UNIVERSITY OF CAPE TOWN

MAPPING THE POTENTIAL RISK OF CLIMATE CHANGE TO SOUTH AFRICA'S HEALTH SECTOR

An analysis of the Health Risk and Vulnerability Assessment Tool developed for the South African health sector.

By

Zachariah Weaver

WVRZAC001

A dissertation submitted to the School of Economics, Faculty of Commerce, in partial fulfilment of the degree of a Master of Commerce, Specialising in Economic Development (CM031ECO12).

Supervisor: Mike Morris

February 2022

Plagiarism Declaration

This work has not been previously submitted in whole, or in part, for the award of any degree. Each significant contribution to, and quotation in, this dissertation from the work, or works of other people has been attributed, and has been cited and referenced.

I have used the OneWorld (a modified Harvard referencing convention) referencing convention for citation and referencing.

Signature:

Signed by candidate

Date: 13/02/2022

ABSTRACT:

Health Risk and Vulnerability Assessments are key resources for national health departments to understand how to properly prepare for the impact of climate change on a country's health sector. However, countries often lack the required estimates of future burden of disease and of health services to undertake these assessments. This thesis examines the development and application of a Health Risk and Vulnerability Assessment Tool built by OneWorld Sustainable Investments for the South African National Department of Health to develop an understanding of the risk of climate change to the South African health sector by addressing the lack of estimates of future burden of disease and of health services. The thesis examines how the Tool was developed, and was able to build capacity on the impact of climate change on the South African health sector among district health officials, capture their estimates of future burden of disease and of health services to calculate the risk of climate change to the health sector, and then present the resulting risk data in an easy to understand and approachable manner for health officials to integrate into their climate change adaptation planning work.

ACKNOWLEDGEMENTS

Special thanks are given to OneWorld Sustainable Investments which gave the author access to the project data and information from the Capacity Building on Risk and Vulnerability Assessment Tool and Development of National Climate Risk and Vulnerability Assessment for the Health Sector (the project), and the Deutsche Gesellschaft Fur Internationale Zusammenarbeit (GIZ) GmbH for funding the project, and the beneficiaries the National Department of Forestry, Fisheries, and the Environment (DFFE) and National Department of Health (NDoH). This project falls under the Climate Support Programme, which is funded by the GIZ. All findings are not representative of the GIZ, NDoH, and DFFE. Further, given that this thesis' submission falls before the completion of the project, this thesis and example HVRA Tool provided are not reflective of the project's final findings, recommendations, risk data, or HVRA Tool. As such in-text refences referencing project documents in progress will have "forthcoming" in lieu of a date.

Particular thanks are given to the project team lead Belynda Petrie who provided project supervision and guidance to the thesis author, and Professor Emeritus Mike Morris for his supervision, and mentorship of the writing of this thesis. Further thanks must be given to the project team, which included Professor Jonny Myers (health sector expert), Dr Anthony Kinghorn (health sector expert, and workshop facilitation) and Arthur Chapman (climate change expert, workshop facilitation). Further thanks to the OneWorld team who supported the project team: Sarah Wewege (research and tool development), Tasneem Steenkamp (research and project management, and workshop facilitation), and Dylan Beukes (workshop facilitation).

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Burden of Disease	BoD
Climate change exposure	CCE
Centres for Disease Control	CDC
Continuing Education Unit	CEU
Climate Change Impact Assessment	CCIA
Communicable, Maternal, Perinatal, and Nutritional	CMPN
Community of Practice	CoP
Chronic obstructive pulmonary disease	COPD
Coronavirus Disease	COVID-19
Council for Scientific and Industrial Research	CSIR
Continuing Professional Development	CPD
Department of Forestry, Fisheries, and the Environment	DFFE
District Health Barometer	DHB
District health official	DHO
Health Professionals Council of South Africa	HPCSA
Health Risk and Vulnerability Assessment	HRVA
Intergovernmental Panel on Climate Change	IPCC
Geographic information system	GIS
Gesellschaft Fur Internationale Zusammenarbeit	GIZ
Greenhouse Gas	GHG
Major infectious diseases	MID
Non-communicable diseases	NCD
National Department of Health	NDoH
Representative Concentration Pathways	RCP
Years of life lost	YLL
World Health Organisation	WHO

1 INTRODUCTION

Climate change poses the most significant threat to human health, and if adaptation to climate change is not built into health systems, climate change has the potential to undermine the last 50 years advancement in medicine (World Health Organisation [WHO], 2021). The economic implications of this are significant. The costs of adaptation will dramatically increase the cost of providing healthcare beyond the expected increases due to population growth, and from labour losses due to workers temporarily being unable to work when sick or injured, or in extreme cases exiting the labour force due to debilitating illness or death. As such it is critical to integrate adaptation to climate change into health systems to reduce its impact on human health, and the economy. However, to achieve this it is first critical to have a clear understanding of the areas of vulnerability to climate change which exist, and from this what are the risks of health impacts due to climate change. To achieve this a health risk and vulnerability assessment (HRVA) needs to be undertaken to understand the specific risks and vulnerabilities which exist in a country, so that informed policy decisions can be taken. The standards for undertaking HRVAs have been set by the World Health Organisation (WHO) through their *Protecting Health from Climate Change Vulnerability and Adaptation Assessment* which is a set of guidelines for healthcare workers, policy makers, and climate change professionals on conducting HRVAs.

In ideal circumstances HRVAs are undertaken using an extensive modelling process which models the expected future changes to burden of disease (BoD), and health services, looking at the demand for these services, what are the future vulnerabilities of the communities they serve, and modelling this data with climate change data to develop a risk profile which helps direct planning activities (World Health Organisation [WHO], 2021). However, conducting HRVAs in this manner is extremely costly and is a highly time-intensive process, requiring a significant number of experts in several fields. Where this method is not feasible to undertake, the WHO recommends undertaking a blended approach, mixing quantitative climate change data and qualitative estimates of future BoD sets through discussions between national health experts to establish an understanding of the risk of climate change to the health sector.

It is within this context that the Capacity Building on Risk and Vulnerability Assessment Tool and Development of National Climate Risk and Vulnerability Assessment for the Health Sector (the project) was undertaken by OneWorld Sustainable Investments. The project was commissioned by the Deutsche Gesellschaft Fur Internationale Zusammenarbeit GmbH in collaboration with the National Department of Forestry, Fisheries, and the Environment (DFFE) and National Department of Health (NDoH) and is an expansion on previous scoping work and development of an HRVA Tool which was undertaken by the Council for Scientific and Industrial Research (CSIR) (CSIR, 2020).

This thesis is based on the work completed by Zac Weaver (the author) on the project while employed at OneWorld under the supervision of the Project Leader Belynda Petrie. The author was the Excel Technical Lead on the project and was tasked with developing the updated HVRA Tool – which is detailed in Chapter 3 Building the Tool – which included climate change risk analysis combined with public sector and BoD analysis, and supporting the project team in the Tool's implementation during a series of Capacity Building and HRVA workshops – whose design is detailed Chapter 4 Methodology, and the results of the workshops in Chapter 5 Applying the Tool. As such this thesis will refer to the project, and work completed by other members of the project team where work was not otherwise completed by the author, and will refer to the project team when work was completed by the author and other members of the project team. OneWorld has given the author permission to use the data from the project and allowed for the inclusion of the work which he conducted on the project and supplementary materials created for the project, although all health officials' names have been omitted when reporting on their feedback, given privacy agreements with the NDoH.

OneWorld is a private consultancy based in Cape Town which focuses on the climate change development in South Africa. The company works at the intersection between scientific research, development, and policy. The company is focused on the African continent and works to assist governments and regional organisations in technical analysis, applied research, and publishing (OneWorld, 2020). OneWorld four main areas of focus are climate change, urban resilience, valuing resources, and green transitions.

The project team took a blended quantitative and qualitative approach to conducting the HRVA. Quantitative climate change data from the CSIR's Greenbook climate change data, the Climate Research Unit's timeseries data, and Habitat INFO's climate change data was used to develop the climate change exposure (CCE) values used in risk modelling. This was combined with qualitative estimates of future BoD and health services collected from district health officials (DHOs) from all 52 health districts in South Africa. A full list of the districts in each province can be found in Appendix 1. DHOs were approached because an understanding of the vulnerability of the South African health system at a district level was required to properly analyse the risk of climate change to the health system at a national level, given the diverse set of circumstances, needs, and concerns present across South Africa. Thus, DHOs presented the best sources of knowledge on future BoD and health services in their communities, and how these are likely to improve or worsen, and thus were the best sources of the primary data needed to model the vulnerability of the health sector to climate change. However, DHOs' training on climate change's impact on the health system varies. As such the project needed to first build climate change knowledge among DHOs to enable them to accurately estimate the severity of future BoD and health services. Further, the resulting risk data and findings needed to be presented to health officials from a district to national level in an easy-to-understand manner that could be integrated into their own planning and decision-making work. As such this approach to analysing the risk of climate change to the health system required the HVRA Tool (the Tool) to be fully redesigned to better meet the NDoH's needs as a capacity building, data collection and data display tool, as per the specifications given by the NDoH.

Through detailing the development and application of the HRVA Tool, this thesis seeks to examine the research question: is the HRVA Tool able to convey complex climate change data to healthcare professionals in an easy-to-understand manner, such that they are able to give estimates of future BoD, which can then be used to model the risk of climate change to the South African health sector, and displayed in a manner which health officials can interpret and integrate into their work? As such this thesis explores how a simple and user-friendly computer program (in this case Excel based) can be one of the tools needed to address the lack of supplementary data needed to model the impact of climate change by collecting vital primary data from professionals. Africa is already experiencing issues with access to historical climate data to enable climate change modelling (Dinku, 2019; Nordling; 2019), and there are similar issues experienced accessing supplementary primary datasets which are required to model the risk of climate change in African countries – estimates of South Africa's future BoD at a district level being an example of this. Further, a significant shortcoming of climate change studies developed for governments is that they are difficult to understand given their significant complexity and are often not properly applied as they are not developed for the specific needs and work of the officials they are developed for (WHO, 2013; Intergovernmental Panel on Climate Change [IPCC], 2021; WHO, 2021). As such this thesis further seeks to examine how this Tool can bridge the gap between complex and difficult to understand climate change information and the professionals whose work will be impacted by climate change, by conveying that impact in a manner which is easily understood.

This thesis begins with a Guidelines Review – in lieu of a traditional literature review – which examines the HRVA guidelines set by the WHO, and examples of their application in other countries, in a manner relevant to the project's context. It then gives an in-depth description of the Tool's workings, modelling process, and thinking which underlines its design. It is recommended that this chapter, Building the Tool, is read in conjunction with the example HRVA Tool which has been provided (note the HRVA Tool has been populated with random data for KwaZulu-Natal to demonstrate its working). This is followed by the Methodology chapter, which examines the methodology of the Tool's application through a series of workshops, examining how the capacity development and data collection process was designed. This is then followed by the Applying the Tool chapter, which reflects on the practical application of the Tool, the responses to it from health officials, and recommendations on its improvement. Following this the Discussion of Findings chapter examines the climate change risk data which resulted from the 52 health districts future BoD estimates. It is important to note that while the Tool models future risk to both BoD and health services, the Discussion of Findings chapter only examines the BoD findings as this was within the author's purview. Finally, the Conclusion chapter provides an overview of the findings made with regard to the research question.

Please note that this thesis will refer to both DHOs and health officials, where DHOs is referring to district health officials specifically, while health officials is used when referring more broadly to health officials from a district, provincial, and national level.

2 GUIDELINES REVIEW

An extensive set of guidelines on conducting HRVAs has been developed by the WHO which has led to a large body of literature on how HRVAs have been conducted globally. This chapter will examine the guidelines established by the WHO and look at examples of their application relevant to the HRVA Tool. Given the collaborative, and discursive nature of the data collection method chosen for the project, a final section will examine communities of practice (CoP), and how discussions between professionals can be facilitated to allow for better engagement and high-quality data collection.

2.1 DEVELOPMENT OF GUIDES ON CONDUCTING HRVAS

The foundation of evidence-based descriptions for the links between climate change and health were laid by McMichael et al (1996) through their description of climate-sensitive diseases, and the direct and indirect pathways through which climate change impacts health. Their guide included tools and methodologies for establishing the interaction between local health and weather and climate conditions, and how tools such as geographic information systems (GIS) and accessing traditional and local knowledge allowed for more robust understandings of climate change's impact on health (McMichael et al, 1996). The guide – tailored for researchers - was found to be too cumbersome and complicated for health authorities utilising it, and as such a new guide was developed between 2007 and 2010 (WHO, 2009; Berry et al, 2018). The updated guide was tailored towards use by the health sector, with greater detail on conducting of assessments, engagement and communication with stakeholders, identifying resources for implementation, and potential barriers to action (WHO, 2009; Berry et al, 2018). After testing the guide in 12 countries, inputs from experts were onboarded, and the guide was released in 2013 as the *Protecting Health from Climate Change Vulnerability and Adaptation Assessment* which has become the standard for HRVAs and the flagship document used by the WHO, on which multiple countries have based their own guidelines, including South Africa (Berry et al, 2018). The guide has been supplemented by several documents which focus on specific areas of health, from vector-borne and zoonotic diseases to building climate-change-mitigating and resilient health infrastructure.

The latest version of the guide was released in 2021 and has seen a simplification of the overall document to be more user friendly, while incorporating the lessons learnt from the guide's use (WHO, 2021). This follows international trends in communicating climate change data and knowledge to policy and decision makers, in that information is intended to be highly targeted, relevant to users' needs, and presented in an approachable manner (IPCC, 2021). These characteristics are highlighted in both the 2013 and 2021 guide as being critical for identifying which areas of the health sector should be focused on, and how to effectively communicate the results of HRVAs (WHO, 2013; WHO, 2021). The updated versions were found to be more approachable and easier to use by health officials.

Overall, the guide follows a similar layout and steps as the 2013 version, with some sections being integrated into each other, while others have been made their own sections. For example, the Capacity Assessment has been moved out of Step 2 Conducting the Vulnerability and Adaptation Assessment, to become its own step named Step 3 Capacity Assessment. This reflects the WHO's learnings that understanding the current capabilities – or lack thereof – of health systems is critical for planning for future impacts. This step further identifies climate-sensitive health outcomes as among some of the leading causes of morbidity and mortality globally, asking users to consider how climate change and variability is currently affecting health (WHO, 2021). This step now includes how to identify policies, programmes, and infrastructure which is important to consider when assessing capabilities to deal with future climate change. Further, this now includes recommendations to assess other sectors which may have upstream impacts on the determinants of health, and forms part of the greater recognition of how climate change mitigating policies – such as reduction of GHG emissions, improving air quality or reducing the destruction of ecosystems – can result in significant improvements in health (WHO, 2021). Gao et al (2018) through a review of 36 peer-reviewed studies demonstrate how reductions in GHG emissions in almost all cases resulted in positive effects on human health, resulting in health outcomes ranging from a reduction in lung disease, to lower numbers of infant deaths. The latter for example is of particular concern in developing countries where electricity access is limited and burning of biomass is heavily relied on for heating, cooking, and light. In 2012 the WHO estimated that 63% of deaths

due to acute lower respiratory infections in children were due to household air pollution (WHO, 2015). As such this represents taking a wholistic view of the benefits from climate change adaptation and mitigation policies, emphasising understanding the interconnectivity of human systems, and the positive externalities which arise from actions taken.

The development of HRVAs since 1996 has seen a greater focus on utilising local and thematic data and knowledge for adaptation for the specific needs of health sectors (Berry et al, 2018). This focus is critical for creating assessments which are approachable, applicable, and relevant to policy and decision makers in health sectors, and thus increases the likelihood of HRVA's findings being correctly and fully integrated into the policy and decision-making process (WHO, 2013). This follows a larger trend in the climate change sector which seeks to make climate data, information, and associated actions needed to combat it easier to access by policy and decision makers. The 2021 Intergovernmental Panel on Climate Change (IPCC) report emphasises the need for this approach, as it has been a critical shortcoming of the climate change sector in the past, and has led to a lack of understanding which drives inaction (IPCC, 2021). As such, this emphasises the fact that mitigating and adapting to climate change is not solely about studying and understanding climate change, but ensuring that the results and outcomes found are easy to understand, approachable, and tailored to the needs and scope of work of policy and decision makers. Without this, inaction - or slow action - on climate change will continue, despite the existential threat it poses to humanity, and the planet's ecology.

HRVAs help health authorities to properly integrate into national climate policy and enable them to contribute to both national and international policy forums, allowing for advocacy which benefits health and combating climate change (Berry et al, 2018). Further, through the international sharing of assessments and evidence, not only is the body of knowledge on climate change and health expanded, but this also leads to more effective HRVAs, as shown by the development of the WHO's *Protecting Health from Climate Change Vulnerability and Adaptation Assessment.* More generally, the cross-sectoral and participatory nature of vulnerability and adaptation assessments facilitates cooperation between sectors, and allows for adaptation and risk management which is cross cutting, and thus can be more cost efficient, effective, and prevent the outcomes which lead to health impacts (Berry et al, 2018).

2.2 WHO'S RECOMMENDATIONS ON CONDUCTING HRVA

As noted above, the 2021 version of the WHO's *Protecting Health from Climate Change Vulnerability and Adaptation Assessment* is an updated, and simplified version of the 2013 guide, and as such both guides are drawn on to understand how HRVA's should be conducted. It is also important to note that while the WHO's *Protecting Health from Climate Change Vulnerability and Adaptation Assessment* (2013) provides a comprehensive guide for policy makers, only select sections are applicable to the scope and focus of this paper, and as such specific areas will be reviewed. Namely, these are those on establishing a scope, stakeholder processes, analysing relationships between current and past weather/climate conditions and health outcomes, understanding future health risks and impacts under climate change, how to estimate the additional burden of disease due to climate change, and how to effectively communicate a study's findings to the target audience (WHO, 2013).

In establishing the scope of an assessment, the WHO recommends beginning with establishing the geographical region and the health outcomes under assessment (2013). Geographical scale is either based on national or subnational area and will be dependent on resource availability and the requirements of the body commissioning the assessment. In terms of determining which health outcomes to study, either a specific focus on climate-sensitive health outcomes can be undertaken, or from the perspective of viewing changes in climate and how those will affect health outcomes (WHO, 2013). The former takes a more focused approach on specific health outcomes, while the latter has a wider scope that creates a more holistic (but more resources intensive) view of the impact of climate change on the health sector. For example, Portugal took a focused approach, looking at heat-related mortality, a selection of vector-borne diseases, and the impact of air pollution on health (Casimiro et al, 2006). This more focused approach was taken due to limited resources, and a specific concern about these diseases in Portugal's urban areas. By comparison, the forthcoming assessment by Health Canada takes a far more comprehensive view, assessing the impact of natural disasters, water and food security, water-, vector-, and food-borne diseases, infectious diseases, and health systems vulnerabilities (Government of Canada, 2021). While the latter represents

how far HRVAs have developed, both hold value in that they deal with the specific needs of users, with the resources available, to enable effective planning.

The United States' Centres for Disease Control (CDC) recommends a similar approach of establishing scope through identifying areas of interest and the associated climate change exposures (CCEs) and identifying the health outcomes associated with CCEs (Manangan et al, 2014). This approach, however, begins with the CCEs and then works outwards to identify which health outcomes are associated with them (Manangan et al, 2014), and is indicative of a more extensive and resource-intensive approach.

Once the geographical region and health outcomes, and CCEs are identified a stakeholder process needs to be established. The WHO notes that HRVA's need to involve all stakeholders involved in the management and prevention of climate change's impact on health (2013). This ranges from universities to ministries of health to non-governmental organisations, and while an initial smaller group of stakeholders may be identified, this group can change to include individuals with the experience and expertise necessary to estimate the changes in BoD (WHO, 2013). This is critical, as often those involved in policy and decision making are not those with the requisite knowledge of local circumstances and conditions, and thus are not able to make sufficiently informed estimates of these changes. The Republic of Macedonia's HRVA provides a good example for developing an adaptive and dynamic stakeholder engagement plan, in that the list of stakeholders engaged was updated as new information was gathered from the research and stakeholder engagement process, allowing for vulnerabilities which were identified to be more fully explored (Kendrovski et al, 2014). This further meant that a wider range of stakeholders were informed and capacitated during the process, and as such led to both a stronger research process, and better prepared and informed stakeholder groups (Kendrovski et al, 2014; WHO, 2013).

Stakeholder engagement extends beyond the consultation process to the distribution of the assessment and its findings, with the assessment's credibility enhanced by informing stakeholders of, and including stakeholders in, discussions on the assessment throughout its lifecycle (WHO, 2013). This level of continued communication means that the findings and inputs of the HRVA are relevant and useful to the stakeholders for whom the HRVA report is developed, and thus increases the likelihood of its use in decision making (WHO, 2013). As such, this helps mitigate the issues noted in the IPCC 2021 report, where stakeholders, and policy makers, are often left out of assessment processes, and thus do not have the requisite knowledge or capacity to integrate the findings presented to them (IPCC, 2021). The WHO (2013) notes that achieving this level of usefulness is aided by summary reports of full reports, which detail the assessment process, policies and programmes recommended, stakeholders involved, inputs considered, and findings made. While this final point seems fairly obvious, the importance of summary reports cannot be understated for achieving climate change assessments which are approachable and useful for stakeholders. This returns to the issue of the complexity of understanding climate change data, and how often this level of complexity results in poor or improper integration of climate change considerations into policy.

Once a stakeholder process has been established, it is important to establish the current BoD, it's vulnerabilities to climate change, and establish a baseline which can be used for future assessments (WHO, 2021). This begins with a description of the current burden and distribution of health outcomes, and usually will be based off existing studies, as undertaking new and comprehensive studies of health outcomes is a costly and time-consuming process (WHO, 2021). In most cases a list of prioritised climate-sensitive health outcomes is established, rather than a comprehensive review of all health outcomes.

After identifying the relevant health outcomes, their relationships with climate and weather patterns must be established - this includes factors such as temperature, humidity, and precipitation, and extends to extreme events such as floods, droughts, storms, wildfires, and sea-level rise (WHO, 2021). It is not strictly necessary to describe these relationships quantitatively, and instead expert judgement can be relied on to describe the relative relationships. Spatial mapping of climate change hazards for the current and future period should then be conducted. This allows for a geographical perspective of hazards which can either be used quantitatively to model relationships, or qualitatively to inform stakeholders of future scenarios so that they are able to make informed estimates of risk (WHO, 2021). It is important to note that the geographical and temporal resolution of health and weather/climate data may not align, and as such the resolution chosen should be one which both data sets can be aggregated to with as much accuracy as possible (Cherish & Wright, 2019). A further dimension which is important to consider are the vulnerabilities of populations to climate change. Vulnerabilities

are the propensity or predisposition of populations, livelihoods, ecosystems, and infrastructure to be negatively affected by climate change (IPCC, 2018). For example, impoverished communities, or individuals with disabilities, are more likely to be impacted by climate hazards, while livelihoods such as rain-fed agriculture are more susceptible to droughts, and infrastructure built along coastlines is more vulnerable to storm surges and rising sea-levels. There are often multiple and overlapping vulnerabilities which need to be considered, with vulnerabilities differing between sub-groups within a given population (WHO, 2021).

Turning to the modelling process, the analysis of the interaction between health outcomes and past and current weather/climate conditions plays a critical role in understanding how climate change will impact health in the future (WHO, 2013). This involves understanding current vulnerability at a geographical scale suitable to the needs of decision makers, for example in the case of South Africa this would be at the district level. In many cases quantitative data is not available to demonstrate these relationships, and instead experts can be relied on to estimate the impact in relative terms, allowing for relative comparison between time periods, and between diseases (WHO, 2013). This method can usually be bolstered by observations of the effects of seasonal changes and extreme weather events on epidemiological trends and disease outbreaks (WHO, 2013).

The most basic quantitative analyses model the relationships between health data and the main climate variables of temperature, relative humidity, and precipitation (WHO, 2013). It is important to note that there can often be a mismatch in the geographical units of health data and climate data and can result in weather/climate data being aggregated to the level of the health data, which reduces its accuracy (WHO, 2013). This becomes a greater issue in larger geographical areas, where altitude and distance changes mean that the aggregated data becomes far less representative (WHO, 2013). Models interacting data on climate change and health are critically needed to allow decision-makers to pragmatically identify key areas for intervention (Cherish & Wright, 2019). A review by Sweijd et al (2014) of South African climate and health studies notes that this type of modelling is critical, however in South Africa there is a mismatch between climate data which is recorded in small geographic units, while health data is at a district level (Cherish & Wright, 2019). However, as the WHO notes, this is less of an issue when making a relative assessment of the probable risks of health impacts given CCEs, as this is intended to give general ideas of risk rather than modelling the exact number of people affected.

The HRVA conducted by the Commonwealth of Dominica, for example, used a mixed quantitative and qualitative methodology, following the WHO's assessment guidelines (Schnitter et al, 2019). This began with a literature review establishing the relevant CCEs impact on health, utilising a distributed lag nonlinear model of the incidence of gastroenteritis in children under five due to rainfall extremes from 1993 to 2008, and finally utilising health sector stakeholders to develop a qualitative risk matrix which described the degree of impact of climate change on health in four priority areas, and the severity of these impacts. (Schnitter et al, 2019). This mixed method approach was utilised due to a lack of sufficient data to model climate change impacts on all four of the identified priority areas, but allowed for a baseline to be established for the future impacts of climate change on health (Schnitter et al, 2019). As such this allowed for the Dominican health sector to implement and steer policy from an informed perspective, strengthening the long-term response and establishing a foundation for future, more in-depth HRVAs.

Portugal presents another case study on utilising a mixed methods approach, where the lack of future projections of BoD was compensated for by utilising expert knowledge (Casimiro et al, 2006). The HRVA first performed a qualitative assessment to determine how vector-borne diseases would be affected by climate change in terms of the abundance and prevalence of associated vectors and pathogens (Casimiro et al, 2006). Then four projections of different impacts of climate change were constructed from current and projected climate conditions to understand how conditions which impact pathogen transmission would change, which a panel of experts used to estimate the transmission risk levels (Casimiro et al, 2006). Thus, even with limited or missing data the use of stakeholder engagement can be an effective means of building an understanding of risk to inform health sector planning. This is critical for developing countries, countries with limited projections of BoD, or constrained budgets, as it allows health systems to begin putting systems in place to deal with the impact of climate change, rather than having to react to BoD increases as they happen. These types of studies are also critical

for establishing a baseline which can then be updated when more comprehensive HRVAs are undertaken, which the WHO recommends are undertaken periodically (WHO, 2021).

This demonstrates how the WHO's guidelines can be adapted to local circumstances, and how even in circumstances of limited data availability, the knowledge of stakeholders and mixed method approaches are able to establish baseline understandings of risk. This makes for a powerful planning tool for policy and decision makers as it enables informed planning that has access to information relevant to the specific areas of interest and need to them. In the Dominican case, by focusing on areas which are already identified as priorities to the health sector, the HRVA can analyse BoD which is relevant to local circumstances, and thus focuses study on a BoD which is likely to continue to be of concern.

2.3 Learning from Communities of Practice as Mediums for Collaborative Knowledge Creation, and Sharing

The WHO's guidelines on conducting HVRAs establish the means for gathering estimates of future risk through discussions held between health professionals, but do not provide recommendations on how to conduct these discussions in a means which optimises and facilitates the collaborative creation and sharing of knowledge. However, this type of discussion between health professionals fits Lave and Wenger's (1991) definition of a CoP as a grouping of individuals with a shared domain of interest and competence who come together to share practical experience and knowledge on a topic, with more current definitions defining a CoP as involving professionals from various organisations working collaboratively on a project or to support a goal (World Bank, 2018). CoPs are intended to establish self-sustaining communities of professionals, and while continued interaction is less important in the short-term vision of the project, CoPs provide a wealth of knowledge on how to facilitate discussions between professionals to enable collaborative knowledge sharing and creating. However, as the WHO (2013) recommends that HVRAs should be repeated periodically, and as is explored later in the paper, the development of a cohort of South Africa health officials trained on, and engaged with climate change, will be critical to the success of future iterations of the project.

