CHALLENGES AND OPPORTUNITIES IN THE ICT SECTOR DURING AND POST-COVID-19 PANDEMIC[1]

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ABSTRACT

This paper highlights the issues of seeking appropriate solutions, especially last year during the COVID-19 pandemic lockdown and other restrictions, and pressure made on the ICT (information and communication technology) sector to accelerate the development of ICT solutions as never before. The biggest pressure was in the health and medicine sector, as well as in education and businesses. The wider ICT community was encountered with intense demands for rapid innovative solutions due to the existing pressure to solve urgent issues associated with pandemic spreading. We review the use of advanced ICT in telemedicine, telework, healthcare mobile applications and online learning that help stop spreading the contagious pandemic disease. We also describe the use and essential role of bioinformatics, immunoinformatics and computational biology to develop COVID-19 vaccines and apply appropriate medical treatments to patients.

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[1] review scientific paper

1. INTRODUCTION

The purpose of this paper is to underline the efforts for seeking innovative ICT solutions, especially last year when the COVID-19 pandemic outbreak. The pandemic that was followed by lockdowns, quarantines, isolations, self-isolations, physical distancing and other restrictive measures, has made pressure on the ICT communities to accelerate the development of appropriate ICT solutions as never before. The biggest pressure was in the healthcare and medicine sector, as well as in education and businesses. The wider ICT community was faced with an intense search for solutions due to the existing pressure and the development of rapid innovative solutions under time limitations.

The pandemic has accelerated many ICT development processes, especially in healthcare and education. The pandemic has speeded up the development and application of distance learning tools and changed the habits of students, teachers and professors. Many problems had arisen when strict measures like lockdowns were ordered and simultaneously the ICT industry was pushed to implement new innovative technologies such as the IoT (Internet of Things), machine learning, AI (artificial intelligence), 3D printing, big data analytics, health mobile applications, bioinformatics, immunoinformatics. The scientific community has applied all the benefits of bioinformatics, computational biology and immunoinformatics to accelerate the discovery and development of COVID-19 vaccines. These findings are increasingly obtained as a result of an interdisciplinary application of data science, big data analytics and machine learning techniques.

One of the most affected sectors that were undergone big and rapid changes and transformations was education. There have been developed many tools for online learning so far, but in the pandemic and lockdown situation, these tools were utilized worldwide and all their advantages and disadvantages were shown. In a very short time, their noticed bugs and drawbacks have to be addressed. The pandemic has prompted all school and university structures to update their knowledge management and governments to invest in online learning infrastructures. The stressful situation of the pandemic has made all the people of the globe be aware that our vulnerability could be reduced by applying ICT collaborative and communication tools and the ICT sector needs to improve and increase its capabilities. This new situation certainly caused a large increase in jobs in the IT sector and a demand for IT staff that has to be involved in urgently solving the arising problems in different sectors.

The rest of the paper is organized as follows. Section 2 describes the global pressure of the pandemic crisis on business and science. The subsequent section

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describes using current ICT to handle the pandemic. The last section provides concluding remarks.

2. THE GLOBAL PRESSURE OF PANDEMIC CRISIS TO THE BUSINESS AND HEALTHCARE SECTORS

The COVID-19 pandemic also has caused major perturbations to various business sectors and affected the global economy. Pandemic disease spreading among the population worldwide has altered the usual consumption causing the global market anomalies. Hence, the supply chains were very affected. There is an emergence need to reshape the global factory and production settings to improve manufacturing resilience and survivability to handle the impact of unpredictable occasions such as COVID-19 [7].

The COVID-19 pandemic has triggered dramatic changes in many domains, especially in healthcare, medicine, education and business. All of these changes have adopted ICT and additionally, employees working remotely have increased the need for urgently digital transformations. Some examples of using advanced ICT technologies are 5G networks, AI, 3D printing. Using ICT and digital transformation is a proper response to the disruptive perturbations caused by the COVID-19 pandemic [3].

