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A new fuzzy FUCOM-QFD approach for evaluating strategies to enhance the resilience of the healthcare sector to combat the COVID-19 pandemic

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Abstract

Purpose – The coronavirus disease 2019 (COVID-19) pandemic has subjected a considerable strain on the healthcare (HC) systems around the world. The most affected countries are developing countries because of their weak HC infrastructure and meagre resources. Hence, building the resilience of the HC system of such countries becomes essential. Therefore, this study aims to build a resilience-based model on the HC sector of Pakistan to combat the COVID-19 and future pandemics in the country.

Design/methodology/approach – The study uses a novel hybrid approach to formulate a model based on resilient attributes (RAs) and resilient strategies (RSs). In the first step, the multi-criteria decision-making (MCDM) technique, i.e. full consistency method (FUCOM) is used to prioritize the RAs. Whereas, the fuzzy quality function deployment (QFD) is used to rank the RSs.

Findings – The findings suggest "leadership and governance capacity" to be the topmost RA. Whereas "building the operational capacity of the management", "resilience education" and "Strengthening laboratories and diagnostic systems" are ranked to be the top three RSs, respectively.

Practical implications – The model developed in this study and the prioritization RAs and RSs will help build resilience in the HC sector of Pakistan. The policymakers and the government can take help from the prioritized RAs and RSs developed in this study to help make the current HC system more resilient towards the current COVID-19 and future pandemics in the country.

Originality/value – A new model has been developed to present a sound mathematical model for building resilience in the HC sector consisting of FUCOM and fuzzy QFD methods. The main contribution of the paper is the presentation of a comprehensive and more robust model that will help to make the current HC system of Pakistan more resilient.

Keywords Healthcare, Resilience, COVID-19, MCDM, FUCOM, Fuzzy QFD

Paper type Research paper

1. Introduction

A pandemic is an epidemic disease that is prevalent over continents or worldwide. It is usually associated with a huge number of deaths along with posing a great threat to the economies. Some pandemics that have taken place over the last century include Asian flu in 1957–58 and Hong Kong flu taking place in 1968, both claiming millions of lives. The most recent pandemic of the 20th century took place in 2008–11, known as influenza A H1N1 virus (Morens *et al.*, 2009), but the gravest of all was the Spanish flu taking place in 1918–19. The particular pandemic resulted in a death toll of 20–50 m people, claiming more lives than the total death toll of 9 m in the First World War (Reid, 2005).

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The coronavirus disease 2019 (COVID-19) was recognized as the sixth public emergency on an international scale by the World Health Organization (WHO) on January 30, 2020, which was later declared as a pandemic by the WHO on March 11, 2020. The virus originated from Wuhan, a city in the Hubei province of China. Some of the symptoms associated with the disease are persistent cough, fever and shortness of breath. Whereas, the transmission of the virus takes place between humans (Lu *et al.*, 2020). COVID-19 has so far claimed thousands of lives and is placing a huge burden on the healthcare (HC) systems around the world. The disease has so far affected a total of 214 countries and territories around the world. According to economists, the particular pandemic has the potential of affecting the world's economy, bringing a reduction in economic growth from 3 to 6 percent for the year 2020, assuming there is no second wave of infection (Jackson *et al.*, 2020).

In order to combat such pandemics, the HC sector should be made resilient to fight any kind of emergencies in a country. The term resilience means the ability of a system to be prepared to avoid disruptions, recover and adapt quickly to the changing hostile conditions. Through enhancing HC resilience, the system can be more proactive to any kind of emergencies (DeWitte *et al.*, 2017). Developed nations over the years from their experiences have developed strategies to cope with such pandemics. For example, the United Kingdom (UK) and the United States of America (USA) closed their borders and schools, to help delay and mitigate the influenza virus, also ensuring household quarantine and mass prophylaxis. In addition to this, the stockpiling of vaccines in advance of the pandemic also helped in hindering the spread of the virus (Ferguson *et al.*, 2006). Furthermore, the use of pharmaceutical interventions such as vaccines and antivirals played an effective role in mitigating the avian influenza epidemic. Moreover, the use of social measures such as household quarantine and social distancing also helped in hindering the spread of the disease (Oshitani, 2006).

Developed nations usually have better mitigation strategies to combat pandemics as compared to low or middle-income countries because of their vast resources (McLeod *et al.*, 2008). On the contrary, developing countries are subjected to financial crises and have a weak HC infrastructure. Therefore, preparing for such kinds of pandemics beforehand is very essential (Oshitani *et al.*, 2008a, b). Affluent nations have the capacity and capability of stockpiling antivirals for future pandemics and can also produce antivirals during the pandemic, whereas middle or low income countries lack in both cases. The distribution of antivirals and other medicines is another problem in developing nations (Coker and Jack, 2006). Evidence from the influenza pandemic in Thailand suggests that the public needs to be on board with the government during such crises. Moreover, support from the locals and international communities is also very essential (Chunsuttiwat, 2008). Along with pandemic preparedness planning, the execution of strategies is equally important which is evident from a study based on avian influenza pandemic in Africa (Ortu *et al.*, 2008).

This study aims to focus on the HC sector of Pakistan and the COVID-19 pandemic. Pakistan reported its first two cases in Karachi on 26th February 2020. At the end of March 2020, Pakistan had to practice a complete country-wide lockdown. From there onwards the number of patients started to increase exponentially in the country, overwhelming the limited number of hospitals in the country. Like other developing countries, Pakistan struggled in conducting tests in a large number. Currently, the existing number of corona testing labs in the country is 20 but the National Disaster Management and Authority (NDMA) is working with the National Institute of Health (NIH) to increase the number of labs to 70. As of now the testing capacity for COVID-19 is 163 tests per million (Shah, 2020). Moreover, the number of infected patients in the country is under-reported due to the lack of testing capacity. Fortunately, the death rate is comparatively low in the country as compared to other

countries. The reason for this is that malarial endemic Asian countries like Pakistan and Africa have a low fatality rate, because of having certain immunization to the COVID-19 disease (Kapata, 2020). Having said that, the number of infected patients is still overwhelming, adding additional burden to an already resource trapped HC sector, which is already indulged in fighting against other infectious and non-infectious diseases such as tuberculosis (TB), cancer, malaria and others.