In CoPs, the desire to share information helpful to colleagues works to create a shared sense of purpose and reciprocity, which helps to develop a sense of inclusion and encourage engagement on the grounds of a shared professional identity (Britt & Paulus, 2016; Riverin & Stacey, 2008). Iyalomhe et al (2013) in their study of the interface between science and policy for climate change adaptation, found that networks are sustained when there is a communal purpose of enhancing and growing a field of knowledge. Schwen and Hara (2003) through a meta-analysis of CoP studies find members who have a strong personal meaning in their work tend to create more healthy CoPs and discussions, and when the exchange of knowledge is meaningful and helpful to their work (Riverin & Stacey, 2008; Cowan, 2012). The formation of identity was rooted in the practise of their profession, and where the goal of CoPs supported their work (Schwen & Hara, 2003). However, despite the importance of these discussions, many professionals will choose not to engage because contributing is time consuming for already time-short individuals, and thus contributing must generate value significant enough to warrant engagement (Cuthell, 2005; Petrie et al., 2018). Further, community recognition of users' contributions is highlighted as a driving force behind users contributing information and participating in discussions, with recognition coming both from members acknowledging repeated contributors, and formalised recognition systems which acknowledge how much and what quality of content members contribute (Bharwani, 2011).

Online CoPs found that while free-form discussions did generate interaction, facilitated conversations led to a substantial increase in engagement (Britt & Paulus, 2016). As with in-person events, a facilitator is required for online communities to provide active moderation, and facilitation to guide and stimulate discussions (Petrie et al, 2018). This can also be organised around a core group of contributors who have significant experience and are consistent in their contributions to discussions, making them recognisable as community 'leaders' (Bharwani, 2011; Britt & Paulus, 2016).

All CoPs will have a core group which will drive participation, and form the initial group which contributes to the development of the CoP, while other members will either be members who actively contribute to discussions, or peripheral members who mainly observe discussions and occasionally contribute (Wenger, 2006; World Bank, 2018). The core group

provides a ‘members’ perspective’ on the development process and the CoP’s operation, drives a sense of ownership by being included in the development process, and the core members act as role models of how to interact (World Bank, 2018). The core group members do not need to be the most experienced experts, instead they should be those who are most enthusiastic about the community and thus most likely to participate and subsequently act as participation and contribution leaders (World Bank, 2018).

For application to the project, CoPs demonstrate that eliciting meaningful engagement from professionals requires that the discussions are directly relevant to their work, that their contributions are reciprocated, and a sense of shared professional identity is established. For the project this will require establishing the significant impact of climate change on health, and providing examples which are relevant to the systems in which health professionals work. Further, discussions should be facilitated to increase the number of individuals who contribute, and to improve the quality of discussions. This is particularly important for the online workshops given that discussions are less free flowing than in-person discussions. Formal recognition of participation in and contribution to the workshops will further encourage engagement and participation during the workshops and will help develop longer-term interest in continued participation in future iterations of the project. Finally, stakeholders who are passionate about and engaged with the project can be identified to form a core group of health professionals to help develop and facilitate future iterations of the project.

3 BUILDING THE TOOL

The following chapter will examine how the Tool works, taking an in-depth view into the decision-making process, and intention behind the design of each section of the Tool to maximise its ability to build climate change capacity among health officials, capture health estimate data, and display resulting risk data. It is advised that the reader have the example version of Tool open when reading this chapter (which can be found in Appendix 2), as it will aid in understanding the flow and layout of the Tool. Note that all relevant sheets have been unhidden for this thesis, while the Tool used by DHO's only has the coloured sheet tabs visible.

3.1 RESEARCH METHOD UNDERTAKEN

The primary purpose of this Tool is on collecting health data in sub-optimal circumstances, and how to present complex climate data and risk profiles in a means which is easy to understand and interpret by DHOs who have varying knowledge of climate change and its impact on the health sector. These circumstances can be viewed as sub-optimal as the health data collected is based on the knowledge, experience, and subjective opinions of DHOs, rather than being modelled through scientific methods, and as there was limited time to train and capacitate DHOs on climate change and its impact on BoD, and to collect data from them.

There is a pressing need to understand the impact of climate change on the health sector in South Africa to allow for proper planning and adaptation (Cherish & Wright, 2019). Crucial to this is being able to model the interaction between future BoD and CCE to form an understanding of potential risks of the health impact (Sweijd et al, 2014). While South Africa has comprehensive climate change models developed by various institutions, and an extensive body of work considering the effects of climate change in South Africa on BoD both from a quantitative and qualitative perspective, none of this work provides comprehensive estimates across the country at a district level, and as such makes this form of risk modelling impossible.

Thus, in the absence of scientifically modelled BoD data, the WHO's approach of discussions between health professionals to estimate future severity of BoD, was followed. The DHOs represent the best authorities on future BoD, given their extensive experience and knowledge of their districts. However, given the number of districts and the distance between them, the Tool presents a means to engage DHOs in discussions of future BoD and capture DHOs estimates through self-assessments across numerous workshops. While using DHOs' estimates does lend a level of inaccuracy to the results, it also represents a level of nuance which can only be gained by incorporating the knowledge and experience of DHOs. Further, the capacity-building aspect of the project was critical as it allowed for the bridging of the gap between climate scientists and stakeholders by presenting complex and difficult to understand climate change data in a means which is easily comprehensible. Thus, the Tool's aim was to address the gap between accessing and understanding climate change data and health officials, by building climate change knowledge, capturing future health estimates, and modelling the risk of CCEs to BoD and health services data at the district level to enable effective planning for climate change's impact on South Africa's health sector which is informed from a local and national perspective.

3.2 DATA UTILISED

The CSIR's Greenbook data was developed for the public and government officials to have access to quantitative data of the likely impacts of climate change and urbanisation in South Africa (CSIR, 2019). The data is mapped spatially at the municipal level and with district markers, and as such was used to build the climate change dataset. This was supplemented by data from the Climate Research Unit's Time Series data, which is a global gridded timeseries climate change dataset (Harris, 2021), with the overall climate change dataset developed by Arthur Chapman for the project. This was supplemented by flood, and fire data mapped, and modelled by Rob Davies of Habitat INFO, using climate change datasets developed by OneWorld. Out of the four Representative Concentration Pathways (RCPs), RCP 8.5 was selected. The RCPs are a series of four greenhouse gas concentration trajectories utilised by the IPCC to make projections based on anthropogenic greenhouse gas (GHG) emissions (IPCC, 2014). RCP 2.6 represents stringent mitigation of GHG, RCP 4.5 and 6.0 represent

intermediate mitigation, while RCP 8.5 represents unmitigated GHG which continues to rise throughout the 21st century (IPCC, 2014; Davis-Reddy & Vincent, 2017). RCP 8.5 was selected as it offers a 'no regrets' option to modelling, as modelling the lower RCP levels may result in overly optimistic projections and an under-prepared health sector.

To provide DHOs with current BoD as a baseline for their estimates of future severity, the Health Systems Trust District Health Barometer (DHB) 2019/2020 data was used (Health Systems Trust, 2020). The DHB is a statistical resource containing primary healthcare data from all 52 health districts and used by the NDoH to monitor district performance and inform planning at a provincial and national level, which is released annually (Health Systems Trust, 2020). Unfortunately, the same data is not available for health services.

Further, note that all maps, graphs, and tables in this chapter were generated by the author – unless otherwise stated – for the project using the Tool under his duties in the project team, and with all maps, graphs, and tables reviewed by the greater project team. As such all maps, graphs, and tables are referenced to the project documents they appear in. The CSIR Greenbook data and Climate Research Unit's Time Series Data was utilised to generate the maps of CCEs, all graphs and tables of baseline BoD data used the DHB health data, and finally all graphs, and tables displaying risk data were generated for illustration purposes using randomly assigned severity rankings. Further, note the because the project is still in progress, the example Tool does not have fire data integrated into it, as it is pending addition from the project team. Thus, while it is noted in this chapter, and later chapters, fire data has not been integrated into the current risk calculations. All tables, and graphs when displaying districts utilise KwaZulu-Natal's districts for illustration purposes.

3.3 DATA MANIPULATIONS PERFORMED

The CCE data from the municipalities forming the districts were averaged to form district CCE values. This was done for number of very hot days (days where temperature exceeds 35°C), extreme precipitation days (where precipitation exceeds 20mm), relative humidity, floods, and drought. These CCEs were selected as they are the most common CCEs which impact BoD, and as very hot days, extreme precipitation days, and relative humidity form the three basic CCEs that the WHO recommends for all HVRAs (WHO, 2013). As the CCEs are probabilistic projections of future climate events, by separating the data into quartiles (Table 1) it is possible to then give a probability of occurrence to each of the districts for their specific CCEs relative to the national CCE dataset. The probabilities approach, and the probabilities which were assigned were developed by Professor Jonny Myers as part of the project, and are shown in Table 2 (Petrie et al, 2021b). As such the risk of a health impact due to CCEs should be considered a relative risk, as the risk factor is compared relative to national CCE values, and thus risk values should be understood as showing the risk to a district's BoD, or health service, sub-category relative to other districts.

Table 1 Climate Change Data Represented as Quartiles

	EXTREME PRECIPITATION DAYS	VERY HOT DAYS	RELATIVE HUMIDITY	FLOOD	DROUGHT
MINIMUM	-2.1	0.23	0.01136	2	1
0.25	0.01	5.065	0.03623	6	6.5
MEDIAN	0.6	12.59	0.04425	8	50.5
0.75	1.625	29.655	0.05322	13	118
MAXIMUM	4.06	79.8	0.13274	256	1844

(Petrie et al, 2021b; data from CSIR, 2019)

Table 2 Probabilities of Climate Events Occurring

DESCRIPTOR:	VERY RARE	POSSIBLE	LIKELY	ALMOST CERTAIN
LIKELIHOOD FACTOR	0.1	1	3	10
QUARTILES	Minimum<X<0.25	0.25<X<Median	Median<X<0.75	0.75<X<Maximum

(Petrie et al, 2021b)

Baseline BoD was established using two sets of data from the DHB. Firstly, the years of life lost (YLL) by percentage for the four main categories of BoD by district from the year 2017 (the latest available), and secondly, the DHB ranking of each of the top 26 diseases in South Africa for each district as of 2020 was used (shown in Table 3) (Massyn et al, 2020). The latter ranks BoD from one (most significant contributor to BoD) to 20 (least significant contributor to BoD) and was used to indicate the current severity of each sub-category. The scale was reversed by Professor Jonny Myers for easier interpretation when represented graphically, as follows:

$$\text{BoD ranking} = 21 - X$$

Thus, the most significant health impacts have a higher numerical value, beginning ranking at zero for no data and then scaling upwards to 20 for the highest rank. The sub-categories then had their quintiles determined, shown in (Petrie et al, 2021b; data from Massyn et al, 2020)

Table 4. Quintile rankings of districts' sub-categories of BoD allows DHOs to compare their district' current severity of BoD to the national dataset as a point of reference when making their estimates of future severity of BoD.

Table 3 Burden of Disease Categories and Sub-Categories

Injury	Major Infectious Diseases	Communicable, Maternal, Perinatal, and Nutritional	Non-communicable Diseases
Interpersonal violence	HIV/Aids	Lower respiratory tract infections	Cardiovascular disease
Road injuries	Tuberculosis	Diarrhoeal diseases	Diabetes mellitus
Mechanical forces		Preterm birth complications	Hypertensive heart disease
Exposure to natural forces	Septicaemia		Ischaemic heart disease
Hanging, strangulation	Meningitis/encephalitis		Endocrine, nutritional, blood, immune system
Other transport accidents	Sepsis/other new-born infections		Chronic obstructive pulmonary disease
		Other perinatal conditions	Nephritis/nephrosis
		Malaria	Epilepsy
			Asthma
			Prostate

(Petrie et al, 2021b; data from Massyn et al, 2020)

Table 4 Quintiles for BoD Sub-categories[1]

	Minimum	0.2	0.4	0.6	0.8	Maximum
HIV/Aids	17	19	20	20	20	20
Tuberculosis	17	18	19	19	19	20
Cardiovascular disease	12	15	15	16	18	18
Diabetes mellitus	8	12	13	14	15	17
Hypertensive heart disease	6	11	13	14	16	17
Ischaemic heart disease	0	8.6	11.2	14	16	20
Endocrine, nutritional, blood, immune system	5	10	12	13	16	18
Chronic obstructive pulmonary disease (COPD)	0	0	5	8	12	19
Nephritis/nephrosis	0	1	5.2	8	9	14
Epilepsy	0	0	0	2	4.4	9
Asthma	0	0	0	0	4.4	10
Prostate	0	0	0	0	0	6
Interpersonal violence	0	9	11.2	14	16	18
Mechanical forces	0	0	4	8	11.4	19
Road injuries	0	1.2	8.2	13	16	17
Hanging, strangulation	0	7	9	10	12	15
Exposure to natural forces	0	0	0	0	0	0
Other transport accidents	0	0	0	0	0	0
Lower respiratory tract infections	10	15	17	18	18.4	20
Diarrhoeal diseases	0	3.2	9	11	14	17
Preterm birth complications	0	0	4	6	8	13
Septicemia	0	0	2	3.8	7	10
Meningitis/encephalitis	0	0	0	0	4	9
Sepsis/other new-born infections	0	0	0	0	0	2
Other perinatal conditions	0	0	0	0	0	4
Malaria	0	0	0	0	0	10

(Petrie et al, 2021b; data from Massyn et al, 2020)

[1] Note that data on several sub-categories was either non-existent or severely limited to only a few districts, with missing data represented as a zero.

Finally, a table of interactions between the CCEs and BoD sub-categories was developed. As noted previously, there has been no attempt to develop a consolidated list of interactions between CCEs and BoD in South Africa, however an extensive body of work looking at individual diseases exists – although none give definitive, quantitative interactions. Thus, based on the literature, a table of interactions between CCEs and BoD sub-categories was developed by the project team's two health experts, Professor Jonny Myers and Dr Anthony Kinghorn, and climate change adaptation expert Arthur Chapman (Petrie et al, 2021b) to inform the Tool's risk model.

The Interaction Table (Table 5) uses a simple method of ranking the interaction between CCEs and BoD sub-categories, with ranks of zero (no effect), one (increase), or two (significant increase). This then allowed for the DHOs' severity estimates and CCE data to be modelled to estimate the probable relationship between the two datasets. There is no recognised or formalised quantitative ranking on which these interactions could be based, and as such is a quantitative representation of qualitative knowledge.

Table 5 Interactions between Climate Change Parameters and BoD Sub-categories

	EXTREME PRECIPITATION DAYS	VERY HOT DAYS	RELATIVE HUMIDITY	FLOOD	DROUGHT
HIV/AIDS	0	0	0	0	1
TUBERCULOSIS					
LOWER RESPIRATORY TRACT INFECTIONS	1	0	0	1	0
DIARRHOEAL DISEASES	2	2	1	2	1
PRETERM BIRTH COMPLICATIONS	2	1	0	0	1
SEPTICAEMIA	2	1	1	1	
MENINGITIS/ENCEPHALITIS	0	0	0	0	1
SEPSIS/OTHER NEW-BORN INFECTIONS	2	2	1	1	1
OTHER PERINATAL CONDITIONS	2	0	0	1	1
MALARIA	2	2	1	1	0
CARDIOVASCULAR DISEASE	0	2	2	1	0
DIABETES MELILITES	0	0	0	0	0
HYPERTENSIVE HEART DISEASE	0	2	2	0	0
ISCHAEMIC HEART DISEASE	0	2	2	0	0
ENDOCRINE, NUTRITIONAL, BLOOD, IMMUNE SYSTEM	0	0	0	0	0
CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)	0	1	1	1	0

NEPHRITIS/NEPHROSIS	0	1	0	0	1
EPILEPSY	1	0	0	0	1
ASTHMA	2	1	1	1	0
PROSTATE	0	0	0	0	
INTERPERSONAL VIOLENCE	0	2	0	0	1
MECHANICAL FORCES	0	2	2	0	0
ROAD INJURIES	2	2	2	1	
HANGING, STRANGULATION		2	2	0	0

(Petrie et al, 2021b)

3.4 TOOL METHODOLOGY

The main consideration behind the design of the Tool was to present baseline health and CCE data in the most simple and user-friendly manner, allowing individuals with varying Excel and climate change competency to use the Tool with ease. As such most of the calculations and interactions of DHO's inputted data with the CCE data happens in the Tool's hidden sheets, namely in the various dataset sheets and the Data Process – Injury, Data Process – MID, Data Process – CMPN, Data Process – NCD, and Data Process - Services sheets. As the focus of this thesis is on the process of data collection and its final presentation, the front-end Dashboard sheets are presented first, before turning to the hidden sheets which calculate the risk of health impacts given CCEs.

The method which the Tool attempts to model the risk of climate change to the health system is through the risk of a health impact due to climate change. This means what is the risk to a given disease, or health service, being worsened by CCEs, such that there is either a higher incidence of the disease or demand for the health service, or that existing cases of the disease are aggravated by CCEs, or the provision of a health service is made more difficult given the impacts of CCEs? Thus, the risk of a health impact considers an increase in number of patients, and a worsening of patients' conditions or reduced ability to treat patients due to the impact of climate change.

3.4.1 Tool Capacity Building Sheets

DHOs were guided through the Tool during a Capacity Building Workshop, which was then followed by a later HRVA Workshop where data was collected. The Capacity Building Workshop involved a brief overview of the project for which the Tool was commissioned, and then running through how the Tool works. This begins with the capacity building sheets (sheet tabs' colour coded green in the Tool), which are critical for building knowledge of climate change and its potential impacts on South Africa's health sector. This also served as a time for DHOs to raise any questions and suggestions on the Tool before data collection.

The Tool begins with a brief Instruction Sheet which describes each stage of using the Tool. This serves as a basic guide to the processes employed in the Tool and which DHOs can refer to when utilising the Tool outside of the HVRA Workshops. The Instruction sheet also captures the information of the DHOs entering data into it and allows them to choose their province from a dropdown list which will filter what data is presented throughout the Tool.

The process of capacity building within the Tool begins with the Climate and Health Impact Sheet. This is intended to give the DHOs an overview of the impact of the CCEs across South Africa, CCEs interactions with the BoD sub-categories, and an overview of current BoD in DHOs' selected province. The expected changes in the three main CCEs are demonstrated through three maps, shown in Figure 3, which were generated by using the district CCEs dataset and the Excel 3D Maps tool. Excel 3D Maps spatially maps data, with varying means of displaying the data. A colour gradient display was used, following the standard means of presenting mapped CCE data modelled with GIS. This format is easy to understand and

interpret, even if the user has limited knowledge of the subject matter. By visualising the data, it is intended to establish baseline knowledge on CCEs among the DHOs which can later be referenced when estimating future BoD and health services.

A portion of the Interaction Table (Table 5) is then presented to DHOs, as shown in

Interaction of Climate Change Exposures on Health Categories							
	Climate Change Parameters						
BoD Sub-category	Very Hot days	Relative Humidity	Extreme precipitation days	Flood	Drought	Fire	Reasoning
Cardiovascular disease	Significant Increase	Significant Increase	No Effect	Increase	No Effect	Increase	Could cause stroke via stress or aggravate cerebral perfusion insufficiency via drought conditions with dydration. Also heat exhaustion and heatstroke.
Diabetes mellitus	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Hypertensive heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	Could aggravate and reduce cardiac output through venous pooling and deydration
Ischaemic heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	As for hypertensive heart disease
Endocrine, nutritional, blood, immune system	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Chronic obstructive pulmonary disease	Increase	Increase	No Effect	Increase	No Effect	Increase	Aggravate via the work of breathing, growth of mould and fungus in damp/humid conditions and via smoke particulates
Nephritis/nephrosis	Increase	No Effect	No Effect	No Effect	Increase	No Effect	No relationship
Epilepsy	No Effect	No Effect	Increase	No Effect	Increase	No Effect	No relationship
Asthma	Increase	Increase	Significant Increase	Increase	No Effect	Increase	Hot and humid conditions could promote allergens such as pollens and moudly fungal growth indoors
Prostate	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship

.

This is a dynamic table which can display any one of the four BoD categories to the DHOs using a dropdown list. As with the maps of the CCEs, this serves to capacitate the DHOs and establish a baseline understanding of how CCEs will affect BoD in South Africa.

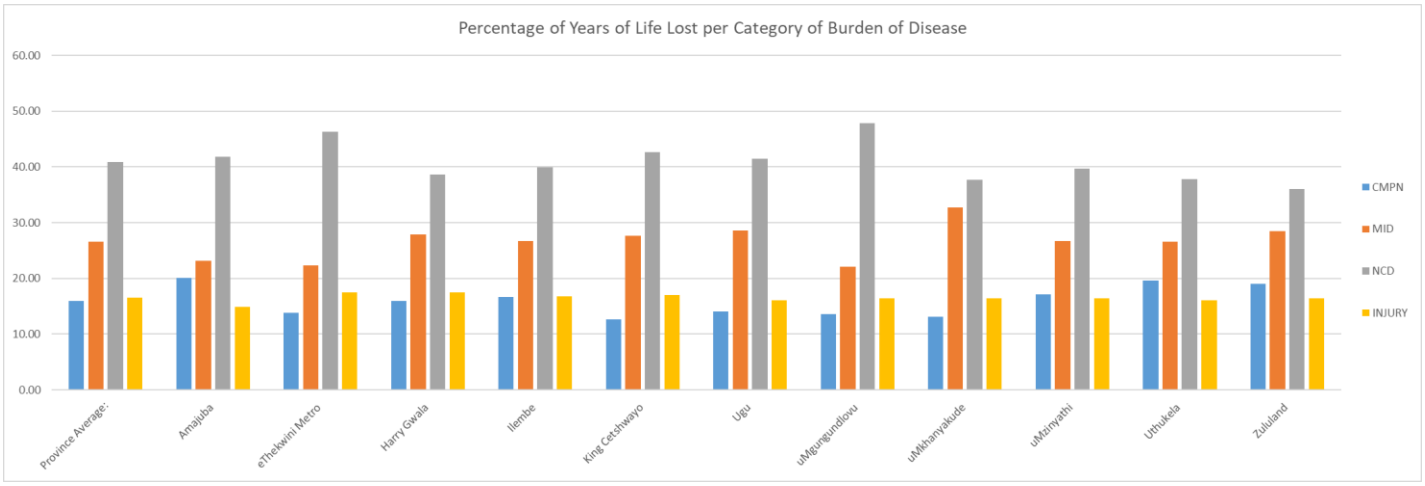
Figure 1 Interaction Table of Climate Change Impacts on Health Categories Displayed to Stakeholders

Interaction of Climate Change Exposures on Health Categories							
	Climate Change Parameters						
BoD Sub-category	Very Hot days	Relative Humidity	Extreme precipitation days	Flood	Drought	Fire	Reasoning
Cardiovascular disease	Significant Increase	Significant Increase	No Effect	Increase	No Effect	Increase	Could cause stroke via stress or aggravate cerebral perfusion insufficiency via drought conditions with dydration. Also heat exhaustion and heatstroke.
Diabetes mellitus	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Hypertensive heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	Could aggravate and reduce cardiac output through venous pooling and deydration
Ischaemic heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	As for hypertensive heart disease
Endocrine, nutritional, blood, immune system	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Chronic obstructive pulmonary disease	Increase	Increase	No Effect	Increase	No Effect	Increase	Aggravate via the work of breathing, growth of mould and fungus in damp/humid conditions and via smoke particulates
Nephritis/nephrosis	Increase	No Effect	No Effect	No Effect	Increase	No Effect	No relationship
Epilepsy	No Effect	No Effect	Increase	No Effect	Increase	No Effect	No relationship
Asthma	Increase	Increase	Significant Increase	Increase	No Effect	Increase	Hot and humid conditions could promote allergens such as pollens and moudly fungal growth indoors
Prostate	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship

(Petrie et al, 2021b)

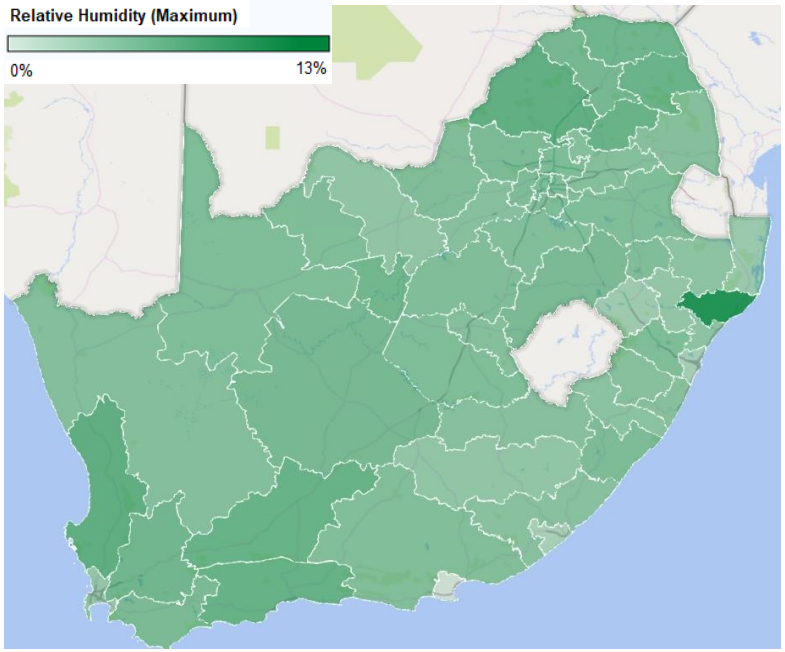
The final component of the Climate and Health Context Sheet is a dynamic graph of the latest data on years of life lost (YLL) for the four categories of BoD, shown in Figure 2, which displays data based on the province DHOs selected in the Instructions sheet. While the DHOs represent the best authorities on BoD in their districts, it is acknowledged that it is difficult to recall exact values for a BoD category, the impacts in comparison to each BoD category, and between districts in the province.

