*BUFT Journal of Business & Economics (BJBE)*
*ISSN 2664-9942 (Print)*
*2024 Volume 5, Pg: 35-54*
*DOI: https://doi.org/10.58481/BJBE/2403*

# The Prospects and Challenges of Internet of Things (IoT)-based Public Healthcare System in Bangladesh

Dr. Mohammad Masudur Rahman[1]*, Nayyab Alam[2], Sumiya Barkat Ullah[3]
Muhammad Ataur Rahman[4]

ARTICLE INFO

*Article History*
Received : January 30, 2024
Accepted: May 04, 2024

Keywords:
Internet of things (IoT), Public, Healthcare, Prospects, Challenges.

*JEL Classification:*
M15, M21

## ABSTRACT

**Purpose:** The purpose of this study is to discern the prospects and challenges of integrating Internet of Things (IoT) into the public healthcare sector of Bangladesh. This is timely because the present public healthcare status of the country needs dire improvement. Hence, this study explores the future scope of IoT-based public healthcare systems to be introduced to the Directorate General of Health Services (DGHS) of Bangladesh henceforth recommends how the country can integrate the implementation of this technology to deliver better public healthcare services to its population.

**Methodology:** The authors reviewed extensively literature from several reputed sources to identify the current public healthcare conditions, as well as the benefits and impediments of IoT-based public healthcare system in Bangladesh. Based on the searches pertaining to the data base, this study then outlines appropriate future scopes of IoT in the public healthcare of Bangladesh.

**Findings:** This research identified major impediments such as lack of infrastructure, low motivation, awareness and acceptance as well as poor healthcare startups prevalent in the public health services of Bangladesh. To surmount the inefficiencies of the current services, the authors deliberated how IoT-based public healthcare system could foster better monitoring; management and rehabilitation thereby improve the overall Bangladesh's public healthcare system.

**Practical Implications:** IoT healthcare organizations can also use technology to improve patient outcomes and increase efficiencies, which will lower the cost of treatment, reduce death rates and make it possible to give public healthcare to people who live in rural areas.

**Originality/Value:** The researchers of this study are confident that the findings of this study will benefit other researchers, policymakers, healthcare service providers/designers and professionals to realize the potentials of IoT-based public healthcare system that could overcome the challenges faced and finally could deliver sound public healthcare facilities and services for Bangladeshis in the near future.

**Limitations:** In the future, we plan to develop the Central Repository of patient database system using blockchain technology.

* Corresponding Author

1. Assistant Professor, Department of Business Administration, East West University, Dhaka, Bangladesh. Email: masudur@ewubd.edu
2. Graduate Student, Department of Business Administration, East West University, Dhaka, Bangladesh. Email: nayyabalamturjo@gmail.com
3. Graduate Student, Department of Business Administration, East West University, Dhaka, Bangladesh. Email: sumiyabarkat@gmail.com
4. Senior Lecturer, Department of Business Administration, East West University, Dhaka, Bangladesh. Email: ataur@ewubd.edu

## 1. Introduction

Chronic diseases and the recent COVID-19 pandemic have made us comprehend the significance of continuous public health monitoring in general and the elderly and disabled in particular via enhanced use of technology. In fact, to cater for the latter segment of the population, several studies have accelerated the notion of creating a remote healthcare system through computer and biosensor-aided technologies (Garg et al., 2020; Hosseinzadeh et al., 2021; Jain et al., 2021; Javaid & Khan, 2021; Mukati et al., 2021). Such technologies include Internet of Medical Things (IoMT), Healthcare Internet of Things (HIoT) and Internet of Things (IoT)-based healthcare. In fact, these technologies have been found capable of revolutionizing the healthcare delivery system and enable healthcare professionals to provide personalized healthcare services (Emon et al., 2018; Gatouillat et al., 2018; Kelly et al., 2020). The IoT could be used as an enabling innovation in the health management systems since there is an increase for the need to make healthcare more individualized, proactive, and affordable.

The current state of IoT healthcare applications includes various improvements in testing, health, and medicine. The use of Cloud Computing alongside IoT devices such as Actuators and Sensors, Radio Frequency Identification (RFID) technology and other advanced rehabilitation systems have already transformed the healthcare sector (Aledhari et al., 2022; Bisio et al., 2019; Raj et al., 2022; Senbekov et al., 2020). By linking medical equipment to the Internet and providing various healthcare facilities like the oversight of elderly people, real-time monitoring, consultations utilizing mobile network, and computer-assisted rehabilitation, the use of IoMT technology in healthcare systems, establishes effective therapeutic approaches for patients and caregivers (Haghi Kashani et al., 2021). Additionally, using IoT enables hospitals to track, assess, and keep track of data on each patient, employee, and assetonline (Al-Shargabi & Abuarqoub, 2020; Vishnu et al., 2020). Meanwhile, the Wireless Body Area Network (WBAN) is becoming increasingly prevalent for IoT-based healthcare systems as wearable technology enters the sector. The placement of several sensor nodes on various body parts of a person may be used to assess heart rate, map out body temperature distribution, and even detect falls (Poongodi et al., 2020).

However, the infrastructure on which IoT-enabled healthcare system works is complicated and costly to implement in a large scale.There are open issues of IoT-based healthcare that are yet to be addressed (Michele & Furini, 2019; Shakeel et al., 2022). Thus, it is not surprising that the adoption of IoTin the healthcare sector of developing countries such as Bangladesh meets with numerous barriers despite the technology being proven to be resilient, effective, and highly efficient (Hossain, 2020; Alam et al., 2020). On top of that, people living in the rural areas are lagging behind in technological literacy which poses additional threat in the face of the implementation of healthcare based on IoT (Khan, 2020; Zobair et al., 2020). That is why, this study attempts to look at the explores the current status of Bangladeshi healthcare system and the use of IoT.

### 1.1 Objectives of the Study

Despite the impediments, HIoT or IoT-based healthcare can revolutionize the public healthcare delivery system of developing countries. Subsequently, this study examines the various prospects and challenges of IoT-based public healthcare systems by answering of the following Research Questions (RQs):

- What is the current status of healthcare in Bangladesh?
- How systems based on IoT could significantly improve the healthcare sector in Bangladesh?
- What are the major impediments for the adoption of HIoT technology in Bangladesh?
- What are the future trends of IoT-based healthcare systems and scope for further research in HIoT domain using the evidence from Bangladesh experiences?

## 2. Literature Review

The idea behind today's Internet of Things (IoT) has been around since the 1970s. It has been

commonly referred to as the 'embedded internet' and the 'pervasive computing. 'In fact, the term Internet of Things (IoT), was pioneered by Kevin Ashton in 1999 while he was employed at Procter & Gamble. IoT refers to the growing network of physical objects that are embedded with sensors, software and connectivity, allowing them to collect and exchange data. These devices are often connected to the internet and can be controlled remotely or automatically through smartphone applications (apps) or other means of remote control. The goal of IoT is to improve efficiency, convenience, and quality of life by enabling devices to communicate and share data with each other and among human users.

The use of IoT or internet-connected devices in the healthcare industry is a relatively new concept. And, it is on an inclining trend. IoT devices used in healthcare can range from wearable fitness trackers and smart watch devices to medical equipment and hospital systems (Poongodi et al., 2020). The use of Healthcare IoT (HIoT) or Internet of Medical Things (IoMT) can help to improve patient care and outcomes by providing real-time data and alerts to healthcare professionals. It also has the potential to improve efficiency in the healthcare industry by automating certain tasks and streamlining workflows (Aledhari et al., 2022; Senbekov et al., 2020). Overall, healthcare IoT has the potential to revolutionize the way that healthcare is delivered, making it more efficient, effective, and personalized. Telehealth, e-health, and m-health are some of the applications of IoT in healthcare systems.

### 2.1 Telehealth, E-health, M-health

Telehealth or telemedicine refers to the use of electronic communication technologies, such as video conferencing and phone calls that provide healthcare services remotely. It allows healthcare providers to diagnose, treat, and monitor patients from a distance, without the need for in-person visits (Prodhan et al., 2020). It can be used for a variety of purposes, including consultations with doctors or other healthcare professionals, prescription refills, follow-up appointments and monitoring of chronic conditions (Akhtar et al., 2019).

