median	Std. Error of Mean	Variance	Std. Deviation
S_WearableSensor	117	4.3675	5	1.16411	1.355	1.16411
S_DiagnosesRespiratory	117	4.3846	5	0.99867	1.387	0.99867
S_DiagnosesLeukemia	117	4.5726	5	0.98538	0.971	0.98538
S_PredicitDiabetes	117	4.5983	5	0.91971	0.846	0.91971
S_Drones2Deliver	117	4.4017	5	1.14515	1.311	1.14515
S_Drones2Sanitize	117	4.5726	5	1.02819	1.057	1.02819
S_Robots4Collection	117	4.6068	5	0.96452	0.930	0.96452
S_NurseRobot	117	3.5983	4	0.58146	2.501	1.58146
S_AssistanceRobot	117	3.1966	3	1.57699	2.487	1.57699
S_OptimizeNonMedical	117	3.5556	4	1.38617	1.921	1.38617
S_ContMeeting	117	4.4615	5	1.13364	1.285	1.13364

department, sup-ported the idea of reducing the workmanship number on-site and added that making sure the divided working groups never meet on-site will help the safety precaution measures.

It can be seen that there are many contradicting points of view, but most of them agree that social distancing is essential to decrease the viral transmission risk, especially if the digital technology. This will enable the engineers to work with the same efficiency while they are at home. To compare medical staff with the common people in their acceptance level point of view, the Kruskal-Wallis test is used. Kruskal-Wallis test is a nonparametric (distribution-free) test it searches for substantial differences between continuous and categorical dependent variables (with two or more groups). As a result, the Kruskal-Wallis test applies to both straight and ordinal dependent variables. The hypothesis that is used in the Kruskal-Wallis test is as follows:

- **Ho**: The variable's distribution is the same for each category (medical staff or common people).
- **H*a***: The variable's distribution is not the same for each category (medical staff or common people).

With the use of the following test statistic:

$$H = \frac{12}{n(n+1)} \cdot > \frac{\tau_i^2}{n_i} - 3(n+1) \tag{1}$$

where:

n i = sample size for a population.

T i = rank sum for population.

n = total number of observations.

The rejection region for α =0.05 is H $\geq$ X $\geq$ α.

The Kruskal-wallis test outcome analyzed as that for the test results, the p-values suggest that there is a not equal distribution between the two categories (medical staff and common people) for the variables (wearable sensors, diagnoses respiratory) variables for rejecting the null hypothesis at α = 0.05. While fail to reject the null hypothesis for the variables (diagnosis leukemia, predict diabetes, sanitize drones, delivery drones, waste collection robots, nurse robot and surgery assistant robots), this indicates the variables distribution for each category is the same as shown in table 4. The result of the Kruskal-wallis can be interpreted as below: A Kruskal-Wallis test statistic value showed that there was a statistically significant difference in wearable sensors and

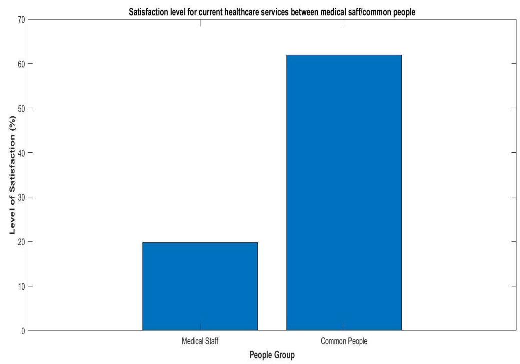

FIGURE 4. Satisfaction level between medical staff/common people.

diagnoses respiratory variables between the medical staff and common people, with a value between 6.354 and 6.798.

V. SUGGESTED INNOVATION STRATEGY (ROAD MAP)

Despite billions of dollars invested in digital health innovations by both start-ups and existing technology firms, the transformation of healthcare delivery continues to lag. As seen in the previous section, both the common people and medical staff have a similar perception of their level of satisfaction. In light of this, Qatar released an Innovation Strategy as part of its National Vision 2030. The strategy vision is "Our Health, Our Future," with a four-part mission:

1. Governance and policy 2. Services and Technology 3. people and training 4. Communication and adoption The proposed developed strategy will have the following features

Vision: To deliver outstanding digitized health services that are precise, sustainable, time-saving, and easily reachable to community members.