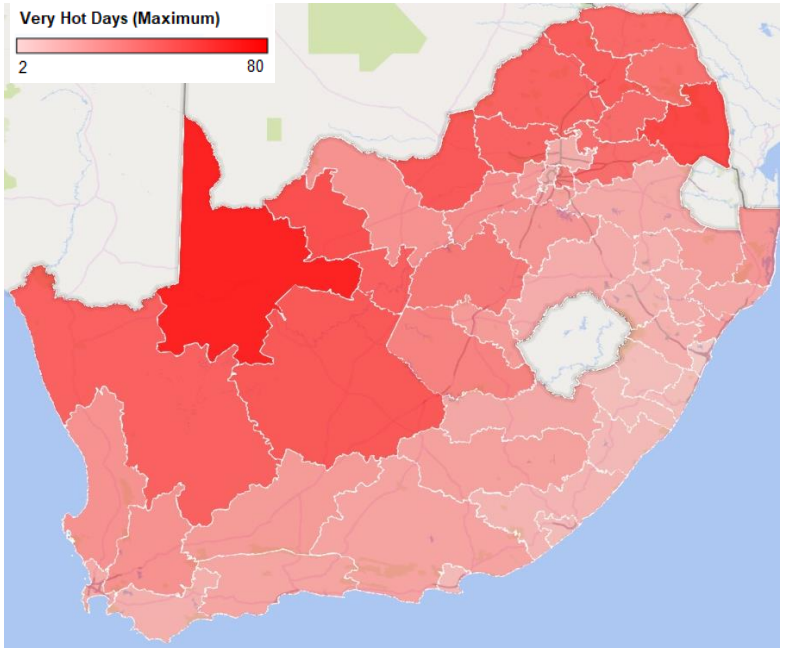
Figure 2 Percentage of years of life lost per category of burden of disease from Climate and Health Context sheet

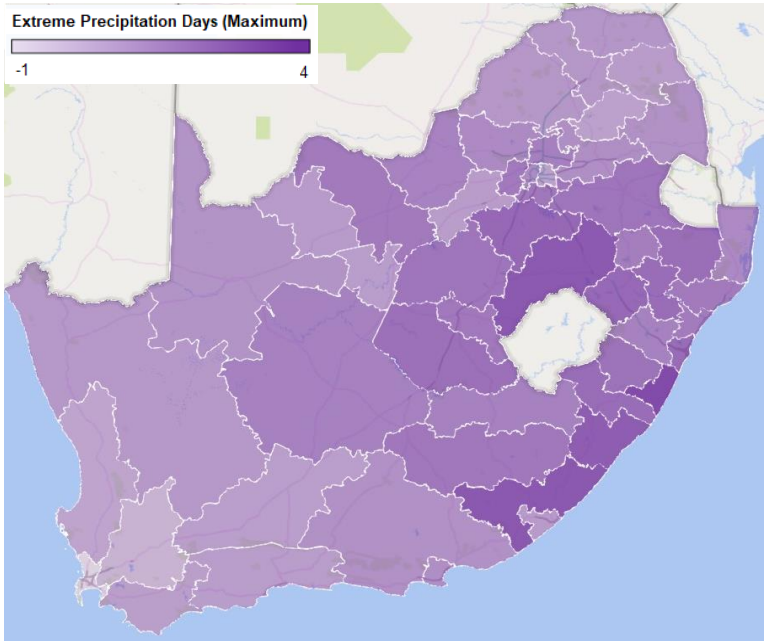


(Petrie et al, 2021b; data from Massyn et al, 2020)

Figure 3 CCE Maps displayed in Climate and Health Context sheet







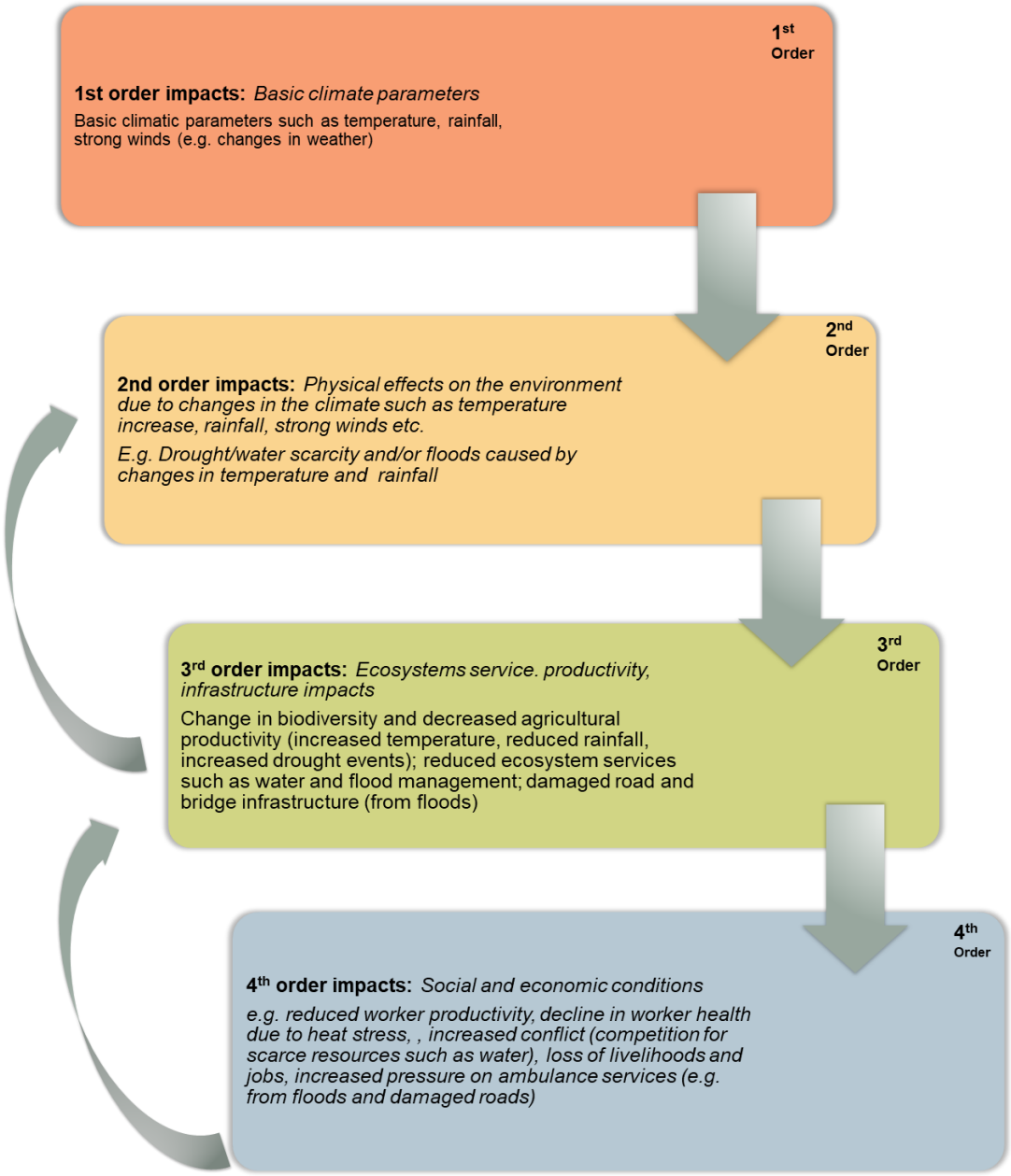
(Petrie et al, 2021b; data from CSIR, 2019)

The next sheet which the DHOs interact with is the Climate Change Impact Assessment (CCIA), which helps to assess the impacts of CCEs and develop an understanding how they cascade through the district health system. By taking the DHOs through the various stages of impact, starting from those outside the control of the healthcare system, it allows DHOs to conceptualise, and then plan for how these impacts will affect them (Petrie et al, 2021b). This employs a 1st-to-4th Order Impact Assessment, which is a tool developed by, and intellectual property of OneWorld (Petrie et al, 2016), an example of which is shown in Figure 4.

The 1st-to-4th Order Impact Assessment was developed by OneWorld to convey the complex and less tangible drivers of climate change vulnerability and impact through a system to stakeholders (Petrie et al, 2021b). By moving from the basic climate parameters through to the social and economic conditions, stakeholders can better conceptualise the connections between climate change and the real impacts these will have on the systems which they inhabit. This is an important framing tool, as it allows for the less obvious impacts of climate change to be understood in a manner which is tangible and personalised to the experiences of stakeholders (Petrie et al, 2021b). The Assessment begins with the First Order Impacts which are basic climate parameters – such as increased temperature - which the CCEs fall under. It then moves to the Second Order Impacts which are the effects which these changes will have on the environment, such as droughts or water scarcity caused by rising temperatures. The Third Order then describes how the Second Order impacts on ecosystem services and production potential, such as increased food-, water-, and vector-borne diseases due to increased temperatures. Finally, the Fourth Order Impacts view how the proceeding impacts cascade through systems to impact social and economic conditions, such as increased acute malnutrition from diarrhoea caused by increased food- and water-borne diseases.

In the Tool the 1st-to-4th Order Impact Assessment is implemented through a series of dropdown menus and textboxes for DHOs to input information into (*Figure 6*). They are first presented with a brief description of what a 1st-to-4th Order Impact Assessment is, and the example shown in Figure 4, as well as a table which gives the quartile ranking for the province's CCEs (Figure 5). The CCE quartiles allow DHOs to understand what are the most significant CCEs in their province, and thus act as a baseline for the First Order. This is the final sheet utilised for capacity building, and from here onwards the DHOs will interact with the various Dashboard sheets which are utilised to capture their estimates of future BoD.

Figure 4 1st-to-4th Order Impact Assessment Model example shown to DHOs



(Petrie et al, 2016)

Figure 5 Quartile Rankings of the Province's CCEs

Main Climate Concerns for Your Province:	Quartile Ranking:
Extreme precipitation days	3
Very Hot days	2
Relative Humidity	2
Drought	3
Flood	4

(Petrie et al, 2021b; data from CSIR, 2019)

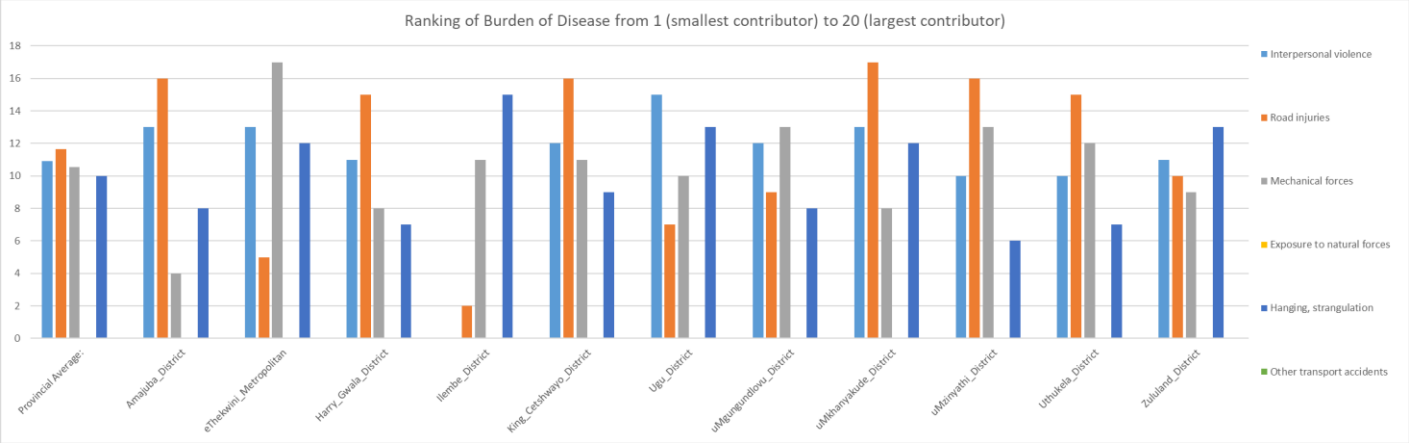
Figure 6 1st-to-4th Order Impact Assessment used by DHOs

1. Select First Order Impact	
Please select	
Please select	
2. Select Second Order Impact	
Please select	
Please select	
3. Third Order Impacts- How will the 2nd order impact affect the ecosystem and your environment, your infrastructure or daily business operations? Please list these below:	
flooding will lead to damage in healthcare infrastructure and roads	
Increased water scarcity will lead to dehydration and malnutrition as a result of decreased crop yields	
4. Fourth Order Impacts- How will the 3rd order impacts affect your social and economic conditions in the health sector? (e.g. things like health, productivity, access, employment etc.)	
Increase in number of road accidents and injury	
Pressure on the healthcare system due to increased illness (dehydration, malaria, malnutrition etc.)	
In summary, what impact will climate changes have on communities and livelihoods as well as the health sector?	
Impact on communities & livelihoods	**Impact on the economy & health sector**
loss of jobs	loss of productivity
decreased health in communities	Pressure on systems

(Petrie et al, 2021b)

3.4.2 Tool Data Capture and Display Sheets

All the BoD Dashboard sheets follow the same layout, with each capturing severity estimates and displaying risk data for one of the BoD categories, as such the Injury category will be used to demonstrate its workings and have sheet tabs colour coded blue. The Dashboard begins by displaying the current BoD data for the Injury sub-categories for the selected province. Firstly, a graph of the BoD sub-categories for all the districts in the selected province are displayed, shown in



. This gives the values of the sub-categories as their values from one (smallest contributor to BoD in district) to 20 (largest contributor to BoD in district) as per the DHB. Secondly, the quintile BoD data from Table 4 is displayed as

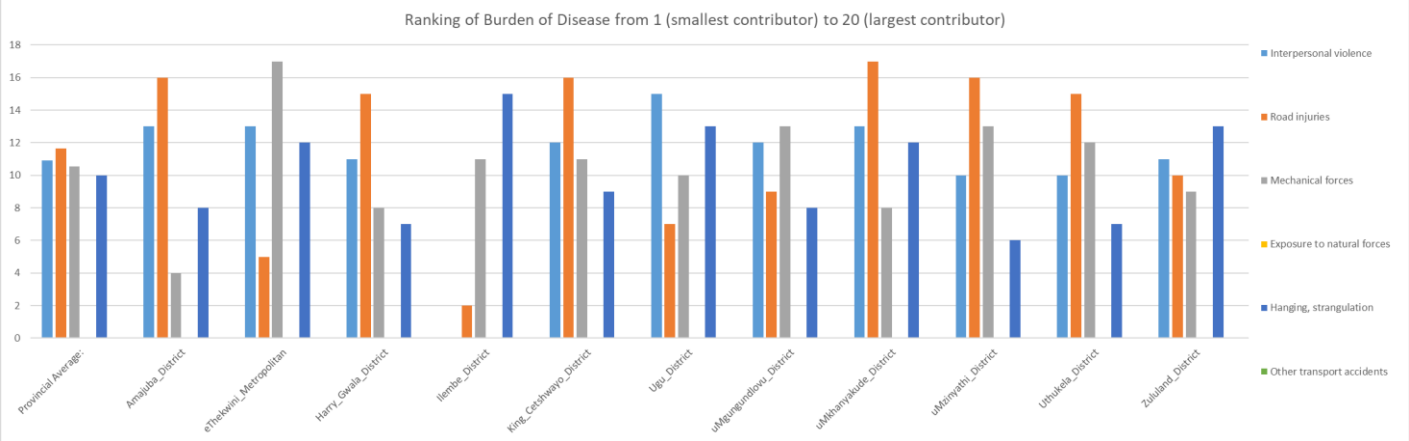
District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

. Note in

District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

a zero represents when there is no data in the DHB for a district. Presentation of current BoD data is intended as a point of reference for DHOs when they are providing estimates of future BoD severity.

Figure 7 Ranking of Burden of Disease from 1 (smallest contributor) to 20 (largest contributor)



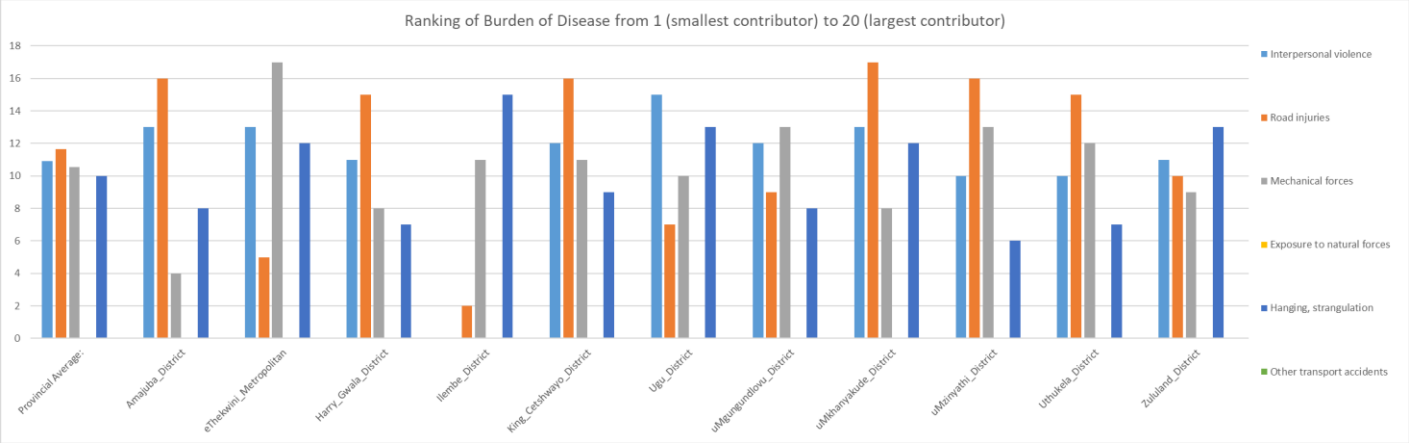
(Petrie et al, 2021b; data from Massyn et al, 2020)

Table 6 Burden of Disease Sub-Categories by Quintile

District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

(Petrie et al, 2021b; data from Massyn et al, 2020)

With a baseline for current BoD established with DHOs, DHOs' estimates of future BoD will be in the 2020 to 2050 period and are captured by assigning severity rankings for the BoD sub-categories. DHOs are asked to consider their districts' socio-economic circumstances, population changes, and the impact of climate change, and based on this how better or worse they expect a sub-category to be for the 2020-2050 period. The severity ranks have five ranks: Very Low, Low, Medium, High, and Very High. Five ranks were used to give DHOs the same scale as the baseline BoD data, as this gives the DHOs a more concrete baseline to compare against, rather than the absolute values represented in the graph in



. As such when read in comparison to the baseline BoD quintiles, the severity ranks indicate if sub-categories will be more or less severe in the future. The severity ranks are chosen through a series of drop-down lists, as shown in Table 7.

Table 7 Table Used for Assigning Severity Ranks

Assigning Severity Rankings:

In the below table you will be using the dropdown lists in each of the cells to assign a severity ranking. This ranking is a representation of the health impact which you expect for the 2020-2050 period based on the climate change exposures detailed in the Climate and Health Context sheet. This ranking should be assigned considering the above baseline established by the graph and quintile ranking. While the quintile ranking does not directly relate to the severity ranking, it can be taken as a representation of the level of severity of burden of disease as the values are generated based on the top 20 most impactful burden of disease sub-categories.

District:	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Road injuries	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Mechanical forces	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Exposure to natural forces	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Hanging, strangulation	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
Other transport accidents	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

(Petrie et al, 2021b)

These severity ranks are then run through an equation which calculates risk of a health impact due to climate change, which is explained in detail in 3.4.3 Data Processing Sheets. The resulting numerical risk values are displayed as text and follow a traffic-light colour coding system for easy interpretation, as shown in

Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

.

Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

is further supported by

Figure 8, which displays the same data as its numerical values in a graph to further aid in comparison and understanding of the potential risk profiles. This follows the core tenet of the Tool of displaying complex climate change data in a

means which is easy for DHOs to understand, and integrate into their planning activities. By providing a colour coding system and text-based values, DHOs can quickly and easily compare the different sub-categories within their district and understand where and how to prioritise planning based on the probable risk of health impacts given CCEs. Further, by displaying all districts in a province together this allows for provincial health officials to quickly understand the probable risks facing their province.

Table 8 Combined Risk Rankings for all Districts

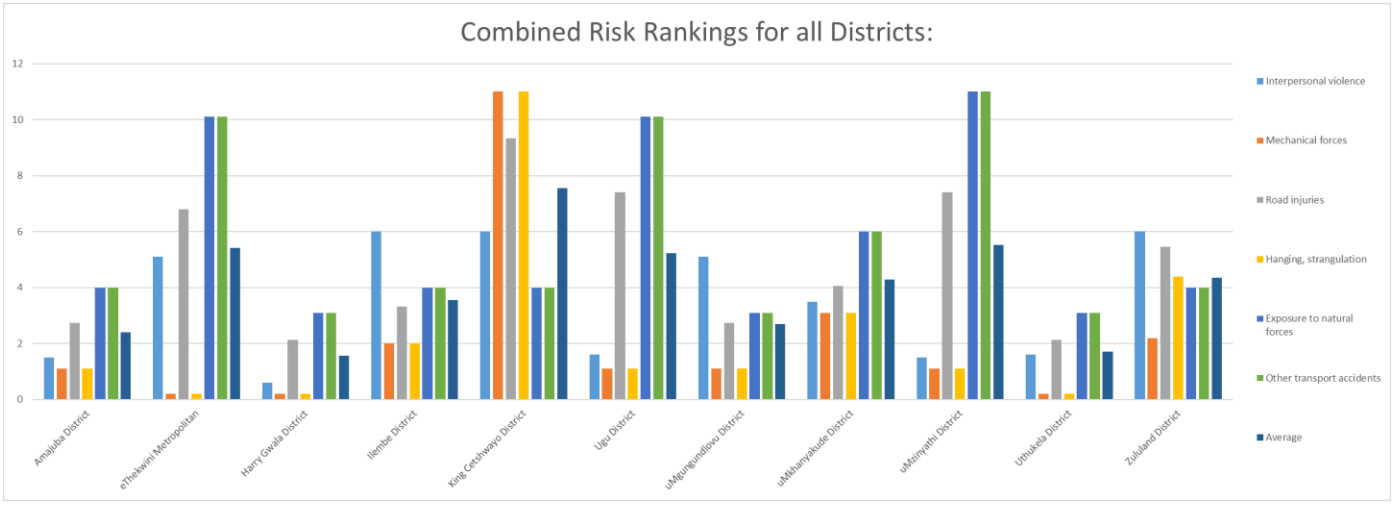
Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

(Petrie et al, 2021b)

Figure 8 Combined Risk Ranking for all Districts – Graph



(Petrie et al, 2021b)

To ensure a balanced opinion, severity rankings are assigned by a group of DHOs representing different health expertise who discuss each sub-category before assigning a severity rank. Each district nominates a 'champion' or 'scribe', who was tasked with leading the group discussion and inputting the severity ranks. The scribes were identified by the districts and were individuals who showed a willingness to contribute to discussions and who interrogated the topic deeply.

While some of the scribes did have a better knowledge of climate change than other DHOs, this was not a requirement for selection, as the primary characteristic was willingness to share knowledge and to engage.

The decision to select a scribe to lead the assigning of severity rankings was based on the literature on CoPs, particularly those held in an online setting. In CoPs a champion (which the scribe filled the role of) is critical for engaging non-participating members and driving discussions by leading the sharing of knowledge (Hew & Hara, 2006; Barret et al, 2009; Britt & Paulus, 2016). CoPs which hold facilitated and led discussions tend to have a higher level of engagement, sharing of knowledge, and a higher quality to discussions than free-form discussions (Britt & Paulus, 2016). As such a scribe would ensure that the maximum amount of data would be captured, and that it would be of higher quality. This has the further benefit of continuing to build ownership of the Tool by DHOs, which is a critical component for ensuring that it continues to be used and applied after the projects end, and also increases the level of engagement in the Tool by DHOs (World Bank, 2018; Petrie et al, 2021a).

The final sheet used in the BoD data capture and display is the BoD Summary Dashboard. This sheet displays all the Combined Risk Rankings for all Districts from the end of each BoD Dashboard in a single, consolidated table. This allows the DHOs a single place to reference and compare the risk data of all the BoD categories and their sub-categories.

Following this is the Services Dashboard, where DHOs' estimates for the impact of climate change on health services is captured. This sheet tab is colour coded orange. This follows the same principles as the BoD Dashboard sheets, however as there is no data available on the status of districts' health services, no baseline data is provided. Similar to the Climate and Health Context sheet, a dynamic table of interactions between health services and the CCEs is provided, as shown in Table 9. Severity rankings are similarly captured using the same five severity rankings, as shown in (Petrie et al, 2021b)

Table 10. The categories of Ambulatory; Community; Hospital Casualty, Inpatient, and Specialist Ambulatory Services; Emergency Services and Referrals; and Support Services were chosen for the health services categories by Dr Anthony Kinghorn (Petrie et al, 2021b).

Table 9 Table of Interactions Between CCEs and Health Services

	Very Hot Days	Extreme precipitation Days	Relative Humidity	Examples of Reasoning
1. Acute curative - minor ailments including diarrhoea, malaria, minor trauma etc	Worsen	Worsen	No Effect	Can deter attendance but probably less deterrence for severe cases. Possible exceptions are e.g. early malaria, pneumonias, malignancies, NCD deterioriation that might be under-diagnosed Certain outbreaks may overwhelm capacity
2. Preventive, promotive - Maternal, child, reproductive including PrEP	Worsen	Significantly Worsen	No Effect	Often more deterrence of attendance for preventive and promotive services, than curative; CC may disrupt mobile or outreach P&P services. PrEP (with Family Planning) hopefully will become less affected if adminstered as long acting depot dose within a few years.
3. Chronic care - communicable diseases	Worsen	Significantly Worsen	No Effect	Short or longer term disruptionsdue to migration or diplacement of people. Temporary deterrence of attendance for chronic routine service; may cause less (or more) disruption of more accessible new models of community based ART/ chronic medicine distribution; HIV and TB adherence has been quite resilient to COVID 19 lockdown after an initial dip. TB testing rates have been the most disrupted.
4. Chronic - non-communicable (HT, asthma, diabetes, other)	Worsen	Worsen	No Effect	Short or longer term disruptions due to migration or diplacement of people.Temporary deterrence of attendance for chronic routine service; some more chronic challenges for elderly with heat.
5. Chronic - Mental health	Worsen	Worsen	No Effect	Effects of disruption and displacement. Chronic severe psychiatric illness may be more vulnerable to CC disruption through disruption of client routine and control.
6. Other specific conditions to consider	No Effect	No Effect	No Effect	-

(Petrie et al, 2021b)

Table 10 Table for Capturing the Severity Rankings for the Ambulatory Category of Health Services

	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Ambulatory											
Acute curative - minor ailments incl diarrhoea, malaria, minor trauma etc	Low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Preventive, promotive	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
Chronic care - communicable disease; mental; non-communicable	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low

(Petrie et al, 2021b)

The final sheet which the DHOs interact with is the Risk Overview sheet, which displays summarised risk data from all the BoD Dashboards and Services Dashboard, and has a sheet tab colour coded grey. The top five at-risk BoD sub-categories for each category of BoD are presented first, with an example of the Injury category shown in Table 11. The same data is then displayed below this as graphs, shown in Figure 9, allowing for DHOs to better compare the difference in magnitude of the risks. Displaying the top five sub-categories at risk of a health impact gives a more summarised overview of risk, allowing DHOs to understand the most pressing issues and make informed decisions when comparing across the BoD categories, and when deciding how to prioritise budgets. It is important to note that more than one sub-category can have the same risk value, and as such more than one sub-category can occupy each rank. Therefore, the inclusion of the graphical representation of risk is important, as it allows for a better comparison of the risk values as it demonstrates the nuances of the differences in risk, which are not made clear by the purely text descriptions.