The COVID-19 pandemic has increased the process of digital transformation of the economy. The digital economy is the economy that is more affected by emerging digital technologies. Digitalization enables companies to become more global and digital, from production to consumption. However, digital transformation is not only using ICT to make some changes in the business but also applying these technologies to accelerate business processes, eliminate inefficiencies, lower costs, increase the sell and make significant changes in the companies' business model. The COVID-19 pandemic has significantly sped up the digital transformation of businesses and industries, such as restaurants, shopping, tourism, education, healthcare, etc. as a solution to avoid total economic collapse. Digital transformation does not mean that companies should abandon their existing business models but improve the traditional models. Working remotely by using video-conference tools and virtual meetings was used in the large. There was an issue of whether people will lose their jobs because of automation. However, ICT has created many other jobs to enable automation, especially in the sector of cloud computing, AI, machine learning, robotics, smart manufacturing, big data, blockchain and robotics, and hence the productivity of the companies is increased. The digital economy enables the setup of digital startups from incubators, technological and science parks. Establishing of traditional companies might be constrained by their organizational structure especially during the COVID-19 pandemic. Digitalization provides many sources for value creation for front-end and back-end business activities. To automate order processing, businesses can integrate B2C and B2B e-commerce with their warehouse management with enterprise resource planning (ERP) systems. Integration of customer relationship management (CRM) and ERP systems can facilitate and increase the sellers'

productivity. Blockchain technology and IoT can make real-time information to the supply chain to become more transparent [2].

Digitalization has required the creation of new business models in established companies. These new business models increase the organizational complexity and hence the organizational design has to accommodate this complexity. Transformation of business models supported by the ICT can be performed using two models: recombination and invention. Recombination refers to the integration of new business models with the existing one in one model, while by the invention a completely new business model is developed. Integration of ICT with organizational resources and capabilities can produce essential changes in the business models of the organizations. The long-term impact of the pandemic in the business sector is still difficult to foresee as well as when the pandemic will end, but opportunities for post-pandemic business recovery will be greater if organizations are using ICT and suitable solutions during the pandemic. However, the digital transformation of businesses does not have to be radically but implemented gradually and at different levels of change. It depends on the level of the digital literacy of the companies (organizations). This digital literacy affects the capabilities of companies to adopt suitable innovative transformations. It seems that the pandemic will last several years which means that companies should integrate online and offline business by developing a suitable symbiosis between these two models [3].

Pupils, students, teachers and professors were also faced with e-learning challenges in pandemic circumstances. Distance learning, when the number of users was dramatically increased, requires more quality Internet access and suitable ICT. Due to the noticed shortcomings of the distance learning tools by all stakeholders, the development of new tools as well as updating of the existing tools were needed.

The COVID-19 pandemic will have lasting impacts on the traditional businesses even in the post-pandemic era such as flexible and virtual working. Digitalization will be the most significant transformation of the global value chain strategy in the post-COVID-19 era. In the digital era, many hospitals, healthcare providers and institutions will use innovative contactless services and operational processes to improve organizational agility and productivity. Although some contactless services existed in the pre-COVID era, more and more contactless services will be used in the post-COVID-19 age because of the time efficiency, simplicity, convenience. During the COVID-19 pandemic, numerous contactless services have been used in telemedicine, AI-based medicine and safety management of patients and staff. In the healthcare, medicine and pharmaceutical industries, emergence technologies like AI, machine learning and data science have been employed to develop vaccines, drugs and wearables to stop spreading infectious diseases. There is still an urgent need for future strategies for contactless services in the healthcare industry by employing relevant ICT such as AI, remote monitoring, blockchain, big data and online platforms. All companies and organizations, including those in healthcare and medicine, should be prepared for the "new normal" in the post-COVID-19 age [8].

