






## Article

# Resilience and Sustainability of the Water Sector during the COVID-19 Pandemic

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**Abstract:** The COVID-19 pandemic brought unprecedented socio-economic changes, ushering in a “new (ab)normal” way of living and human interaction. The water sector was not spared from the effects of the pandemic, a period in which the sector had to adapt rapidly and continue providing innovative water and sanitation solutions. This study unpacks and interrogates approaches, products, and services adopted by the water sector in response to the unprecedented lockdowns, heralding novel terrains, and fundamental paradigm shifts, both at the community and the workplace. The study highlights the wider societal perspective regarding the water and sanitation challenges that grappled society before, during, after, and beyond the pandemic. The premise is to provide plausible transitional pathways towards a new (ab)normal in adopting new models, as evidenced by the dismantling of the normal way of conducting business at the workplace and human interaction in an era inundated with social media, virtual communication, and disruptive technologies, which have transitioned absolutely everything into a virtual way of life. As such, the novel approaches have fast-tracked a transition into the 4th Industrial Revolution (4IR), with significant trade-offs to traditional business models and human interactions.

**Keywords:** adaptive management; transition; sustainability; transformation; industrial revolution

## 1. Introduction

The emergence of the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), the virus that causes the COVID-19 disease, has seen humankind traversing unprecedented times. Its impacts have reverberated throughout the globe, taking lives, destroying livelihoods, and changing how people interact with each other [1]. COVID-19 caught humankind unexpectedly, as evidenced by the high data usage as the industry was adapting to the new norm of working from home [2]. COVID-19 has unleashed a new era of

human interaction and managing and conducting business across the globe, forming part of the 4th Industrial Revolution (4IR). Although the pandemic was neither unpredictable nor unforeseen, its abrupt emergence and swift global spread blind-sided policymakers, leading to unprecedented restrictions on human activities [3]. Since its emergence in 2019, the COVID-19 pandemic has introduced new ways of human interaction protocols. These include social distancing, which has affected drastic socio-economic changes at the individual and household levels, including the workplace [4]. The effect of social distancing has witnessed an upsurge in the use of Information and Communications Technologies (ICTs) to minimise economic disruption and to circumvent the obstacles associated with adapting to the new way of living, such as working from home, online purchases, home delivery, and home-schooling for children [5]. The sudden social changes and the increase in digital use and e-commerce have ushered the globe into the 4IR, as people resort to using ITC to conduct business from home [1].

In South Africa, the water sector had to adapt rapidly at a time when it was expected to provide solutions to the multiple prevailing challenges such as the emergence of novel infectious diseases, climate change, and depleting water resources, among others [6,7]. Past experiences of such changes that required quick solutions and adaptations have assisted the water sector in adapting quickly during the sudden changes brought about by the COVID-19 pandemic [8]. The sector has had to adapt to the “new norm”, while at the same time providing clean water and sanitation to reduce the impact of the pandemic. The water sector needed to provide the following critical interventions during the pandemic: (i) influence policy and decision-making processes at the height of the pandemic, (ii) develop human capital in the water science sector to provide the much-needed knowledge to mitigate the spread of the virus, (iii) create new products, innovation, and services for socio-economic development, (iv) empower communities and reducing poverty in support of transformation and redress, and (v) develop sustainable solutions [8,9]. As a result of the need to provide these essential services, the water sector had to adapt to new ways of doing business, taking into consideration that this was a time when water and sanitation solutions were even more critical, and the efficacy and stability of the sector as a whole could not be jeopardised.

The fight against the COVID-19 and possible future disease outbreaks go beyond the analysis of wastewater and emphasising the efficacy of drinking water treatment processes, as the impact on water systems also affects engineering and treatment processes with social, economic, and environmental consequences that include increasing water demand and decreasing revenue [10]. In the case of South Africa, there was an urgent need for the water sector to adapt, and be resilient and innovative, particularly since water is a scarce resource in the country, and yet demand increased during the pandemic [11]. Water institutions had to move swiftly and show resilience as they transformed their operational processes and took a key role to combat the pandemic. This is critical to responding to anticipated and unanticipated threats and hazards amid scarcity [12]. This study demonstrates how the water sector in South Africa moved swiftly to adjust and adapt its process to mitigate, cope, and learn from the COVID-19 pandemic.

The key for any transformational change at the workplace is to understand the impact of the change and the effectiveness of new business models at a crucial time when society is looking for solutions to current challenges [6]. The urgent need was to develop innovative products and services, and a solution-oriented sector agenda that transition society towards uncharted territories full of uncertainties and strengthen the resilience of communities [13,14]. This had to happen when the workplace was disrupted from both the inside and outside as social media, and virtual communication took centre stage [1]. The office boardroom has transitioned into a virtual e-boardroom. Indeed, the water sector needed to take decisive decisions to re-organise and re-orient the way of doing business outside the offices, which have been the familiar meeting place. The key concern for essential services organisations that include water research is to ensure that their impact is not reduced, as the need for impact on society is more urgent than ever before. The structure of the virtual

office that is now the new norm is being designed to embrace innovation and change in a way that essential services remain available, and future sustainability is assured.

As already alluded to, during the COVID-19 pandemic, the water sector was expected to continue providing innovative and smart water and sanitation solutions to reduce the spread of the virus and its impact on lives and livelihoods. This is based on the provision of safe water, sanitation, and hygienic (WASH) services essential to protecting and enhancing human health during the outbreak of infectious diseases such as the COVID-19 [6,15]. Water is an essential resource in the fight and treatment of diseases. Therefore, water demand for public health and human consumption will increase during a disease outbreak like what happened during the COVID-19 outbreak [10]. However, due to hard lockdowns with limited human interactions and movement, there were always going to be challenges in meeting these essential services.