The graphs are followed by

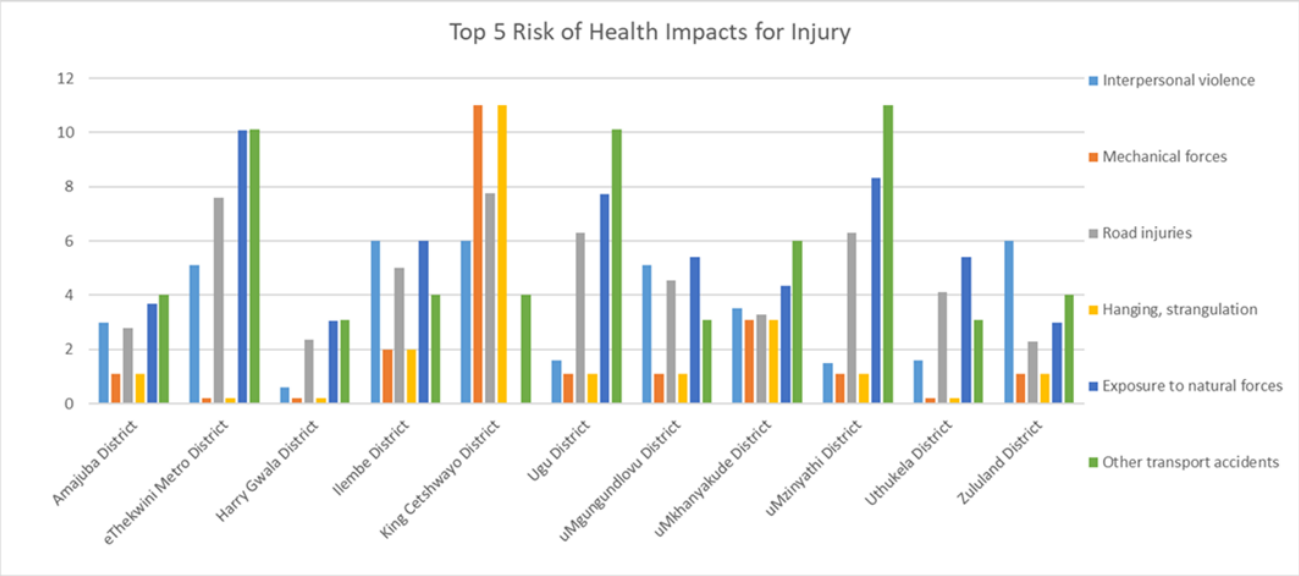
Table 12 which displays the top five sub-categories at risk for each category of BoD for the province. This is used as a means of comparison for the DHOs, but also to provide an overview for provincial health officials in their planning. After the BoD data has been displayed, the Health Services data is displayed to DHOs in the exact same format and layout as the BoD data, providing a summarised and focused overview of the risks of a health services impact given CCEs.

Table 11 Table Displaying Top Five Sub-categories for Injury Category

Injury:					
District:	1st	2nd	3rd	4th	5th
Amajuba	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Interpersonal violence;	4th - Road injuries;	5th - Mechanical forces; Hanging, strangulation;
eThekwini Metro	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Road injuries;	4th - Interpersonal violence;	5th - Mechanical forces; Hanging, strangulation;
Harry Gwala	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Road injuries;	4th - Interpersonal violence;	5th - Mechanical forces; Hanging, strangulation;
Ilembe	1st - Interpersonal violence; Exposure to natural forces;	2nd - Road injuries;	3rd - Other transport accidents;	4th - Mechanical forces;	5th - Hanging, strangulation;
King Cetshwayo	1st - Mechanical forces; Hanging, strangulation;	2nd - Road injuries;	3rd - Interpersonal violence;	4th - Other transport accidents;	5th - Exposure to natural forces;
Ugu	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Road injuries;	4th - Interpersonal violence;	5th - Mechanical forces; Hanging, strangulation;
uMgungundlovu	1st - Exposure to natural forces;	2nd - Interpersonal violence;	3rd - Road injuries;	4th - Other transport accidents;	5th - Mechanical forces; Hanging, strangulation;
uMkhanyakude	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Interpersonal violence;	4th - Road injuries;	5th - Mechanical forces; Hanging, strangulation;
uMzinyathi	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Road injuries;	4th - Interpersonal violence;	5th - Mechanical forces; Hanging, strangulation;
Uthukela	1st - Exposure to natural forces;	2nd - Road injuries;	3rd - Other transport accidents;	4th - Interpersonal violence;	5th - Mechanical forces; Hanging, strangulation;
Zululand	1st - Interpersonal violence;	2nd - Other transport accidents;	3rd - Exposure to natural forces;	4th - Road injuries;	5th - Mechanical forces; Hanging, strangulation;

(Petrie et al, 2021b)

Figure 9 Graph of Top Five Risks of Health Impacts



(Petrie et al, 2021b)

Table 12 Table Displaying the Top Five Risk Rankings for the Province per Burden of Disease Category

Top Risk Ranking for the Province per Burden of Disease Category:			
In the below table you are able to see the top 5 sub-categories of each category of burden of disease. Note that this represents a count of the number of provinces which have the particular sub-category for each ranking, rather than their numerical values of risk.			
Injury	**Major Infectious Diseases**	**Communicable, Maternal, Perinatal and Nutritional**	**Non-Communicable Diseases**
1st - Other transport accidents;	1st - HIV/Aids;	1st - Other perinatal conditions;	1st - Asthma;
2nd - Exposure to natural forces;	2nd - Tuberculosis;	2nd - Other perinatal conditions;	2nd - Nephritis/nephrosis; Epilepsy; Asthma;
3rd - Road injuries;	-	3rd - Diarrhoeal diseases;	3rd - Cardiovascular disease;
4th - Interpersonal violence;	-	4th - Malaria;	4th - Chronic obstructive pulmonary disease; Nephritis/nephrosis;
5th - Hanging, strangulation;	-	5th - Sepsis/other newborn infections;	5th - Chronic obstructive pulmonary disease;

(Petrie et al, 2021b)

3.4.3 Data Processing Sheets

All data processing is completed using hidden sheets, which automatically pull CCEs data and the severity rankings to calculate the potential risk of health impacts utilising a standard equation. As with the Dashboard sheets, the Data Process – BoD sheets (namely Data Process – Injury, Data Process – MID, Data Process – CMPN, and Data Process – NCD) all have the same layout and function, and as such the Data Process – Injury sheet will be used to explain the calculations.

The only exception to the uniformity of the sheets is the District Health Indicators and CCE Parameters table, shown in Table 13, which is only contained in the Data Process – Injury Sheet. This table contains the YLL data for each of the districts in the selected province, which is then used to populate Figure 2 Percentage of years of life lost per category of burden of disease from Climate and Health Context sheet and the CCE data used to populate the table of CCE quintile data in the CCIA sheer, and so was only necessary to tabulate the data once in the Tool.

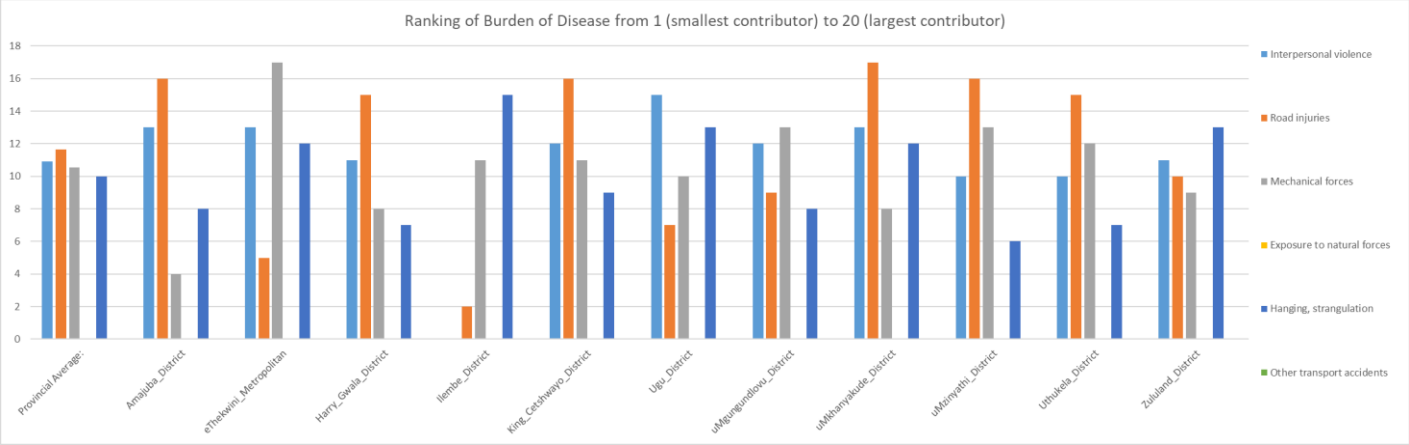
Table 13 District Health Indicators and CC Exposure Parameters

PROVINCE	DISTRICT	District Code	CMPN	MID	NCD	INJURY
	Province Average:		**15.97**	**26.64**	**40.88**	**16.51**
KwaZulu_Natal	Amajuba	DC25	20.10	23.17	41.82	14.91
	eThekwini Metro	ETH	13.86	22.39	46.26	17.49
	Harry Gwala	DC43	16.01	27.84	38.63	17.52
	Ilembe	DC29	16.62	26.67	39.90	16.81
	King Cetshwayo	DC28	12.65	27.66	42.65	17.05
	Ugu	DC21	14.01	28.55	41.42	16.02
	uMgungundlovu	DC22	13.59	22.14	47.83	16.44
	uMkhanyakude	DC27	13.14	32.75	37.64	16.47
	uMzinyathi	DC24	17.09	26.76	39.71	16.45
	Uthukela	DC23	19.61	26.57	37.79	16.04
	Zululand	DC26	19.02	28.54	36.03	16.41

PROVINCE	DISTRICT	District Code	Average Very Hot days	AVG EXTREME PPTN DAYS	AVG RELATIVE HUMIDITY	Flood	Drought
	Province Average:		**5.16**	**2.44**	**24.34%**		
KwaZulu_Natal	Amajuba	DC25	5.54	1.94	5.15%	10	8
	eThekwini Metro	ETH	1.12	6.26	6.18%	256	332
	Harry Gwala	DC43	1.32	1.85	4.60%	12	10
	Ilembe	DC29	7.19	1.82	23.02%	24	138
	King Cetshwayo	DC28	8.41	1.42	172.05%	8	246
	Ugu	DC21	1.39	4.41	23.24%	9	67
	uMgungundlovu	DC22	2.82	1.06	16.05%	14	118
	uMkhanyakude	DC27	10.72	1.12	4.30%	7	18
	uMzinyathi	DC24	5.86	3.64	4.62%	8	27
	Uthukela	DC23	3.70	1.76	4.28%	20	53
	Zululand	DC26	8.67	1.59	4.22%	6	235

(Petrie et al, 2021b; data from CSIR, 2019)

After this, the BoD Data Display table pulls the DHB BoD data top 26 BoD contributors as raw values (Table 14), and then converts this data into quintiles for Table 15. These tables are used to populate the



, and Table 4 Quintiles for BoD Sub-categories in each of the BoD Dashboard sheets.

Table 14 BoD Data Display Table - Raw Values

BoD Dashboard - BoD Data display:

Province:	District Code		Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
		Provincial Average:	12	12	11		10	
KwaZulu_Natal	DC25	Amajuba	13	16	4	0	8	0
	ETH	eThekwini Metro	13	5	17	0	12	0
	DC43	Harry Gwala	11	15	8	0	7	0
	DC29	Ilembe	0	2	11	0	15	0
	DC28	King Cetshwayo	12	16	11	0	9	0
	DC21	Ugu	15	7	10	0	13	0
	DC22	uMgungundlovu	12	9	13	0	8	0
	DC27	uMkhanyakude	13	17	8	0	12	0
	DC24	uMzinyathi	10	16	13	0	6	0
	DC23	Uthukela	10	15	12	0	7	0
	DC26	Zululand	11	10	9	0	13	0

(Petrie et al, 2021b)

Table 15 BoD Data Display Table - Quintiles

Province:	District:	District Code	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
KwaZulu_Natal	Amajuba_District	DC25	3	4	3	0	2	0
	eThekwini_Metropoli	ETH	3	2	5	0	4	0
	Harry_Gwala_District	DC43	2	4	4	0	2	0
	Ilembe_District	DC29	0	2	4	0	5	0
	King_Cetshwayo_Dist	DC28	3	4	4	0	3	0
	Ugu_District	DC21	4	2	4	0	5	0
	uMgungundlovu_Dist	DC22	3	3	5	0	2	0
	uMkhanyakude_Distri	DC27	3	5	4	0	4	0
	uMzinyathi_District	DC24	2	4	5	0	1	0
	Uthukela_District	DC23	2	4	5	0	2	0
	Zululand_District	DC26	2	3	4	0	5	0
	Provincial Average:		2	3	4	0	3	0

(Petrie et al, 2021b)

This is followed by Table 16 Risk Calculator, which interacts the severity rankings captured from DHOs in Table 7 Table Used for Assigning Severity Ranks, the CCE exposures from each of the districts, and the relevant interaction terms from Table 5 Interactions between Climate Change Parameters and BoD .

Table 16 Risk Calculator

Risk Calculator:	District code:	Interpersonal violence	Mechanical forces	Road injuries	Hanging, strangulation	Exposure to natural forces	Other transport accidents	Average
Amajuba_District	DC25	7.5	2.2	11.2	4.4	18.33333333	4	7.938888889
eThekwini_Metro_District	ETH	5.1	0.6	38	1	50.33333333	10.1	17.52222222
Harry_Gwala_District	DC43	3	0.6	7.05	0.2	15.33333333	6.2	5.397222222
Ilembe_District	DC29	24	4	15	8	18	20	14.83333333
King_Cetshwayo_District	DC28	18	55	38.75	11	18.33333333	12	25.51388889
Ugu_District	DC21	3.2	5.5	6.3	2.2	30.93333333	40.4	14.75555556
uMgungundlovu_District	DC22	20.4	1.1	18.2	3.3	16.2	6.2	10.9
uMkhanyakude_District	DC27	14	6.2	3.3	15.5	4.333333333	18	10.22222222
uMzinyathi_District	DC24	1.5	3.3	6.3	4.4	25	22	10.41666667
Uthukela_District	DC23	4.8	0.8	4.1	0.8	16.2	15.5	7.033333333
Zululand_District	DC26	18	4.4	4.6	1.1	15	4	7.85

(Petrie et al, 2021b)

It is important to note that the Tool was developed to be able to have new CCE data added to it, to allow updating, or to have new CCEs added which are found to influence BoD. Currently the Risk Calculator incorporates very hot days, extreme precipitation days, relative humidity, drought, flood, and fire data into its calculation, utilising the following equation to calculate potential risk:

$$Potential\ of\ Health\ Impact\ Risk = SF * \frac{(CCE_1 * CCEi_1) + (CCE_2 * CCEi_2) + \cdots + (CCE_n * CCEi_n)}{NNZCCE}$$

CCE_1: Climate Change Exposure 1

$CCEi_1$: Climate Change Exposure 1 Interaction Term

NNZCCE: Number of Non-Zero Climate Change Exposure with Interaction Terms

As such with the current CCEs data used results in the following equation:

$$Potential\ of\ Health\ Impact\ Risk = SF * \frac{(VHD * VHDi) + (EPD * EPDi) + (RH\ * RHi) + (D * Di) + (FL * FLi) + (FI * FIi)}{NNZCCE}$$

SF: Severity Factor

VHD: Very Hot Days

VHDi: Very Hot Days interaction term

EPD: Extreme Precipitation Days

EPDi: Extreme Precipitation Days interaction term

RH: Relative Humidity

RHi: Relative Humidity interaction term

FL: Flood

FLi: Flood interaction term

FI: Fire

FIi: Fire interaction Term

The Risk Calculator calculates a district's risk values by multiplying each of the CCEs by its relative interaction terms for the sub-category, which are then summed and divided by the number of non-zero CCEs after multiplication by their interaction term to get an average CCE value, which is then multiplied by the severity rank assigned by the DHOs. Importantly the equation only averages the non-zero CCE values which ensures that the risk values are not biased towards BoD sub-categories which have less than six non-zero interaction terms. If not, a sub-category such as interpersonal violence which has the interaction terms of two for very hot days, and one for drought, but zero for extreme precipitation days, relative humidity, flood, and fire would have a significantly lower risk value even if it is anticipated as being at significant risk given climate change. The interaction terms ensure that CCEs which have no effect on the

BoD sub-category are excluded, while CCEs which result in a significant increase in the BoD sub-category are doubled, this as the scale utilised is zero (no effect), one (increase), and two (significant increase).

For example, looking at exposure to natural forces for the Amajuba district, with a severity rank of Very High, the equation would produce the following results:

$$Potential\ of\ Health\ Impact\ Risk = SF * \frac{(VHD * VHDi) + (EPD * EPDi) + (RH\ * RHi) + (D * Di) + (FL * FLi) + (FI * FIi)}{NZCCE}$$

$$Potential\ of\ Health\ Impact\ Risk = 5 * \frac{(1 * 2) + (3 * 0) + (0.1\ * 0) + (1 * 1) + (3 * 0) + (3 * 0)}{NZCCE}$$

$$Potential\ of\ Health\ Impact\ Risk = 5 * \frac{(2) + (0) + (0) + (1) + (0) + (0)}{2}$$

$$Potential\ of\ Health\ Impact\ Risk = 5 * 1.5$$

$$Potential\ of\ Health\ Impact\ Risk = 7.5$$

The resulting risk values are numeric values which hold no meaning to DHOs, and as such are converted into text-based results, which utilise the matrix shown in Table 17 developed by Professor Jonny Myers for the project. Note that Table 17 displays the matrix with both an interaction term of one and two, as the likelihood of CCES with an interaction term of one are 0.3, 1, 3, and 10 (as noted in Table 2):

Table 17 Probability of Climate Change Exposure Multiplied by Severity Ranking Matrix to Form a Risk Matrix

Probability of CC Event

Severity Factor	0.3	0.6	1	2	3	6	10	20
1	0.3	0.6	1	2	3	6	10	20
2	0.6	1.2	2	4	6	12	20	40
3	0.9	1.8	3	6	9	18	30	60
4	1.2	2.4	4	8	12	24	40	80
5	1.5	3	5	10	15	30	50	100

Probability of CC Event

Severity Factor	0.3	0.6	1	2	3	6	10	20
1	Very Low	Very Low	Very Low	Low	Medium Low	Medium	Medium High	Medium High
2	Very Low	Low	Low	Medium Low	Medium	Medium High	Medium High	High
3	Very Low	Low	Medium Low	Medium	Medium	Medium High	High	Very High
4	Low	Medium Low	Medium Low	Medium	Medium High	High	High	Very High
5	Low	Medium Low	Medium	Medium High	Medium High	High	Very High	Very High

(Petrie et al, 2021b)

The bands of values which each risk category falls into were selected by setting upper and lower bounds which would allow for a gradient increase in the values which followed the interactions within the matrix. The Risk Matrix is used as the reference point for the Risk Calculator Translator, which converts the numerical risk values to text values, as shown in

Table 18, which are then used to populate

Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

in the Injury Dashboard. The Risk Calculator Translator achieves this by employing the following IF function:

$$If\ 0 \leq x \leq 1\ then\ "Very\ Low"$$

$$Else\ 1 < x \leq 2\ then\ "\text{Low}"$$

$$Else\ 2 < x \leq 4\ then\ "Medium\ \text{Low}"$$

$$Else\ 4 < x \leq 9\ then\ "Medium"$$

$$Else\ 9 < x \leq 20\ then\ "Medium\ High"$$

$$Else\ 20 < x \leq 40\ then\ "High"$$

$$Else\ 40 < x\ then\ "Very\ High"$$

Table 18 Risk Calculator Translator

Risk Calculator Translator:	**District Code:**	Interpersonal violence	Mechanical forces	Road injuries	Hanging, strangulation	Exposure to natural forces	Other transport accidents	Average
Amajuba_District	DC25	Medium	Medium Low	Medium High	Medium	Medium High	Medium Low	Medium
eThekwini_Metro_District	ETH	Medium	Very Low	High	Very Low	Very High	Medium High	Medium High
Harry_Gwala_District	DC43	Medium Low	Very Low	Medium	Very Low	Medium High	Medium	Medium
Ilembe_District	DC29	High	Medium Low	Medium High	Medium	Medium High	Medium High	Medium High
King_Cetshwayo_District	DC28	Medium High	Very High	High	Medium High	Medium High	Medium High	High
Ugu_District	DC21	Medium Low	Medium	Medium	Medium Low	High	Very High	Medium High
uMgungundlovu_District	DC22	High	Low	Medium High	Medium Low	Medium High	Medium	Medium High
uMkhanyakude_District	DC27	Medium High	Medium	Medium Low	Medium High	Medium	Medium High	Medium High
uMzinyathi_District	DC24	Low	Medium Low	Medium	Medium	High	High	Medium High
Uthukela_District	DC23	Medium	Very Low	Medium	Very Low	Medium High	Medium High	Medium
Zululand_District	DC26	Medium High	Medium	Medium	Low	Medium High	Medium Low	Medium

(Petrie et al, 2021b)

This concludes the section of the Data Process – Injury sheet which calculates data for the Injury Dashboard, and as such the remaining tables are used to calculate the data which is displayed in the Risk Overview sheet. The first tables utilised are the Risk Hierarchy tables, shown in *Table 19*.

The Risk Hierarchy Tables are used to sort the sub-categories of BoD from highest to lowest risk. This is first done with the Risk Hierarchy Calculator which sorts each of the risk values for the districts and aligns the values under the ranks from 1st to 6th (with sheets such as Data Process – CMPN going up to an 8th rank). It is possible for different BoD sub-categories to have the same risk value, and thus the Risk Hierarchy Value Assign table is used to identify the rank of each of the risk values. Each cell in the Risk Hierarchy Value Assign table utilises a formula which first checks to see if there are any of the same risk values in the cells to its left in the Risk Hierarchy Calculator. If there are, then it returns the risk ranking of the first matching risk value in the Risk Hierarchy Value Assign, as all matching risk values will have the same ranking. If there are no matching risk values in the same district, then the formula takes the preceding cell's risk ranking and adds one to it. As such this allows for the risk rankings to increase linearly by one, and all matching risk values to have the same risk rank.

To explain how this is achieved, the Amajuba District is used as an example: the first cell in the Risk Hierarchy Value Assign checks and sees that in the Risk Hierarchy Calculator that it is the first cell and the first cell with the value of four, and thus assigns a risk ranking of one. The next cell in Column 2 notes that it is the second cell with a value of four and thus assigns the same value as the first matching value in the Risk Hierarchy Calculator which is one. Thus, when the cell in Column 3 is reached, it notes its corresponding cell in the Risk Hierarchy Calculator is the first with a value of 2.73 and thus it takes the value of the cell in Column 2 in the Risk Value Assign and adds one to it to get a risk ranking of two. This continues until all the cells in the Risk Hierarchy Value Assign are filled.

The Risk Hierarchy Name Assign then uses the values in the Risk Hierarchy Value Assign to determine the risk ranking position of the corresponding value in the Risk Hierarchy Calculator to identify the sub-category name in the Risk Calculator. Once identified, the rank is added before the sub-category name and then populates Table 11 Table Displaying Top Five Sub-categories for Injury Category.

Table 19 Risk Hierarchy Tables

(Petrie et al, 2021b)

1. Risk Hierarchy Calculator:	District code:	1	2	3	4	5	6
DC25	Amajuba_District	18.33333333	11.2	7.5	4.4	4	2.2
ETH	eThekwini_Metro_District	50.33333333	38	10.1	5.1	1	0.6
DC43	Harry_Gwala_District	15.33333333	7.05	6.2	3	0.6	0.2
DC29	Ilembe_District	24	20	18	15	8	4
DC28	King_Cetshwayo_District	55	38.75	18.33333333	18	12	11
DC21	Ugu_District	40.4	30.93333333	6.3	5.5	3.2	2.2
DC22	uMgungundlovu_District	20.4	18.2	16.2	6.2	3.3	1.1
DC27	uMkhanyakude_District	18	15.5	14	6.2	4.333333333	3.3
DC24	uMzinyathi_District	25	22	6.3	4.4	3.3	1.5
DC23	Uthukela_District	16.2	15.5	4.8	4.1	0.8	0.8
DC26	Zululand_District	18	15	4.6	4.4	4	1.1

2. Risk Hierarchy Value Assign:	District code:	1	2	3	4	5	6
Amajuba_District	DC25	1	2	3	4	5	6
eThekwini_Metro_District	ETH	1	2	3	4	5	6
Harry_Gwala_District	DC43	1	2	3	4	5	6
Ilembe_District	DC29	1	2	3	4	5	6
King_Cetshwayo_District	DC28	1	2	3	4	5	6
Ugu_District	DC21	1	2	3	4	5	6
uMgungundlovu_District	DC22	1	2	3	4	5	6
uMkhanyakude_District	DC27	1	2	3	4	5	6
uMzinyathi_District	DC24	1	2	3	4	5	6
Uthukela_District	DC23	1	2	3	4	5	5
Zululand_District	DC26	1	2	3	4	5	6

3. Risk Hierarchy Name Assign:	District code:	1	2	3	4	5	6
Amajuba_District	DC25	1st - Exposure to natural forces	2nd - Road injuries	3rd - Interpersonal violence	4th - Hanging, strangulation	5th - Other transport accidents	6th - Mechanical forces
eThekwini_Metro_District	ETH	1st - Exposure to natural forces	2nd - Road injuries	3rd - Other transport accidents	4th - Interpersonal violence	5th - Hanging, strangulation	6th - Mechanical forces
Harry_Gwala_District	DC43	1st - Exposure to natural forces	2nd - Road injuries	3rd - Other transport accidents	4th - Interpersonal violence	5th - Mechanical forces	6th - Hanging, strangulation
Ilembe_District	DC29	1st - Interpersonal violence	2nd - Other transport accidents	3rd - Exposure to natural forces	4th - Road injuries	5th - Hanging, strangulation	6th - Mechanical forces
King_Cetshwayo_District	DC28	1st - Mechanical forces	2nd - Road injuries	3rd - Exposure to natural forces	4th - Interpersonal violence	5th - Other transport accidents	6th - Hanging, strangulation
Ugu_District	DC21	1st - Other transport accidents	2nd - Exposure to natural forces	3rd - Road injuries	4th - Mechanical forces	5th - Interpersonal violence	6th - Hanging, strangulation
uMgungundlovu_District	DC22	1st - Interpersonal violence	2nd - Road injuries	3rd - Exposure to natural forces	4th - Other transport accidents	5th - Hanging, strangulation	6th - Mechanical forces
uMkhanyakude_District	DC27	1st - Other transport accidents	2nd - Hanging, strangulation	3rd - Interpersonal violence	4th - Mechanical forces	5th - Exposure to natural forces	6th - Road injuries
uMzinyathi_District	DC24	1st - Exposure to natural forces	2nd - Other transport accidents	3rd - Road injuries	4th - Hanging, strangulation	5th - Mechanical forces	6th - Interpersonal violence
Uthukela_District	DC23	1st - Exposure to natural forces	2nd - Other transport accidents	3rd - Interpersonal violence	4th - Road injuries	5th - Mechanical forces	5th - Hanging, strangulation
Zululand_District	DC26	1st - Interpersonal violence	2nd - Exposure to natural forces	3rd - Road injuries	4th - Mechanical forces	5th - Other transport accidents	6th - Hanging, strangulation

The final two tables in the Data Process – Injury sheet are used to calculate the Top 5 Risk for the province, as shown in Table 20. The first table counts how many times each of the BoD sub-categories appear in each of the rankings in the Risk Hierarchy Name Assign. A count of the BoD sub-categories is used rather than comparing the sub-categories' summed risk values, because a sum would skew the results towards districts which have a higher risk value for their sub-categories. As such by utilising the count method, the top risks posed to each district are considered equally, and thus provide a more accurate picture of risk across the province. The Province Top 5 Risk Name Generator then takes the largest value in each column in the Province Top 5 Count to assign the name of the sub-category for the first to fifth most at risk sub-category. This data is then used to populate

Table 12 Table Displaying the Top Five Risk Rankings for the Province per Burden of Disease Category.