Developing countries like Pakistan face a dearth of HC facilities due to the lack of finances and budget allocations to the HC sector. The weakness in Pakistan's HC facility is inadequate laboratories and modern technology and medical equipment (Hassan *et al.*, 2017). Pakistan's HC sector lacks intensive care unit (ICU) beds along with essential medical equipment such as ventilators. According to the Economic Survey 2018–19, Pakistan has 1,279 public sector hospitals, 5,527 basic health units, 686 rural health centres and 5,671 dispensaries. Pakistan is the sixth largest populated country in the world, and as per the requirement of the population, the country faces a dearth of HC force and is ranked as one of 57 countries with critical HC force deficiency (Rana *et al.*, 2016). Pakistan's health force includes 220,829 registered doctors, 22,595 registered dentists and 108,474 registered nurses which means there is one HC practitioner for 963 people and one hospital bed for 1,608 people in the country of 210 m people. The doctor-to-patient ratio in Pakistan today is 1:1300, the doctor-to-nurse ratio is 1:2.7; whereas, the nurse-to-patient ratio is 1:20 (Nishtar, 2006). As per the WHO's requirement, the doctor to patient ratio should be 1:1000 and a doctor to nurse ratio of 1:4 is considered appropriate.

According to NDMA, there are around 3,800 ventilators in total across the country, both in public and private sector hospitals with a limited number of testing kits and protective gear (Ahmed, 2020). Out of these 3,800 ventilators, 2,200 are in public hospitals on which critically ill COVID-19 patients are treated, whereas the rest are owned by private hospitals. Private hospitals try to avoid taking COVID-19 patients on ventilators, which has resulted in a further dearth of ventilators in the country. The safety of HC staff is the foremost responsibility of the government because they are the frontline warriors against the virus. Unfortunately, the availability of the personal protective equipment (PPE) to HC workers is inadequate. Due to the lack of PPE and proper safety from the virus, three doctors have already been reported dead from the virus so far, also leaving many HC staff infected (Saeed, 2020). Out-patient departments (OPDs) in the hospitals have stopped working and all of the attention is diverted to the COVID-19 patients, which are endangering and neglecting patients with other life-threatening diseases. As for the management and governance, there does not seem to be a joint resilient strategy to deal with the crises, which has further deteriorated the situation in the country.

The HC and education are the most neglected sectors in Pakistan. Both the sectors are the main indicators against which the human capital is measured. The foundation of any country's HC system is based on the primary HC facilities because it helps hinder the spread of diseases and infant mortality. Unfortunately, the primary health sector in Pakistan is not given its due attention. Pakistan is ranked 154 out of 195 countries to have a lack of both quality and accessibility to HC, even lagging behind Bangladesh, Sri Lanka and India (Dawn, 2018). Furthermore, Pakistan's HC sector faces an inadequate HC staff, deficient funding and limited provision of quality HC services (Mahmood, 2017). Therefore, the current crises that have originated because of the coronavirus on the HC system should be made into an opportunity. Both the quality and access to the HC sector should be enhanced. So that it does not only fulfil the requirement of the people under normal circumstances but should also be made resilient enough to combat the COVID-19 and future pandemics in the country.

The aim of this study is based on formulating a resilient based framework for the HC sector of Pakistan, making it more resilient to combat the COVID-19 and future pandemics in the country. For this, the paper adopts 10 resilient attributes (RAs) (WHATs) and 14 resilient

strategies (RSs) (HOWs) by going through an extensive literature review. The complete list of RAs and RSs is outlined in the data collection and methodology section in Tables 1 and 2, respectively. The study further uses a novel hybrid methodology to analyse the RAs and RSs. The hybrid methodology used in this study includes the multi-criteria decision-making (MCDM) technique, i.e. full consistency method (FUCOM) to prioritize the RAs, whereas the fuzzy quality function deployment (QFD) technique is used to rank the RSs in accordance with the prioritized RAs. Finally, in the light of the achieved results, the study provides policy recommendations to the concerned stakeholders.

The literature review would be discussed in section 2, which would be followed by the data collection and methodology section in section 3. The results and discussion along with the conclusion would be outlined in sections 4 and 5, respectively.

2. Literature review

The concept of improving the quality of HC has come a long way through discussions and research by pioneers and visionaries such as Ernest Codman and Avedis Donabedian in the 1970s. Due to the pandemics that have taken place over the century, the concept of resilience building in the HC is a recent development (Jeffcott *et al.*, 2009). The concept of resilience building in HC systems can benefit patient safety and avoid any kind of risk to the system. It helps the HC sector to have a proactive approach towards uncertainties rather than reactive (Stevens, 2009). The particular approach helps in controlling and hindering the spread of disease (Oshitani *et al.*, 2008a, b).

Several strategies have been developed through the help of other studies based on resilience building in HC systems. The goal of these strategies was to focus on developing resilience in HC systems so that it can avoid any kind of breakdowns (Heath *et al.*, 2020). These strategies include maintaining a balance between family and work, antiviral treatment, and removing mistrust between patients and HC workers (Andria *et al.*, 2011). Similarly, pandemic preparedness for the avian flu virus and influenza A (H5N1) in the United States

Table 1. List of RAs (WHATs)

RAs (WHATs)	Explanation
RA1. Skilled health workforce (Oraebosi *et al.*, 2020)	A fit-for-purpose staff that delivers quality services
RA2. Resilient health infrastructure (Zank *et al.*, 2019)	Infrastructure that meets the people needs for health services
RA3. Epidemic preparedness, surveillance and response system (Mandyata *et al.*, 2017)	Strengthen epidemic preparedness, surveillance, and response so that it can detect and respond to current COVID-19 and future health threats
RA4. Management capacity of medical supplies and diagnostics (Ying *et al.*, 2021)	Management of essential medicines, diagnostic kits and other medical equipment at all levels
RA5. Quality service delivery system (Nuzzo *et al.*, 2019)	Providing a safe working environment for medical staff and delivering quality care to the patients
RA6. Comprehensive information, research and communication (Zeng *et al.*, 2020)	Strengthening health information, research and communication systems
RA7. Sustainable community engagement (Key and Lewis, 2018)	Ensuring that households are aware of the health threats and practizing proper health-seeking behaviours
RA8. Leadership and governance capacity (Car *et al.*, 2018)	Competent leadership and governance to ensure the smooth running of hospitals
RA9. Health financing systems (Liu *et al.*, 2020)	Ensure efficient health financing system that ensures efficient use of health resources
RA10. Cross-border cooperation (Brown and Susskind, 2020)	Cross-border priority interventions, and focussing on improving hospitals and laboratory equipment