The water sector was not immune to the impacts of the pandemic and the subsequent lockdowns. Research staff that had successfully conducted physical meetings and consultations with stakeholders and partners found themselves unable to continue conducting their work as usual, a situation that threatened the sector's viability during this critical time. There was an urgent need to rapidly transform the sector as it adapted from physical to virtual meetings and continues providing sufficient water and sanitation services. The sector had to find innovative solutions to adjust and adapt swiftly to the new norm of conducting business and mitigate the spread of the virus. Thus, in this study, we undertook a detailed assessment of how the sector adapted, and highlighted the pathways adopted to provide uninterrupted water and sanitation services. The aim was to provide policy, decision-makers, and managers with pathways adapted to adjust and adapt quickly during a shock or hazard. The study focuses on how the research sub-sector adapted rapidly during the pandemic and continued providing water and sanitation services, contributing to reducing the spread of the virus. To our knowledge, this is the first work to undertake such a study as previous studies tended to focus on the relationships between infrastructure with water and electricity and working environment [16] and the implications of social distancing policies on drinking water infrastructure [17]. Other studies focused on the opportunities and challenges of water and wastewater utilities during the pandemic [18–20].

This study assessed the impact of the COVID-19 on the way the water sector had to conduct its business and continue providing essential services such as the provision of clean water and sanitation. This was achieved through a trajectory analysis to evaluate the changes before and after the COVID-19. The sector's response capability was assessed by analysing the interventions adopted from within and outside to continue providing water and sanitation solutions at both the local and international levels during the pandemic and beyond. The study focuses mainly on water research, providing insights into sub-sector readiness and preparedness in managing the present shocks and 'bounce back' and continuing on as a positive trajectory as before the shock of the pandemic. The timeous response to radical change imposed within an extraordinarily short space of time enabled the water sector to respond to the shocks of the pandemic. The manuscript is divided into three main sections: (a) the description of the pilot organisation, (b) data collection methods and analysis, (c) proposed pathways and actions towards organisational resilience, and (d) discussion and conclusion sections.

## 2. Materials and Methods

### 2.1. Case Study Description: Water Research in South Africa

The water research sub-sector is critical in South Africa as the country is water-scarce and is the thirtieth driest country in the world [11,21,22]. As a result, the Government of South Africa established the Water Research Commission (WRC) in 1971 to spearhead water research and guide informed water decision-making through science and innovation [9]. Most of the data used in this study were obtained from surveys conducted by the WRC through its stakeholders and partners. Since its establishment in 1971, the WRC has developed products and innovations that guide policy and decision-making on formulating

coherent strategies to enhance resilience and adaptation to the changing environment [9]. Access to sufficient water and adequate sanitation of appropriate quality is necessary for life, human dignity, economic growth, and social development. Therefore, it plays an important part in enhancing public health during disease outbreaks like COVID-19 [23]. During the peak of the COVID-19 pandemic and the subsequent lockdown, the water research community was faced with an urgent need to provide strategic policies that culminate in water access and sanitation to all, as a means of reducing the spread of the disease and enhancing the resilience of communities.

The WRC is a state-owned enterprise established in terms of the Water Research Act (Act No. 34 of 1971), with a mandate to spearhead water research in South Africa. Its establishment was motivated by the water insecurity challenges faced by the country. The organisation has a staff complement of 90 employees. The Research and Development Unit (R&D) of the WRC, which is the core of the organisation, comprises 31 staff members, with 15 being Research Managers. The organisation completes 90 projects per annum, but the target is 80 projects. The WRC supports approximately 350 postgraduate students on an annual basis. Moreover, the organisation engages with over 3500 stakeholders and partners annually, most of whom are project committee members who sit once a year to evaluate the progress being done on projects and reports (deliverables). There are 1750 project leaders who regularly interact with Research Managers. The project leaders were the main target of the survey used in this study. Apart from the financial resources from government levies, the WRC also partners with over 25 industry partners and other funders to leverage research funding. The annual budget spent by the WRC on funding research projects is approximately R170 million (US\$12 million).

## 2.2. Data Collection and Methods

An urgent first measure was to tap into the research sector's knowledge regimes and assess whether and in what ways the community of practice operating within, and outside, was affected. To obtain relevant information, questionnaires were developed and administered to project leaders (1750 in total). In anticipation of the impact of COVID-19 and the imposed lockdown on the trajectory of its projects, the WRC conducted an online survey that targeted project leaders. The purpose of the survey was to assess the impact of the pandemic on research deliverables on the one hand and the capacity building component, which is determined by student progress reports. The online surveys were conducted in two phases, allowing participants to highlight the challenges they were facing to meet their obligations, suggestions to improve on the current way of conducting research, expectations from the funder, proposed changes in deliverables submission dates, and the way forward. This data was processed in The Statistical Package for the Social Sciences version 27 (SPSS) and Nvivo software version 12.

The stakeholder engagement exercise was meant to ensure the availability of tools and approaches to achieve water security and sanitation during the pandemic. The surveys gauged the impact of the COVID-19 lockdown on research and reassured the stakeholders that they get the necessary support. The principal objective of these engagements was to provide support in the pandemic and build collaborations capable of framing problems together to ensure the sustenance of long-term research.

### 2.2.1. Surveys Conducted and Systematic Data Analysis

In anticipation of the impact of COVID-19 and the imposed lockdown on the trajectory of projects, the organisation conducted an online survey that targeted stakeholders. The survey's main purpose was to determine the impact of the COVID-19 pandemic on water research. The surveys were conducted in two phases and were captured and processed in SPSS and NVivo software.

The quantitative data from the study were analysed using the Statistical Package for the Social Sciences version 27 (SPSS). A descriptive statistical analysis was run to generate bar graphs and pie charts presenting the results. In addition, NVivo software (version 12)