Table 20 Province Top 5 Risks Count

Province Top 5 Count:	1	2	3	4	5
Interpersonal violence	2	1	3	5	0
Mechanical forces	1	0	0	1	9
Road injuries	0	3	5	3	0
Hanging, strangulation	1	0	0	0	10
Exposure to natural forces	3	6	1	0	1
Other transport accidents	6	1	2	2	0

	1	2	3	4	5
Province Top 5 Risk Name Generator:	1st - Other transport accidents;	2nd - Exposure to natural forces;	3rd - Road injuries;	4th - Interpersonal violence;	5th - Hanging, strangulation;

(Petrie et al, 2021b)

4 METHODOLOGY

This chapter will discuss the methodology which was developed for the Tool's implementation. As such, this chapter examines the practical application of the Tool in the Capacity Building, and HVRA Workshops, describing how the capacity building and data collection process were designed by the project team.

As recommended by the WHO's HRVA guidelines, a process of gathering health officials to discuss the future impact of climate change on health was followed, due to the absence of quantitative models for the impact of CCEs on health in South Africa. The HRVA workshops' design was supplemented by the learnings gained from the CoPs literature, which demonstrated that facilitated discussions between professionals, with a targeted set of discussion points, were found to be more effective in stimulating long-form discussions (Hew & Harra, 2006; Britt & Paulus, 2016; World Bank 2018). Thus, the Tool was implemented through a series of workshops, held through a blend of online and in-person workshops that would be split into two sessions. In-person workshops were opted for when COVID-19 restrictions were eased, while online workshops were utilised during high COVID-19 periods which resulted in restrictions.

The Capacity Building Workshop would be held first, which built climate change capacity among DHOs to assist their severity estimates, and to introduce them to the Tool. The second session would be the HVRA Workshop which would involve a summary of the initial Capacity Building Workshop, and then the facilitated discussions between DHOs, and capture of future severity estimates using the Tool. The workshops were split as it was understood that DHOs are extremely time constrained, especially due to pressure of managing South Africa's COVID-19 response, and as such two half-day sessions would likely have better attendance than full-day sessions. However, certain provinces did request, and held, full-day workshops. The same methodology was followed in online and in-person workshops, and for the half-day and full-day workshops. One set of workshops was organised per province with DHOs representing all districts meeting at a central location, or in the case of larger provinces, multiple workshops were held and attended by DHOs based on their districts' geographic proximity. A full list of the types of workshops held in each province, and the number of workshop attendees, can be found in Appendix 1: List of Provinces, Districts, and Workshops. In addition to the DHOs, all workshops were attended by workshop facilitators from the project team, and representatives from the NDoH, DFFE, and provincial health officials, all of which were involved in conducting, and facilitating the workshops.

It is important to note that the methodology was updated and amended by the project team during the project as new issues and opportunities were presented by the workshops, and as such an approach of adaptive management was followed. Thus, as plans were tested through the workshops, the results and outcomes were learnt from, and the process optimised. While this does mean that there was slight variation between the initial workshops and subsequent workshops, this did mean that subsequent workshops were more robust, and tailored to DHOs' needs.

4.1 CAPACITY BUILDING WORKSHOPS

The Capacity Building Workshops were focused on building initial capacity on climate change and its impact on the health sector to establish a baseline level of knowledge among healthcare officials, and to demonstrate how the Tool works, answer any questions on its operation, and take feedback on its improvement.

Workshops began with establishing the initial intention and purpose of the workshops. This established the context for the project, how it contributes to South Africa's adaptation to climate change, the impact which this project will have on DHOs' work, and how the work will contribute to South Africa's and the international knowledge base on the impact of climate change on health. As such this sought to establish both the importance of the work, and to develop a sense of ownership among the officials, which has been found to be a critical component in integrating climate change into processes and ensuring that the processes established continue to be used by stakeholders after projects' completion. This included outlining the data inputs which were used, and the considerations undertaken when designing the Tool, establishing the DHOs' role in the project, and how their contributions fit into the greater development of the project. Further, the limitations and assumptions made, as outlined in the Building the Tool section above, were outlined to ensure that there was full transparency and understanding by the DHOs.

Once these initials points were established the DHOs were introduced to the Tool. Capacity building began with the Climate Change and Health Context Sheet, where DHOs were guided through the CCE maps in Figure 3, where the CCES and their potential impacts were explained for the province. This was then followed by an overview of the impact of the selected CCES on the health sub-categories, as detailed in

Interaction of Climate Change Exposures on Health Categories							
	Climate Change Parameters						
BoD Sub-category	Very Hot days	Relative Humidity	Extreme precipitation days	Flood	Drought	Fire	Reasoning
Cardiovascular disease	Significant Increase	Significant Increase	No Effect	Increase	No Effect	Increase	Could cause stroke via stress or aggravate cerebral perfusion insufficiency via drought conditions with dydration. Also heat exhaustion and heatstroke.
Diabetes mellitus	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Hypertensive heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	Could aggravate and reduce cardiac output through venous pooling and deydration
Ischaemic heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	As for hypertensive heart disease
Endocrine, nutritional, blood, immune system	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Chronic obstructive pulmonary disease	Increase	Increase	No Effect	Increase	No Effect	Increase	Aggravate via the work of breathing, growth of mould and fungus in damp/humid conditions and via smoke particulates
Nephritis/nephrosis	Increase	No Effect	No Effect	No Effect	Increase	No Effect	No relationship
Epilepsy	No Effect	No Effect	Increase	No Effect	Increase	No Effect	No relationship
Asthma	Increase	Increase	Significant Increase	Increase	No Effect	Increase	Hot and humid conditions could promote allergens such as pollens and moudly fungal growth indoors
Prostate	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship

. Certain diseases were given greater emphasis based on the province's impacts identified in the maps, and the DHOs were asked if the interactions reflected their own experiences.

Using the baseline knowledge established, the DHOs were then led through the CCIA Sheet and the 1st-to-4th Order Impact Assessment detailed in Figure 4. The main CCEs were further contextualised through Figure 5 Quartile Rankings of the Province's CCEs, which provided a hierarchy of concerns. The 1st-to-4th Order Impact Assessment allows the DHOs to practically apply the baseline knowledge established through a group exercise, helping to solidify and test their understanding. This exercise further sought to begin the discussion process, make DHOs comfortable with contributing, and to situate their thinking on the pathways in which climate change will impact their districts. This final point is critical, as it is the transition point from moving DHOs from considering climate change theoretically to considering how it will tangibly impact their district's individual circumstance, and allow them to provide estimates to describe these relationships. The exercise also enables further primary data collection on DHOs' own experiences of climate change, their concerns for the future, and how they expect to be more broadly impacted by climate change, which would later be used in workshop feedback reports.

Following this exercise, the DHOs were then guided through the four BoD dashboards, the BoD Summary Dashboard, Services Dashboard, and finally the Risk Overview Dashboard. While the data collection dashboards follow the same layout, each dashboard was presented in turn to build a sense of familiarity and allow for a wider range of questions which might only be thought of as familiarity with the Tool was developed. Emphasis was placed on ensuring that the DHOs clearly understood how the severity rankings and severity ranking tables (Table 7) worked, as these were the primary means of data collection, and thus the most critical area for the officials to understand.

A series of standard questions - developed by the author, and project team - would be posed to the DHOs during the Capacity Building Workshops to gauge their levels of understanding, and to increase engagement during the workshops, and was supplemented by a post-workshop Feedback Survey. The questions asked during the Capacity Building Workshop were as follows:

1. Do the maps give you an adequate understanding of the effects which climate change will have in your district?

2. Would you find a map with the interaction between the three maps useful to you?

3. How clear are the interactions between the climate change parameters and the burden of disease?

4. Is the explanation of severity rankings clear?

The questions were focused on: the level of understanding gained from the maps, and how these could be improved, as the maps were understood as the primary means of conveying CCE data; the clarity of the interactions between CCEs and BoD, as these established the context for officials to provide data; and finally, the level of understanding of the severity rankings, as these were the primary means of data collection.

After the overview of the Tool, participants were asked to complete the Feedback Survey - developed by the author, and project team - if the workshop was conducted online, and if conducted in person they were asked to complete the survey after the workshop. The survey sought a more holistic understanding of the DHOs' views on the Tool than the questions asked during the workshop, and any improvements they might suggest. Questions one and four above were repeated in the Feedback Survey given that DHOs might have a better understanding of them after the workshop's completion. The questions asked are listed below:

1. Does the HRVA tool meet your needs in terms of identifying and measuring climate change impacts and related risks in the Health Sector for your Health District? From 1 (No, not at all) to 5 (Yes, the Tool fully meets my needs).
2. Do the maps give you an adequate understanding of the effects which climate change will have in your district? From 1 (No understanding) to 5 (Full understanding).
3. In the Climate and Health Context sheet do the interactions between the climate change parameters and burden of disease reflect your own experiences? From 1 (No similarity) to 5 (Completely the same).
4. Is the presentation of burden of disease data as a graph and quintile table in the burden of disease dashboards useful for considering the future impact of burden of disease? From 1 (Not helpful) to 5 (Very helpful).
5. Is the explanation of severity rankings clear? From 1 (Not clearly explained) to 5 (Very clearly explained).
6. Is sufficient information provided for you to estimate the severity ranking for burden of disease in 2050? From 1 (Not clearly explained) to 5 (Very clearly explained).
7. Are the severity rankings a useful way of projecting the future health impact of burden of disease? From 1 (Not useful) to 5 (Very useful).
8. Is the Combined Risk Ranking for all Districts, which is displayed at the end of each of the burden of disease dashboards easy to use and clear regarding the risk posed to your district? From 1 (Not useful) to 5 (Very useful).
9. Are the various categories of services and infrastructure clear and applicable to your Health District? From 1 (Not applicable) to 5 (Very applicable).
10. Do the top 5 ranked diseases on the Risk Overview sheet provide sufficient information regarding the risk posed to your district? From 1 (Not useful, needs more information) to 5 (Very useful, perfect amount of information).
11. What suggestions do you have for improving the user-friendliness and accessibility of the tool?
12. What aspect of the Health Risk and Vulnerability Tool did you find to be the most useful?
13. What would you like to see in future iterations of this tool?

The Capacity Building Workshops were concluded by giving an overview of the process going forward to ensure that the DHOs would be prepared for subsequent workshops, and to establish a precedence for the project going forward.

4.2 HEALTH RISK AND VULNERABILITY ASSESSMENT WORKSHOPS

The HRVA Workshops were the primary means of data collection, in which DHOs would be grouped by district to enter data into the Tool. The HRVA workshops were intended to only have a brief overview of the Capacity Building Workshop's content, however during the implementation of the workshops it was found there was often limited overlap in participants between the Capacity Building, and HRVA Workshops. As such the HVRA Workshops initial section

was extended to have a shortened version Capacity Building Workshops content, with a strong focus on the 1st-to-4th Order Impact Assessment as a means of initiating participants in thinking of the impact of climate change on health.

DHOs were then broken up into their separate districts, with each district working on one copy of the Tool to ensure consistent data from the district, and were assisted by roaming workshop facilitators. Facilitators assisted with data entry, explanation of terminology or the Tool's use, and to help stimulate discussions on the severity rankings and how CCEs might impact those results. In the cases where there was limited representation from a district (one to two members), districts would be supplemented with provincial health officials, or in some cases if more than one district had limited representation, then the districts would be grouped together.

An important point which was emphasised to DHOs was that this process was to establish an initial, and baseline knowledge base, for the impact of climate change on the health sector in South Africa and would be built upon in future HVRAs. This was a critical addition after the initial workshops, which found that the enormity and importance of the task presented meant that in some cases DHOs experienced decision paralysis. While this did not stop them from contributing, it slowed the DHOs' data entry into the initial BoD Dashboards, which placed additional time constraints on already short workshops. Learning from these initial experiences, by placing the DHOs' contributions within the context of a greater process reduced their anxiety, but also further developed the sense of ownership and participation in a larger process.

Each district group then nominated a scribe, who would lead the discussion, and enter data into the Tool. Initially it was intended that the scribe would be a 'champion', who would be chosen from the Capacity Building Workshop by the project team, as someone who demonstrated a keen interest in the exercise, and who had some climate change knowledge - although a less important criteria. However, given the issues of participant overlap, there was difficulty in identifying active participants from the Capacity Building Workshop, and as such the scribe was instead chosen by the group itself. Despite this deviation from the original planned approach, the scribe still was able to play the role intended in guiding the groups discussion, as was observed by Britt and Paulus, and Hew and Hara (2016; 2006).

The district groups would then work through the Tool sequentially, beginning with the BoD Dashboards, and then moving to the Services Dashboard. Data entry was aided by several supplementary information packages in addition to the BoD baseline provided. These were the CCE maps (Figure 3), and interaction table between climate change and health categories (

Interaction of Climate Change Exposures on Health Categories							
	Climate Change Parameters						
BoD Sub-category	Very Hot days	Relative Humidity	Extreme precipitation days	Flood	Drought	Fire	Reasoning
Cardiovascular disease	Significant Increase	Significant Increase	No Effect	Increase	No Effect	Increase	Could cause stroke via stress or aggravate cerebral perfusion insufficiency via drought conditions with dydration. Also heat exhaustion and heatstroke.
Diabetes mellitus	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Hypertensive heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	Could aggravate and reduce cardiac output through venous pooling and deydration
Ischaemic heart disease	Significant Increase	Significant Increase	No Effect	No Effect	No Effect	No Effect	As for hypertensive heart disease
Endocrine, nutritional, blood, immune system	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship
Chronic obstructive pulmonary disease	Increase	Increase	No Effect	Increase	No Effect	Increase	Aggravate via the work of breathing, growth of mould and fungus in damp/humid conditions and via smoke particulates
Nephritis/nephrosis	Increase	No Effect	No Effect	No Effect	Increase	No Effect	No relationship
Epilepsy	No Effect	No Effect	Increase	No Effect	Increase	No Effect	No relationship
Asthma	Increase	Increase	Significant Increase	Increase	No Effect	Increase	Hot and humid conditions could promote allergens such as pollens and moudly fungal growth indoors
Prostate	No Effect	No Effect	No Effect	No Effect	No Effect	No Effect	No relationship

) in the Climate Change and Health Context Sheet, and a terminology guide - developed by Dylan Beukes of OneWorld Sustainable Investments - which gave the definitions of all the BoD and climate change terms used.

During the implementation of the HRVA Workshops it was found that in many cases the districts lacked full representation from all areas of health, and as such their ability to fully complete all information which the Tool required was limited. As such the approach to the HRVA Workshops was updated, and the DHOs were encouraged to work with

additional colleagues after the workshops to complete the Tool. Thus, after the HRVA Workshops, all the DHOs were contacted and sent the Tool, Terminology Guide, and a Participants Guide which was developed to guide them through the Tool and answer frequently asked questions. This enabled the most complete set of data to be gathered, and to access a wider cohort of DHOs who would otherwise be outside the project team's reach. Districts which had no representation during the HRVA workshops or had limited representation and as such did not fully complete all sections, had proxy data generated by taking the average severity ranks of the three geographically closest districts within their province.

The resulting risk data was presented to the DHOs through the Combined Risk Rankings for all Districts at the end of each data capture dashboard, BoD Summary Dashboard, and Risk Overview sheets during the HRVA Workshops, and later through District Reports prepared for all 52 districts. The District Reports were tailored to each of the districts, presenting an initial provincial version of the maps in Figure 3 and a description of the district's average CCE values, and the municipalities which would experience the smallest, and greatest, changes in CCEs. This was followed by graphs and tables detailing the BoD baseline data provided in the Tool, an overview of the severity rankings assigned by DHOs as a description of vulnerability and an assessment of the areas which were correctly and incorrectly identified as vulnerable to climate change. This was then followed by an assessment of the risk data, which focused on the areas of highest risk, and explained how CCEs would impact these sub-categories and was conducted for both the BoD and health services. The District Reports followed the recommendations of both the WHO (2021), and the IPCC (2021), which state that for climate change data and information to be properly integrated into policy and decision-makers' processes, the information provided must be tailored to their work. As such the DHOs' severity rankings, and the resulting risk rankings were presented in terms of the areas of most significant concern and within the larger climate change context, and with reference to academic literature, enabling DHOs to expand their knowledge base if desired.

5 APPLYING THE TOOL

This chapter will examine how the HRVA Tool was received by DHOs during the Capacity Building and HRVA Workshops by reviewing their feedback which was given in person during the workshops, and through the Feedback Survey. The majority of the feedback from DHOs was received during the workshops where there were high amounts of engagement. The Feedback Survey received fewer than the expected number of responses, with a total of 25 respondents, however the results do reflect the feedback received during the workshops. Any divergent opinions are noted, recognising the importance of the diversity of DHOs' experience with the Tool. It is important to note that no individual names or positions are stated in relation to quotes. This is to comply with the protection of personal information, as all survey responses and feedback from the workshops were given with the understanding that anonymity would be maintained. As with previous sections, the responses to the Tool will be broken into sections relating to the Tools design, beginning with the overall responses to the Tool, then looking at the capacity building sheets, and then the data collection and risk overview sheets.

5.1 GENERAL OVERVIEW OF RESPONSES TO THE TOOL

In almost all workshops there was found to be a positive response to the Tool by DHOs who stated that while the Tool was initially fairly daunting both technically and in the volume of data required, it was found to be approachable and easy to use once engaged with. This was evident practically, as most district groups spent the most time on the initial Injury Dashboard, but then significantly increased the pace of data entry as they become accustomed to the Tool. It was found that most groups were able to complete full data entry in an hour-and-a half to two-and-a-half hours. This was a highly favourable result, as the project team had originally estimated that three or more hours would be required.

This indicates that the Tool achieved its primary design goal of being user-friendly and accessible to individuals with a range of Excel knowledge. Question 11 of the Feedback Survey sought suggestions on improving the Tool's user-friendliness, with most respondents indicating that they had no suggestions for improvements and were satisfied with the Tool. One respondent did note that there was "a little bit of going back and forward to get references" referring to returning to the Climate Change and Health Context sheet to review the Climate Change and Health Categories Interaction Table, and the BoD Baseline data at the beginning of each dashboard. However, they then did state that once they had become more familiar with the Tool that this became less of an issue. It is noted that this is an improvement which should be considered, however, due to the nature of the Tool being Excel based, it is difficult to surmount the issue to changing between sheets to reference previous data without having the interaction data repeated on every sheet.

Several DHOs did suggest that a live feed of BoD baseline data be provided which is updated directly from district health departments. While this would be a significantly useful feature, and one which could be considered for future iterations of the Tool, in practice this would be difficult to implement, and likely would involve moving the Tool to a web-based platform. Currently baseline BoD data is sourced from the DHB, and as such could be updated annually. However real-time health data updates from the districts would require a much more significant information sharing and access system to be established by the NDoH, as the required data is usually stored on district internal systems which is currently shared manually. Currently the Tool allows for the easy updating of baseline BoD data, CCE data, and the addition of new CCEs by updating the Tools databases. However, this then requires the Tool to be redistributed to the various DHOs and could result in outdated versions of the Tool being utilised. Regardless of whether or not live baseline BoD updating is implemented, if the Tool was moved to a web-based platform it could easily be updated, eliminating concerns about the version being used and would allow for severity and risk data to be entered and accessed by all districts, allowing for a better comparative understanding of the impact of climate change on the health sector between provinces.

The DHOs were also asked what additions they would like in future iterations of the Tool. The number of improvements suggested were limited, with many respondents stating they were happy with the Tool, and one even going so far as to say, "The Tool is perfect, but very technical". However, there were some common requests made. Firstly, the most common request was to add more diseases and health services to the Tool. While this is an important consideration, other participants did note that there were already a large number of diseases and health services listed, and that the volume of data required from them was already significant. As such, the addition of future diseases and health services

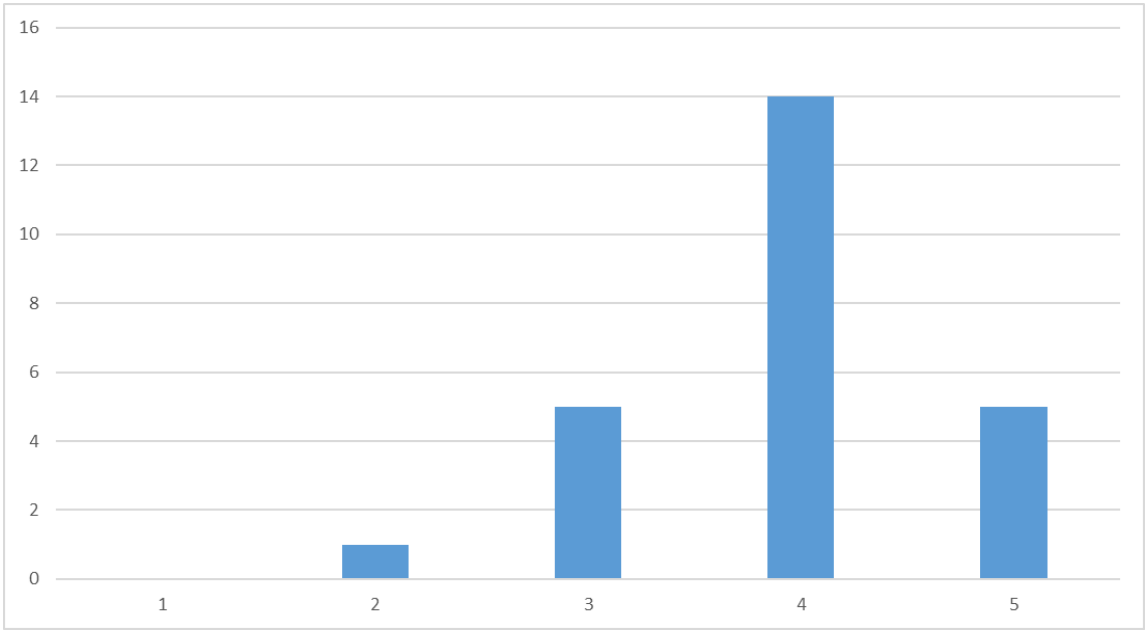
should be balanced between keeping the data collection process accessible and not overly onerous, and making additions which have been identified as key areas of concern due to the impact of climate change on the South Africa health system. For example, it is highly likely that COVID-19 will need to be added into future iterations, given the extended impact anticipated, but also new and emerging diseases which will increase as habitat loss and climate change progress.

Secondly, more practical examples of how climate change impacts health and health services were requested. DHOs stated that it was incredibly useful to have case studies and practical examples from South Africa on how climate change will impact human health and health systems, which allowed for a better understanding of how climate change is likely to be experienced in their districts. Practical examples were given to a certain extent through the 1st-to-4th Order Impact Assessment by facilitators during the exercise, and to help prompt discussions on points which were raised in other provincial workshops and expected to be relevant to the province in question. Expansion of practical examples is likely to be of significant use in further contextualising the impact of climate change and making these impacts tangible to DHOs, and could be made as additions to the Terminology Document.

Overall, there was a highly positive response to the HRVA Tool, with numerous DHOs stating after the HRVA Workshops that they were very impressed with the Tool, that they were excited to work with their colleagues on it to build further capacity in utilising the Tool, and to integrate the results from the Tool and the knowledge they had gained in their work. This as the Tool would help to enable better climate change adaptation planning both in their district health system, and in the NDoH through the data it could provide. These in-person responses are reflected in the results of Question 1 from the Feedback Survey (shown in

Figure 10 below), which sought to establish the overall usefulness of the Tool to the DHOs in terms of its ability to identify and measure the relative risks of climate change. On a scale of one (no, not at all) to five (yes, the Tool fully meets my needs), 20% of respondents gave a five, while 56% gave a ranking of four, 20% gave a three. As such 76% of respondents rated the Tool as being highly useful for understanding the impact of climate change on their district's health sector. This is a strongly positive result, as one of the primary intentions of the Tool was to provide DHOs with accessible information on the risk of climate change to the health sector to better enable planning in district health systems. This demonstrates that the Tool is successful in helping identify key areas of future concern, and as such meets the WHO's recommendations for a blended quantitative and qualitative approach to HVRAs. It is clear that improvements and updates will be needed, but as with the data given by the DHOs, this Tool serves to establish a baseline approach for quantifying the risk of climate change to the health sector and enabling evidence-based planning in South Africa.

Figure 10 Feedback Survey Question 1: Does the HRVA Tool Meet Your Needs in Terms of Identifying and Measuring Climate Change Impacts and Related Risks in the Health Sector for Your Health District? From 1 (No, Not at All) to 5 (Yes, the Tool Fully Meets My Needs)



(Petrie et al, 2021c)

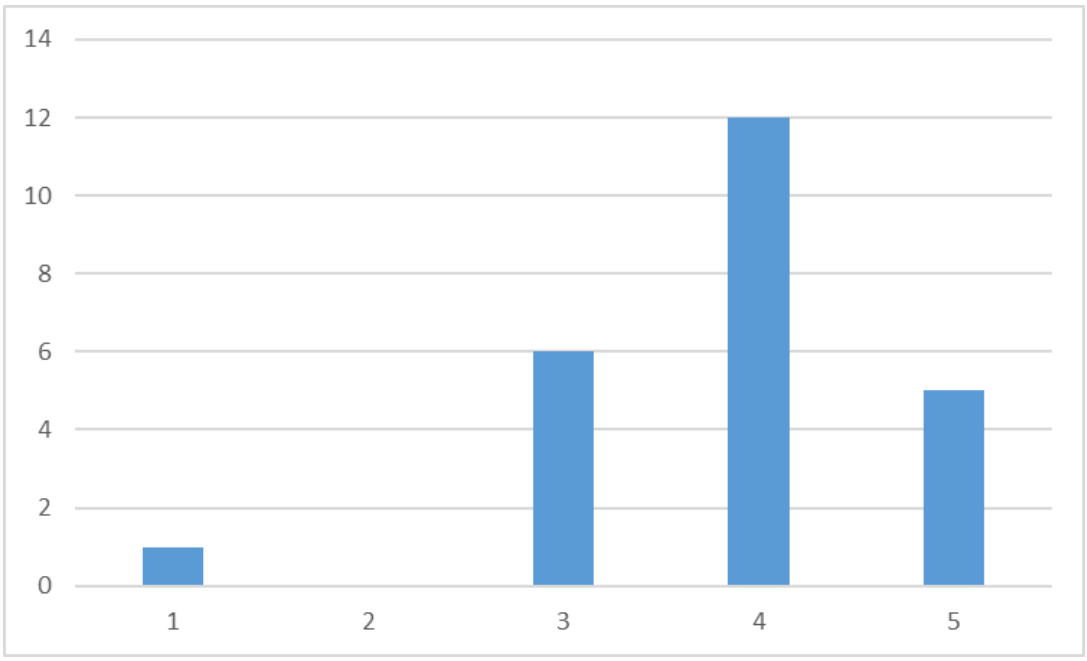
5.2 RESPONSES TO THE CAPACITY BUILDING COMPONENTS OF THE TOOL

DHOs' responses to the capacity building during the workshops was generally positive, with general feedback that the capacity building component was understandable, applicable to their districts, and increased their knowledge of the impact of climate change on health. It is important to note that the 1st-to-4th Order Impact Assessment was found to be particularly useful, as it helped to contextualise the cascading impact of climate change on the health system and to direct DHOs' thinking for the data collection process. This is echoed in the responses requesting more practical examples in Question 13, which were found to increase the amount of engagement during the 1st-to-4th exercise.

For example, a health official from the Gauteng HRVA noted that during heavy rains and flooding, there is an increase in waterborne and diarrhoeal diseases, as in rural areas sewage from long drop toilets overflows into water sources used for washing and drinking, and in urban areas poorly maintained sewerage and stormwater systems overflow resulting in standing water source contamination – particularly in informal settlements. Facilitators used this as an example during subsequent workshops in the 1st-to-4th exercise, and was found to resonate with DHOs across the country. It further spurred discussions resulting in a variety of other examples raised by DHOs, such as droughts in increasing the number of diarrhoeal diseases due to decreased handwashing. This demonstrates how using health and climate/weather dynamics which are currently being experienced as practical examples of what could happen in the future due to climate change helps to guide DHOs' thinking, enabling them to better apply their own knowledge to contextualise future impacts. Thus, a critical component of the capacity-building process is to guide DHOs' mode of thinking on how current climate and extreme weather conditions impact health, and how these will be worsened and change in the future.