RSs (HOWs)	Explanation
RS1. Strengthening laboratories and diagnostic systems (Alemnji *et al.*, 2014)	Building capacity of laboratories and ensuring procurement of testing and diagnostic kits
RS2. Building the operational capacity of the management (Leite *et al.*, 2020)	Efficient delivery of planning and strategies proposed by the leadership and management
RS3. Resilience education (Peterso and Brommelsiek, 2017)	Providing seminars and workshops to the medical staff to educate and prepare them for current and future pandemics
RS4. The resilient supply chain of medicine and medical equipment (Bradaschia and Pereira, 2015)	Strengthening the supply chain of essential medicines and other medical equipment
RS5. Decentralized HC system (Rubio and Gómez, 2017)	Transfer of power and authority from higher to lower levels of government
RS6. Efficient HC Information Technology (IT) system (Boddy *et al.*, 2017)	Proficient IT systems for patients data's collection
RS7. Mass prophylaxis and vaccine stockpiling (Rubió, 2020)	Treatment to prevent diseases and stockpiling vaccines for future emergencies
RS8. Identification, isolation and treatment (Parodi and Liu, 2020)	Carrying out vast tests to identify, isolate and treat
RS9. Infodemic containment (Hua and Shaw, 2020)	Containment of false or misleading information
RS10. Continual provision of clinical services in crises (Institute of Medicine, 2015)	Access to both public and private clinical services
RS11. Global disease detection and collaboration (McCloskey *et al.*, 2014)	Exchange of information, medical equipment, funding or lending loans to developing nations
RS12. Developing Continuity of Operations (Institute of Medicine, 2015)	Continual of critical functions through alerting, notifying, activating, and deploying HC force
RS13. Improve post-pandemic recovery planning (Barach *et al.*, 2020)	A pre-devised plan on getting things back on track after the pandemic is over
RS14. Incentivizing HC force (Christopher *et al.*, 2020)	Working conditions, risk allowance, managing workload, provision of PPE equipment etc.

Table 2. List of RSs (HOWs)

focused on spreading awareness among people to avoid exposure and prevent themselves from the spread of infection (Reissman *et al.*, 2006). A similar study based on UK's HC sector under stressful conditions focused on well-trained medical staff along with an international experience. Moreover, good communication among the HC workers and different branches was also advocated (Achour and Price, 2010).

Infectious diseases pose a great threat to HC systems especially to those in developing countries. Therefore, identifying strategies to enhance the resilience of HC systems in such countries becomes more important (Bhandari and Alonge, 2020). Thus, when it comes to a developing country like West Africa, due attention was given to waste management, patient identification and isolation, HC staff issues, and PPE during the Ebola epidemic (Meyer *et al.*, 2018). A similar study based on Afghanistan's HC sector suggests the provision of resilience education to the HC workers. Hence, this, as a result, would help the HC staff to deal with any kind of burnout or stress (Janine *et al.*, 2017). Also, the use of mobile technology plays an effective role in the management of vaccinations and quarantine during such situations (Kafsi *et al.*, 2013). Moreover, giving incentives to health professionals and improving clinical IT further enhances the quality of HC (Casalino *et al.*, 2003). In addition to this, contracting out primary HC services in developing countries can further enhance the overall HC services (Liu *et al.*, 2008). The application of prophylaxis and social distancing along with the proper distribution of antivirals played a key role among other strategies during the influenza A virus pandemic in Southeast Asia (Ferguson *et al.*, 2005). Furthermore, in dealing with the flu pandemic in India, the government had to focus on governance, socio-economic strata and coordination in logistics (Chawla *et al.*, 2009). Whereas, strengthening disease surveillance

was found to be the most important strategy during the 2008–11 influenza A virus pandemic in Pakistan (Badar *et al.*, 2013).

The current COVID-19 pandemic has the potential to create new opportunities for future HC systems (Iyengar *et al.*, 2020). There needs to be an understanding of disaster management among the HC staff to be prepared for future pandemics (Djalante *et al.*, 2020). Furthermore, the governments should focus on implementing public–private partnership programs to tackle the current crises that have originated because of the COVID-19 pandemic. Developing countries in particular need to focus on adopting communication strategies on effective transferring of information related to the risk involved with the COVID-19 disease (Ataguba and Ataguba, 2020). The challenges faced by the health workers due to the current pandemic can be overcome by adopting digitization, particularly focussing on adopting technologies like the Internet of things (IoT) and artificial intelligence (AI) (Kumar *et al.*, 2020). When it comes to Pakistan, training of the HC staff for tackling extraordinary situations like COVID-19 is very important (Khan *et al.*, 2020a, b). Along with the knowledge of the disease, the country has to further focus on the test, isolation and treatment approach (Noreen *et al.*, 2020a, b).

The aim of this study is to provide a resilience-based model for the HC sector of Pakistan. For this purpose, in the first step of the study, a novel MCDM technique is used for the prioritization of RAs. In the literature, various MCDM techniques have been used over the years to determine the weights of criteria. Some of these techniques include the Best Worst Method (BWM), analytic hierarchy process (AHP) and stepwise weight analysis ratio assessment (SWARA), etc. Studies based on MCDM techniques include the evaluation of enterprise resource planning of software packages by using a hesitant fuzzy AHP-Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) hybrid approach (Ayağ and Samanlioglu, 2020). Similarly, the concept of Yager operators with the picture fuzzy set environment has been employed in emergency program selection. Moreover, failure mode and effects analysis (FMEA) along with extended multi-objective optimization by ratio analysis plus the full multiplicative form (MULTIMOORA) is used in a Pythagorean fuzzy environment for emergency risk assessment (Li *et al.*, 2020). Furthermore, a probabilistic linguistic interactive and multicriteria decision-making (TODIM) approach has been used for evaluating IoT platforms (Lin *et al.*, 2020a, b). Also, for the selection of a car-sharing station, a novel picture fuzzy MULTIMOORA method has been proposed (Lin *et al.*, 2020a, b). For an edge node selection problem, a novel probabilistic linguistic ELECTRE II method has been used (Lin *et al.*, 2019). Furthermore, for the prioritization of sustainable transportation with zero-emission, a new hybrid approach of BWM and extension of the TODIM along with the application of d numbers is proposed (Pamucar *et al.*, 2021).