Mission: To build a sustainable digital-based health care system that improves civic and public people well-being that provides all the needs of the current and future generations that aim to achieve the country's national vision by catalyzing the society to be a positive factor in achieving QNV.

As shown from Figure. 4 the core values consist of three pillars:

Community Involvement: Community involvement refers to the idea of partnership and shared responsibility with health services rather than using the community to reduce the burden on health services.

TABLE 5. Comparative analysis for common people group.

	Null Hypothesis	T-value	P-value	Decision
1	The distribution of wearable_sensor is the same across categories of type	6.798	0.009	Reject the null hypothesis
2	The distribution of diagnoses_respiratory is the same across categories of type	6.354	0.12	Reject the null hypothesis
3	The distribution of diagnoses_leukemia is the same across categories of type	0.134	0.715	Retain the null hypothesis
4	The distribution of predicts_diabetes is the same across categories of type	0.044	0.833	Retain the null hypothesis
5	The distribution of delivery_drone is the same across categories of type	0.006	0.939	Retain the null hypothesis
6	The distribution of sanitize_drone is the same across categories of type	1.714	0.191	Retain the null hypothesis
7	The distribution of waste_collection_robots is the same across categories of type	0.224	0.636	Retain the null hypothesis
8	The distribution of nurse_robot is the same across categories of type	0.468	0.494	Retain the null hypothesis
9	The distribution of dr_assistant_robot is the same across categories of type.	0.998	0.318	Retain the null hypothesis

FIGURE 5. Core values.

Innovation: Innovation is needed to improve the existing processes, develop the care models, enhance the efficiency by which work is completed or reduce the cost of a process or services. A healthcare system built based on innovation, continuous research, and development will ensure human life development.

Patient-Focused Excellence: Patient-focused excellence is to find the link be-tween empowerment, co-creation and satisfaction to reach the maximum of high quality, readily accessible, and best services.

A. STRATEGIC GOALS AND OBJECTIVES:

In order to achieve the vision, mission and core values, a strategic goals and objectives will be the road to be set, the strategic goals will be defined as follows:

Goal 1 (Efficient Health Care Delivery): Enhance healthcare quality by giving the best available evidence on the outcomes by using the AI to create a healthcare system that optimizes the use of the available resources and provides extensive quality care at lower costs.

Goal 2 (Focus on Community Health): Through extensive education and health campaigns, the healthcare system will enable the people to take responsibility and be part of the shift toward a healthier society.

Goal 3 (Global Corporation): Internationally coordinated policies can facilitate recovery and rebuild social and economic systems in comprehensive and sustainable ways and help prepare for future risks and epidemics.

Goal 4 (Improve Patient Safety and Quality): Improving patient quality and safety is the absence of harm to the patient through the healthcare process. The risk of the harm related with healthcare should be reduced to an acceptable minimum.

Figure 5. shows the objectives related to each goal:

VI. CONCLUSION

The COVID-19 pandemic has accelerated digital transformation. However, the successful evolution of IT-enabled collaboration has revealed concerns about the digital distribution of medical information along the patient care pathway. Despite the challenges, AI, big data, distributed systems in healthcare services must be further driven to ensure on demand healthcare services, cost and process efficiency and immediate interaction with caregivers. This paper proposed an extensive review on recent technological solutions were used in past literature. Moreover, a survey was distributed between various users (patients, physicians and medical staff) to understand their expectations and to identify the multitude of factors (patient and healthcare staff) that will drive the road map of healthcare digital transformation as well as provide an inclusive process of validation, integration and transparency to strengthens the healthcare services for next technological generation. In order to achieve the healthcare digital transformation roadmap, four strategic goals and it is corresponding objectives were defined. First, efficient healthcare delivery, second, focus on community health. Third, global corporation and finally is to improve patient safety and quality.