Contextualising this mode of thinking in the workshops began with the primary CCE maps displayed in the Climate Change and Health Context Sheet. The respondents found the maps helpful, with 70% of respondents indicating that the maps gave them a high to full understanding of the effects which climate change will have in their districts by 2050, while 25% indicated that it gave them a moderate understanding, as shown in Figure 11. These responses were further confirmed during the workshops, were several DHOs indicated that the maps were a useful tool for understanding CCEs by 2050. However, it was noted during the workshops that it was the combination of the maps and facilitators' explanations which allowed for this level of understanding. This indicates that while the CCE maps were a successful medium for depicting the expected changes by 2050, further explanation by facilitators is required for them to be fully useful. As such in the District HRVA Reports, districts were given provincial maps of the CCEs and the average change for their district, and the municipalities which would experience the smallest, and largest change in their districts.

Figure 11 Feedback Survey Question 2: Do the Maps Give You an Adequate Understanding of the Effects which Climate Change Will Have in Your District? From 1 (No Understanding) to 5 (Full Understanding)

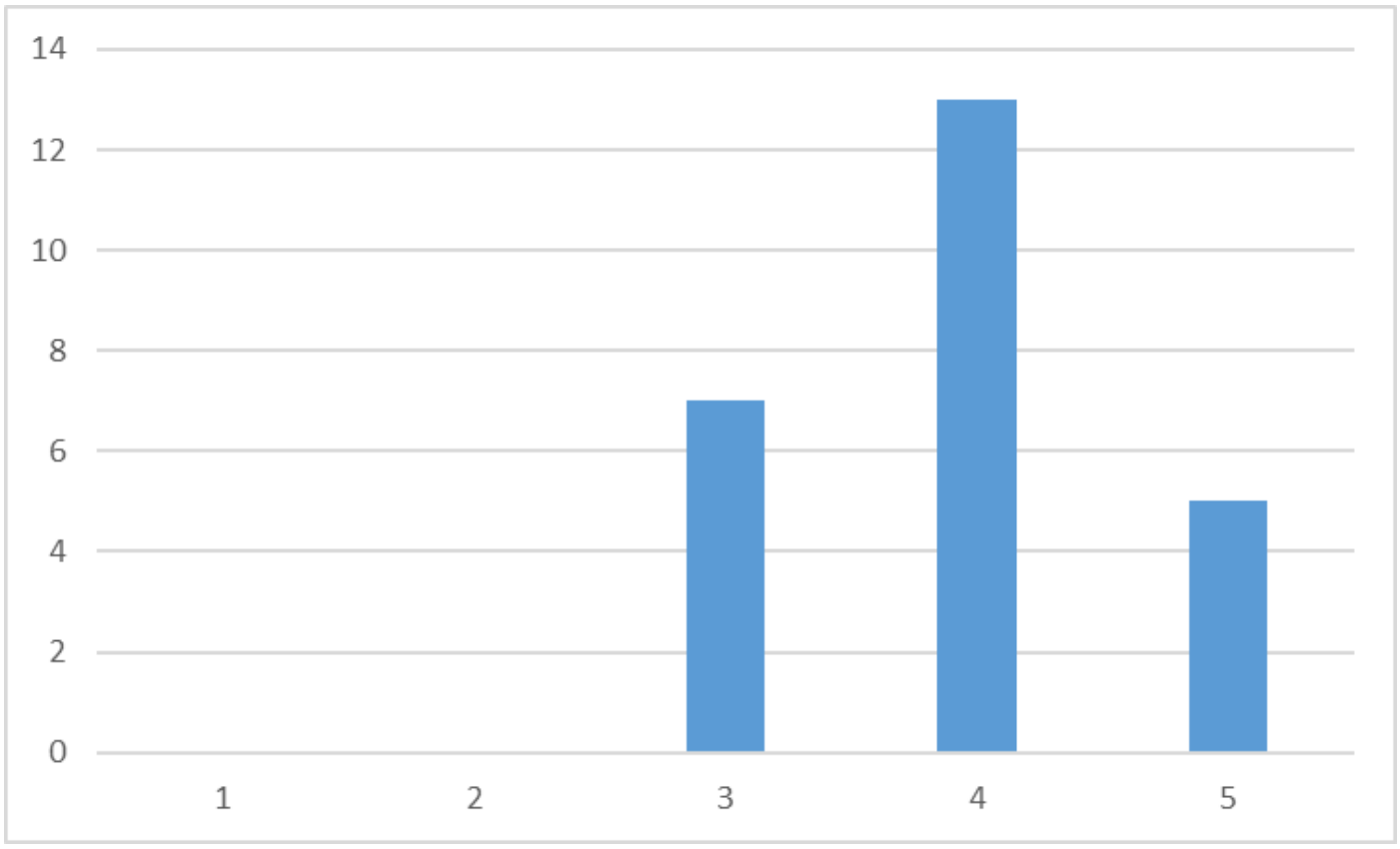


(Petrie et al, 2021c)

During the workshops it was noted that DHOs made extensive reference to the tables of interactions between CCEs and BoD, and health services, which several respondents noted in Question 12 of the Feedback Survey as one of the most useful aspects of the Tool. DHOs noted that these tables were significantly useful for understanding the impact of climate change and helped to guide their thinking on assigning severity rankings when used in conjunction with the maps and their own knowledge. The interaction tables were also useful in stimulating debates between DHOs during the workshops on whether the interactions were accurate. For example, a DHO in the Eastern Cape Capacity Building Workshop indicated he did not believe that heat increased interpersonal violence as it made people more lethargic. This resulted in a lengthy debate which branched into other impacts of weather on mental health, and mood, and proved to be a highly fruitful discussion which resulted in more practical examples being raised based on DHOs' experience.

It is interesting to note that most respondents to the Feedback Survey indicated that the interactions listed matched their own experiences, as shown in Figure 12. These results were confirmed during the various 1st-to-4th exercises, where the links between diseases and CCEs were correctly drawn by DHOs when giving their examples of 3rd and 4th order impacts.

Figure 12 Feedback Survey Question 3: In the Climate and Health Context Sheet do the Interactions between the Climate Change Parameters and Burden of Disease Reflect Your Own Experiences? From 1 (No Similarity) to 5 (Completely the Same)



(Petrie et al, 2021c)

5.3 Responses to the Data Collection Components of the Tool

In almost all workshops DHOs' initial reactions to the data collection section of the Tool was that it was overly technical, and lengthy. However, once the Tool had been demonstrated and DHOs began to work through the Tool, they found it to be easy to work with. This was demonstrated practically as the Injury Dashboard took the longest of all the dashboards to complete, with the pace of data entry increasing steadily as the district groups became more familiar with data entry. DHOs found the standardised layout of the dashboards to be useful as it aided in familiarising the data entry process.

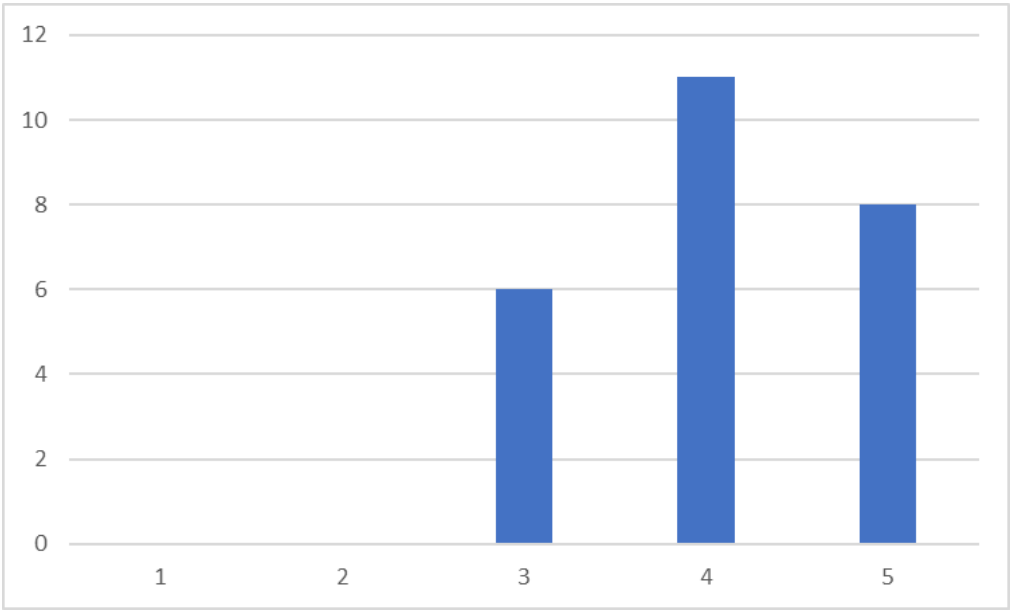
The scribes proved critical for driving the data collection process, as they were able to direct the discussions to ensure they stayed on topic and kept the groups working at a steady pace. It is interesting to note that in cases where the scribe was not confident in leading the discussions, one or two individuals usually led the group discussion, which led to more fruitful discussions. Conversely, in district groups which did not have clear leadership, data entry took significantly longer as discussions did not stay on topic, resulted in more uncertainty in the group, and required more support by facilitators. This reflects the literature on CoPs, which state that facilitated discussions tend to be far more productive, increase participation by normally non-contributing individuals, and improved the quality of information shared (Britt & Paulus, 2016).

All survey respondents indicated that the baseline BoD data graphs and tables were moderately to very helpful for considering the future impact of climate change on BoD, as shown in *Figure 13*. DHOs were seen continuingly referring to the baseline BoD data when assigning severity rankings, with the quintile tables referenced more. DHOs relied heavily on the quintile ranking values to help inform their severity ranking value estimates by using the values as baselines to estimate if BoD would increase, decrease, or stay the same. While this was the suggested use for the tables, it was not expected that DHOs would use this as one of the main comparison points. In hindsight, this should have been expected given the complexity of the estimates expected from DHOs, and this emphasises the importance of providing baseline health data.

DHOs did however state that they had more complete and extensive records of BoD data on their internal systems, and suggested that data management, and information systems personnel be included in future workshops due to their knowledge and ease of access to such data. This was exemplified in the Gauteng HRVA, where a DHO had direct access to their district's health information systems. The DHO was able to give more extensive BoD baseline data, which aided in assigning severity rankings, particularly on mental health and suicide.

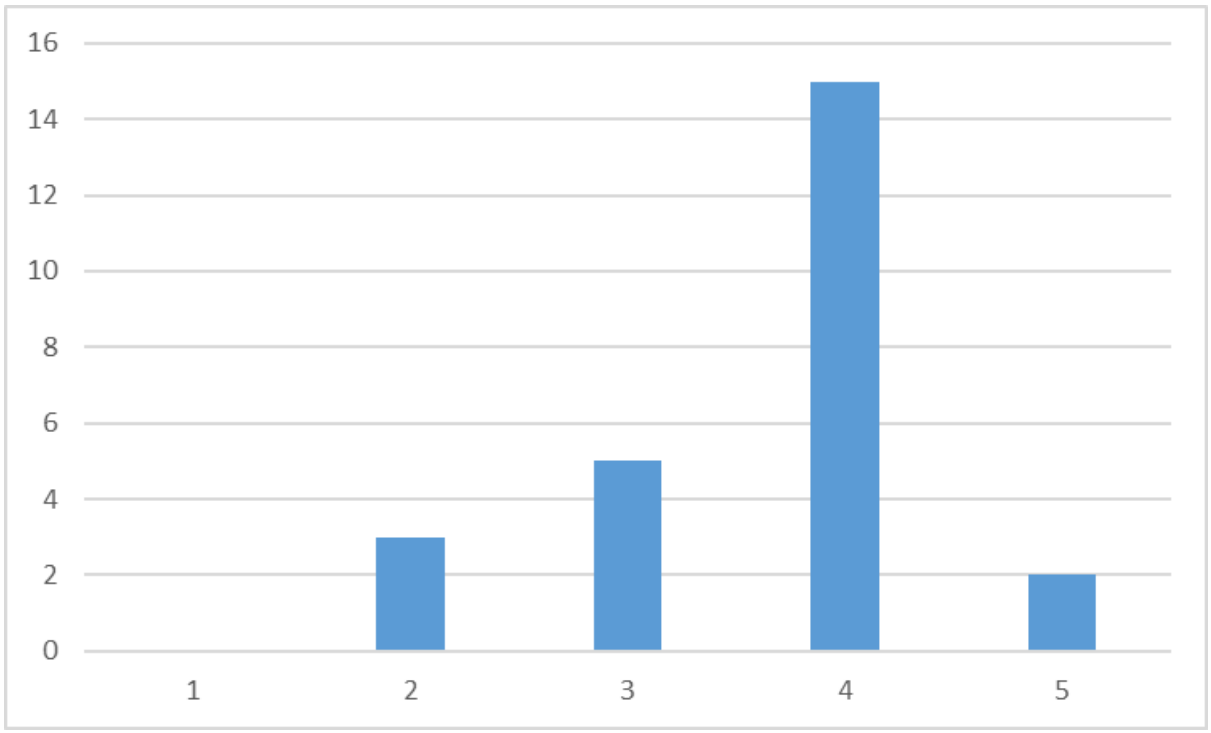
The combination of the maps, interactions tables, baseline BoD data, and the DHOs' own knowledge was seen by the DHOs as sufficient information to provide estimates for the severity rankings, which is demonstrated by Figure 14. However, almost every district group noted that not all areas of the health sector from their district were sufficiently represented, and thus they were not able to give fully informed estimates. This was a limitation of the workshops which was expected due to the more limited number of DHOs who were able to attend, given that at the time the health departments had most of their resources allocated to dealing with COVID-19. While this did reduce the quality of data provided, in most cases DHOs were able to complete most or all of the data entry required.

Figure 13 Feedback Survey Question 4: Is the Presentation of Burden of Disease Data as a Graph and Quintile Table in the Burden of Disease Dashboards Useful for Considering the Future Impact on Burden of Disease? From 1 (Not Helpful) to 5 (Very Helpful)



(Petrie et al, 2021c)

Figure 14 Feedback Survey Question 6: Is Sufficient Information Provided for You to Estimate the Severity Ranking for Burden of Disease in 2050? From 1 (Not Clearly Explained) to 5 (Very Clearly Explained)



(Petrie et al, 2021c)

When DHOs were first presented with the data collection requirements, many stated that they were uncertain how to provide the estimates due to their complexity, however once introduced to the severity rankings as the medium for describing future severity of BoD, and health services, DHOs found it to be a useful medium. The district groups engaged in robust discussions when assigning severity rankings, and despite the issues raised about certain sectors of health not being fully represented, there was a diversity of opinions and knowledge present. While there tended to be core members who contributed the most to discussions, groups tended not to be dominated by any one individual or group of individuals. As such, this hopefully indicates that the high levels of engagement and discussion resulted in good quality severity estimates. Further, this demonstrates that the WHO's approach of expert discussions to estimate future climate change impacts on health is a medium which can be successfully employed in South Africa.

Finally, there was a noticeable difference between the level of engagement and discussions held between officials who were in the half-day workshops compared to the full-day workshops. As noted in the Methodology, the content from the Capacity Building Workshops needed to be repeated in the HRVA Workshops as often the individuals present had not attended their province's Capacity Building Workshop. This meant that the capacity-building content had to be repeated swiftly during the HVRA Workshops to still allow enough time for data collection. While the data collection process was still able to take place effectively, it did mean that there was a lower level of engagement and understanding among DHOs in the half-day, compared to full-day, workshops because they had less time to work through and internalise the information given. As such, it is felt that these DHOs will have a lower climate change capacity level developed than those in the full-day workshops which allowed for longer discussions, and a higher level of engagement with the capacity-building material. However, it is important to note that full-day workshops were more difficult to organise given the high workload and number of engagements which DHOs have.

Several DHOs did suggest that a further incentive which could increase attendance and recognition of the work done by DHOs, would be to register the workshops with the Health Professionals Council of South Africa (HPCSA). This would allow DHOs to receive Continuing Education Units (CEU) which contribute towards their Continuing Professional Development (CPD) points which health professionals are required to maintain to demonstrate knowledge of emerging health needs and priorities (Health Professionals Council of South Africa, 2021).

Figure 15 demonstrates that 76% of respondents found the severity rankings to be useful to very useful. Some DHOs did note that they felt the severity rankings were too broad to be able to be accurate and needed more severity rankings.

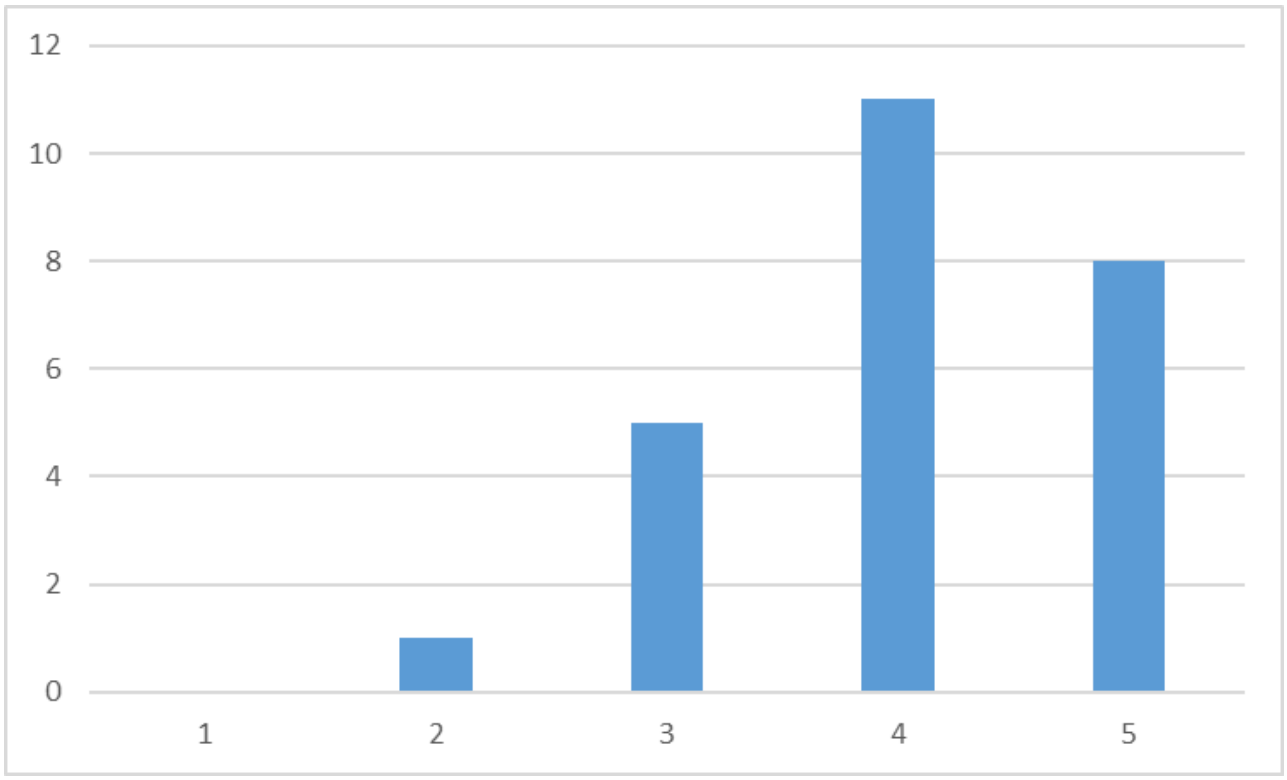
However, it was noted that the severity rankings and resulting risk rankings are intended to be indicators of vulnerability, rather than exact estimates. While a more extensive scale of severity rankings could be used, this could result in an over complication of data input considerations which DHOs already found to be extensive, increasing the time commitment needed to complete the Tool, and the complexity in deciding what severity ranking to assign.

The district groups engaged in robust discussions when assigning severity rankings, and despite the issues raised about certain sectors of health not being fully represented, there was a diversity of opinions and knowledge present. While there tended to be core members who contributed the most to discussions, groups tended not to be dominated by any one individual or group of individuals. As such, this hopefully indicates that the high levels of engagement and discussion resulted in good quality severity estimates. Further, this demonstrates that the WHO's approach of expert discussions to estimate future climate change impacts on health is a medium which can be successfully employed in South Africa.

Finally, there was a noticeable difference between the level of engagement and discussions held between officials who were in the half-day workshops compared to the full-day workshops. As noted in the Methodology, the content from the Capacity Building Workshops needed to be repeated in the HRVA Workshops as often the individuals present had not attended their province's Capacity Building Workshop. This meant that the capacity-building content had to be repeated swiftly during the HVRA Workshops to still allow enough time for data collection. While the data collection process was still able to take place effectively, it did mean that there was a lower level of engagement and understanding among DHOs in the half-day, compared to full-day, workshops because they had less time to work through and internalise the information given. As such, it is felt that these DHOs will have a lower climate change capacity level developed than those in the full-day workshops which allowed for longer discussions, and a higher level of engagement with the capacity-building material. However, it is important to note that full-day workshops were more difficult to organise given the high workload and number of engagements which DHOs have.

Several DHOs did suggest that a further incentive which could increase attendance and recognition of the work done by DHOs, would be to register the workshops with the Health Professionals Council of South Africa (HPCSA). This would allow DHOs to receive Continuing Education Units (CEU) which contribute towards their Continuing Professional Development (CPD) points which health professionals are required to maintain to demonstrate knowledge of emerging health needs and priorities (Health Professionals Council of South Africa, 2021).

Figure 15 Feedback Survey Question 7: Are the Severity Rankings a Useful Way of Projecting the Future Health Impact of Burden of Disease? From 1 (Not Useful) to 5 (Very Useful)



(Petrie et al, 2021c)

5.4 Responses to the Presentation of Risk Data

The risk of health impacts due to climate change was displayed to DHOs at the end of each of the BoD Dashboards, the end of the Services Dashboard, BoD Summary Dashboard, and in the Risk Overview Sheet. In the first two of these sheets, risk data is presented both as text values, demonstrated in

Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

, and as a graph

Figure 8. The BoD Summary Dashboard contained all the BoD dashboards' risk ranking tables, while the Risk Overview sheet ranks all the risk values for the districts, and gives summary statistics for the selected province.

During the Capacity Building Workshops, the combined risk rankings in the Dashboards were generally well received and were seen as a useful means of understanding the risk comparatively. It was raised that the risk rankings do not give the exact likelihood or risk of a health impact due to climate change, and as such it was found necessary to emphasise that the risk rankings only inform the level of risk to a given BoD or health service relative to others in the model. This point was continually stressed to DHOs to avoid DHOs comparing the numerical values in the graphs to other risk studies or being used as exact values to represent the level of risk. It was critical to ensure that this was well understood, as given the approach used, this would be an inaccurate representation of the risk data provided.

Unfortunately, during the HRVA Workshops there was a certain level of confusion among some DHOs when working with the Tool and what the Table 8 Combined Risk Rankings for all Districts were used for. Table 8 was confused with the

District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

, or as a table which required data entry. This may have been an issue with a lack of clarity when explaining the Tool, or the similarity in appearance between

District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

and

Combined Risk Rankings for all Districts:

The Risk Ranking Matrix below displays each districts risk status for Injury. This status is calculated by multiplying the relevant climate change parameters by the severity number associated with the severity ranking assigned in the Severity Table above, and then multiplied by the Interaction Table demonstrated in the Climate Context sheet. A matrix of all the risk rankings is provided below the table for easy reference.

POTENTIAL HEALTH IMPACT	IMPACT DEFINITION	Amajuba	eThekwini Metro	Harry Gwala	Ilembe	King Cetshwayo	Ugu	uMgungundlovu	uMkhanyakude	uMzinyathi	Uthukela	Zululand
Interpersonal violence	Behavioural changes due to very hot days	Medium Low	Medium	Very Low	Medium	Medium	Low	Medium	Medium Low	Low	Low	Medium
Mechanical forces	Behavioural changes due to very hot days but good road infrastructure	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Road injuries	Occupational and environmental destruction	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium Low	Medium	Medium	Medium Low
Hanging, strangulation	Behavioural changes due to very hot days	Low	Very Low	Very Low	Low	Medium High	Low	Low	Medium Low	Low	Very Low	Low
Exposure to natural forces	destruction of dwellings and infrastructure	Medium Low	Medium High	Medium Low	Medium	Medium Low	Medium	Medium	Medium	Medium	Medium	Medium Low
Other transport accidents		Medium Low	Medium High	Medium Low	Medium Low	Medium Low	Medium High	Medium Low	Medium	Medium High	Medium Low	Medium Low
Average		Medium Low	Medium	Low	Medium	Medium	Medium	Medium Low	Medium Low	Medium	Medium Low	Medium Low

, which both use the traffic light colouring system. However, once facilitators had re-explained the tables use, DHOs' understanding of the risk tables and graphs was clear.

DHOs' responses to the risk ranking tables and graph were strongly positive during the workshops, with DHOs finding it easy to understand, which was reflected in the results shown in Figure 16. When asked which aspects of the Tool DHOs found most useful, the risk rankings were the most noted feature. DHOs found it a useful means for understanding where their focus and planning should be prioritised to minimise the impact of climate change in their districts. A further reflection of risk tables' and graphs' usefulness was the request by DHOs that the tables and graphs be accessible, such that they can be integrated into their presentations and reports. As with the

District:	Interpersonal violence	Road injuries	Mechanical forces	Exposure to natural forces	Hanging, strangulation	Other transport accidents
Amajuba District	3	4	3	0	2	0
eThekwini Metropolitan	3	2	5	0	4	0
Harry Gwala District	2	4	4	0	2	0
Ilembe District	0	2	4	0	5	0
King Cetshwayo	3	4	4	0	3	0
Ugu District	4	2	4	0	5	0
uMgungundlovu District	3	3	5	0	2	0
uMkhanyakude District	3	5	4	0	4	0
uMzinyathi District	2	4	5	0	1	0
Uthukela District	2	4	5	0	2	0
Zululand District	2	3	4	0	5	0
Provincial Average:	2	3	4	0	3	0

, the DHOs found the colour coding system useful, and an easy to understand means of displaying the data given that the colour coding made it visually easy to distinguish between the risk levels.

It was interesting to note that DHOs were seen comparing and discussing the results of the risk rankings which in some cases resulted in officials changing the severity rankings they had assigned. This was done in cases where DHOs felt that the risk results did not reflect the level of severity which they had assigned. In cases where facilitators where aware of this, they emphasised that while there may be less of a risk from climate change for a particular disease or health service than expected, this did not diminish the expected severity of the disease external to climate change.