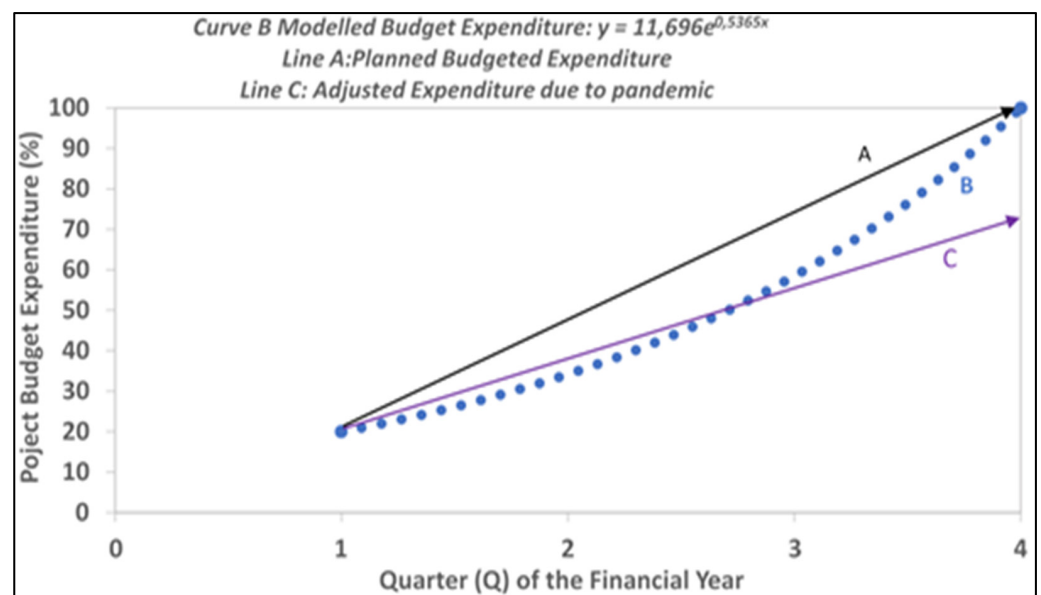
was utilised to conduct a thematic analysis and code the textually rich qualitative data to generate themes and various visual representations, such as word clouds, word trees, and mind maps. This type of analysis is useful and effective in illustrating textually rich qualitative data.

### 2.2.2. Crosstabulation and Chi-Square Analysis

The data for the research study was analysed utilising crosstabulation coupled with the chi-square statistical test. This method is utilised to determine the relationship between two or more variables. For this study, the crosstabulation was combined with a chi-square test to assess the degree of association between variables. The chi-square test was used to determine a score and a  $p$ -value, which indicated the significance of that score. This method determined the observed frequencies against expected frequencies.

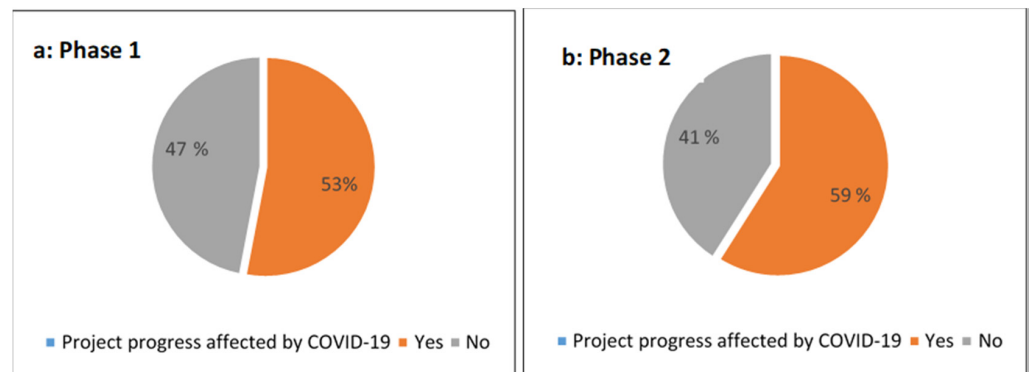
## 3. Results

The results showed that 46% of research projects were negatively impacted (Figure 1), which reduced the total planned project budget expenditure (Lines A and C) by about 36% in Quarter 4 (Q4) of the financial year. The modelled budget expenditure (line B) indicates that research project progress might improve if the situation normalises in Q3. However, reports or deliverables to be submitted in Q3 should be work done in Q1 and Q2. Project performance and expenditure may not remarkably improve as predicted by line B, which implies that the Line C expenditure pattern may be indicating the reality about the 2020/21 Financial Year project performance and budget expenditure.



**Figure 1.** Research project budget expenditure based on a survey of Project Leaders.

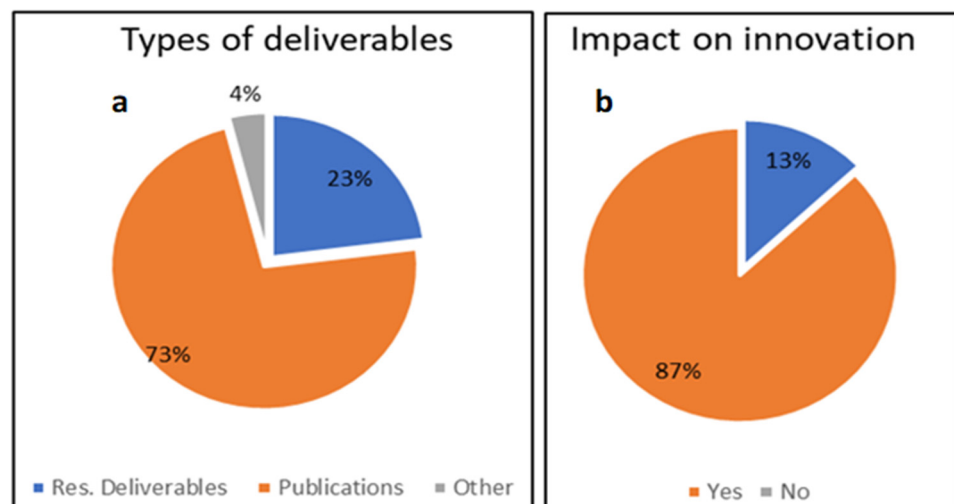
Results depicted in Figure 2a,b illustrate the responses from respondents regarding how project progress has been affected by the COVID-19 pandemic. During phase one of the surveys, more than half (53%) of the respondents stated that project progress had been affected by the lockdown due to the COVID-19 lockdown (Figure 2a). In addition, further analysis was done to compare whether there was a difference in project progress between phase 1 and phase 2 of data collection. The chi-square test results revealed no significant difference ( $p > 0.05$ ) between responses, indicating that project progress was affected in both phases of the data collection process.



**Figure 2.** Water research project progress affected by COVID-19: (a) situation at first survey (b) situation at the second interview.