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3. THE USE OF ADVANCED ICT TO HANDLE THE COVID-19 PANDEMIC

The most usage of ICT in crisis management is to connect, inform and save lives; to restore connectivity between peoples, to help with business recovery and to analyze and study this global contagion in order to find rapid adequate solutions to prevent infection spreading and medicaments including vaccines. The first role of the ICT in crisis management is to provide infrastructure while the second role is to provide managing information flow. Without modern ICT physical distancing and lockdowns would lead to full social isolation. Using this technology enables remotely working, education and many e-services. To monitor the condition of patients and suspects, neural networks and machine learning techniques were used for disease tracking and to find drugs that correspond to the symptoms and symptoms. Besides AI, blockchain technology was used to deal with this pandemic. The use of blockchain technology has increased diagnostic accuracy and treatment effectiveness, track and supply chain of drugs and medical supplies, as well to identify patterns of disease symptoms and manage medical and healthcare data. Using various technologies such as video conference applications, AI, blockchain, big data analytics, robotics, drones is very helpful when handling pandemics for treatment and recovery as well as stopping disease mitigation [5].

ICT plays an essential role in many domains such as healthcare, medicine, risk management, emergency response, clinical decision support. Development of products to combat the coronavirus, tracking and predicting disease spread, big data analysis and protecting hospitals and other healthcare institutions from cyberattacks is provided by using modern ICT. The COVID-19 pandemic has uncovered the urgent need to redesign the national public health systems from reactive to proactive and develop innovative solutions that can provide information for decision-making at the local, national and global levels in real-time. Effective and innovative application of the modern digital technologies can help to identify coronavirus spread through communities, monitor the health condition of the infected and recovered patients, improve the treatment of the patients as well as develop effectively and save medical treatments, drugs and vaccines in a very short time. AI techniques such as image recognition, machine learning, deep learning are suitable for early detection and infection diagnosis, contact tracing as well as rapid drug and vaccine discovery. 3D printing technology has been used for producing personal protective equipment like protective face masks and visors. Another area of computer science, big data analytics is used to identify people that need isolation, self-isolation, or quarantines based on their travel history and contacts, accelerate antiviral drugs, vaccines and treatments development, predict COVID-19 spread across space and time. To resolve very complex scientific problems and rapidly process big data to develop new drugs and vaccines, high-performance computing and supercomputer play crucial roles. Mobile applications, smartphones, various medical and healthcare wearable sensors are used to track people's movements,

aware people when close to the COVID-19 hotspots. Moreover, video-conferencing tools enable many services in telemedicine and telehealth, as well as online learning, shopping, meetings and telework. To combat coronavirus outbreaks, robots were used in hospitals as support systems for food and drug delivery, disinfecting rooms without direct human contacts. IoT, which includes collection, transfer, analytics and storage of data, is used to reduce infection spread. Blockchain technology is a distributed ledger technology and enables applications to give each participant a digital identity controlled by a private key that brings access to the digital certificates issued by a government and other organizations. Blockchain technology prevents information and data to be manipulated by unauthorized parties. Above mentioned technologies require the combining of data, people and systems and they can be categorized into three categories: data-centric, people-centric and system-centric technologies, but most of them are interrelated. To make collective decisions and develop smart strategies concerning pandemic challenges, many stakeholders such as governmental officials, healthcare experts and epidemiologists need to be connected through innovative information systems based on emerging ICT. Big Data analytics and geographic information systems were used to find the patient zero of each coronavirus variant and hence to identify the close contacts of the infected patients. Medical and healthcare and sensor data can be collected by IoT and stored and shared on the blockchains. Nowadays, huge amounts of data are generated on an hourly basis. These data should be reliable and of high quality but unfortunately, they are not all standardized. Thus, the integration of heterogeneous data generated from various sources is still a challenging task. To detect and diagnose patients and provide decision support for involved healthcare parties during pandemics on a local, national and global level, expert systems and intelligent decision techniques are used. Data mining and visualization are used to identify clusters and patterns that help to stop the spreading of diseases. However, many people are concerned about using different anti-COVID-19 mobile applications that involve tracing locations and contacts, especially about the privacy, security and ethical issues related to their data and the possibility of their abuse. Companies and institutions should enhance the investments in better ICT infrastructure and tools in order to provide their teams to work online and collaborate virtually. However, as a very challenging issue during and post-COVID-19 era remains data management policies needed to prevent misuse of the people and patient data and a suitable design and development of the future mobile application as tracing and tracking tools. Additionally, handling the fake news spreading across social networks, known as infodemics (or misinfodemics), and applying proper algorithms to find and prevent fake news mitigation are still challenging tasks [6].