This does reflect an issue with the Tool, where health officials could enter a feedback loop of changing their assigned severity ranks until the risk data matches their expectations. This is an issue, as the risk ranking is dependent on the CCEs for a particular district, and as such in cases of lower increases in the exposures, there may be a lower risk level. While this is reflective of the data inputs, it may not reflect the DHOs' expectations given the emphasis placed on certain

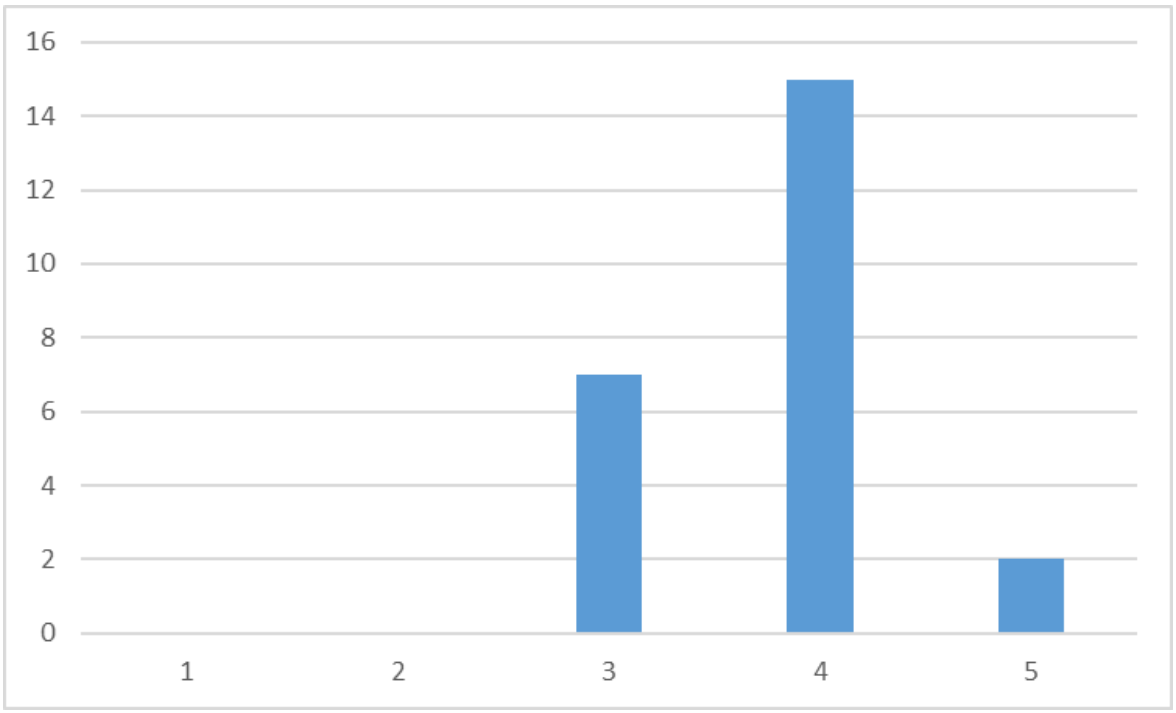
diseases and health services during the capacity building. The risk rankings may further serve to influence the estimates which DHOs give, and as such could result in DHOs giving inaccurate estimates which are under- or over-estimated to ensure the risk ranking meets their expectations. To avoid this issue, it is advisable that future iterations of the Tool should consider moving the risk ranking results off the data collection dashboards to summary dashboards if it is felt that this will reduce the instances of this issue, and will not decrease the user friendliness and clarity of the dashboard.

The final means of displaying the risk rankings was in the Risk Overview Sheet. This sheet gives a final summary and overview of the risk levels for the districts, as well as providing summary statistics for the province. The level of engagement with the Risk Overview Sheet was more limited, given that while it was introduced and worked through during both the Capacity Building and the HRVA Workshops, the focus during the HRVA Workshop was on data collection. As such, only district groups which finished early and took time to work through the Risk Overview were able to engage with the sheet practically. From discussions with DHOs on other aspects of the Tool, it was clear that a fuller understanding of the Tool only came with practical interaction, and as such the responses from DHOs on the Risk Overview where more limited.

The DHOs found that the Risk Overview sheet was a useful means of displaying the risk data, and there was particular interest in how the sub-categories for each of the BoD and health services categories were listed in descending order of risk. It was felt that this gave a clearer idea of what should be prioritised in comparison to the risk tables, which only had six categories of risk. Provincial health officials who were present at the workshops found the provincial summary statistics to be useful and noted that they agreed with the decision to rank the sub-categories based on a count of their rankings among the districts rather than an average of the risk values. It was confirmed that this would be a more accurate representation of the province, given that districts with higher risk rankings would outweigh the results from districts with lower risk rankings. This is an issue which was particularly apparent in KwaZulu-Natal, where Harry Gwala District had comparatively lower risk rankings, with significantly higher risk rankings of other districts overpowering Harry Gwala's results when an average was used.

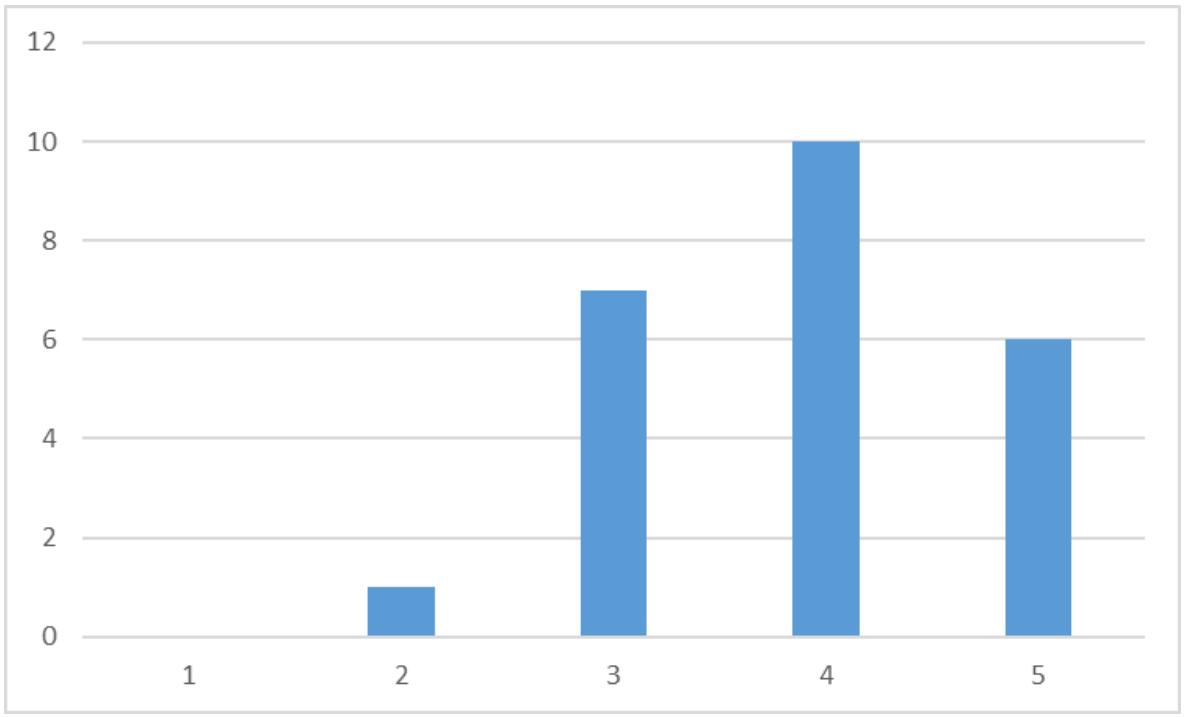
Figure 17 displays the results from the Feedback Survey, which shows that 67% of the respondents gave a useful to very useful ranking for the Risk Overview Sheet, however, 42% indicated that they felt it was somewhat useful. This suggests that there are improvements which can be made to the Risk Overview Sheet to present the risk ranking data in a more useful manner, such as having comparisons between the top risk for the categories. However, as limited feedback was given by those who found the Risk Overview sheet to be less than useful, it is only possible to speculate on possible improvements.

Figure 16 Feedback Survey Question 8: Is the Combined Risk Ranking for All Districts, which is Displayed at the End of Each of the Burden of Disease Dashboards Easy to Use and Clear Regarding the Risk Posed to Your District? From 1 (Not Useful) to 5 (Very Useful)



(Petrie et al, 2021c)

Figure 17 Feedback Survey Question 10: Do the Top 5 Ranked Diseases on the Risk Overview Sheet Provide Sufficient Information Regarding the Risk Posed to Your District? From 1 (Not Useful, Needs More Information) to 5 (Very Useful, Perfect Amount of Information)



(Petrie et al, 2021c)

5.5 Overview and Recommendations on Tool, and Capacity Building

Overall, the feedback from DHOs on the Tool was strongly positive, with DHOs finding it useful for understanding the future impact of climate change on health, that the data entry process was easy to complete and understand, and that the means of displaying the risk data was clear. This assessment is reflected by the strongly positive responses given in the

Feedback Survey, and from in-person discussions with DHOs during the workshops. While there are certain improvements to the Tool which were raised, none are substantial changes to the Tool and are easy to implement, and which are listed in the recommendations below. One aspect which does clearly need improvement is the description of tables in the Tool to distinguish between which tables are for data entry, and which give risk results. However, as the Tool was designed with these types of issues in mind, the cell locking prevented DHOs from changing any formula or values which would have disrupted the Tool's workings.

Based on the feedback from DHOs and the experiences from the workshops, there are several enhancements and improvements to the HRVA Tool that should be considered for future iterations of this project to increase the usability and accessibility, and to improve the data collection process:

- **Improve the list of interactions between CCEs and BoD, and health services**: The initial list of interactions developed by the project team should be tested, validated, and improved on by a cohort of health officials, climate change, and public health experts. While the interactions are based on the latest academic literature, and extensive experience of the OneWorld experts, discussion by a larger group of health professionals representing a broader range of areas of health and expertise will result in a more robust set of interactions. This will also be necessary as the body of knowledge on the impacts of climate change on health will continue to develop and expand.
- **Review the list of diseases examined:** based on the findings of this project, continuing research into the impact of climate change on health globally and within South Africa, and the findings made following the first recommendation, the diseases selected for the Tool should be reviewed and narrowed to focus on climate sensitive diseases. This will allow for the Tool to take a more focused approach to climate-sensitive BoD, rather than focusing more broadly on the top 26 diseases affecting South Africa today. This should include more robust categories for mental health. However, this should not result in expanding the list too significantly, which would increase the time required to complete the Tool and increase its complexity.
- **Improve baseline BoD data:** Currently, baseline BoD data is captured from the Health Systems Trust's DHB, and while this does provide extensive, and in-depth data, several districts have incomplete data. As such Information and Communications Technology personnel from the health districts should be included in the Tool's development process, enabling them to update the Tool's baseline district BoD data where gaps are found.
- **Improve table descriptions:** Descriptions of tables in the Tool should more explicitly state whether they are for data collection, or provide baseline data, to improve the clarity of the Tools use.
- **Move to a web-based application:** The ultimate enhancement of the Tool would be to move off Excel to a web-based application. This would allow health officials to access the Tool at any time and place and allow for baseline BoD and CCE data to be easily updated. A web-based application would have three distinct advantages: firstly, it would allow for the Tool to have its architecture and baseline data updated without having to distribute new versions of the Tool. This would remove any issues of DHOs working with outdated versions of the Tool after updates, and would allow for baseline BoD data to be more easily updated each year when the latest DHB is released. Secondly, this would enable central storage of districts' severity rankings, allowing different districts to view and compare the risk of climate change in their district to others. Beyond allowing district and provincial health officials a better comparative understanding of the impact of climate change on the health sector, it would allow a wider cohort of health officials to access the Tool, expanding capacity building efforts. Finally, this would allow districts to iteratively update their severity rankings as new DHOs are trained on it, providing an improved capacity and knowledge in the district, and supporting more robust risk data.

Further, to continue improving the capacity development of the impact of climate change on the health sector, future iterations of the project are recommended to make the following improvements:

- **Focus on full-day rather than half-day workshops:** The workshops demonstrated that there were higher levels of understanding of and engagement with the capacity building material and Tool in the full-day workshops compared to the half-day workshops. DHOs in the half-day workshops found that they had forgotten much of the material which had been discussed in the Capacity Building Workshop by the time they engaged in the HRVA Workshops. Further, because of scheduling conflicts, in almost all the half-day HRVA Workshops it was found that many of the

DHOs had not attended the Capacity Building Workshops, and thus required the capacity building material to be repeated in a much shorter timeframe. As such, holding full-day workshops which include both capacity development and HRVA data collection would improve the quality of data collected, engagement with the capacity building material, and the level of understanding of the work conducted. Further, many DHOs noted that it was only once they had worked on the Tool that they fully understood its working and purpose. Thus, full-day workshops, or consecutive half-day workshops, would allow for optimal capacity development, and collection of more robust data.

- **Include more practical examples:** The inclusion of more practical examples of how climate change impacts the health sector is likely to increase the level of understanding and engagement with the Tool. Practical examples provide health officials with material they can relate to their daily experience and help guide their thinking when considering the future impacts of climate change on health. These could be included in the Terminology document.
- **Develop a cohort of district facilitators:** One of the most important outcomes of this project is likely to be the development of a cohort of DHOs who are informed on the impact of climate change on the health sector and utilising the HRVA Tool. Individuals who are engaged with, and interested in, the work conducted during the workshops should be identified and undergo further capacity development on understanding and addressing the impact of climate change on the health sector. This cohort will be able to reach more health professionals than the project was able to, thus increasing the capacity within the health sector, and the robustness of future data collection by assisting in facilitating the process. This would also increase health professionals' ownership of the project, and thus increase the longevity of its capacity building activities and ultimately enhancing the integration of climate change adaptation into the South Africa health sector.
- **Register the workshops with the HPCSA:** By registering the workshops with the HPCSA, DHOs would be able to earn CEU points. This would likely increase the number of workshop participants by increasing the benefit to DHOs from attending. Further, the literature on CoPs notes that providing formalised recognition of professionals' contributions is often a driving force behind participation in discussions and encouraging continued contributions, which will aid in the development of a cohort of district facilitators.
- **Increase the number of sectors of health represented:** A common issue raised by districts was that there was not sufficient representation from all sectors of health in the workshops to fully complete the data required for the Tool. As such a wider range of health professionals should be included in future iterations of the project, particularly those involved in primary care, hospital and healthcare infrastructure management, epidemiology specialists, and psychologists. An increased diversity of knowledge will improve the quality of discussions when assigning severity rankings, and thus lead to more robust data.

6 DISCUSSION OF FINDINGS

In this chapter the results of the Tool will be reviewed at a national level through examining risk distribution maps, and then looking at the most significant risks for each province and drawing comparison to the CCE maps to understand what the factors are driving the risk of health impacts due to climate change. This chapter's main purpose is to illustrate how the risk data from the Tool can be used to inform health officials of the risk of a health impact from climate change, through simple to follow descriptions of the impacts of climate change on health. All the maps and box and whisker graphs used in this chapter were generated by the author using the Excel 3D Maps tool, and the risk data generated by the Tool using the severity ranking data gathered from all 52 districts.

This chapter will be broken into four sections for each of the BoD categories. Note that there are three main metrics which are reviewed to establish the level of risk at a provincial level. Firstly, the Top 5 Tables from the Risk Overview for each province are reviewed. These tables give a count of the number of times a sub-category is ranked from highest risk value to lowest risk value in a district, giving a value from one to five. This gives an indication beyond the risk ranking of how significant of an issue a given sub-category is to the province. Secondly, the percentage of each risk level represented in the province is reviewed to understand the distribution of relative risk. Finally, box and whisker graphs are compared and reviewed in conjunction with the previous metric to understand what the overall levels of relative risk are. This aids in understanding the risk to health, as simply relying on the risk distribution maps at a national level does not properly illustrate the specific risks experienced by provinces.

6.1 INJURY

The Injury category was found to have the highest risk values among the BoD categories. From Table 5 Interactions between Climate Change Parameters and BoD these risk values are driven by the significant impact which very hot days has on all sub-categories, and that most sub-categories are significantly increased by either relative humidity, extreme precipitation days, or both in the case of road injuries. These similarities in interactions between the Injury sub-categories and the CCEs is why a similar national risk distribution is seen.

The maps in Figure 20 to Figure 24 demonstrate that there is a band of higher risk which runs from the northern Western Cape up and across to the east of Limpopo, which can be seen to closely follow the very hot days exposure values in Figure 3. In the case of road injuries, exposure to natural forces, and other transport accidents, the higher extreme precipitation days values in the districts in the north east of the Eastern Cape, and central and south of KwaZulu-Natal are causing the increased risk in these sub-categories compared to other sub-categories. It is interesting to note that mechanical forces appear to have some of the lowest risk values from a national perspective, however, this is because Mopani District in Limpopo, which has the highest risk value, is significantly higher than other districts which skews Figure 23's colour gradient. Mopani District's significantly higher risk is due to DHOs assigning a severity rank of very high, and it falling into the highest category for very hot days, and relative humidity.

Beginning with the Eastern Cape, other transport accidents are at the highest average risk level, followed by road injuries, and then exposure to natural forces. Road injuries, and other transport accidents both experience significant increases from very hot days and extreme precipitation days, while relative humidity significantly increases road injuries only. Hot and humid conditions lead to increased fatigue, carelessness, and irritability which decrease concentration and thus increase the chances of accidents occurring (Young et al, 2010; Myers et al 2011; Myers & Rother, 2012). Extreme precipitation leads to wet and dangerous roads, increasing the likelihood of road injuries, while flooding creates treacherous driving conditions both during floods and after the fact by leaving roads damaged (Young et al, 2010; Myers et al 2011; Myers & Rother, 2012).

Mortality and morbidity due to exposure to natural forces is significantly increased by very hot days, and extreme precipitation days, and an increase due to flood, and fire. This creates concern for summer months when high temperatures increase the risk of dehydration, while extreme precipitation increases the chances of death and illness from exposure, while flooding can result in injuries or drowning (Fields, 2005; McMichael, 2009; Ziervogel et al, 2014). As such the road injuries, other transport accidents, and exposure to natural forces values are driven mainly by the extreme precipitation days values in the Eastern Cape. It is interesting to note that the same sub-categories of disease

are the most at risk in the Free State, although exposure to natural forces outweighs road injuries. This is due to the Eastern Cape districts giving on average a lower severity ranking to exposure to natural forces than road injuries than was given by the Free State. Further, the Free State has higher risk rankings than the Eastern Cape as the Free State has more significant values in all CCE categories.

In Gauteng, road injuries and mechanical forces are the two sub-categories at most concern, with both having 40% medium high, 40% high, and 20% high risk ranks. However, the distribution of the risk ranks in Gauteng means that when considering the province's Risk Overview sheet, all sub-categories appear at least once in a district's most at risk sub-category, with interpersonal violence and road injuries appearing twice. A similar risk rank distribution is seen among the sub-categories other than road injuries, and mechanical forces which have a greater percentage of very high risk ranked districts. Mechanical forces experience a similar impact from CCEs to that of road injuries, where heat and humidity lead to increased fatigue, carelessness, and irritability which increase the likelihood of injuries occurring (Young et al, 2010; Myers et al 2011; Myers & Rother, 2012). This poses an issue both for workers operating machinery indoors in hot conditions, and workers outdoors in exposed conditions. As such, Gauteng is likely to experience elevated risk across the Injury category.

Turning to KwaZulu-Natal, road injuries, exposure to natural forces, and other transport accidents are the sub-categories which rank between the first to third most at-risk sub-categories in the province. Road injuries risk rankings across the districts are 73% medium high, and 27% high, while exposure to natural forces has 36% medium high, 45% high, and 9% very high, and other transport accidents has 64% medium high, 9% high, and 9% very high. Further, interpersonal violence has elevated risk ranks, with 36% medium, 9% medium high, and 45% high, but is only the fourth most at-risk sub-category in six districts, and the remaining five districts are between the first and third most at-risk sub-categories. Interpersonal violence is significantly increased by very hot days, which leads to increased stress, irritability, and worsening mental health which can cause increased aggression (Myers & Rother, 2012; Chersich et al, 2018; Chersich et al, 2019). As such interpersonal violence is of concern, but secondary to road injuries, exposure to natural forces, and other transport accidents in KwaZulu-Natal. Further, KwaZulu-Natal has the widest range in its risk ranks among the provinces, and this is due to having the largest number of districts, and less uniformity in CCE values across the districts than other provinces.

The higher risk levels displayed in the maps for Limpopo is reflected by

Figure 18. The box and whisker graphs display the risk values for the districts in the province for each disease sub-category, showing the maximum, minimum, mean, and 25% and 75% quartiles. The vast majority of the sub-categories lie in the very high risk rank, with exposure to natural forces estimated to have marginally less at risk with 80% high, and 20% very high. As such, Limpopo has the highest risk in this category out of all the provinces. Hangings and strangulation, mechanical forces, and road injuries are at the most significant risk across the districts, falling between the first and third highest risk value. Hangings, and strangulation are significantly increased by very hot days and relative humidity, as these CCEs have a direct negative impact on mental health, and an indirect impact as they diminish rural agricultural livelihoods, and living conditions generally, and thus in extreme cases contributes to suicide (Myers & Rother, 2012). While these are the most at-risk sub-categories, Limpopo's high to very high risk in all the Injury sub-categories poses significant concern for health officials.

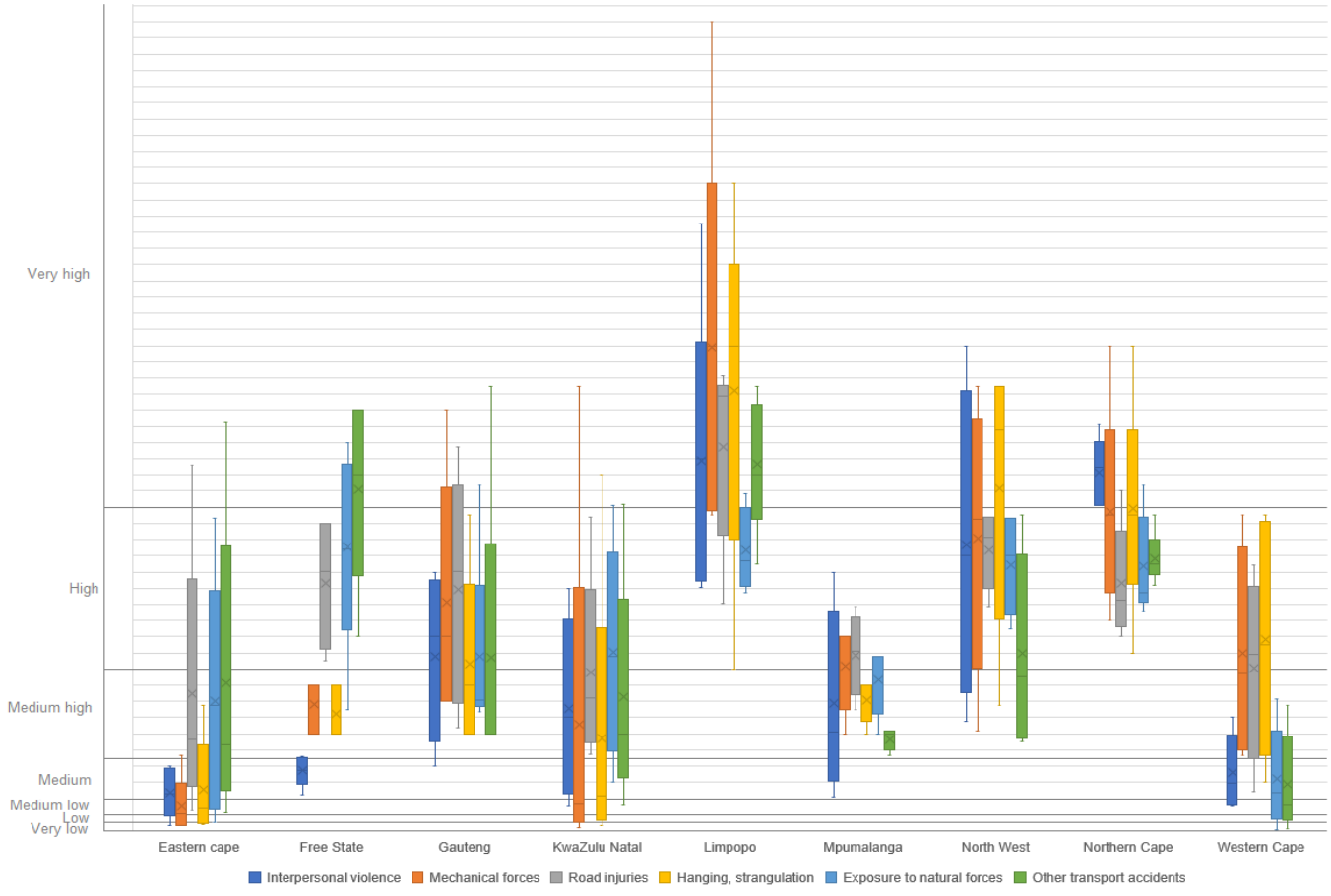
By contrast, in Mpumalanga interpersonal violence, mechanical forces, road injuries, and exposure to natural forces are all the most significant concern. This difference between the two provinces is mainly driven by Limpopo's significantly higher very hot days values, which on average are double that of Mpumalanga, while Mpumalanga has higher extreme precipitation days values. This is why Mpumalanga's exposure to natural forces value are more significant relative to other sub-categories when compared to Limpopo's distribution, and is why Mpumalanga has lower risk values than Limpopo. It is important to note that Mpumalanga only has three districts, and as such one district with lower values can skew its distribution. For example, for exposure to natural forces only one district has a medium high risk ranking, while both others have a high risk ranking.

The Northern Cape's sub-categories all either fall into the high, or very high risk ranks, presenting a similar risk distribution as Limpopo and concern for the impact on its health system. Interpersonal violence is at the highest risk, with only very high risk ranks, although all sub-categories fall in to the high, and very high risk ranks. However, other

transport accidents is comparatively of the least concern as it only has high risk ranks. These elevated risk levels are mainly driven by the high very hot days values estimated for the Northern Cape. By contrast, the North West has a wider distribution of risk ranks, including some medium high risk ranks, but as with the Northern Cape the majority are high and very high. Finally, turning to the Western Cape, mechanical forces, road injuries, and hangings and strangulations are the categories which are most at risk. All three of these subcategories have a majority of medium high to high risk ranks, and are mainly driven by the comparatively higher relative humidity values. The Injury category is among the most at risk for the Western Cape, with elevated risk ranks in all sub-categories compared to other categories of BoD.

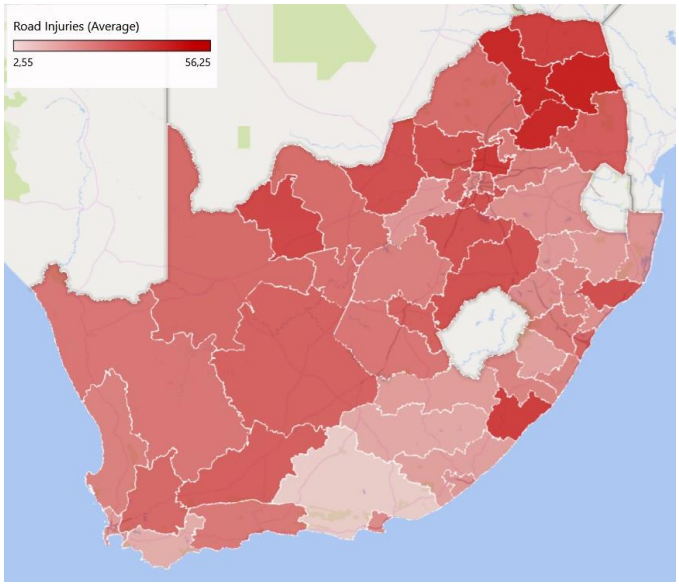
In summary, there will be a high level of risk from climate change on the Injury category. In the case of very hot days, and relative humidity, an increase in the amount of cooling equipment in homes, workplaces, and vehicles will be vital for mitigating these impacts, but as noted by DHOs, the poor do not have the means to purchase such equipment. This exemplifies the fact that the poor will be the most significantly impacted by climate change (WHO, 2021), and as such will require significant state support either to provide adaptation measures to mitigate these impacts, and to provide far more substantial public health facilities to deal with the increased case load.