E-health, otherwise known as electronic health or digital health, refers to the use of electronic communication and information technologies to support and promote health and healthcare. The goal of e-health is to improve access to healthcare, reduce costs, and enhance the quality of healthcare services (Jha et al., 2021). M-health, also dubbed as mobile health or wireless health refers to the use of mobile and wireless technologies to support and promote health and healthcare. M-health technologies can be used to support a variety of healthcare activities including disease management, prevention, and treatment (Alam, 2018). Telehealth, e-health, and m-health have become increasingly popular in recent years as they make it possible for more convenient and flexible healthcare delivery and can help reduce costs and improve access to healthcare. They have been particularly beneficial for individuals who live in rural or remote areas or for those who have mobility issues that make them difficult to travel to a healthcare facility (Khan, 2020). Remarkably, the practice of tele health, e-health, and m-health has been crucial during the COVID-19 pandemic. Patients were able to receive healthcare conveniently and protected them from the risk of COVID-19 virus exposure (Javaid & Khan, 2021; Khan et al., 2021; Singh et al., 2020; Sultana &Tamanna, 2021).

### 2.2 Related Works

Implementation of emerging technologies such as megatrends in IoT-based healthcare systems has drawn attention to numerous researchers. In Bangladesh, a country where the rural population is close to 70 percent, according to Khan (2020) identified constraints regarding technical resources, patient interest and acceptance, awareness, marketing, startup infrastructure, and motivation as the core impediments to IoT-based healthcare system.

The advancement of the IoT-based healthcare system along with its prospects and drawbacks were later scrutinized by Selvaraj and Sundaravaradhan (2020). Their study highlighted the superiority of HIoT especially concerning efficient patient monitoring through optimized algorithms and machine

learning. However, privacy concern was deemed as a significant issue due to Cloud Data Integration in HIoT (Michele & Furini, 2019; Papaioannou et al., 2022). There are three vital components of HIoT i.e. data acquisition, communication, and data analytics (Habibzadeh et al., 2020). In addition, they emphasized that legal, ethnographic, and regulatory measures also slowed the deployment of HIoT.

Apart from distant health and recovery monitoring, mechanized and transparent aid, and effective control, the use of IoT deployment in healthcare encouraged easy access to information and is time-saving. In addition, convenient communication is another advantage enjoyed by users during the COVID-19 pandemic (Sultana & Tamanna, 2021). However, social problems arose because of decreasing interpersonal interactions and increasing social distancing that became the new way of life.

A thesis by Adnan Hossain (2020) stressed that Hospital Information Management Systems (HIMS), Electronic Healthcare Records Systems (EHR), and mobile healthcare are vital uses of IoT-based public healthcare in Bangladesh. He further pinpointed five obstacles namely inadequacy of connectivity support, adept human resource, accessibility of smart devices and IoT services, power resources, and financial soundness that thwarted efficient public healthcare service delivery.

Alam et al. (2020) examined Bangladesh's state of digital transformation in the healthcare industry especially pertaining to the management and technical aspects of Bangladeshi healthcare projects that ventured into digitalization. They found that those projects could not operate successfully in most cases due to inferior infrastructure, low technological know-how, minimal trust, poor literacy, bad attitudes, reluctance to change and hard-core poverty.

The WBAN-based IoT healthcare system was described by Dhanvijay and Patil (2019), along with a review of the network topology and applications in IoT-based healthcare solutions. Additionally, glitches such as scalability, security, cost and quality, confidentiality, and network architecture were identified as open challenges for IoT- based healthcare systems (Papaioannou et al., 2022). IoT implementation in the healthcare sector would make primary healthcare increasingly accessible through self-management, surveillance, and disease prevention while making secondary and tertiary healthcare efficient, incessant, and harmonized. These were discussed in a paper by (Kelly et al., 2020). They regard policy support, accessibility of technology and enhanced cyber security as Enablers whereas open issues and challenges are Barriers. Bhuiyan et al. (2021) identified several IoT healthcare methods, networks and standards protocols as important they firmly maintain that data freshness, non-repudiation, resiliency, fault tolerance, self-healing are open issues on security requirements that need to be addressed too. They also identified computation restrictions, memory limitation, and uncertainty as challenges while enhancement of telehealth, m-health, information and drug management, context prediction, emergency attendance etc. as prospects. A study by Rayan et al. (2001) revealed several cases of IoT deployment which includes cancer care, diabetes, and asthma aggravations supervision, drug delivery and observance and degenerative mental health circumstances assistive care. They also identified IoT applications in healthcare to include clinical practice, patient management and research. Furthermore, they regard constraints to be technical, cost-related, and ethical. Makkar et al. (2020) explored the plentiful opportunities of HIoT in HealthCare. This includes advantages such as diminished cost and errors, improved treatment, drugs and disease management etc. (Bhuiyan et al., 2021). Meanwhile, emerging challenges such as data blending, assortment and interoperability, data execution and progression of usage were concentrated on by other researchers (Michele & Furini, 2019). Michele and Furini (2019) highlighted the most promising medical sectors to apply to IoT. This is especially where remote patient monitoring was addressed as an open sector and electronic healthcare records and preventive healthcare need to be engaged. They also brought to attention current approaches to HIoT. A study by Alraja et al., (2019) sought to comprehend how patients view IoT applications in healthcare services. Overall, patients were inclined by their perceptions on security, privacy, and familiarity as well as the impact of trust on those perceptions. However, a study exposed the application of the proposed model and actual usage behaviour of IoT but they cautioned that it needs to be explored further by (Papaioannou et al., 2022).

Bhuiyan et al. (2021) firmly suggested data freshness, non-repudiation, resiliency, fault tolerance and self-healing as well as addressing open issues as the security requirements for IoT-based healthcare. They identified computation restrictions, memory limitation and uncertainty as challenges while enhancement of telehealth, m-health, context prediction, alert emergency attendance etc. as prospects.

Integration of IoT technologies in healthcare applications can be largely characterized into three technological clusters namely identification, communication and location (Pradhan et al., 2021). Elements of these clusters enable IoT to expand into healthcare and provide a large pool of services transforming the sector from clinic-centric to a more patient-focused system. Table 1 below is the summary of the literature reviews done by this study.

**Table 1.**
*Related Works on IoT-based Public Healthcare Systems*

| Author | Year | Context | Methods | Factors | Focus |
|---|---|---|---|---|---|
| Mohammad Monirujjaman Khan | 2020 | Bangladesh | Secondary research | Smart healthcare, rural and underprivileged population, current situation, challenges | Implementation of IoT is facilitating portable and remote healthcare for rural population while facing numerous impediments |
| Md. Adnan Hossain | 2020 | Bangladesh | AHP, FGD, KII and Survey | Strategic approaches for IoT in healthcare, telemedicine, benefits, realized constraints, nteraction models | Telemedicine was recommended as a reliable IoT opportunity alongs de proposing two models for interactions among patient, doctor, and IoT devices |
| Nahida Sultana, MarziaTamanna | 2021 | Bangladesh | Primary data survey | Use of IoT services, benefits experienced, challenges faced during COVID-19 | Use of IoT was prominent in education, banking, and healthcare sector as the it helped to maintain social distance but reduced personal communication |
| Mohammad Zahedul Alam, Wang Hu, Md. Aslam Uddin | 2020 | Bangladesh | Secondary research | Digital transformation in health sector, administrative and technical challenges | Existence of numerous challenges makes digital revolution in healthcare problematic.However, policy initiatives and digital startups may help to mitigate that |
| Mohammad Nuruzzaman Bhuiyan, Dr. Md. Mahbubur Rahman, MdMasum Billah, Dipanita Saha | 2021 | Bangladesh | Review and survey | IoT healthcare method, network architecture, security, standard protocols, applications, and challenges | Survey conducted on IoT healthcare, networks, security protocols, and market development, as well as proposed a security architecture model for IoT-based healthcare systems |
| Roberta De Michele, Marco Furini | 2019 | | Secondary research | Smart objects, current approaches for IoT-based healthcare, applications, issues | IoT can significantly improve monitoring, disease prevention, efficiency, accuracy. However, it is met with open issues and weak business model |
| Sandhya Makkar, Ashirwad Kumar Singh, Sweta Silpa Mohapatra | 2019 | | Review and survey | IoT-based healthcare structures, applications, security and protection, threat models, wearables, open issues, difficulties | Identifies opportunities of IoT-based healthcare for all stakeholders, benefits of the technology as well as challenges, emerging challenges, and future |