However, the technique utilized in this study for the evaluation of the weights of criteria is called FUCOM. The chosen technique is a novel MCDM approach that has been developed by Dragan Pamučar in 2018 (Pamučar *et al.*, 2018). The particular technique has been employed in this study due to its unique set of advantages over the other MCDM techniques. For example, the technique has the ability to use a small number of only $(n-1)$ pairwise comparisons of criteria along with using any kind of scale, i.e. either integer or decimal. Moreover, the model uses a simple algorithm, along with the ability to validate the model by determining the deviation from full consistency (DFC) of the comparison. The consistency of the model is based on the validation of mathematical transitivity conditions in the pairwise comparison of criteria (Pamučar *et al.*, 2018).

The installation of solar panels and the selection of the best contractor uses the FUCOM method for weight calculation (Cao *et al.*, 2019). The weight coefficient of the quality dimension for improving the service quality of logistic services uses the same technique (Prentkovskis *et al.*, 2018). Ranking dangerous sections of the road use the FUCOM method to evaluate the significance of the criteria (Nenadić, 2019). Path planning for multi-robot in complex and

crowded situations uses FUCOM to determine the weight of factors affecting the robot's motion (Zagradjanin *et al.*, 2019). The selection of a sustainable supplier uses the FUCOM technique to compute the weights of the criteria (Stević *et al.*, 2019). Employee evaluation for a transport company uses the FUCOM technique for determining the significance of the criteria (Stević and Brković, 2020). The best route selection for the transport of hazardous material uses the FUCOM technique for calculating weights of the criteria (Noureddine and Ristic, 2019). To rationalize cost for stock management in inventories for logistic purposes, the significance of the three parameters has been determined, using the FUCOM technique (Erceg *et al.*, 2019). For the prioritization of transport demand management measures, the same technique has been used (Pamucar *et al.*, 2020a, b). FUCOM has also been integrated with the VIKOR approach for the development of integrated water systems (Ong *et al.*, 2021). Moreover, a hybrid approach of FUCOM and rough simple additive weighting (SAW) methods have been used for ranking a sustainable supplier selection (Durmić, 2019; Durmić *et al.*, 2020). However, the technique has no application in the HC sector.

The prioritized weights of REs determined by the FUCOM are then used in the house of quality (HOQ) in fuzzy QFD. The QFD is a total quality management tool that involves the construction of HOQ. It is widely used to give voice to the customer demands and is normally utilized in developing a new product to translate customer requirements (WHATs) into preferable products using the required engineering characteristics (HOWs) (Liu, 2009). The most critical step in QFD is to construct the HOQ properly. This step involves calculating the weights of customer requirements (WHATs) and engineering characteristics (HOWs) and the correlations matrix between HOWs (Chan and Wu, 2005). The technique has also been used for product design and as a developmental tool. Hence, these properties of QFD have made it a multi-attribute decision-making tool (Yazdani *et al.*, 2019). The fuzzy QFD methodology was adopted for this study because it has the ability to determine a relationship between WHATS and HOWs and a correlation between HOWs and HOWs. Thus, the results achieved through the particular methodology are more consistent and robust. Moreover, the fuzzy set theory used for assessment purposes further helps in the data collection process from the experts.

Experts in fuzzy QFD are essentially involved in assessing the relationship between RAs (WHATs) and RSs (HOWs), and a correlation between RSs in the HOQ. The fuzzy logic approach employed in the HOQ was to capture vagueness in people's assessment or judgement during data collection (Zadeh, 1965). Fuzzy QFD has been used in assessing the market competitiveness for electric vehicles (Babar and Ali, 2021). The same approach has been used in the development of solar voltaic technology development (Haktanır and Kahraman, 2019). For selecting lean tools in a manufacturing company, a hybrid technique of FMEA along with fuzzy QFD has been used (Bhuvanesh and Parameshwaran, 2018). QFD technique has been widely used in manufacturing, strategy development and supply chain management, but very few studies have been conducted in the service sector especially in the HC sector. For example, the QFD approach was found to be used for enhancing the service quality of a private hospital in Turkey (Akdağ *et al.*, 2013). Similarly, for assessing the service quality of a hospital and giving policy recommendations to the engineering professionals in the hospital a hybrid approach of group decision-making (GDM), service quality measurement (SERVQUAL) and QFD has been used (Raziei *et al.*, 2018). Similarly, for enhancing the service quality of the HC sector, QFD along with the TODIM approach has been used for improving the physiological behaviour of patients (Nie *et al.*, 2020). Moreover, a combination of fuzzy QFD with the Kano model and SERVQUAL has been used for improving hotel services (Beheshtinia and Azad, 2019). However, there was no study in the literature that used fuzzy QFD for building a resilient based framework for the HC sector.

Recent studies based on the HC sector of Pakistan and the COVID-19 pandemic do not provide a holistic resilient-based model for the country. Secondly, most of the studies related

to the COVID-19 pandemic are based on commentary and review articles, i.e. mainly depending on the secondary data. Furthermore, almost all the studies, based on Pakistan's HC sector and the COVID-19 pandemic primarily deals with strengthening the psychological resilience of the HC workers. However, this particular study aims to provide a resilient model for the overall HC sector of Pakistan, where almost all the factors for enhancing the resilience of the HC system are taken into consideration. To achieve this goal, the study adopts a novel hybrid approach, where experts are involved in evaluating strategies for combating the COVID-19 and future pandemics in the country. The hybrid approach includes FUCOM for allocating weights to the RAs (WHATs), whereas, fuzzy QFD is used to rank the RSs (HOWs) for the systematic adoption of the strategies.

3. Data collection and methodology

The first step in data collection was to go through an extensive literature review to determine the required set of RAs and RSs. The shortlisted and finalized list of 10 RAs and 14 RSs with the help of medical experts has been outlined in Tables 1 and 2, respectively.

The next step was to collect data from the experts in the medical field to prioritize or allocate weights to the list of ten RAs (WHATs). The scale used to evaluate the RAs is given in Table 3 below. A total of 16 experts belonging to the medical field were involved in this part of the survey. The medical experts involved in the data collection process were, HC managers (particularly medical directors and medical superintendents), highly specialized medical practitioners and policymakers, and members from the Drug Regulatory Authority of Pakistan (DRAP) respectively. The most experienced among the respondents was 25 years and the lowest among them was 4 years. Whereas, the average number of experience of the respondents was 9.7 years.