Interestingly, Figure 2a indicates that most of the research and development projects are mostly community-based. In other words, research teams were restricted to conduct their fieldwork, engaging with communities, or running experiments in different sites as it was per Level 5 (hard lockdown) rules. The second phase of survey responses, illustrated in Figure 2b, indicates that 59% of respondents stated that project progress was affected by the pandemic, and 41% stated that project progress had not been affected.

The results in Figure 3a demonstrate that publications (73%) were the main type of deliverable that remained to be submitted, followed by a final research report deliverable (23%). Figure 3b indicates that 87% of respondents felt that the innovation of the deliverables would be impacted. This was because most of the innovations were supposed to be tested in the field, while the remaining 13% stated that innovation would not be impacted. Results obtained from chi-square analysis revealed an association between types of deliverables and impact on innovation. The chi-square test results revealed a score of  $p < 0.05$ , which is significant. The correlation between the two variables could result from the fact that the projects' innovations were impacted positively due to the number of publications, which scored as the highest type of deliverable.



**Figure 3.** Illustration of deliverable type (a) and innovation impact (b).

The respondents' major concern regarding various projects was the inability to meet project stakeholders (68%) due to the stringent lockdown regulations (Figure 4). Additional concerns were field/lab work which had stopped (24%), no concern (5%), and unreliable internet (3%). As a result of these challenges, there was a need to realign some of the deliverable schedules, which caused delays in getting deliverables from the project leaders.

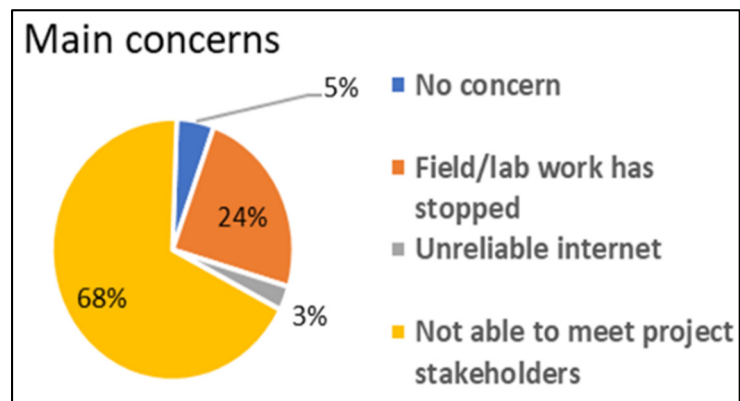


Figure 4. Main concerns of project leaders.

Capacity building is a key performance indicator within the WRC. This relates mainly to student training. Figure 5a shows that most respondents (69%) required no support for students during the lockdown period. The results in Figure 5b, from phase 2 of surveys, illustrate that most respondents (29%) stated that students were fully supported by their project leaders despite the lockdown restrictions and the lack of face-to-face meetings. This indicated the effectiveness of the internet and virtual meetings. However, 15% of the respondents mentioned the need to support students with data, and (9%) required laptops.

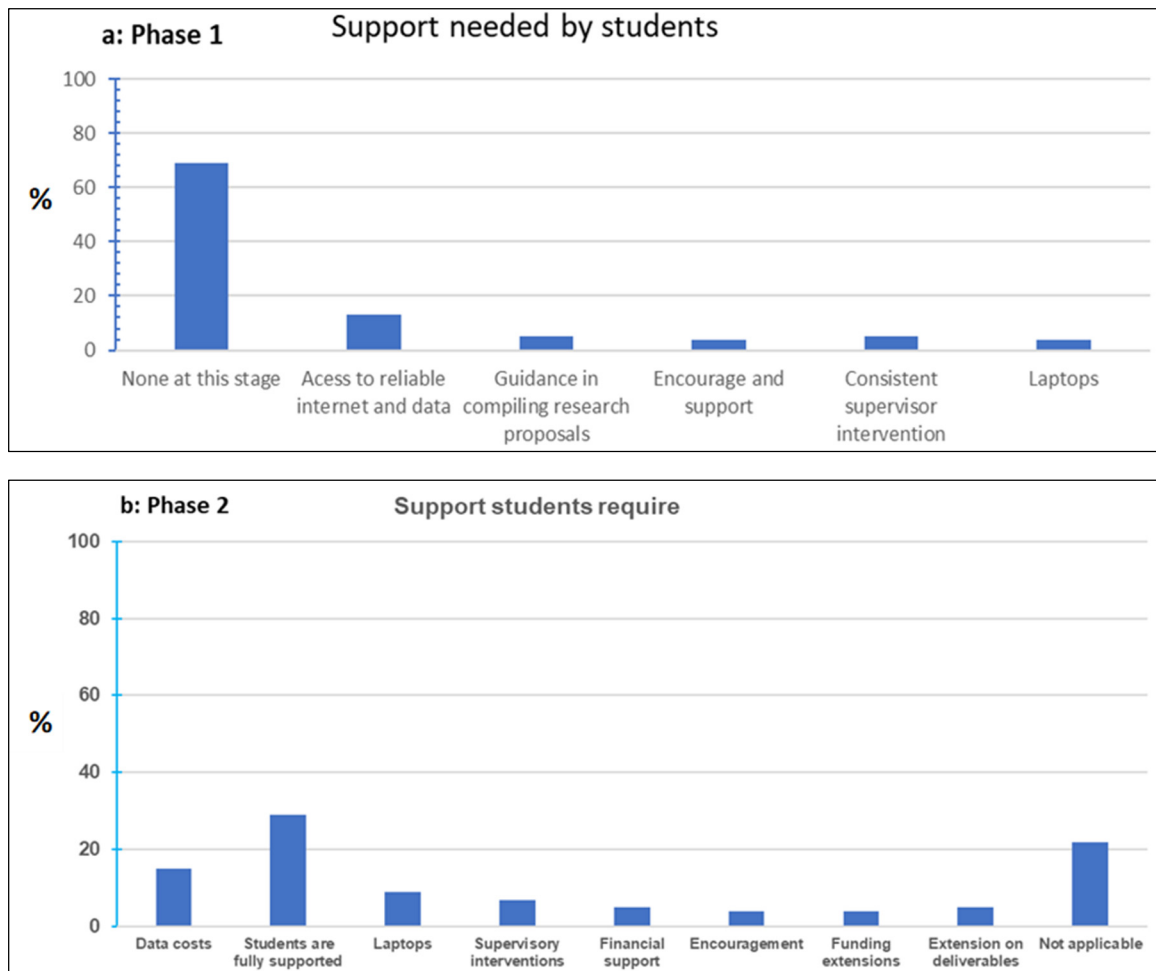


Figure 5. Student support during Phase (a,b) during the COVID-19 induced lockdown.