| | | | | | |
|---|---|---|---|---|---|
| Hadi Habibzadeh, Karthik Dinesh, Omid Rajabi Shishvan, Andrew Boggio-Dandry, Gaurav Sharma, Tolga Soyata | 2019 | | Review and Survey | Healthcare IoT, trends, applications, challenges, system architecture, security and privacy | Analyzed existing and potential technologies behind HIoT development underlining sensing communication, and data analytics; as well as visualized trends and discussed open issues |
| Suresh Kumar Selvaraj, Suresh Sundaravaradhan | 2019 | | Systematic review | IoT healthcare, applications, architecture, clouding computing, big data, security | Examined cloud integration, data management, advantages, and limitations of IoT healthcare; concluded that IoT systems are very efficient for monitoring while the open issues pose impediments |
| Mrinai M. Dhanvijaya, Shailaja C. Patil | 2019 | | Review and survey | IoT healthcare, WBAN body sensors, IoT policies and systems, possibilities, future prospects | Investigated WBAN technology, different security and privacy problems associated with it. Tried to project how development of IoT systems can be eased and explained challenges |
| Mansour Naser Alraja, Murtaza Mohiuddin Junaid Farooque, Basel Khashab | 2019 | Oman | Primary data survey | IoT-based healthcare, risk perception, trust in IoT, use of IoT | Security, trust, and familiarity affects users' risk perception and adoption of IoT. Risk perception is correlated with users' adoption |
| Maria Papaioannou, Marina Karageorgou, Georgios Mantas, Victor Sucasas, Ismael Essop, Jonathan Rodriguez, Dimitrios Lymberopoulos | 2019 | | Review and survey | IoMT, system architecture, security, cyber-attacks, security threats, countermeasures | To help in developing security models to secure IoMT devices from cyberattack, the study analyzed different categories of threats and reviewed counter measurements |
| Jaimon T Kelly, Katrina L Campbell, Enying Gong[4], Paul Scuffham | 2019 | | Secondary research | IoT-based healthcare, digital devices, architecture, care delivery, enablers, barriers | Demonstrate how IoT is disrupting healthcare and improving healthcare delivery to picture the potential of IoT, as well as the barriers that IoT face i.e., open issues |
| Bikash Pradhan, Saugat Bhattacharyya, Kunal Pal | 2021 | | Secondary research | HIoT, architecture, services and applications, challenges and limitations | Using sensors and chips i.e., RFID, ZigBee, NFC, etc., HIoT can contribute in numerous healthcare service efficiently. However, open issues and challenges remain |

Source: Authors Compilation

## 3. Research Methodology

This paper systematically reviewed the research papers published in different reputed journals since 2018. Investigations focused on general benefits, impediments, adoption models, user acceptance, etc. of IoT healthcare, e-health, m-health, telemedicine, smart healthcare and digital healthcare and paying attention to the context of Bangladesh in particular. The following keywords were searched in the databases of top ranked journals:

("Prospects" OR "Challenges") AND ("Internet of Things" OR "IoT") AND "Public Healthcare" AND"Bangladesh"

After deducting the irrelevant titles and perspectives, a total of 58 research papers were reviewed to identify the key prospects, challenges, and future trends of IoT-based healthcare in Bangladesh. This is thought sufficient to pave the path for policymakers of the country to integrate HIoT with the existing public healthcare system.The study demonstrates the aggressive growth of HIoT research and highlights the necessity of integrating IoT into the healthcare delivery systems. The conclusions of this study are noteworthy especially for:

- Researchers and academicians interested in IoT and who have a desire to really understand the paradigm of healthcare based of IoT peculiar to Bangladesh case.
- Policymakers and healthcare professionals of Bangladesh interested in implementing the latest approaches, plans, procedures, and technologies within the confines of HIoT systems.
- Individuals who are interested to explore studies related to IoT, HIoT, IoMT in the context of a Developing Nation like Bangladesh.

## 4. Results and Findings

### 4.1 Present Public Healthcare Status of Bangladesh

Bangladesh, a country of 166.303 million people, was identified as one of the 57 countries that were facing critical shortage of primary, secondary, and tertiary healthcare workforces (Alam et al., 2020). However, public health improvements over the years in terms of life expectancy, mortality rate, birth and death rate paint a positive picture about the healthcare sector of Bangladesh. This is illustrated in Table 2 below.

**Table 2.**
*Demographic Indicators and Public Healthcare Status of Bangladesh (2017-2021)*

| Indicator | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| Total population (million) | 159.685 | 161.376 | 163.046 | 164.689 | 166.303 |
| Population growth (annual %) | 1.076 | 1.054 | 1.029 | 1.003 | 0.975 |
| Population ages 0-14 (% of total population) | 28.225 | 27.706 | 27.214 | 26.755 | 26.311 |
| Population ages 15-65 (% of total population) | 66.626 | 67.136 | 67.605 | 68.018 | 68.358 |
| Population ages 65 and above (% of total population) | 5.149 | 5.158 | 5.180 | 5.227 | 5.331 |
| Life expectancy, at birth (total, years) | 72.052 | 72.320 | 72.591 | 72.868 | - |
| Mortality rate, infant (per 1000 live births) | 28.200 | 26.800 | 25.500 | 24.300 | - |
| Fertility rate (births per woman) | 2.062 | 2.036 | 2.011 | 1.987 | - |
| Birth rate, crude (per 1000 people) | 18.501 | 18.184 | 17.868 | 17.549 | - |
| Death rate, crude (per 1000 people) | 5.533 | 5.529 | 5.526 | 5.524 | - |

Source: The World Bank, 2022.

Data accumulated by The World Bank depicts a decline in population growth over time (2017-2021) as the fertility rate falls. However, the decreasing mortality rate and death rate hints positive developments in Bangladesh's public healthcare delivery. As a result, life expectancy of the population reached an all-time high of approximately 73 years. However, the rise of e-health and telemedicine mobile applications during the COVID-19 has provided the population with a newer and smarter medium to receive consultation from a remote location (Khan, 2020). This has lowered the pressure on the workforces as people are getting introduced to m-health. Table 3 shows the manpower strength of the Directorate General of Health Services (DGHS) in Bangladesh in 2020.

**Table 3.**
*Healthcare Workforce under DGHS in Bangladesh*

| Criteria | Total |
|---|---|
| Number of Personnel | 78,619 |
| Number of Doctors | 25,594 |
| Number of Registered Physicians (MBBS) | 101,538 |
| Number of Registered Physicians (BDS) | 9,875 |
| Number of Medical Technologists | 5,208 |
| Number of Sub-Assistant Community Medical Officers | 3,709 |
| Number of Community Healthcare Providers | 13,907 |
| Number of Domiciliary Staff | 19,830 |

Source: Directorate General of Health Services.(2020)

The number of healthcare professionals is yet to reach the standard strength enough to serve the population by the DGHS (Directorate General of Health Services, 2020). For a population as large as 166.303 million, only 101,538 MBBS physicians and 9,875 BDS physicians are serving. This ratio of population to healthcare service is very low compared to the rest of the world. Furthermore, the amount of healthcare facilities (as shown in Table 4) both public and private, are not adequate to serve the large population. This created panic among patients and the general public as observed during the COVID-19 pandemic when the healthcare system failed to provide enough hospital beds for the ailing COVID-19 patients (Sakib, 2021). Thus, COVID-19 which caused the migration into IoT-based healthcare system serve as a blessing for developing countries like Bangladesh.

**Table 4.**
*Healthcare Facilities in Bangladesh*

| Criteria | Total |
|---|---|
| Total public facilities under DGHS | 2,258 |
| Number of hospital beds under DGHS | 55,660 |
| Total registered private facilities and clinics | 5,321 |
| Number of beds in registered facilities and clinics | 91,537 |
| Total registered private Diagnostic Centres | 9,529 |

Source: Directorate General of Health Services, 2020.