After the assessment of RAs with the help of medical experts, the results were then analysed using a novel MCDM technique, i.e. FUCOM to evaluate the weights of RAs for their further usage in the HOQ as "WHATs". The FUCOM is an MCDM technique that has been devised by Dragan Pamučar in 2018 (Pamučar *et al.*, 2018). The technique works on the principle of pairwise comparison and validation of results through deviation from maximum consistency. The advantage of using the FUCOM method is a small number of pairwise comparisons of criteria (only $n-1$ comparison), enabling to validate the results by defining the deviation from maximum consistency (DMC) of comparison and appreciating transitivity in pairwise comparisons of criteria (Badi and Abdulshahed, 2019; Bozanic *et al.*, 2020). Furthermore, the technique also eliminates the problem of redundancy of pairwise comparisons of criteria, which exists in other MCDM techniques for determining weights of criteria (Pamucar and Ecer, 2020).

The following steps are associated with the technique:

Step 1: The technique starts with the evaluation of the pairwise comparison of criteria from experts.

Table 3. Scale used for prioritizing RAs by FUCOM

Linguistic variable	Associated number
Very low (VL)	1
Low (L)	2
Medium (M)	3
High (H)	4
Very high (VH)	5

Source(s): Khan *et al.* (2020a, b)

Step 2: After the evaluation of criteria from the experts, an average of all the responses is taken which are then ranked according to the significance of the criteria. The criteria having the highest weight are ranked first, whereas the criteria having the least weight coefficient get the last ranking. The ranks obtained are presented in descending order given below.

$$C_{l(1)}^{(a)} > C_{l(2)}^{(a)} > \ldots > C_{l(n)}^{(a)} \tag{1}$$

where "a" represents the numbers of experts involved and n shows the rank of the respective criterion.

Step 3: The resultant weights after their evaluation and prioritization have to meet the following two conditions:

(1) The ratio of the weight coefficient of criteria should be equal to the comparative significance among the observed criteria, meeting the condition given below:

$$\frac{W_l^{(a)}}{W_{l+1}^{(a)}} = \varphi_{\frac{l}{l+1}} \tag{2}$$

(2) Along with condition (2), the values of weight coefficients should satisfy the mathematical sensitivity:

$$\varphi_{\frac{l}{(l+1)}}^{(a)} \times \varphi_{\frac{(l+1)}{(l+2)}}^{(a)} = \varphi_{\frac{l}{(l+2)}}^{(a)} \tag{3}$$

Step 4: After solving the conditions in step 3, the final values for calculating the weight coefficients of the criteria is calculated as:

Min χ

$$\left| \frac{W_l^{(a)}}{W_{l+1}^{(a)}} - \varphi_{\frac{l}{(l+1)}}^{(a)} \right| \leq \chi, \ \forall j \tag{4}$$

$$\left| \frac{W_l^{(a)}}{W_{l+1}^{(a)}} - \varphi_{\frac{l}{(l+1)}}^{(a)} \times \varphi_{\frac{(l+1)}{(l+2)}}^{(a)} \right| \leq \chi, \ \forall j \tag{5}$$

$$\sum_{j=1}^{n} W_j^{(a)} = 1, \ \forall j \tag{6}$$

$$W_j^{(a)} \geq 0, \ \ \forall j \tag{7}$$

Step 5: By solving the above mathematical model, the values of the weight coefficient of criteria are evaluated as $(w_1^{(a)}, \ w_2^{(a)}, \ldots \ w_n^{(a)})^T$.

After prioritizing or allocating weights to the RAs using the FUCOM technique. The next step was to use those RAs with their weights as "WHATs" in the HOQ. The total quality management tool, i.e. fuzzy QFD was used in this step to rank the list of 14 RSs (HOWs). For the assessment of the relationship and correlation matrices in the HOQ, two types of fuzzy linguistic variables were used. These scales are given in Tables 4 and 5 below.

A total of five medical experts were involved in assessing the relationship matrices, i.e. between WHATs and HOWs and correlation matrices, i.e. between HOWs and HOWs. After collecting data from health experts, the linguistic variables were then transformed into their respective fuzzy numbers. The fuzzy logic was used to capture ambiguity in the assessment of experts. The fuzzy set theory was first introduced by Lotfi Asgharzadeh, from the University of California in Barkley (Zadeh, 1965). The particular concept helps in capturing vagueness in people's assessment.

The fuzzy numbers range between [0, 1] and are all non-negative numbers. For example, if A is a member set having members such as (x), then the ordered pairs associated with fuzzy set A is as follows.

$$F = \{(x,\ \mu_f(x))\ \ |x \in A \tag{8}$$

The function (x) μF is a degree of membership that shows to what extent (x) belongs to a fuzzy set of F. The range from [0, 1] shows a range of non-negative real numbers that has a minimum and maximum value of 0 and 1, respectively.

There are various shapes associated with fuzzy numbers, however, this paper uses the simplest form of shape, i.e. triangular fuzzy numbers. Triangular fuzzy numbers are associated with three distance variables, i.e. the lower, mean and upper bound, expressed in the order of (l, m, n) shown in Figure 1 below.

The following Equation (9) below shows the membership of the fuzzy numbers (Simic *et al.*, 2021),

Table 4. Fuzzy scale for assessing relationship matrix

Degree of relationship	Weight
Strong	(0.7; 1; 1)
Medium	(0.3; 0.5; 0.7)
Weak	(0; 0; 0.3)

Source(s): Bottani and Rizzi (2006)

Table 5. Fuzzy scale for assessing correlation matrix

Degree of correlation	Weight
Strong positive (SP)	(0.7; 1; 1)
Positive (P)	(0.5; 0.7; 1)
Negative (N)	(0; 0.3; 0.5)
Strong negative (SN)	(0; 0; 0.3)

Source(s): Bottani and Rizzi (2006)

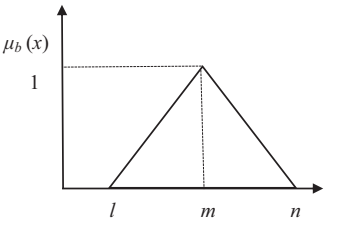


Figure 1. Triangular numbers

$$\mu_b(x) = \begin{cases} x - l/m - l & l \le x \le m \\ n - x/u - m & m \le x \le n \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

here $l,\ m,\ and\ n$ are real numbers, where $l < m < n$. The value of x at n gives us the maximum value of $\mu_f(x)$ i.e. $\mu_f(x) = 1$, giving the most probable value for the data. On the other hand, the value of x at l will give us the minimum grade of $\mu_f(y)$ i.e. $\mu_f(x) = 0$, giving us the least probable value of the evaluation data (Pamucar *et al.*, 2020a). Here, l and n are constants that give us the lower and upper bounds of the area available for the data to be calculated. The constants here are the fuzzy numbers that are to be evaluated. The interval between l and n shows us the range of fuzziness in the data. The lower the degree of an interval between the range $[l,\ n]$, the lower there is fuzziness in the evaluation data.