A. FUTURE WORK

Future studies could focus more on specific areas of healthcare technology management systems, such as surveillance health systems, telemedicine systems, health diagnostic systems, clinical decision-making tools, medical drone systems, and medical robot systems.Future work could also assess the level of influence of various interconnected social, financial, and technical variables, as well as develop extensive hypotheses based on the CLD model to conduct an empirical analysis. The proposed healthcare digitalization roadmap has a general plan. However, due to the many parameters involved with the different healthcare systems, crafting a general technological solution is complex because of system constraints. Thus, future research can be performed on a local healthcare institute to accelerate the roadmap implementation. As defined by [50], "New digital technologies can fuel innovation and improve company performance, but only if

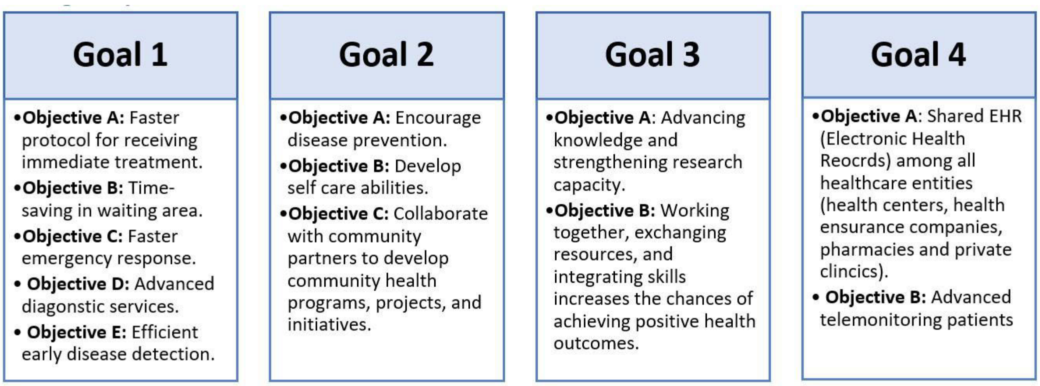

FIGURE 6. Strategic Goals and Objectives.

TABLE 6. Survey questions for common people group.

	Question	Type
1	Please state your level of satisfaction with the process of booking an appointment with your doctor?	Likert-scale
2	Please state your level of satisfaction with the process of the waiting time to see your doctor?	Likert-scale
3	How often did you receive conflicting information from different medical care professionals in the hospital?	Likert-scale
4	For simple health issues, how much do you wish to meet your doctor online while you're at home instead of going to the clinic?	Likert-scale
5	How do you think it is helpful to have a wearable sensors to track patient's vital signs from home (Remote monitoring)	Likert-scale
6	How do you think it is helpful to have a system that diagnoses respiratory infections automatically	Likert-scale
7	How do you think it is helpful to have a system that diagnoses chronic lymphocytic leukemia automatically	Likert-scale
8	How do you think it is helpful to have a system that predicts the diabetes risk before it happens	Likert-scale
9	How do you think it is helpful to use drones to deliver medical supplies to rural areas or quarantine people	Likert-scale
10	How do you think it is helpful to use drones to sanitize areas	Likert-scale
11	How do you think it is helpful to use robots for hazardous waste collection	Likert-scale
12	How do you think it is helpful to use robots as nurse robot	Likert-scale
13	How do you think it is helpful to use robots as assistance for surgery	Likert-scale

TABLE 7. Survey questions for medical staff group.

	Question	Type
1	Optimizing the number of non-medical staff in the hospitals; by facilitating the work-from-home?	Likert-scale
2	Continuous training for the non-medical staff on the new diseases and infections prevention.	Likert-scale
3	How do you think it is helpful to have a wearable sensors to track patient's vital signs from home (Remote monitoring)	Likert-scale
4	How do you think it is helpful to have a system that diagnoses respiratory infections automatically	Likert-scale
5	How do you think it is helpful to have a system that diagnoses chronic lymphocytic leukemia automatically	Likert-scale
6	How do you think it is helpful to have a system that predicts the diabetes risk before it happens	Likert-scale
7	How do you think it is helpful to use drones to deliver medical supplies to rural areas or quarantine people	Likert-scale
8	How do you think it is helpful to use drones to sanitize areas	Likert-scale
9	How do you think it is helpful to use robots for hazardous waste collection	Likert-scale
10	How do you think it is helpful to use robots as nurse robot	Likert-scale
11	How do you think it is helpful to use robots as assistance for surgery	Likert-scale

applied in the right places." To innovate in the healthcare industry, choosing the right factors that influence the healthcare systems and understand the perceptions and agility of the current processes have a high impact on the digital transformation process. Implementing the right technology to the right place is too critical in this situation. In that light, future research can investigate selecting the right technologies in the proper health departments of healthcare institutes to meet the requirements and expectations.

APPENDIX

Table 5 and Table 6 show the survey questions that were distributed to common people and medical staff groups.

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