Thirteen percent of the students required support for data costs, 5% needed guidance in compiling research proposals, 4% encouragement and support, 5% consistent supervisor intervention, and 4% required laptops.

The word-cloud (Figure 6a) generated in NVivo illustrated that the major challenges associated with researching during the lockdown period were time, data analysis, and conducting sampling, especially in the laboratory. Teaching, working in teams, and access were also additional challenges mentioned by respondents. Access to the internet became imperative for students who could not meet their supervisors face to face and who relied on virtual meetings or other interventions to continue with supervision. The word-cloud in Figure 6b illustrates the main concerns that the research teams had during the COVID-19 pandemic: fieldwork, acquiring data, internet access, the teaching load, and the inability to access equipment and the laboratory during the lockdown period.



**Figure 6.** Major challenges associated with water research during the lockdown: (a) situation during the first survey, (b) situation during the second survey.

The results depicted in the word-tree (Figure 7a) conducted in the first phase of surveys indicate that most students continued with their work during the lockdown period, mainly through desktop activities such as working on proposals and writing literature reviews. Students who required various software for their projects utilised open-source software to conduct their work during the lockdown period and were, therefore not negatively affected in this regard. Results in Figure 7b show that most students (61%) continued their research during the lockdown period. Only 10% of respondents were unable to continue their research due to various challenges.



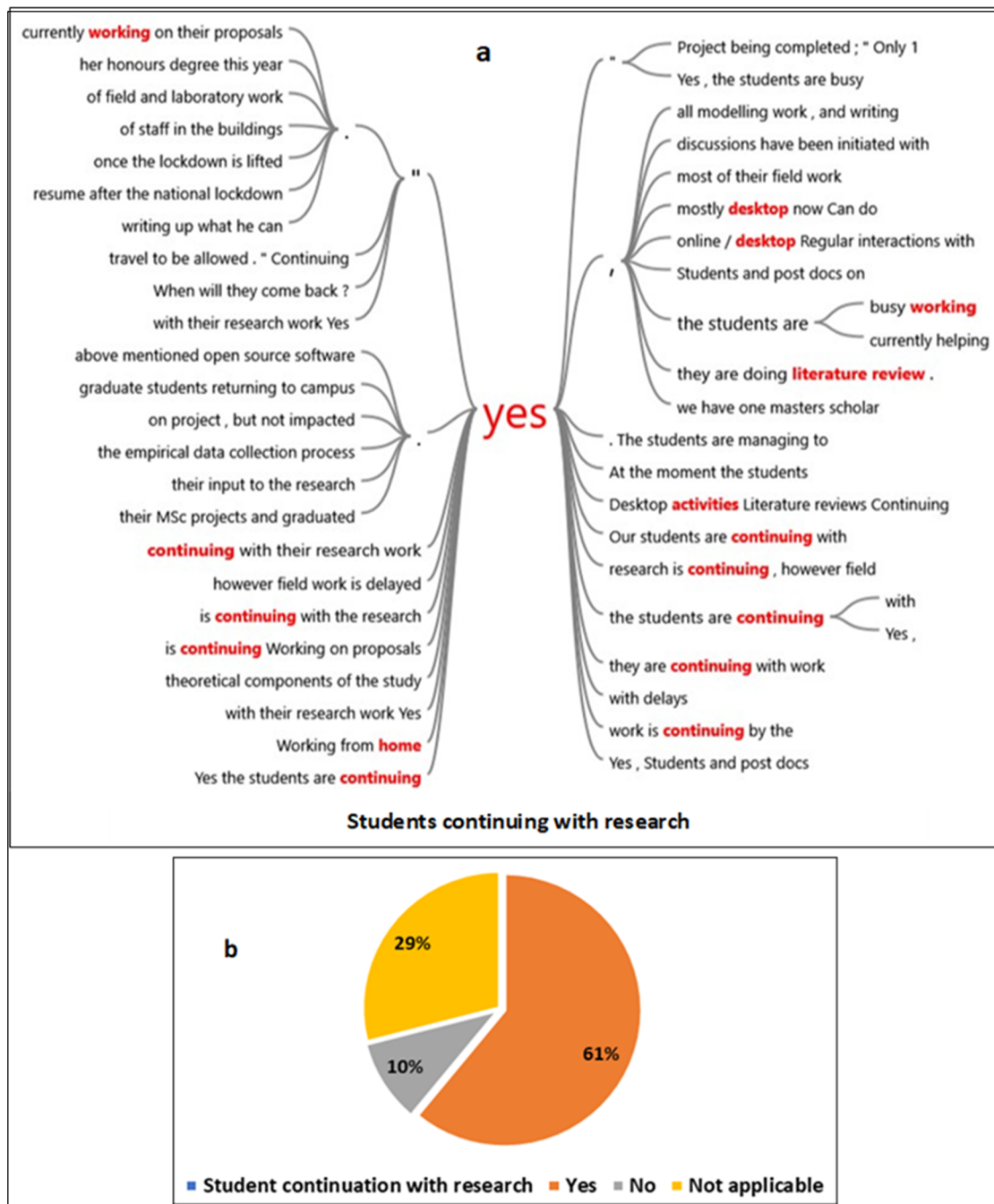
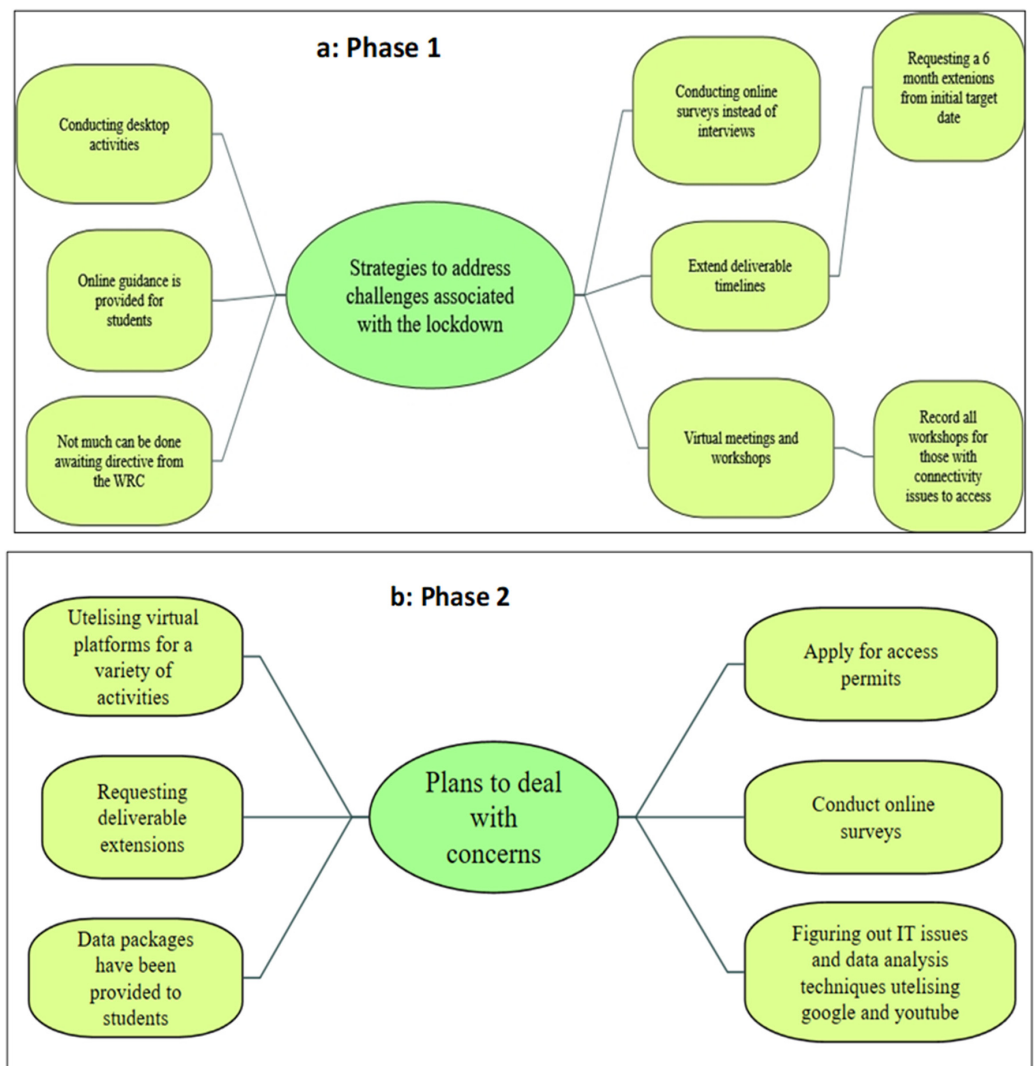