Let us consider any two triangular fuzzy numbers, i.e. $\alpha = l,\ m,\ n$ and $\beta = l,\ m,\ n$. The distance between these two triangular numbers is given by equation (10) below.

$$d(\alpha,\ \beta) = \sqrt{\left(\frac{1}{3}\right)[l - l']^2 + [m - m']^2 + [n - n']^2} \tag{10}$$

After the assessment of relationship and correlation matrices with the help of the experts, the results were then analysed using the fuzzy QFD technique. The particular methodology has been adapted from Zarei *et al.* (2011), where it has been used to attain food supply leanness. After the assessment from the experts, the resultant HOQ was analysed using the following steps.

The first step is to find the Relative Importance (RI_j) which can be calculated as

$$\mathrm{RI}_j = \sum_{i=1}^{n} W_i \times R_{ij} \quad \text{where } j = 1, \ldots, m \tag{11}$$

The second step is to find the priority weights of RSs, i.e.

$$PI_j^* = \mathrm{RI}_j + \sum_{k=j} T_{kj} \times \mathrm{RI}_k \tag{12}$$

Where T_{kj} represents the rooftop shown in Figure 3.

Furthermore, the normalization of the priority weights, i.e. normalized (NPI_j^*) was found by diving each PI_j^* by the highest value of priority weights among the PI_j^*.

The final step is to de-fuzzify the resultant normalized NPI_j^* values using the formulae below.

$$(e + 4f + g)/6 \tag{13}$$

The resultant de-fuzzified values are then ranked according to their significance of the final results. For example, the highest value will get the first ranking, whereas the lowest will get the last ranking.

The overall summary of the proposed FUCOM-fuzzy QFD framework is given with the help of the flow chart given in Figure 2 below.

Whereas, the structure for the proposed HOQ is shown in Figure 3 below.

4. Results and discussion

The step associated with the FUCOM technique starts with determining the weights of the RAs (WHATs) by the experts in the medical field. After the evaluation of criteria from experts, the resultant criteria were ranked and were sorted in descending order by using

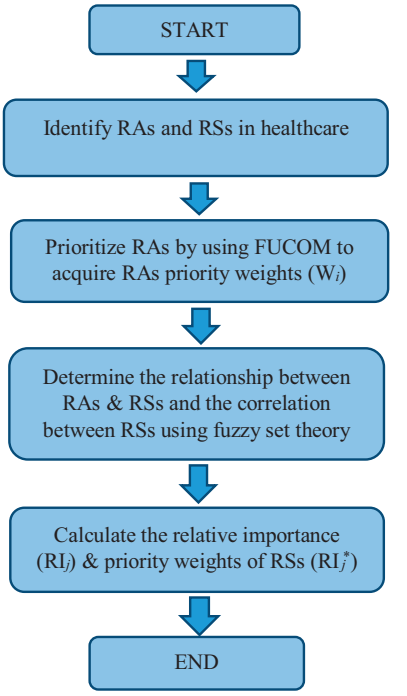


Figure 2.
Schematic representation of the algorithm

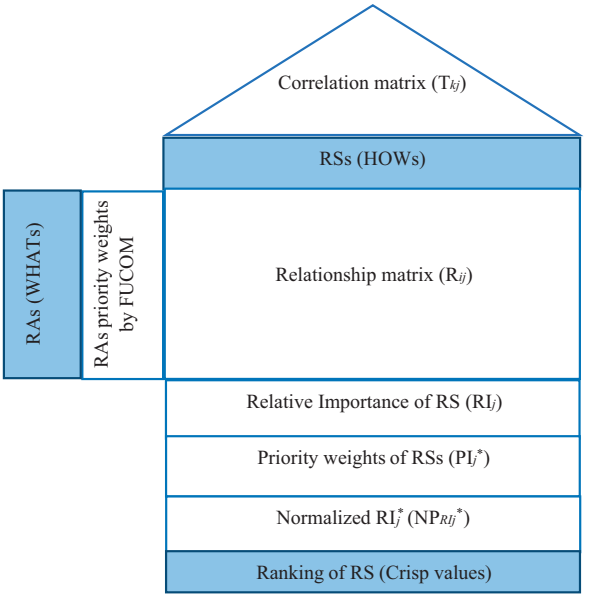


Figure 3.
Structure of the HOQ

equation (1). The sorted criteria have to fulfil two conditions. The first condition is fulfilled through equation (2) and checks whether the weight coefficients of criteria are equal to the comparative significance. Whereas, the second condition determines whether the values of weight coefficients is satisfying the mathematical sensitivity using equation (3). After the fulfilment of the two conditions, a mathematical model is developed, based on non-linear equations using equations (4)–(7). The resultant non-linear model is solved with the help of the LINGO software. The weights achieved as a result are then arranged in the descending order shown in Table 6 below. The criteria having the highest weight is ranked first, whereas the one having the least weight is ranked last.

From Table 6, it is evident that "leadership and governance capacity" has been given the highest importance by the experts. The particular RA has been given the weight of "0.113", which is the highest among the list. Whereas, "Comprehensive Information, research and communication" has been given the least importance by the experts by allocating it a weight of "0.085". Hence, the top prioritized RA, i.e. "leadership and governance capacity" should be given the most attention when it comes to the HC sector of Pakistan. The weakness in the HC capacity of Pakistan has also been highlighted by the Brookings report. For this purpose, the Brookings examines the health governance capacity of 18 lower and middle-income countries in sub-Saharan African and Asian countries. The report determines the Health Governance Capacity Index (HGCI) based on 18 indicators. These indicators were related to the five aspects of management capacity which include regulatory processes, health infrastructure, financing, health system and policy conditions. Based on the results, the report puts Pakistan in 17th position among the total 18 countries, even ranking behind its neighbouring countries like Bangladesh and India (West *et al.*, 2017).