Collaborative intelligent manufacturing (CIM) enabling technologies integrating 5G networks, cloud computing, edge computing, IoT, big data analytics and digital twins can solve most of the business issues caused by COVID-19. 5G networks are the fifth generation cellular networks and their advantages are high speed, massive connections, low power consumption and low latency. They incorporate SDN/VNF (software-defined networks/virtual network functions),

massive MIMO, mobile edge computing and millimeter-wave communication. 5G networks are applied in HMIs (human-machine interfaces) and production IT, process and factory automation, logistics and warehousing. IoT enables a horizontal integration of numerous devices and resources in different stages of business planning processes and manufacturing. Edge computing integrates network connection, computing and storage from the cloud to the edge of the network and provides agility, processing in real-time and autonomy. Big data analytics enables the application of AI algorithms to obtain knowledge and make precise decisions to handle a pandemic. Digital twins can improve the efficiency of design, operations, control and management and can be applied to remote installation, testing, monitoring and maintenance. Agent-based dynamic scheduling and control methods can make the manufacturing systems more flexible and responsive [7].

Concerning the pandemic, satellite monitoring can provide information about physical distancing at the micro and macro levels. Neural networks and machine learning models used in face mask detection can be used to find when people are wearing face masks by eye lines' identifying. Drones were also used for face recognition, detection when people do not wear face masks, and sanitization of public places and hospitals. Using drones is less expensive, faster, longer, safer than manual disinfection. Using AI algorithms can help to recognize early symptoms in patients and start suitable treatments. Mobile health applications are easily accessible, adaptable and acceptable for quarantine monitoring, contact tracing and physical distancing. GIS and epidemic map service in order to early warning, visualize the infected areas such as towns, cities and countries. Machine learning, AI and data science techniques play a key role in the battle with the COVID-19 pandemic for effective resources' management, carrying appropriate safety measures and public awareness [1].

Regarding the design of a vaccine for SARS-CoV-2 as an urgent need worldwide, immunoinformatics approaches are both cost-effective and convenient, as in silico predictions can reduce the number of experiments needed [12]. Standard techniques of vaccine development are very time-consuming and labor-intensive. Dong et al. have employed immunoinformatics to predict multiple immunogenic proteins from the SARS-CoV-2 proteome and in that way design a multi-epitope vaccine [12]. They have used the C-ImmSim online server for computational immune simulations in order to determine the immune response profile of the novel vaccine, as well as many other tools and techniques described in [12].

4. CONCLUSION

The COVID-19 pandemic, as a current global healthcare crisis, has changed all the habits and behavior of people worldwide, both in their professional and private life. These changes are affecting our interactions such as physical distancing, social networking and using of ICT for meetings, workshops, seminars, conferences, etc. The COVID-19 pandemic has faced the world with

major challenges in almost all domains. The international research community and industry with joint efforts enable understanding of the disease and the development of new suitable diagnostics, therapeutics and vaccinations with the most rapid speed in the health research history.

Due to the COVID-19 pandemic, organizations, companies and institutions have been faced many uncertainties and obstacles therefore all stakeholders have to develop multiple scenarios as future strategies [4].

In order to take advantage of digitalization, companies, organization and institutions need to be agile and have capabilities rapidly to survive the environmental changes. These capabilities include product re-development, identifying and working with new partners and strategic decision making that create value by manipulating available resources. For instance, educational institutions have adopted online platforms for virtual classes, meetings and conferences, only a few weeks after pandemic lockdown restrictive measures [9]. The economic crisis generated by restrictive measures such as lockdowns, quarantines and physical distancing against coronavirus has been a good starting point for big digital transformations in businesses and industries [11].

However, the COVID-19 pandemic will have lasting impacts on traditional businesses even in the post-pandemic era such as flexible and virtual working. Digitalization will be the most significant transformation of the global value chain strategy in the post-COVID-19 era.

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