Nevertheless, despite the low number of facilities, healthcare services provided by the DGHS-run public hospitals are getting better as time progresses. With the integration of advanced medical equipment within the healthcare system and the DGHS investing a significant part of the allocated health budget especially for the development of state-run healthcare facilities, the government is pushing hard to make quality public healthcare accessible for the entire population. However, the low ratio of number of populations to healthcare personnel and the inadequate hospital beds per 10,000 still remains as Bangladesh's phenomena. This is as illustrated in Table 5 where Bangladesh when compared to World standards falls very far behind.

**Table 5.**
*Population-to-Healthcare Workforce/Facilities Ratio*

| Criteria | Bangladesh | World |
|---|---|---|
| Registered physicians (per 10,000 population) | 6.73 | |
| Doctors working under DGHS (per 10,000 population) | 1.55 | |
| Medical technologists working under DGHS (per 10,000 population) | 0.60 | 17.57 |

| | | |
|---|---|---|
| Community and Domiciliary Staff working under DGHS (per 10,000 population) | 2.26 | |
| Number of beds in public facilities under DGHS | 3.30 | |
| Number of beds in registered private facilities | 5.53 | 28.95 |

Source: (Directorate General of Health Services, 2020; The World Bank, 2022).

Bangladesh's average is only 6.73 physicians per 10,000 population while the world's average is approximately thrice of that i.e., at 17.57 physicians per 10,000 people. The number of available beds per 10,000 is significantly lower for Bangladesh too i.e., at 8.83 while the world's average is 28.95. However, despite the limitations, the country is praised highly due to its low-cost healthcare service. In DGHS-run hospitals, patients can get healthcare for as low as 10 Bangladesh Taka (BDT) which is equivalent to only 0.096 US Dollar (USD). Bangladesh has been reputed as an excellent example for other developing nations in the area because of its astounding example of attaining high health at very cheap costs (Sultana, 2019). Moreover, Bangladesh spends a very low healthcare expenditure against its GDP whencompared to the neighboring countries as well as other International Development Association (IDA) and International Bank for Reconstruction and Development (IBRD) countries. Table 6 compares Bangladesh's Healthcare expenditure against the IDA and IBRD countries.

**Table 6.**
*Healthcare Expenditure of Bangladesh (% of GDP)*

| Location | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Bangladesh | 2.639 | 2.473 | 2.432 | 2.508 | 2.484 |
| India | 3.596 | 3.504 | 2.936 | 2.952 | 3.014 |
| Pakistan | 2.687 | 2.893 | 2.902 | 3.202 | 3.380 |
| Nepal | 5.466 | 5.424 | 4.722 | 4.528 | 4.445 |
| Indonesia | 2.924 | 3.021 | 2.904 | 2.868 | 2.905 |
| South Asia* | 3.515 | 3.435 | 2.983 | 3.040 | 3.094 |
| East Asia & Pacific* | 4.710 | 4.742 | 4.813 | 4.916 | 5.071 |
| Europe & Central Asia* | 5.237 | 5.336 | 5.349 | 5.371 | 5.585 |

*IDA and IBRD countries
Source: The World Bank (2022).

Looking at the country's healthcare expenditure per capita, we can witness a significantly lower numbers for Bangladesh as compared to the world's average. According to The World Bank's 2019 data, Bangladesh recorded a health expenditure of $45.86 per capital whereas the world's average is $1,121.97. Though the number is on an increasing trend for Bangladesh, yet it is astonishingly low.

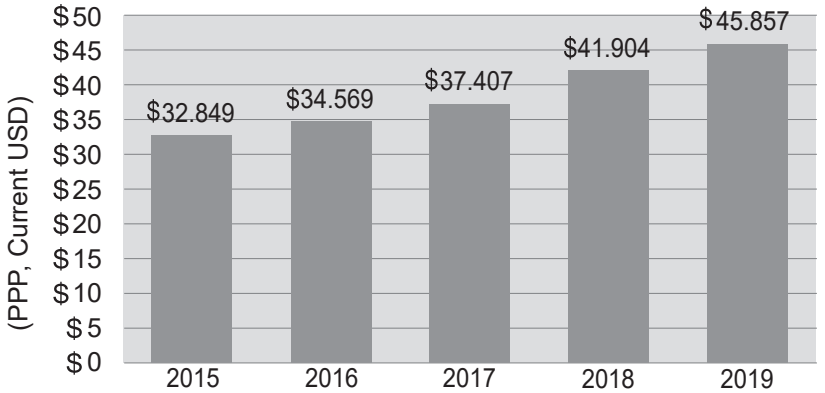


**Figure 1.**
*National Health Expenditure Per Capita of Bangladesh (2017-2021)*
Source: The World Bank (2022).

According to the Bangladesh Bureau of Statistics (BBS), per capita income of Bangladesh stands at $2,824 in the Fiscal Year (FY) 2021-22 (Bangladesh Bureau of Statistics, 2022). So, the population cannot spend much on healthcare due to the income barriers. However, the government is allocating a noteworthy portion of its national budget for the improvement of public healthcare and medical education. In the FY2021-22, the Ministry of Finance has proposed a budget of BDT 25,914 crore to operate and develop the healthcare system of the country. Table 7 shows the increasing trend in terms of budget allocation for public health purposes.

**Table 7.**
*Budget Allocation for Public Healthcare from FY2017-18 to FY2021-22*

| Criteria | FY17-18 | FY18-19 | FY19-20 | FY20-21 | FY21-22 |
|---|---|---|---|---|---|
| Health services - operating (in crore BDT) | 8,340 | 9,118 | 10,008 | 12,830 | 12,914 |
| Health services - development (in crore BDT) | 7,842 | 9,041 | 9,937 | 10,054 | 13,000 |
| Medical education and family welfare (in crore BDT) | 4,470 | 5,224 | 5,788 | 6,363 | 6,817 |
| Budget allocation for health (% of total budget) | 5.2% | 5.0% | 4.9% | 5.1% | 5.4% |

Source: (Unnayan Shamannay, 2021; Ministry of Finance, 2022).

Apparently, the allocation of budget in the development of Bangladesh's public healthcare sector has increased drastically in the last five FYs. The government is investing a giant portion to medical education as well to mitigate the workforce shortage that the country has been facing for a long time. Overall, the public healthcare sector of Bangladesh is heading towards an improvement and the introduction of digital technologies in this industry couldfurther accelerate the process.

## 5. Prospects of IoT-based Public Healthcare System in Bangladesh

With the rapid progress achieved by the ICT Division of the Government of the People's Republic of Bangladesh, the country is envisioning a future surrounded by advanced technology and innovation in almost every sector. Notably, the health sector has led the concerned authority to develop the country's first national Internet of Things (IoT) strategy in 2020 which has acknowledged the potential of IoT implementation in relation to the healthcare sector at large. The Government has projected the use of IoT as part of a smart healthcare infrastructure that can be developed as an outcome of concurrent connections of healthcare facilities, services, and commodities (ICT Division, 2020). The field of implementation of IoT in the public healthcare sector of Bangladesh appears to be interminable.

In short, the most optimistic areas of Bangladesh's Healthcare services that warrant the implementation of IoT technologies include: -

1) Remote and Clinical Monitoring
2) Patient and Drug Management
3) Telehealth, E-health, and M-health
4) Ambient Assistance and Rehabilitation
5) Cognitive Computing and Research

### 5.1 Remote and Clinical Monitoring

The implementation of IoT will definitely bring about revolutionary improvements in terms of healthcare delivery utilizing the remote monitoring and care delivery systems as the public healthcare sector of Bangladesh is short of medical workforce and healthcare facilities. Inadequate healthcare facilities include monitoring patients' health condition i.e. blood pressure, sugar level, oxygen saturation, temperature, asthma, etc. These tests could use Biomedical Sensor from a distant place in real time while connecting physicians to their patients through IoT devices. Doctors can get notified about any health hazards and drug adherence to ensure quick clinical healthcare delivery (Bhuiyan et al., 2021; de Michele & Furini, 2019; Dhanvijay & Patil, 2019; Habibzadeh et al., 2020).

To carry out such monitoring and healthcare delivery systems, the use of Biomedical Wearable Sensors like RFID, ZigBee, GP Sand Wireless Body Area Network (WBAN) etc. can be easily deployed (Poongodi et al., 2020; N. Sultana &Tamanna, 2021). For instance, ECG and diet monitoring systems are already under development in this subcontinent which may allow patients to get continuous feedbacks from the physicians (Md. O. Rahman et al., 2021; Suganyadevi et al., 2022). Moreover, low-cost IoT devices can be implemented at homes to monitor for example a child's overall wellbeing through constantly analyzing nutrition values, physical, mental and psychological state, behaviour, and correlated factors. This is crucial as the numbers of daycare facilities for children in Bangladesh are inadequate and IoT devices could simultaneously resolve dilemmas for working mothers (Liakat, 2022).