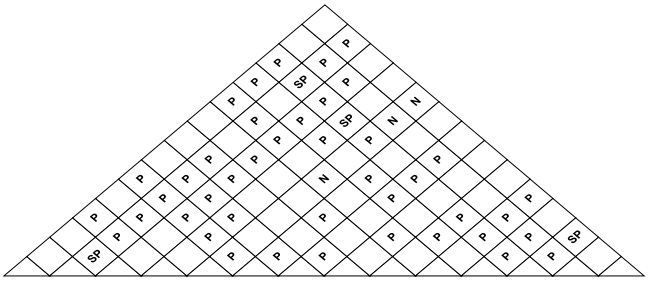
Good governance is a contributing factor to an overall resilient HC system. Hence, supporting policies and legislation by the political leadership of the country can play a vital role in enhancing the leadership and governance capacity of the HC sector in Pakistan. Supportive policies can include strengthening accountability, legitimacy and bringing transparency in the overall HC operations. However, the political leadership should refrain from taking control of the internal matters of the hospitals. The inductions of the leadership in the HC sector, particularly the Board of Governors (BoGs), hospital directors and medical superintendents should be based on merit rather than on political recommendations. Moreover, a collaborative framework between the management of inter-hospitals and intra-hospitals would further improve the exchange of expertise and other resources. The collaborative framework can further extend to public-private partnerships between the hospitals, which as a result would further increase the overall resilience of the HC sector. Moreover, for keeping accountability and transparency on the institutional level, an operational audit of the hospitals should be made mandatory.

Table 6. Prioritized RAs (WHATs) using FUCOM

Prioritized resilient attributes	Weights
RA8. Leadership and governance capacity	0.113
RA1. Skilled health workforce	0.112
RA2. Health infrastructure	0.110
RA3. Epidemic preparedness, surveillance and response system	0.108
RA9. Health financing systems	0.106
RA4. Management capacity of medical supplies and diagnostics	0.098
RA7. Sustainable community engagement	0.090
RA10. Cross-border cooperation	0.090
RA5. Quality service delivery system	0.087
RA6. Comprehensive Information, research and communication	0.085

The next step after the prioritization of RAs was to construct the HOQ for ranking the RSs (HOWs). For this purpose, the weights determined by FUCOM for RAs were used as WHATs in the HOQ. After the assessment of the relationship and correlation matrices in the HOQ through the help of experts, the following steps were involved in ranking the RSs. At first, the relative importance of the relationship matrix was found by using equation (11). Subsequently, this was followed by calculating the priority weights of the RSs by using equation (12). Whereas, the normalized weights, i.e. NPI_j^* were calculated by dividing each PI_j^* by the highest priority weight. Finally, the fuzzy numbers were then converted into their crisp numbers using equation (13), for ranking purposes. Thus, the RS holding the highest weight was ranked first, whereas the one with the lowest weight was ranked last. The complete HOQ along with all the computed variables is shown in Table 7 below.

From the HOQ in Table 7, it is evident that RS2 which is "building the operational capacity of the management" has been ranked as the most important RS. The operational capacity of an institution is interlinked with the competence of the leadership and management. Hence, in order to enhance the operational resilience of the hospitals in Pakistan, the management needs to be highly specialized and experienced. The same report by Brookings gives Pakistan the lowest scores on the dimensions of "management capacity" and "health systems" (West *et al.*, 2017). Thus, these results further support the weak operational performance of the hospitals in Pakistan. In order to solve this problem, the leadership and government should introduce interventions based on workshops, short courses, certifications and seminars to educate the HC managers. The curriculum should include training the managers to effectively



HOQ		Wi	RESILIENT STRATEGIES (HOWs)													
			RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	RS11	RS12	RS13	RS14
RESILIENT ATTRIBUTES (WHATs)	RA8	0.113		S	M		W		S	S		S		S	S	S
	RA1	0.112	S	M			W	M	W	S		S	W	S		W
	RA2	0.110	S	S	S	S	W	M	S	S	S	M	S	S	S	M
	RA3	0.108			M					M	S		W	S	W	
	RA9	0.106	S	M		S	W	W	S	S		S	S	S	M	S
	RA4	0.098	S	S	W	S	M	M	S	S		S		S	M	S
	RA7	0.090		M	W						S	M	S		S	M
	RA10	0.090	S	S	M	S	S	S	S	S	S	S	S	S	S	S
	RA5	0.087	S	W	M	M	S	S	S	S	W	S		M	M	S
	RA6	0.085	W		S	M			S		S		S	S	M	W
Relative Importance (Rij)			(0.422; 0.603; 0.628)	(0.381; 0.566; 0.653)	(0.256; 0.394; 0.531)	(0.335; 0.49; 0.525)	(0.1533; 0.226; 0.378)	(0.22; 0.337; 0.433)	(0.483; 0.690; 0.723)	(0.534; 0.77; 0.792)	(0.339; 0.484; 0.510)	(0.485; 0.707; 0.747)	(0.338; 0.482; 0.548)	(0.602; 0.866; 0.883)	(0.396; 0.592; 0.700)	(0.406; 0.595; 0.694)
Priority weights (Pij*)			(1.412; 2.620; 3.764)	(2.367; 4.651; 6.406)	(1.955; 3.844; 5.867)	(1.277; 2.412; 3.112)	(0.564; 1.636; 2.765)	(0.8; 1.496; 2.214)	(1.418; 2.587; 3.646)	(0.777; 1.265; 1.539)	(1.339; 1.884; 2.51)	1.187; 2.144; .024	(0.837; 1.503; 2.131)	(0.482; 1.875; 2.277)	(0.396; 0.592; 0.7)	(0.406; 0.595; 0.694)
Normalized (NPij*)			(0.220; 0.563; 1.590)	(0.370; 1.000; 2.706)	(0.305; 0.826; 2.478)	(0.199; 0.519; 1.315)	(0.088; 0.352; 1.168)	(0.125; 0.322; 0.935)	(0.221; 0.556; 1.540)	(0.121; 0.272; 0.650)	(0.209; 0.405; 1.060)	(0.185; 0.461; 1.277)	(0.131; 0.323; 0.900)	(0.075; 0.403; 0.962)	(0.062; 0.127; 0.296)	(0.063; 0.128; 0.293)
Crisp Values			0.677	1.179	1.015	0.598	0.444	0.391	0.664	0.310	0.482	0.551	0.387	0.442	0.144	0.145
Ranking			3	1	2	5	8	10	4	12	7	6	11	9	14	13

Table 7.
The HOQ

and efficiently monitor and evaluate systems, with strong accountability mechanisms. The curriculum should further have the potential of enhancing the project management and strategic planning skills of the HC managers. In addition to this, there should be a proper and efficient communication system between the HC managers. An efficient communication system can be developed through a team-building approach as well as bringing digitalization into the HC systems. Pakistan's HC sector still relies on documenting records on paper. Bringing digitalization would mean uploading all the relevant data related to the patients and HC operations onto a software or website. Hence, this as a result would help all the stakeholders to monitor the relevant data and act accordingly. Furthermore, focus should not only be relied on developing strategic plans, but its timely implementation should also be made sure.