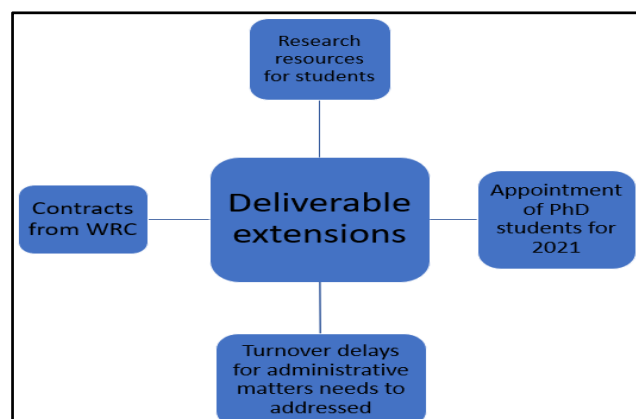
Figure 7. (a) Students continuing with research as presented in the word tree. (b) Students continuing with research.

The mind map (Figure 8a) shows that respondents adopted various strategies to address the challenges associated with the lockdown during phase 1 of surveys. These strategies include virtual meetings and workshops, conducting online surveys instead of physical interviews, and requesting date extensions from the initial target date. There was also online guidance required for students, increased desktop activities, and the need to record workshops for those with connectivity issues who could not be present at workshops. The mind map in Figure 8b illustrates the various plans the research teams employed to deal with the concerns raised during the lockdown period in phase 2 of surveys. These include utilising virtual platforms for a variety of activities, applying for special permits for access to the field, and requesting deliverable extensions.



**Figure 8.** Mind maps showing (a) strategies employed to address challenges, and (b) plans to deal with concerns.

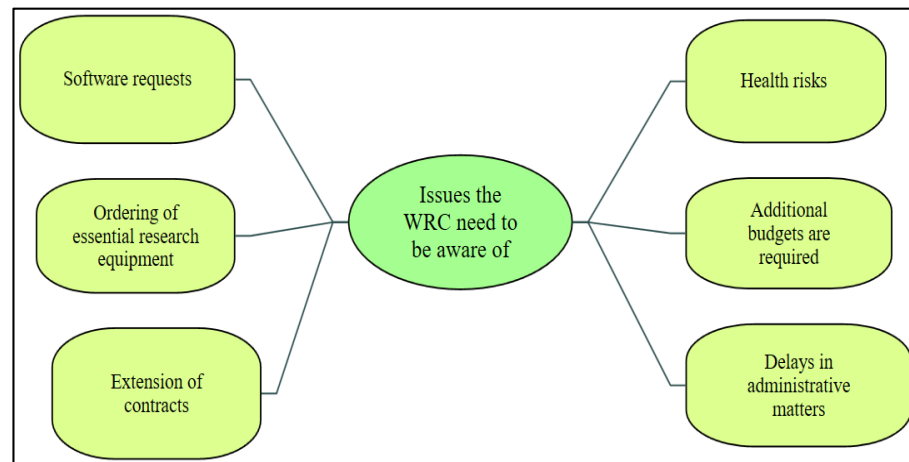
Stakeholders were asked about the challenges that the WRC needed to address. Figure 9 illustrates the various concerns and challenges that the WRC needed to address.