### 5.2 Patient and Drug Management

The use of IoT enabled state-of-the-art Hospital Information Management Systems (HIMS) and Electronic Healthcare Recordsystems (EHR) will drastically improve patients' management at the healthcare facilities in Bangladesh (Hossain, 2020; Makkar et al., 2020). Care providers can track the incoming and outgoing of patients in the Emergency Department (ED) as well as identify patients' admission and the average flow of patients to reduce emergency waiting time (Dhanvijay & Patil, 2019). Moreover, patients can be provided with unique smart ID through which all the medical records of patients may be easily retrievable by authorized personnel.

Using IoT devices that include medical sensors, allow physicians to control drug doses from a distant place and prevent overdosing as well as collect data about the drug's effectiveness on patients (Patra et al., 2021; Pradhan et al., 2021). In the long run, adoption of IoT in Dispensaries and Hospitals of the country can keep track of the availability of lifesaving drugs which may prove to be instrumental in specific cases.

### 5.3 Telehealth, E-health, and M-health

With the help of IoT enabled medical services like e-health, m-health, and telehealth, primary care can be made accessible even to people in remote locations (Kelly et al., 2020). The population residing in rural areas can avail better healthcare service through their smart devices very easily. During the COVID-19 pandemic, the use of such services over the mobile network and internet has proven to be useful for remote consultations (Chowdhury et al., 2021; Khan et al., 2021; Zabeen et al., 2021). These platforms played an indispensable role in terms of delivering essential information to the ailing patients as well as the general mass. However, the numbers of digital startups working within the health sector are quite low and can be drastically increased as investments in IoT upsurge.

It has been revealed that application of IoT in telehealth through remote consultation using smart devices like Real-Time Tracking Location System (RTLS), development of e-health and m-health mobile applications as well as virtual health assistant expand the horizon of healthcare delivery system (Jha et al., 2021). Moreover, integration of IoT and telehealth in healthcare facilities can be an efficient and low-cost medium of care delivery that the population may enormously benefit from (Emon et al., 2018; Prodhan et al., 2020; Rahman et al., 2021). Nevertheless, the downside of such platforms remains quite vulnerable but fortunately user data protection could be mitigated by using secure technologies like Block Chain (Hossain et. al., 2022; Nusrat et al., 2019).

### 5.4 Ambient Assistance and Rehabilitation

As the elderly population (65 years old and above) is increasing in Bangladesh with every passing year, use of Artificial Intelligent (AI) integrated to IoT-based assistive devices help elderly patients to navigate at home independently, easily and safely. This also enables real-time monitoring and emergency support which are significant addition to the healthcare system (Bhuiyan et al., 2021; Pradhan et al., 2021). Moreover, developing IoT-based smart devices or rehabilitation systems would help patients to reintegrate into normal life after surviving major chronic medical conditions like

cancer, heart attack, brain stroke, disabilities, etc. The rehabilitation systems also can remarkably improve post-treatment care (Bisio et al., 2019; Dhanvijay & Patil, 2019).

### 5.5 Cognitive Computing and Research

The chunk of budget proposed by the Government of the People's Republic of Bangladesh in the development of healthcare and medical sciences can indeed accelerate the number of clinical research in this field. Use of the collected patient data through IoT implementation in healthcare can help researchers to classify and examine hidden patterns, and impersonate the decisions made by the human brain using different sensors and AI to assist in critical conditions (Patra et al., 2021; Pradhan et al., 2021). Besides, using Big Data alongside IoT in research about future diseases can develop preventive measures before handand will be instrumental to combat future healthcare crisis (Michele & Furini, 2019; Makkar et al., 2020; Rayan et al., 2021). This will not only make the healthcare system more functional but also make the healthcare delivery system more efficient as the medical professionals will be prepared to tackle future incidences of any disease outbreak.

## 6. Challenges of IoT-based Public Healthcare System in Bangladesh

Implementation of IoT in the public healthcare sector of Bangladesh will require convincing the population to perform trials and responses. If the population of a country resist change, public healthcare based on IoT will naturally encounter a lot of hurdles to overcome. Inferior ICT infrastructure and low financial capabilities are other factors that distort the rate of progress in using IoT. Other open issues that the IoT technology will face areas follows: -

### 6.1 Inadequate Infrastructure and Financial Constraints

IoT is a relatively new concept to Bangladesh because the country only had its first national Internet of Things (IoT) strategy in 2020. So, the infrastructure is not yet ready to launch a full-fledged IoT implementation in the healthcare sector. Moreover, the country is lagging behind world current standards in terms of ICT infrastructure (Ara et al., 2020; Chowdhury et al., 2021). The mobile communication operators of the country are still far from rolling out the 5G network which is the key element for IoT-based healthcare systems (Gupta et al., 2021).

Besides, being a developing country, Bangladesh heavily depends on foreign institutional investors, grants and loans from WHO, IDB, The World Bank etc. for its development projects (Alam et al., 2020). As IoT implementation in healthcare involves sophisticated network of infrastructure, expensive equipment with considerably high maintenance expenses, as well as trained staff, it is therefore a huge risky investment for a country like Bangladesh to spend on its own expenditures.

### 6.2 Organizational and Staff Motivation Barriers

Since the current e-health, m-health, and telemedicine programs in Bangladesh have not achieved their organizational objectives as evidenced from its low effectiveness indicators, the adoption of IoT-based public healthcare system has been somewhat stalled. It is found that the existing digital healthcare initiatives paid insufficient priority to health organizations, strategy development, infrastructural architecture, operational instructions, and management assistance (Zobair et al., 2020). Therefore, the success rate of the current IoT-based public healthcare system has been found to be insignificant, unambiguous and not proactive.

In addition, Senior administrative personnel in the healthcare sector of Bangladesh lacks the will to implement the new structure and is resistant to change as well (Chowdhury et al., 2021). Moreover, the supposedly "smart" healthcare initiatives introduced earlier did not sufficiently reward medical professionals to support more efficient work culture, promote financial and professional rewards or devote enough funds to meet patient health aspirations (Zobair et al., 2020).

### 6.3 Lack of Trust and Patient Acceptance

Acceptability of IoT-based healthcare maybe quite high as many studies suggest (Alraja et al., 2019) but lack of patient trust and acceptance of the technology remains one of the main challenges (Khan, 2020). While the urban population may be exposed to the use of modern technology, the rural and underprivileged population is still skeptical about it. Moreover, generally the population of Bangladesh is still resistant to changes in terms of sensitive matters such as healthcare. From a socio-cultural standpoint, a lot of patients do not feel comfortable discussing their illnesses in the presence of others (Zobair et al., 2020). Thus, many projects regarding various form of IoT-based healthcare like telemedicine, e-health, etc. were unsuccessful because of this social taboo or secretive culture.

### 6.4 Low ICT Literacy and Access

As of August 2022, the total number of internet subscribers were 126.18 million and 181.67 million mobile phone subscribers Bangladesh Telecommunication Regulatory Commission's (BTRC, 2018 Report). Seemingly, thisshows a high degree of ICT inclusion when compared to the total population but the number does not represent unique connections. Accesses to smartphones through which modern IoT-based mobile applications may be used are comparatively less in the rural and remote parts.

Moreover, it is discovered that 67% of the populations of Bangladesh do not know how to browse the internet and 27% even lack the knowledge of basic mobile phone operations (LIRNEasia, 2018). Also, the gender gap in terms of access to internet is considerably high as welli. i e., 39.54% (Ahmed, 2022). According to an article from The Business Post, only 21.25% of the entire female population of the country use internet.

### 6.5 Lack of Awareness and Skilled Workforce

As the concept of IoT-based healthcare system is relatively new to the country, people lack the awareness of it. Not being familiar with the benefits and services that the technology offers naturally push patients away from the system. Evidence from studies conducted on telemedicine and e-health suggest that people residing in distant villages and remote locations significantly lack awareness of smart healthcare (Khan, 2020). Moreover, the healthcare facilities that provide such healthcare delivery do not have enough skilled healthcare workers (Ara et al., 2020). Doctors and general physicians also lack IoT knowledge which is required to be resolved before mass IoT healthcare services could be implemented.