The second-ranked RS as evident from the HOQ is RS3 i.e. the provision of "resilience education" to the HC staff. Resilience education can be achieved through organizing seminars, workshops, short courses or education related to management functions. It can further be provided through internships, clinical experience courses, work-based learning and other changes in workplace culture. Resilience education should be taught to both the nursing staff as well as health professionals. It should also be taught to pre-professional HC students. The education should be taught in a way that it is reflected through their performance, giving them strength, focus and forbearance in the workplace. The education should not only focus on enhancing skills related to managing disasters and pandemics, but it should also focus on developing the physiological resilience of the HC staff. Pandemics like COVID-19 usually come with infectious diseases. Hence, the fear of getting the disease is usually the concern of the HC staff. Thus, focussing on mental resilience in such stressful conditions can further help in building overall resilience in the workplace.

From Table 7 in HOQ, the third-ranked RS is "strengthening of labs and diagnostic systems". The COVID-19 pandemic made it clearer that Pakistan lacks both the testing capacity and the required medical equipment such as ventilators to fight the disease. In order to strengthen the laboratories, not only the number of laboratories should be increased but the staff employed there should also be well trained. Also, access to supplies such as reagents, diagnostic equipment should be made available. Furthermore, laboratories should operate according to the standards of International Health Regulations. It is a legal step that corresponds to public health emergencies of an international scale. In addition to this, adherence to laboratory quality standards and improving its capacity at the same time is also very important for well-functioning laboratories. Apart from the COVID-19 pandemic, Pakistan is already going through other various known diseases such as dengue virus, tuberculosis, diabetes, cancer, hepatitis A and E, etc. Thus, in order to fight these diseases along with the current extraordinary situation, the strengthening of labs and diagnostic systems becomes really essential so that the HC system is not only capable of handling the ongoing diseases, but it should also be prepared to tackle other pandemics or disasters as well. In this regard, the international community can also play its part in transferring expertise and resources to developing countries like Pakistan.

The unique set of systematically ranked RSs in Table 7 can further help the government to devise policies for the HC sector of Pakistan accordingly. Apart from the policy recommendations given above, the government of Pakistan should also focus on increasing the HC budget of the country. Unfortunately, health and education are the most neglected sectors in the country. The government of Pakistan is spending less than 0.75% of its gross domestic product (GDP) on the HC sector (Noreen *et al.*, 2020a, b). Due to which 78% of the general population pays out of their pocket for medical treatment. Whereas, the WHO recommends that countries should spend at least 5% of their GDP on the HC sector. The current crises originated because of the COVID-19 pandemic should be made into an opportunity to enhance the overall resilience of the HC sector of Pakistan. The shortcomings

that have originated through the pandemic can be used as an opportunity to make the HC system more anti-fragile. The concept of anti-fragility has been developed by Nassim Taleb (Aven, 2014), which states that a system can become more anti-fragile or resilient if it is subjected to burnouts or stress. This means that the factors that contribute to the stresses and distresses in a system, if identified and mitigated accordingly, can make a system more resilient towards future disasters.

5. Conclusion

The COVID-19 pandemic has significantly affected the HC systems around the world. So far, thousands of people have been infected and several have been reported dead. The most hit countries are developing ones because these countries have to face both financial crises and a dearth of HC facilities. Hence, special attention should be paid to enhance the resilience of the HC sector of these countries. Therefore, this study aims to enhance the resilience of the current HC sector of the developing country, Pakistan. The study aims to evaluate strategies to make the current HC sector of Pakistan fighting fit to combat the current COVID-19 and future pandemics in the country. For this, the study identifies 10 RAs and 14 RSs from previous literature along with engaging medical experts at the same time. The study further uses a novel hybrid approach, i.e. FUCOM-fuzzy QFD to develop a resilience-based model for the HC sector of Pakistan. The MCDM technique, i.e. FUCOM technique is used to allocate weights to the RAs (WHATs), whereas the fuzzy QFD approach is used to rank the RSs (HOWs). The results of the study suggest "competent leadership and governance" to be the most RA. Whereas "building the operational capacity of the management" followed by "resilience education" and "strengthening of labs and diagnostic system" were found to be the top three RSs, respectively.

The results of the study focus on improving the leadership and management skills of the HC professionals. The preceding goal can be achieved by providing resilience education to both the HC managers and medical staff. Hence, this as a result would enhance the overall strategic planning and operational capacity of the hospitals in the country. Furthermore, focus should also be made on increasing the capacity building of labs and diagnostic systems so that the HC sector is not only capable of handling the ongoing diseases in the country, but it should also be made resilient enough to tackle other disasters and pandemics as well. Moreover, the government should also consider increasing the HC budget of the country. Lastly, the COVID-19 pandemic has manifested several flaws in the HC system. The shortcomings that have originated because of the current situation in the country should be used as an opportunity to rectify and work on those problems. Thus, this as a result would help the HC sector of Pakistan more anti-fragile, making it fighting fit to combat future pandemics and disasters in the country.

The limitation of the study lies in the possibility that there could be other factors in the literature that can contribute in enhancing the resilience of the HC in a developing country. However, the resilience factors used in this study has been adopted from the secondary data with the help of the experts. Further studies in this regard can be conducted in enhancing the resilience of any other developing country in the world. For this, other sets of methodologies or MCDM techniques such as AHP, TOPSIS, DEMATEL or VIKOR, etc. can be used for further studies.

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Appendix

Table A1. Abbreviations

Words	Abbreviations
Coronavirus disease 2019	COVID-19
Healthcare	HC
Resilient attributes	RAs
Resilient strategies	RSs
Multi-criteria decision-making	MCDM
Full consistency method	FUCOM
Quality function deployment	QFD
House of quality	HOQ

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