**Figure 9.** Challenges the WRC needed to address during the COVID-19 lockdown.

Results indicate that deliverable submission date extensions were the main concern respondents had regarding deadlines for research reports.

The mind map represented in Figure 10 shows the various challenges the WRC needed to be aware of. These issues included the requests for software, the ordering of essential equipment for research-related purposes, additional budgets for certain projects that were required, and the health risks associated with going into the field during this time.



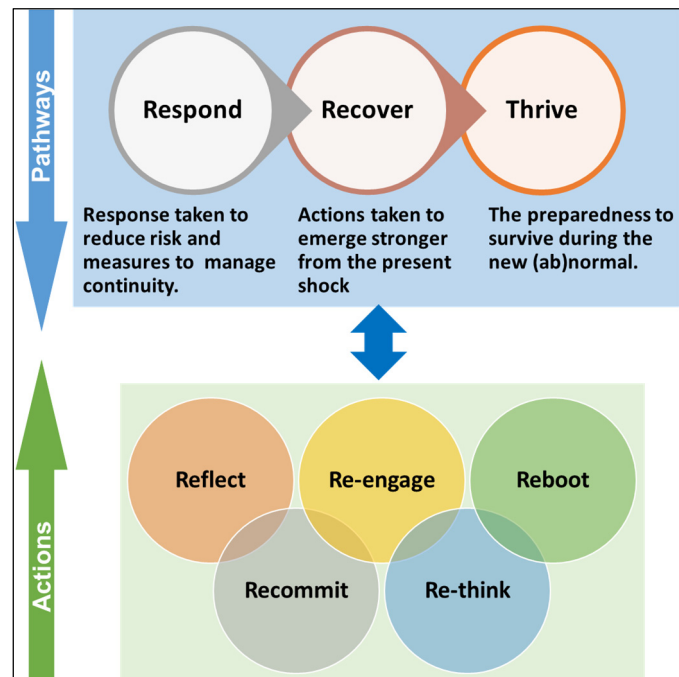
**Figure 10.** Issues the WRC needed to be aware of during the COVID-19 lockdown.

### 3.1. Rethinking Organisational Priorities

The responses by the water research sector stakeholders to the pandemic were immediate and responded through appropriate activities in areas that needed urgent action. A series of meetings and workshops were held virtually, and international engagements with partners focussed on designing new research topics with a focus on COVID-19. The research sector changed its modus operandi and business as usual in response to the pandemic. The change process ensured that the water research sector remains relevant, practical, and continues to contribute meaningfully to those important topics such as climate change, water provision, sanitation, and components that resonate directly with concerns around public health and now specifically with aspects of COVID-19. It is no longer business as usual in the water sector as the COVID-19 precipitated a paradigm shift. Although data and mobile phone usage has drastically risen due to the new virtual working environment, office expenditure has also significantly gone down due to limited use of printing and electricity, reduced travel by staff, and other daily office expenses. There are more savings for the organisation than when staff physically meet at the office.

### 3.2. Adopted Pathways and Actions towards Organisational Resilience

The WRC experiences facilitated the identification of three fundamental themes or pathways that organisations need to adopt from now onwards to reduce the risk of future shocks and enhance their resilience (Figure 11). These pathways include how organisations respond, recover, and thrive during a shock and after a shock [24]. Five critical actions drive the three pathways: reflect, recommit, re-engage, rethink, and reboot [24]. The actions form an important part of the recovery and response processes as they bridge response and the new (ab)normal.



**Figure 11.** Fundamental pathways towards organisational resilience and the actions needed to achieve sustainability at the workplace.

The reflect action point refers to the lessons learned during a shock and how these are used to prepare for future preparedness. The recommit action stands for the refocusing of the well-being of workers, preparing them physically and psychologically, meeting the resource needs that they continue to be productive. Re-engaging refers to the organisation's redeployment choices to capitalise and maximise the contribution and potential of individual employees. Rethinking involves leveraging the reactions, experiences, and responses to the present shock to hasten productivity for future work productivity. The reboot pathway represents strategic realigning of human resources functions for swift adaptation to the present circumstances and priorities and maximising potential.

#### 4. Discussion

Investing in long-term water security and access to clean water and sanitation is critical in achieving a healthy society and public health [25]. Funding for water and sanitation research not only builds more resilient and thriving communities, but also plays a key role in economic development and growth [26]. The vulnerabilities in the water sector need to be effectively addressed to 'build better' and ensure sustainable development. This is the new major challenge for the WRC and related institutions. There is a need to address some of the more pressing challenges, such as unemployment, poverty, and the mental and physical health-related nexus concerns that emanate from the pandemic. This can be achieved through strengthening partnerships between the public, private, and research sectors in driving effective actions that promote sustainability through technological innovation [13]. New and resilient partnerships are being developed. This allows, perhaps for the first time, an opportunity to improve the lives and livelihoods of those deprived of water and decent sanitation and address longstanding issues of dignity and equity in the water sector.

An important contribution of enhancing water security and access to clean water and sanitation is the achievement of Sustainable Development Goals (SDGs). As water is generally a cross-cutting resource, its security will contribute to almost all the SDGs, particularly water-related Goal 6 [27]. Water is a key component of the water-energy-food (WEF) nexus, and the cross-sectoral and integrated management of the three resources enhances their security. The three resources are at the core of the SDGs [28–31].

Studies report that the lockdown exacerbated the existing water and sanitation access inequalities in the densely populated suburbs, informal settlements, and the homeless [32,33]. According to the World Health Organisation (WHO), water, sanitation, and hygiene are key elements in fighting infectious diseases [34]. The importance of water in combating the spread of infectious diseases is highlighted by the call to frequently wash hands with soap and water [35]. In 2017, Statistics South Africa (Stats-SA) reported that 87% of South Africans had access to a safely managed drinking water service. They also reported 75% of the urban population was using safely managed sanitation services. However, the COVID-19 pandemic illuminated a different situation. Poor communities always have challenges accessing water and sanitation, a scenario that increases their vulnerabilities in contracting or combatting diseases [36]. These challenges, exacerbated by the COVID-19 pandemic, could jeopardise the progress towards achieving SDGs if the water sector fails to adapt and adjust rapidly [6,15].