### 6.6 Inadequate Healthcare Startups and Marketing

During the COVID-19 pandemic, upsurges of telemedicine and e-health platforms were quite visible. As the COVID-19 eased up, the relevancy of such platforms seems to be going down due to decline of marketing activities. Moreover, the numbers of IoT-based healthcare startups are inadequate due to lack of operational funds and expert teams (Khan, 2020). Thus, the services are not yet widely available to the general public and therefore emerge as a challenge.

### 6.7 Open Issues of IoT-based Healthcare

Open Issues of IoT-based Healthcare includes:

- *Data privacy and security:* The medical information managed by IoT devices may be accessed by unauthorized individuals without consent or tempered with by cyber-attacks. These form major privacy risk for patients and the entire healthcare system.
- *Power consumption:* Energy requirements to record, assess, transit, analyze data based on service availability pose challenges in the face of IoT implementation as IoT devices are small in nature and cannot be connected to a continuous power source due to remote operations.
- *Interoperability and standardization:* Interoperability of IoT healthcare systems is a huge challenge as the vendors of the equipment are different and there are no standardization

protocols. Currently, neither people nor institutions are using or enforcing security and personal protection norms and regulations.

- *System cost:* The cost of IoT system acquisition, for the time being, is considerably high which restricts general people to acquire IoT devices in order to enjoy the state-of-the-art healthcare service.
- *Flexibility and scalability:* Lack of uniformity among the different medical sensors, wearables, and tiny devices make IoT-based healthcare less flexible and less scalable. Thus, it is tough to make IoT-based healthcare widely available.
- *Quality of service (QoS):* Information recorded and analyzed by IoT devices may be unreliable and delayed at times compared to medical instruments.This poses an uncertainty regarding QoS as healthcare is a sensitive matter.

**7. Future Prospects of IoT-based Public Healthcare**

The future of IoT-based healthcare technology in Bangladesh seems quite bright. With more and more telemedicine, e-Health, and mHealth application launched in the healthcare spectrum and increased amount of people adopting fitness trackers, the interconnectivity of basic healthcare is improving. Moreover, implementation of IoT devices in urban, rural, and remote hospitals would make the healthcare situation a lot better.

Advanced technology such as Artificial Intelligence (AI), Cloud Computing, and Augmented Reality can be incorporated into IoT devices slowly. This would make the gap between physical consultation and virtual consultation be minimized. The use of those technologies in Bangladesh will definitely bring down the mortality rate in remote areas. This is because record shows that rural populations are more susceptible to death due to diseases compared to urban populations.

With the increasing number of smart devices and smart phones in the country, the network infrastructure is also getting more suitable for IoT-based healthcare development. Incorporation of basic healthcare sensors in fitness trackers and even mobile phones will minimize the surprise factor of health issues for the population and make them more aware of personal health monitoring. The use of IoT devices and networks in Hospitals and Care Centres will induce major improvement in the fields of care delivery, patient management, drug management, consultancy, uniformity of information, etc. So, with the increasing IoT implementation in the public healthcare sector of Bangladesh, the country is progressing into a healthier future.

The Internet of Things (IoT) has the potential to revolutionize the public healthcare by increasing the efficiency of medical care delivery and improving patient outcomes. There are several ways that IoT-based healthcare could be used in the future. They are as follows:

- *Clinical decision support:* IoT devices can provide real-time data to healthcare providers. This can be used to inform clinical decision-making quickly. An IoT device could alert a doctor if a patient's vital signs are outside the normal range. This also allows the doctor to take timely action to address the issue.
- *Personalized medicine:* IoT devices can collect data about an individual's health and lifestyle thus allowing for the creation of personalized treatment plans. This could lead to more effective and efficient healthcare.
- *Supply chain optimization:* IoT can be used to track medical equipment, supplies, and medications; allowing healthcare organizations to optimize their supply chain and reduce waste.
- *Clinical trials:* IoT devices can be used to collect data from patients participating in clinical trials. Thislet researchers to track the effectiveness of new treatments.
- *Development of new treatments and therapies:* IoT devices can be used to collect data on patient outcome which can help researchers to develop new treatments and therapies that are

more effective and personalized to individual patients.

- *Hospital asset tracking:* IoT devices can be used to track the location and use of hospital assets such as medical equipment so as to improve efficiency and reduce costs.
- *Predictive maintenance:* IoT devices can be used to monitor the performance of medical equipment and alert maintenance staff when repairs are needed. This can help to ensure that equipment is always in good working order hencereducing the risk of equipment failure during critical procedures.

Overall, the future prospect of IoT-based healthcare looks promising. However, there are also challenges such as data privacy and security to be addressed. Other challenges are the need for standardization and the potential for technical failures. Despite these challenges, it is likely that IoT will play an increasingly important role in the Bangladesh's public healthcare sector in the coming years.

## 8. Recommendations

Overcoming the impediments of IoT-based healthcare is a continuous process. As IoT is in its early age in Bangladesh, it will require additional efforts and time to integrate the technology into the country's public healthcare segment. However, to facilitate the integration and preparation ofIoT technology for mass implementation especially in public healthcare, this study proposes the following recommendations: -

- Concerned authority in partnership with service providers must strengthen the ICT infrastructure to facilitate the integration of IoT in the general healthcare industry.
- Equipment facilities must be ensured in every state-run healthcare facility to improve the affectivity and efficiency of various IoT-based healthcare adoptions.
- A Central Repository of patient data should be developed using the Block Chain technology in order to provide a unique patient ID for every individual of the country. This is similar to the national Identity Card (IC), Birth Certificate and Driver's License system so that electronic medical records of patients can be easily retrievable for authorized personnel.
- Awareness programs should be carried out on regular intervals, especially in rural and remote areas by the DGHS. This aims to educate the general mass about the IoT-based public healthcare system and enroll them for trials in order to gain their trust.
- Physicians and health workers should be trained on IoT-based care delivery systems to improve the operability of such extensive systems and help them to better adopt the technology.
- To significantly reduce the infrastructure and equipment costs for the long term. Meanwhile, Research and Development (R&D) in healthcare IoT should be encouraged and backed by ample funding.

## 9. Conclusion

The Implementation IoT-based healthcare in Bangladesh will change the paradigm of the country's public healthcare. It will not only make the process of getting healthcare intuitive but also add extra layers of accuracy and care efficiency. However, the current status of ICT infrastructure of Bangladesh may hold the country back from implementing it at an aggressive scale. As the world progress towards better integration of IoT, Bangladesh should follow suit. Implementation of IoT will definitely reduce the mortality rates and provide public healthcare to the people in areas that are physically inaccessible. So, the opportunities are endless. Prioritizing IoT technology in order to bridge the limitations will definitely serve the population of Bangladesh with exemplary public healthcare services that they have never experienced before in the near future.

**References**

Ahmed, S. (2022, July 2). 21.25% women use internet, gender gap 39.54%: survey. *The Business Post.* Retrieved from https://businesspostbd.com/front/2125-women-use-internet-gender-gap-3954-survey-2022-07-02

Akhtar, R., Alam, S., &Siddiquee, N. K. A. (2019). Telemedicine: an ICT based healthcare approach to ensure health service for all. *International Journal of Community Medicine and Public Health, 6*(9), 3732. https://doi.org/10.18203/2394-6040.ijcmph20193961

Alam, M. Z. (2018). M-Health in Bangladesh: Current Status and Future Development. The *International Technology Management Review, 7*(2), 112. https://doi.org/10.2991/itmr.2018.7.2.1

Alam, M. Z., Hu, W., & Uddin, A. (2020). Digital transformation in healthcare services sector of Bangladesh: current status, challenges and future direction. *Journal on Innovation and Sustainability RISUS, 11*(1), 30-38. https://doi.org/10.23925/2179-3565.2020v11i1p30-38

Aledhari, M., Razzak, R., Qolomany, B., Al-Fuqaha, A., & Saeed, F. (2022). Biomedical IoT: Enabling Technologies, Architectural Elements, Challenges, and Future Directions. *IEEE Access, 10,* 31306-31339. https://doi.org/10.1109/ACCESS.2022.3159235

Alraja, M. N., Farooque, M. M., &Khashab, B. (2019). The effect of security, privacy, familiarity, and trust on users' attitudes toward the use of the IOT-based healthcare: The mediation role of risk perception. *IEEE Access, 7,* 111341-111354. https://doi.org/10.1109/access.2019.2904006

Al-Shargabi, B., &Abuarqoub, S. (2020). IOT-enabled healthcare: Benefits, issues and challenges?. In R. Kirichek&R. Pirmagomedov (Eds.), *The 4th International Conference on Future Networks and Distributed Systems (ICFNDS) of Russia(pp.* 1-5). doi:10.1145/3440749.3442596

Ara, J. G., Amin, S. M. R., &Sheuli, K. Z. (2020). Providing Community-Based Effective e-Health Services in Bangladesh: An Analysis on Sylhet SadarUpazila. *Journal of Public Administration and Governance, 10*(1), 211. https://doi.org/10.5296/jpag.v10i1.16103

(N.d.). (rep.). Gross Domestic Product (GDP) of Bangladesh 2021-2022 (p. 1). Retrieved May 10, 2022, from http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/057b0f3b_a9e8_4fde_b3a6_6daec3853586/2022-05-10-08-39-8796d375a266de9952d293604426cd1c.pdf

Bhuiyan, M. N., Rahman, M. M., Billah, M. M., &Saha, D. (2021). Internet of Things (IoT): A Review of Its Enabling Technologies in Healthcare Applications, Standards Protocols, Security, and Market Opportunities. *IEEE Internet of Things Journal, 8*(13), 10474-10498. https://doi.org/10.1109/JIOT.2021.3062630

Bisio, I., Garibotto, C., Lavagetto, F., &Sciarrone, A. (2019). When eHealth Meets IoT: A Smart Wireless System for Post-Stroke Home Rehabilitation. *IEEE Wireless Communications, 26*(6), 24-29. https://doi.org/10.1109/MWC.001.1900125

BTRC (2018). BTRC Annual Report 2017-2018.Retrieved from https://btrc.portal.gov.bd/sites/default/files/files/btrc.portal.gov.bd/annual_reports/851d78f5_c1c2_411a_a30d_341cef7775d9/2022-02-09-05-29-11613ef8220844934a991009b770acea.pdf

Chowdhury, S. R., Sunna, T. C., & Ahmed, S. (2021). Telemedicine is an important aspect of healthcare services amid COVID? 19 outbreak: Its barriers in Bangladesh and strategies to overcome. *The International Journal of Health Planning and Management, 36*(1), 4-12. https://doi.org/10.1002/hpm.3064

De Michele, R., &Furini, M. (2019). IoT Healthcare: Benefits, Issues and Challenges. In A.Bujari,&P. Manzoni (Eds.), *Proceedings of the 5th EAI International Conference on Smart Objects and Technologies for Social Good. (pp.* 160-164).doi:10.1145/3342428.3342693

Dhanvijay, M. M., &Patil, S. C. (2019). Internet of things: A survey of enabling technologies in healthcare and its applications. *Computer Networks, 153,* 113-131. https://doi.org/10.1016/j.comnet.2019.03.006

Directorate General of Health Services,Health Bulletin (2019). *Report of the Health Bulletin.* Retrieved from https://old.dghs.gov.bd/images/docs/Publicaations/Health%20Bulletin%202019%20Print%20Version%20(2)-Final.pdf

Emon, T. A., Rahman, K., Prodhan, M. Z., & Rahman, Md. T. (2018). Telemedicine and IoMT: Its importance regarding healthcare in Bangladesh. *International Journal of Scientific & Engineering Research, 9*(2), 1782-1786. https://shorturl.at/MOtNi

Garg, L., Chukwu, E., Nasser, N., Chakraborty, C., & Garg, G. (2020). Anonymity preserving IOT-based covid-19 and other infectious disease contact tracing model. *IEEE Access, 8*, 159402-159414. https://doi.org/10.1109/access.2020.3020513

Gatouillat, A., Badr, Y., Massot, B., &Sejdic, E. (2018). Internet of Medical Things: A Review of Recent Contributions Dealing with Cyber-Physical Systems in Medicine. *IEEE Internet of Things Journal, 5*(5), 3810-3822. https://doi.org/10.1109/JIOT.2018.2849014

Gupta, N., Juneja, P. K., Sharma, S., & Garg, U. (2021). Future aspect of 5G-IOT architecture in Smart Healthcare System. 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS). https://doi.org/10.1109/icicccs51141.2021.9432082

Habibzadeh, H., Dinesh, K., RajabiShishvan, O., Boggio-Dandry, A., Sharma, G., &Soyata, T. (2020). A Survey of Healthcare Internet of Things (HIoT): A Clinical Perspective. *IEEE Internet of Things Journal, 7*(1), 53-71. https://doi.org/10.1109/JIOT.2019.2946359

HaghiKashani, M., Madanipour, M., Nikravan, M., Asghari, P., &Mahdipour, E. (2021). A systematic review of IOT in Healthcare: Applications, techniques, and Trends. *Journal of Network and Computer Applications, 192, 103164*. https://doi.org/10.1016/j.jnca.2021.103164

Hossain, A. M. (2020). Strategic approach to facilitate integration of internet of things (IoT) in health care sector of Bangladesh (dissertation) [Bangladesh University of Engineering and Technology]. http://lib.buet.ac.bd:8080/xmlui/handle/123456789/5700

Hossain, C. A., Mohamed, M. A., Zishan, Md. S. R., Ahasan, R., &Sharun, S. M. (2022). Enhancing the security of E-Health services in Bangladesh using blockchain technology. *International Journal of Information Technology, 14*(3), 1179-1185. https://doi.org/10.1007/s41870-021-00821-9

Hosseinzadeh, M., Koohpayehzadeh, J., Bali, A. O., Asghari, P., Souri, A., Mazaherinezhad, A., Bohlouli, M., &Rawassizadeh, R. (2021). A diagnostic prediction model for chronic kidney disease in internet of things platform. *Multimedia Tools and Applications, 80*(11), 16933-16950. https://doi.org/10.1007/s11042-020-09049-4

Information and Communication Technology Division, National Internet of Things Strategy Bangladesh. (2020). *Report of the National Internet of Things Strategy Bangladesh.Retrieved* from https://shorturl.at/cyDbr

Jain, S., Nehra, M., Kumar, R., Dilbaghi, N., Hu, TonyY., Kumar, S., Kaushik, A., & Li, C. (2021). Internet of medical things (IOMT)-integrated biosensors for point-of-care testing of infectious diseases. *Biosensors and Bioelectronics, 179,* 113074. https://doi.org/10.1016/j.bios.2021.113074

Javaid, M., & Khan, I. H. (2021). Internet of Things (IoT) enabled healthcare helps to take the challenges of COVID-19 Pandemic. *Journal of Oral Biology and Craniofacial Research, 11*(2), 209-214. https://doi.org/10.1016/j.jobcr.2021.01.015

Jha, G., Sharma, L., Gupta, S. (2021). E-health in Internet of Things (IoT) in Real-Time Scenario. In: Singh, P.K., Wierzcho?, S.T., Tanwar, S., Ganzha, M., Rodrigues, J.J.P.C. (eds), *Proceedings of Second International Conference on Computing, Communications, and Cyber-Security. Lecture Notes in Networks and Systems (pp. 679-690).* doi:10.1007/978-981-16-0733-2_48

Kelly, J. T., Campbell, K. L., Gong, E., &Scuffham, P. (2020). The Internet of Things: Impact and Implications for Health Care Delivery. *Journal of Medical Internet Research, 22*(11), e20135. https://doi.org/10.2196/20135

Khan, Dr. M. (2020). IOT based smart healthcare services for rural unprivileged people in Bangladesh: Current situation and challenges. *Proceedings of 1st International Electronic Conference on Applied Sciences*, 10-30. https://doi.org/10.3390/asec2020-07535

Khan, M. M., Rahman, S. M. T., &AnjumIslam, S. T. (2021). The Use of Telemedicine in Bangladesh during COVID-19 Pandemic. *E-Health Telecommunication Systems and Networks, 10*(1), 1-19. https://doi.org/10.4236/etsn.2021.101001