#### *4.1. Mirroring into the Future*

COVID-19, compounded by the increasing frequency and intensity of extreme weather events, is not the first pandemic and is unlikely to be the last [7,35]. As is the case with SARS-CoV-2, many other epidemics, including Ebola, Middle East Respiratory Syndrome (MERS), and Severe Acute Respiratory Syndrome (SARS), originated from various zoonotic microorganisms [37,38]. While the impact of a pandemic can be devastating, it also provides the opportunity to learn and prepare for similar future events. Responsiveness, management of clinical and laboratory environments, networking with subject matter experts, and developing partnerships with stakeholders, become critical directives during a disease outbreak. These can be of natural, accidental, or deliberate origin. Therefore, according to the World Health Organisation (WHO), the provision of specific knowledge and translated practices prepares responsible partners to address the unexpected [28,34].

As zoonotic disease outbreaks are expected to increase due to climate change and the irreversible interconnectivity between nations through globalisation, disruptions to everyday life are predicted, with different intensity levels [15]. Undoubtedly, the lack of access to clean water, sanitation, and basic human hygiene increases the risk of disease transmission. Faced with this possibility, there is an urgent need to formulate strategies for resilience against novel infectious diseases through transformative and nature-based solutions [39]. Water availability is crucial to personal hygiene, which would aid the potential prevention of disease spreads. The COVID-19 pandemic illustrates that personal hygiene activities should be considered an essential public health intervention, whilst managing upstream water resources is essential for urban water supply [40].

The premise is to ensure healthy socio-ecological interactions through transformative approaches and reduce the risk posed by wildlife on human health [6,41]. Understanding natural processes and their associated microbial communities facilitates the compilation of baseline datasets of river profiles, including water quality and microbial quality, focusing on rural and other disadvantaged communities. This is more relevant now than ever as previously marginalised segments of the population (both rural and informal settlements) are increasingly becoming more vulnerable to infectious diseases such as COVID-19.

A key factor learnt during the COVID-19 pandemic involves the transition from sectoral interventions to cross-sectoral considerations, which facilitate a better understanding of the intricate interlinkages between upstream and downstream water resources and users and the interconnections between water, sanitation, environment, and health [6]. As diseases do not know political boundaries, interventions should also consider the transboundary nature of water and other resources as planning and management of both surface and groundwater resources may lead to more resilient systems and increase regional storage [42,43]. Enhancing water security at the regional level has many benefits that include promoting environmental and human health, increasing the resilience of communities to climate change, supporting livelihoods, food security, and economic productivity [44,45].

#### 4.2. Framing of 'Big' and 'New' Problems

During the COVID-19 induced lockdown, water research activities deemed non-essential were suspended indefinitely as budgets were reprioritised to combat the spread of the disease and vaccinate people against the coronavirus. Amidst the restrictions that came with the lockdown, the sector searched around new borders and formidable lockdown restrictions to continue with their work through virtual interactions and desktop studies [46]. These initiatives facilitated the creation of unprecedented global collaboration that focused on providing solutions to the challenges brought about by the COVID-19 pandemic. However, research that does not have a COVID-19 tag and was not considered "essential" according to the lockdown regulations was put on hold. This affected many research projects that required laboratory or fieldwork during the 'hard' lockdown.

The prudence principle will likely entail allocating the limited resources to projects that can achieve immediate returns to address the changing needs of communities across the country. While the costly and reactive short-term interventions are justified through the urgency of a crisis, they are largely a consequence and symptom of lack of preparedness [47]. In the case of South Africa, the long-term priority is to ensure water security, and long-term research funding is key to achieving this objective.

Understanding the links between sectors such as water, health, and economic development is of key concern to address challenges facing countries across the globe [6]. There is an urgent need to do away or break the silos to improve coherence and formulate coordinated and collaborative responses to future pandemics [43]. Preparedness is critical to reducing disruptions in everyday life that impact economies and livelihoods. A concern that has become more evident during the COVID-19 pandemic is that government departments are not well lighted. There is an urgent need to efficiently coordinate future pandemics and disasters and for government departments and policy priorities to be better coordinated. This will require more transdisciplinary approaches that involve multiple actors working together to co-develop and co-implement sustainable and transformative solutions.

#### 4.3. Limitations of the Study

The results of this study are from online surveys conducted in two phases during the COVID-19 induced lockdowns. The online survey was chosen as it was the most effective method to reach out to participants during a period of limited human interaction. However, it was not always suitable for others who could only respond using alternative methods like the traditional manual questionnaire or face to face interviews. As in any other survey, the results could be subjective. However, this study relied that the project leaders needed the survey too and get assistance to complete their research work on time and reduce the spread of the virus.

### 5. Conclusions

The experiences of the water sector to respond, recover, and thrive during the peak of the COVID-19 pandemic allowed the sector to stay afloat and remain relevant to national goals. The unprecedented times that are projected to emerge in various forms require organisations to be flexible and be able to change their modus operandi and business as usual and adapt as rapidly. The flexibility refers to both the way they operate, particularly in adopting appropriate technology, and in the new direction within their vision to ensure that they remain viable and practical. The water sector went through an imminent change, precipitated by COVID-19's urgent demands. This change resonates within the organisation for many years to come. The change has ushered in the 4IR, where technology and science take centre stage. Stakeholders in the water sector in South Africa came together during the pick of the COVID-19, marking a shift from disciplinary to transdisciplinary approaches. They collaboratively embraced the change, which allowed the sector to continue providing the much-needed water and sanitation services. The extraordinary events induced by the COVID-19 pandemic required extraordinary measures and, certainly, the bold decisions taken by the water sector facilitated the continuation of essential services. The new norm

of conducting business brought about by the pandemic highlights the importance of clean water supply and its connections with public health, a need that facilitated the sector to continue playing a critical part in providing water solutions during the crisis.

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