Largan, C., & Morris, T. (2019). *Qualitative Secondary Research: A Step-By-Step Guide.* Retrieved from https://us.sagepub.com/en-us/nam/qualitative-secondary-research/book257022

Liakat, F. (2022, May 21). Children's daycare and working mothers' dilemma. *Prothom Alo English.* Retrieved from https://en.prothomalo.com/bangladesh/childrens-daycare-and-working-mothers-dilemma

LIRN Easia, After Access: ICT access and use in Asia and the Global South. (2018). *Report of the AfterAccess: ICT access and use in Asia and the Global South*. Retrieved from https://lirneasia.net/wp-content/uploads/2018/10/LIRNEasia-AfterAccess-Asia-Report.pdf

Makkar, S., Singh, A. K., &Mohapatra, S. (2019). Challenges and opportunities of internet of things for health care. *Intelligent Systems Reference Library, 301-314*. https://doi.org/10.1007/978-3-030-23983-1_12

Ministry of Finance, Budget in Brief (Archive). (2022). *Report of the Budget in Brief in Bangladesh.* Retrieved from http://www.mof.gov.bd/site/page/f9aab5cd-f644-47bb-bb94-a70cb64c15ce/Budget-in-Brief-(2000-01-to-2016-17)

Mukati, N., Namdev, N., Dilip, R., Hemalatha, N., Dhiman, V., & Sahu, B. (2023). Healthcare assistance to COVID-19 patient using internet of things (IOT) enabled technologies. Materials *Today: Proceedings, 80*(3)*, 3777-3781*. https://doi.org/10.1016/j.matpr.2021.07.379

Nusrat, S. A., Ferdous, J., Ajmat, S. B., Ali, A., & Sorwar, G. (2019). Telemedicine system design using blockchain in Bangladesh. *2019 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE) of Australia, 1-5.* https://doi.org/10.1109/csde48274.2019.9162401

Papaioannou, M., Karageorgou, M., Mantas, G., Sucasas, V., Essop, I., Rodriguez, J., & Lymberopoulos, D. (2020). A survey on security threats and countermeasures in internet of medical things (IOMT). *Transactions on Emerging Telecommunications Technologies, 33*(6). https://doi.org/10.1002/ett.4049

Patra, R., Bhattacharya, M., & Mukherjee, S. (2021). IOT-based computational frameworks in disease prediction and healthcare management: Strategies, challenges, and potential. Studies in Computational Intelligence, 933, 17-41. https://doi.org/10.1007/978-981-15-9897-5_2

Poongodi, T., Rathee, A., Indrakumari, R., & Suresh, P. (2019). IOT sensing capabilities: Sensor deployment and node discovery, wearable sensors, Wireless Body Area Network (WBAN), *Data Acquisition. Intelligent Systems Reference Library, 174,* 127-151. doi:10.1007/978-3-030-33596-0_5

Pradhan, B., Bhattacharyya, S., & Pal, K. (2021). IOT-based applications in healthcare devices. *Journal of Healthcare Engineering, 2021,* 1-18. https://doi.org/10.1155/2021/6632599

Prodhan, U. K., Kanti, T., Shaharin, R., Ahmed, T., & Zahidur, M. (2020). Implementation of Low-Cost Remote Primary Healthcare Services through Telemedicine: Bangladesh Perspectives. *International Journal of Advanced Computer Science and Applications, 11*(11). https://doi.org/10.14569/IJACSA.2020.0111118

Rahman, M., Das, S., Tazim, M. Z., Rana, M., Tuhin, R. A., & Das, A. K. (2021). State of the art of ICT based telemedicine and E-health services in Bangladesh. 2021.*6th International Conference on Inventive Computation Technologies (ICICT) of India.* 1266-1272. https://doi.org/10.1109/icict50816.2021.9358778

Rahman, Md. O., Kashem, M. A., Nayan, A.-A., Akter, Most. F., Rabbi, F., Ahmed, M., & Asaduzzaman, M. (2021). Internet of things (IOT) based ECG system for Rural Health Care. *International Journal of Advanced Computer Science and Applications, 12*(6), 470-477. https://doi.org/10.14569/ijacsa.2021.0120653

Raj, H., Kumar, M., Kumar, P., Singh, A., &Verma, O. P. (2022). Issues and challenges related to privacy and security in healthcare using IOT, fog, and cloud computing. *Advanced Healthcare Systems (2),* 21-32. https://doi.org/10.1002/9781119769293.ch2

Rayan, R. A., Tsagkaris, C., &Iryna, R. B. (2021). The internet of things for healthcare: *Applications, selected cases and challenges. Studies in Computational Intelligence, 933,* 1-15. https://doi.org/10.1007/978-981-15-9897-5_1

Sakib, S. N. (2021). *Hospitals in Bangladesh unable to accommodate more COVID patients.* Retrieved from https://www.aa.com.tr/en/asia-pacific/hospitals-in-bangladesh-unable-to-accommodate-more-covid-patients/2332903#

Selvaraj, S., & Sundaravaradhan, S. (2019). Challenges and opportunities in IOT healthcare systems: A systematic review. *SN Applied Sciences, 2*(1). https://doi.org/10.1007/s42452-019-1925-y

Senbekov, M., Saliev, T., Bukeyeva, Z., Almabayeva, A., Zhanaliyeva, M., Aitenova, N., Toishibekov, Y., & Fakhradiyev, I. (2020). The recent progress and applications of digital technologies in Healthcare: A Review. *International Journal of Telemedicine and Applications, 2020,* 1-18. https://doi.org/10.1155/2020/8830200

Shakeel, T., Habib, S., Boulila, W., Koubaa, A., Javed, A. R., Rizwan, M., Gadekallu, T. R., & Sufiyan, M. (2022). A survey on covid-19 impact in the healthcare domain: Worldwide market implementation, applications, security and privacy issues, challenges and future prospects. Complex; *Intelligent Systems, 9*(1), 1027-1058. https://doi.org/10.1007/s40747-022-00767-w

Singh, R. P., Javaid, M., Haleem, A., & Suman, R. (2020). Internet of things (IoT) applications to fight against COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews, 14*(4), 521-524. https://doi.org/10.1016/j.dsx.2020.04.041

Suganyadevi, S., Shamia, D., &Balasamy, K. (2021). An IoT-based Diet Monitoring Healthcare System for Women.In S. H. Islam, D.Samanta (Ed.), *Smart Healthcare System Design (pp.* 167-202). doi:10.1002/9781119792253.ch8

Sultana, N., &Tamanna, M. (2021). Exploring the benefits and challenges of Internet of Things (IoT) during Covid-19: a case study of Bangladesh. *Discover Internet of Things, 1*(1), 20. https://doi.org/10.1007/s43926-021-00020-9

Sultana, T. (2019). Present health status in Bangladesh: Challenges and achievements. *Journal of Economics and Business, 2(*4), 1201-1212. https://doi.org/10.31014/aior.1992.02.04.161

The World Bank. (2022). *Bangladesh [Data file].* Retrieved fromhttps://data.worldbank.org/country/bangladesh

Unnayan Shamannay, Analysis of Health Budget Allocation and Expenditure in Bangladesh.(2021). *Report of the Analysis of Health Budget Allocation and Expenditure in Bangladesh.* Retrieved from https://shorturl.at/pRU3s.

Vishnu, S., Ramson, S. R. J., & Jegan, R. (2020, March). Internet of medical things (IOMT) - an overview. *Paper presented at the 2020 5th International Conference on Devices, Circuits and Systems (ICDCS) of India.* Retrieved fromhttps://doi.org/10.1109/icdcs48716.2020.243558

Zabeen, B., Bhowmik, B., Huda, K., Naz, F., Tayyeb, S., & Azad, K. (2021). Use of telemedicine for the management of type 1 diabetes in children and adolescents in Bangladesh during the COVID-19 pandemic. *Journal of Diabetology, 12*(1), 18-21. https://doi.org/10.4103/jod.jod_55_20

Zobair, K. M., Sanzogni, L., & Sandhu, K. (2020). Telemedicine Healthcare Service Adoption Barriers in rural Bangladesh. Australasian *Journal of Information Systems, 24,* 1-24. https://doi.org/10.3127/ajis.v24i0.2165