Figure 18 Box and Whisker Graph of Provincial Injury Sub-Categories Risk Rankings



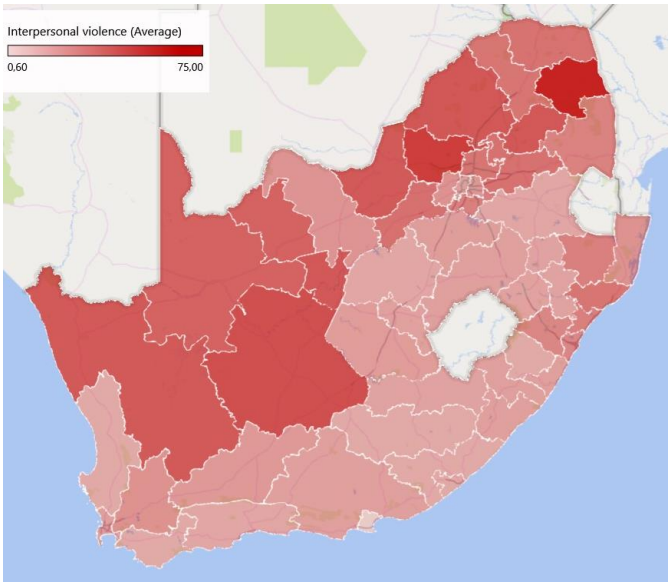
(Petrie et al, forthcoming)

Figure 19 Distribution of Risk of a Health Impact from Climate Change on Road Injuries



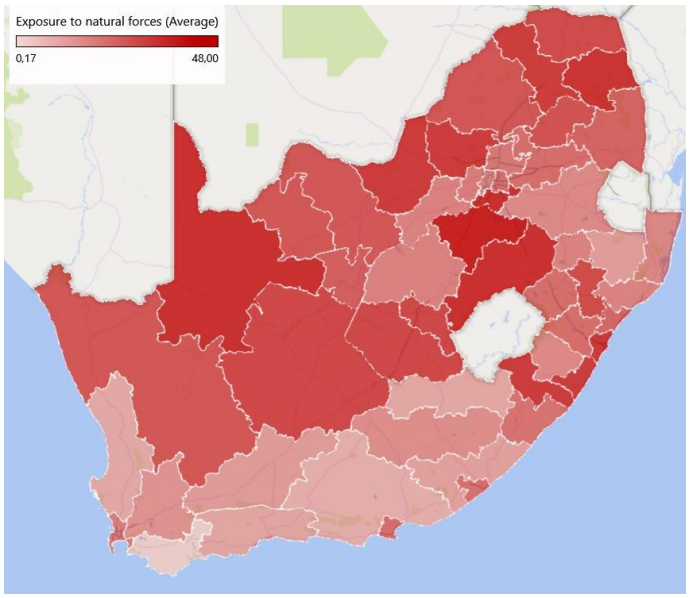
(Petrie et al, forthcoming)

Figure 20 Distribution of Risk of a Health Impact from Climate Change on Interpersonal Violence



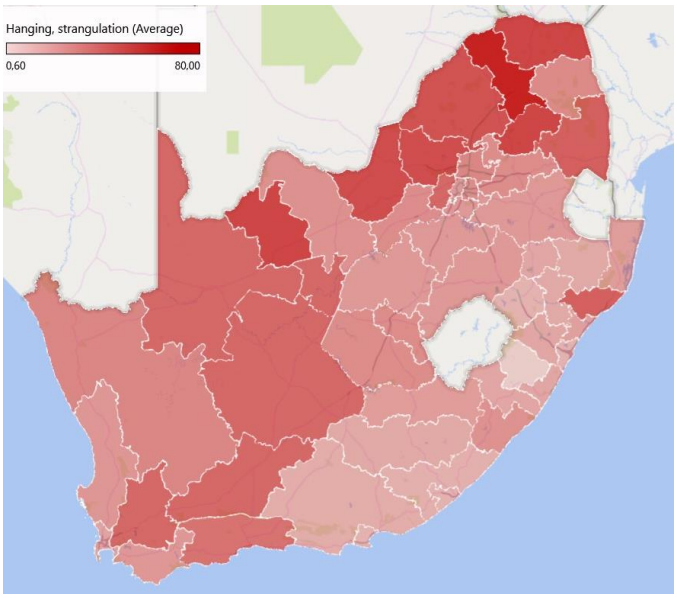
(Petrie et al, forthcoming)

Figure 21 Distribution of Risk of a Health Impact from Climate Change on Exposure to Natural Forces



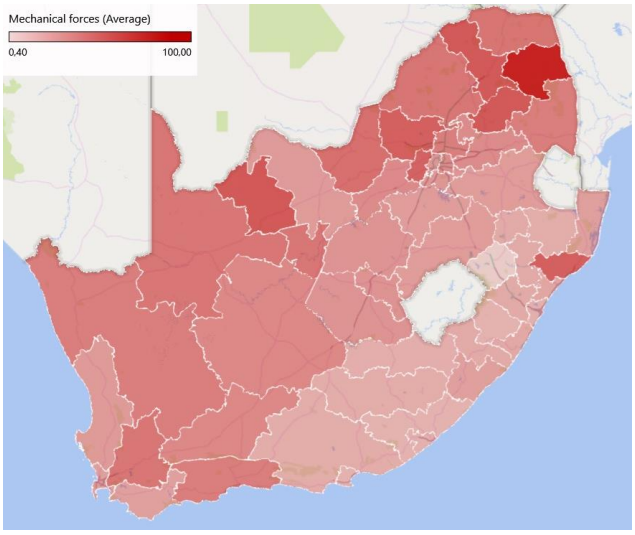
(Petrie et al, forthcoming)

Figure 22 Distribution of Risk of a Health Impact from Climate Change on Hanging and Strangulation



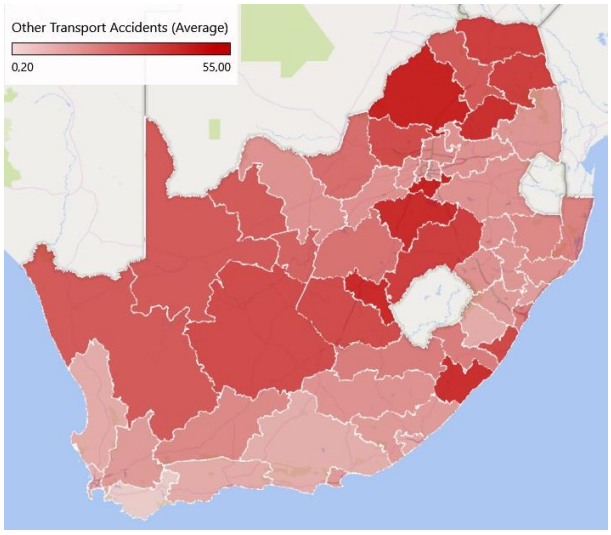
(Petrie et al, forthcoming)

Figure 23 Distribution of Risk of a Health Impact from Climate Change on Mechanical Forces.



(Petrie et al, forthcoming)

Figure 24 Distribution of Risk of a Health Impact from Climate Change on Other Transport Accidents



(Petrie et al, forthcoming)

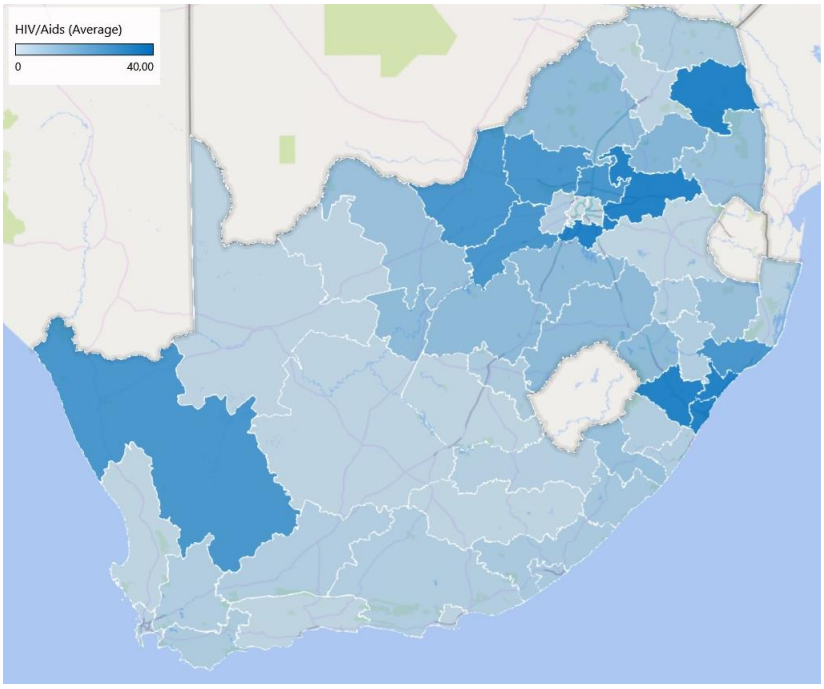
6.2 MAJOR INFECTIOUS DISEASES

The Major Infectious Diseases category has some of the lowest risk ranks out of the four BoD categories. This reflects that the Tool estimates the direct impacts of climate change on HIV/Aids are likely to be low, although drought is expected to impact HIV/Aids through reduced nutrition (Abayomi & Cowan, 2014). The Tool also is unable to model the interaction between CCEs and tuberculosis, based on the interactions developed by the project team, and as such this section will focus on HIV/Aids.

It is important to note that the high burden of HIV/Aids in South Africa is likely to increase the impact of climate change on other diseases because HIV/Aids increases patients' vulnerability to these diseases (Abayomi & Cowan, 2014). For example, HIV/Aids has been found to contribute to more severe malaria cases (Craig et al, 2004). Further, climate change will result in increased migration and population displacement which has been found to increase gender violence, transactional and commercial sex work, and increased risk-taking behaviour, leading to increased HIV/Aids transmission (Myers et al, 2011; Drimie & Casale, 2009). As such, while the Tool is not able to fully model these risks from climate change given its inability to model population growth, migration and the interaction between diseases, climate change will have a significant impact on the Major Infectious Diseases in South Africa.

As the Tool is only able to model the impact of drought on HIV/Aids, the areas of impact are confined to the areas identified as having an estimated high risk of drought, as seen in Figure 25. The risk is expected to be the highest in Gauteng, and KwaZulu-Natal, with hot spots in the Free State, Limpopo, the Northern Cape, and North West. However, it is likely that the Tool is underestimating the significance of the impact of climate change on HIV/Aids given the low values reported across South Africa, and given the limited number of interactions with the CCEs.

Figure 25 Distribution of Risk of a Health Impact from Climate Change on HIV/Aids



(Petrie et al, forthcoming)

6.3 COMMUNICABLE, MATERNAL, PERINATAL, AND NUTRITIONAL

The diseases in the Communicable, Maternal, Perinatal, and Nutritional category are impacted by a wider range of CCEs than the Injury, and Major Infectious Diseases categories, and as such experience a wider distribution of risk across South Africa. However, given the significant impact which very hot days and extreme precipitation days have on this category, the distribution range is similar to the Injury category, as demonstrated by Figure 27 to Figure 34.

It is possible to further cluster diseases together based on the impact which CCEs have on the sub-categories, as demonstrated by Table 5 Interactions between Climate Change Parameters and BoD . Beginning with diarrhoeal diseases, septicaemia, and sepsis/other new-born infections, the similarity in risk distribution is demonstrated by Figure 27 to Figure 29, which show a band of risk running from the Northern Cape across north central South Africa to Limpopo, with increased risk in the northern Eastern Cape and Nelson Mandela Bay, southern KwaZulu-Natal, and elevated risk in some Western Cape districts, particularly the Cape Town Metropolitan area. This distribution is driven by very hot days, relative humidity, extreme precipitation days, and floods which all lead to an increase in diarrhoeal diseases, septicaemia, and sepsis/other new-born infections. Increased temperature, and relative humidity increase the rate of food-, and water-borne diseases, leading to increased cases of diarrhoea (Young et al, 2010; Myers et al, 2011). Flooding and extreme precipitation are of concern as in rural areas this can lead to contamination of above-ground drinking water sources, and in urban areas cause storm water drains and sewerage infrastructure to overflow bringing people into contact with contaminated water – particularly in informal settlements (Myers et al, 2011). These CCEs also create and aggravate conditions for infections, which increases the chances of runaway infections in patients or aggravate existing infections, and thus increases the prevalence of septicaemia (Myers & Rother, 2012; Wright et al, 2014; Matthew et al, 2018), and sepsis/other new-born infections (Myers & Rother, 2012; Wright et al, 2014; Cherisch et al, 2018). The impact on diarrhoeal diseases in South Africa is so significant that diarrhoeal diseases are the sub-category at most significant risk in all the provinces, accounting for 52% of highest risk values in districts, with the remaining 48% falling into either the second or third most at-risk sub-category. This is of particular concern for children under five, as diarrhoea can lead to death from dehydration (Campbell-Lendrum et al, 2012), and malnutrition resulting in increased vulnerability to other diseases (Davis-Reddy & Vincent, 2017). Further, preterm birth conditions share similar CCE interactions and as such have a similar risk distribution demonstrated by Figure 31, with very hot days, and extreme

precipitation days increasing the risk of a health impact as they can impact maternal conditions and increase stress (Rylander et al, 2014; Kuehn & McCormick et al, 2017; Cil & Cameron, 2017).

The distribution of lower respiratory tract infections, meningitis/encephalitis, and other perinatal conditions are similar, with a band of elevated risk running from northern Eastern Cape and southern central KwaZulu-Natal through the Free State and southern Gauteng into the North West and eastern Northern Cape. These similarities are interesting, as while lower respiratory tract infections and other perinatal conditions have almost the same CCEs interactions (only differing in the magnitude of the interactions), meningitis/encephalitis only shares one CCE interaction with other perinatal conditions, and none with lower respiratory tract infections.

Lower respiratory tract infections are aggravated by hot, humid, and damp conditions which impair breathing, and increase the growth of spore-releasing moulds and fungus indoors, while outdoor hot conditions result in an increase in pollens and dust (Vogel et al, 2010; Thompson et al, 2012). Similarly other perinatal conditions are increased by very hot days, extreme precipitation days, and drought, where heat may negatively impact maternal conditions and increase stress, increasing the likelihood of complications (Rylander et al, 2014; Kuehn & McCormick et al, 2017; Cil & Cameron, 2017). By comparison drought is the main impact modelled for meningitis/encephalitis.

Finally, Figure 34 maps the risk to malaria, but an important caveat is that these risk rankings demonstrate the potential for favourable malaria conditions, rather than the actual expected future distribution range of malaria. This is because while the malaria distribution range is expected to spread further west and south by 2050, the extent of how far that range will be is uncertain (Young et al, 2010; Wright et al, 2014; Amis et al, 2014). The risk values reflect that malaria is significantly increased by very hot days and extreme precipitation days, and increased by relative humidity and flooding. Extreme precipitation and flooding create the conditions for mosquitos to breed in, while heat and humidity aids the replication of malaria parasites and thus higher transmission rates (Young et al, 2010; Wright et al, 2014; Amis et al, 2014).

Turning to a provincial perspective, the Eastern Cape follows the national trend with diarrhoeal diseases being the most at-risk sub-category, with a risk distribution of 25% medium, 50% medium high, and 25% high. Lower respiratory tract infections are of the next most significant concern, ranking among the most at-risk, and second most at-risk sub-category, with a similar distribution to diarrhoeal diseases, although with a somewhat lower average risk rank distribution. Preterm birth conditions, septicaemia, sepsis/other new-born infections, and other perinatal conditions are all of similar concern, although other perinatal conditions has a higher percentage of districts with high risk ranks. The Free State is estimated to have a similar most significant at-risk sub-category risk profile, with diarrhoeal diseases, and lower respiratory tract infections being at most significant risk, but with an overall higher risk ranks than the Eastern Cape. In particular, there is increased concern for preterm birth conditions, septicaemia, and sepsis/other new-born infections which all have 60% medium high, and 40% high risk ranks, while other perinatal conditions have 40% medium high, 40% high, and 20% very high.

Gauteng is estimated to have a similar risk distribution to the Free State, with diarrhoeal diseases at most risk, followed by lower respiratory tract infections, preterm birth conditions, septicaemia, and sepsis/other new-born infections which are expected to be at medium high to high risk. Where Gauteng differs is a higher risk to meningitis/encephalitis with 40% medium high, and 20% high risk ranks across its districts which is due to higher estimated drought values. Similarities are seen in KwaZulu-Natal's sub-categories risk ranks, with diarrhoeal diseases, lower respiratory tract infections, preterm birth conditions, and sepsis/other new-born infections all clustered between the medium and high risk ranks, although septicaemia has somewhat lower average risk ranks.

As with previous categories of disease, Limpopo has some of the highest risk ranks, particularly for diarrhoeal diseases which are at 80% high, and 20% very high, although in contrast to other provinces Limpopo has lower risk to lower respiratory tract infections which is concentrated around medium (80%). This is due to Limpopo having lower extreme precipitation days values than national averages. Elevated risk is estimated for sepsis/other new-born infections which are clustered between high, and very high, while preterm birth conditions, and septicaemia both are clustered between medium, and high. Finally, Limpopo has a high risk from malaria, which is already present in the province, and is expected to worsen by 2050 with both an increase in the case load and the territory in which malaria is present. Mpumalanga by comparison has lower risk levels, although diarrhoeal diseases are still the most at-risk sub-category

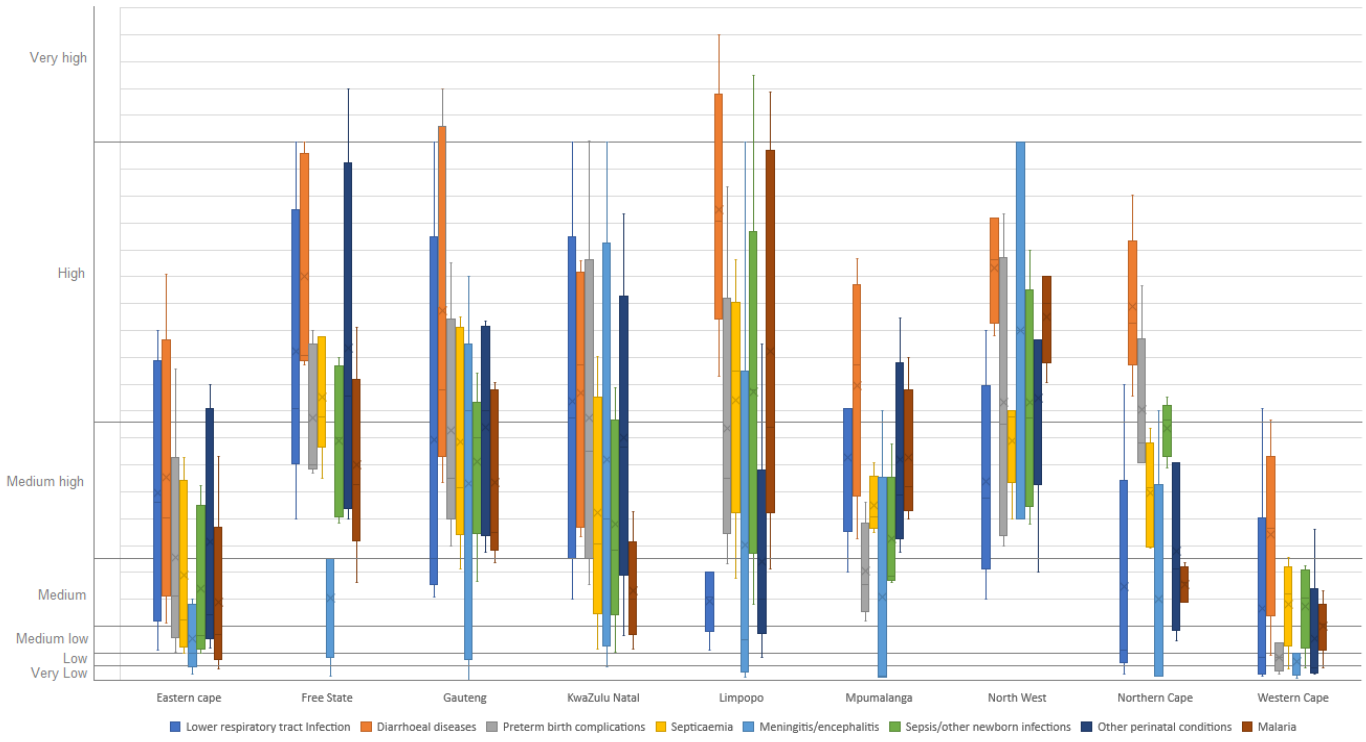
alongside malaria, which has similar impacts to the caseload and territory exposed to infection expected. Mpumalanga differs from Limpopo as lower respiratory tract infections and other perinatal conditions are at higher risk ranks, owing to the higher extreme precipitation values estimated for Mpumalanga.

The Northern Cape is expected to experience the highest risk from preterm birth conditions, and sepsis/other new-born infections alongside diarrhoeal diseases, as well as elevated risk to septicaemia. These values are driven mainly by the high very hot days values estimated for the Northern Cape. By comparison, the North West's risk distribution is more similar to Limpopo than the Northern Cape's and is on average the most significant in the country. Malaria, and diarrhoeal disease are the most at-risk sub-categories in the province with both sub-categories having a 100% high risk rank. All other sub-categories fall entirely in the medium high, and high risk ranks, except lower respiratory tract infections, and other perinatal conditions which both have 25% medium risk ranks.

Finally, as with other categories, the Western Cape has some of the lowest risk ranks in the country which is due to the comparatively lower estimated CCEs by 2050, however climate change will still have a significant impact on the Western Cape health system. This impact will be most significant for diarrhoeal diseases, followed by septicaemia, sepsis/other new-born infections, and lower respiratory tract infections.

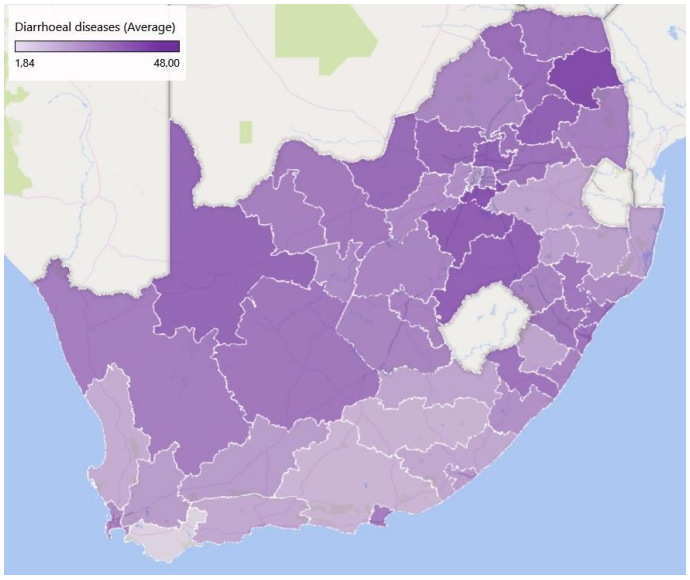
As such there is a particularly high risk to mothers and infants from climate change across the country which will require investment into, and an expansion of mother and child specific care. Further, the high risk of multiple infections means that disease control measures will need to be expanded, both at a community level to minimise infection outbreaks, and at a healthcare facility level to limit the number of in-hospital outbreaks.

Figure 26 Box and Whisker Graph of Provincial Communicable, Maternal, Perinatal, and Nutritional Sub-Categories Risk Rankings



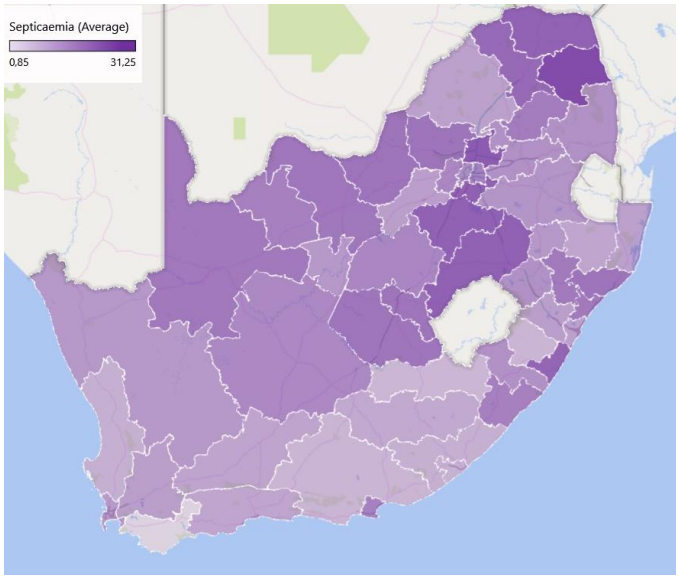
(Petrie et al, forthcoming)

Figure 27 Distribution of Risk of a Health Impact from Climate Change on Diarrhoeal Diseases



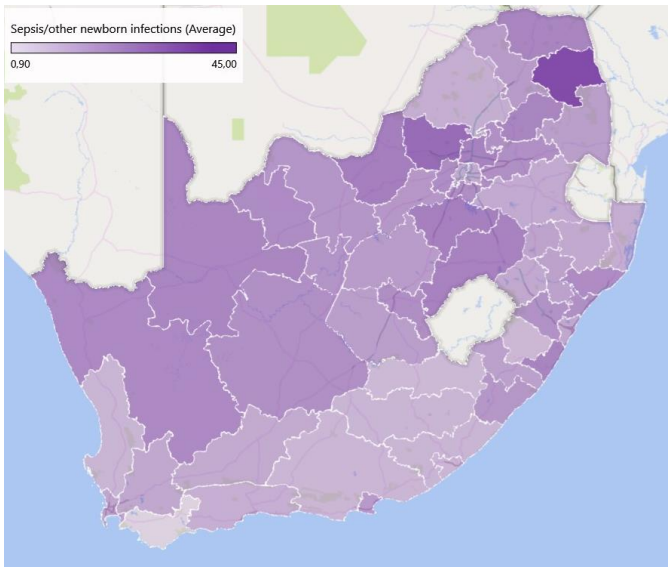
(Petrie et al, forthcoming)

Figure 28 Distribution of Risk of a Health Impact from Climate Change on Septicaemia ……..



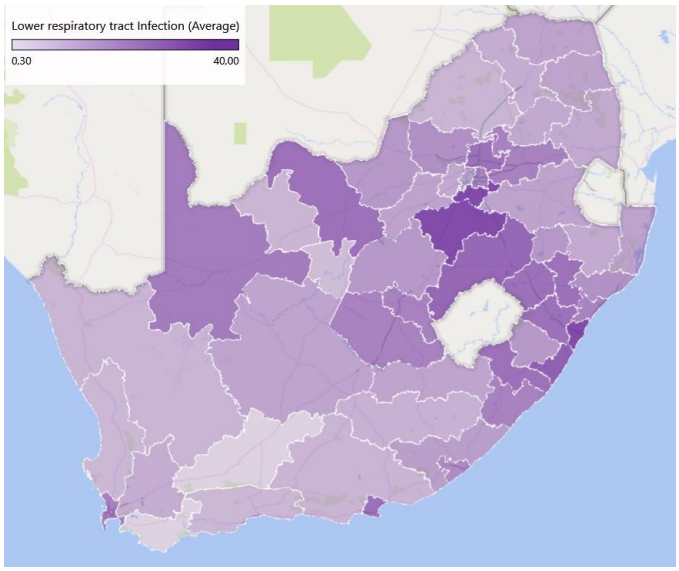
(Petrie et al, forthcoming)

Figure 29 Distribution of Risk of a Health Impact from Climate Change on Sepsis/Other New-born Infections



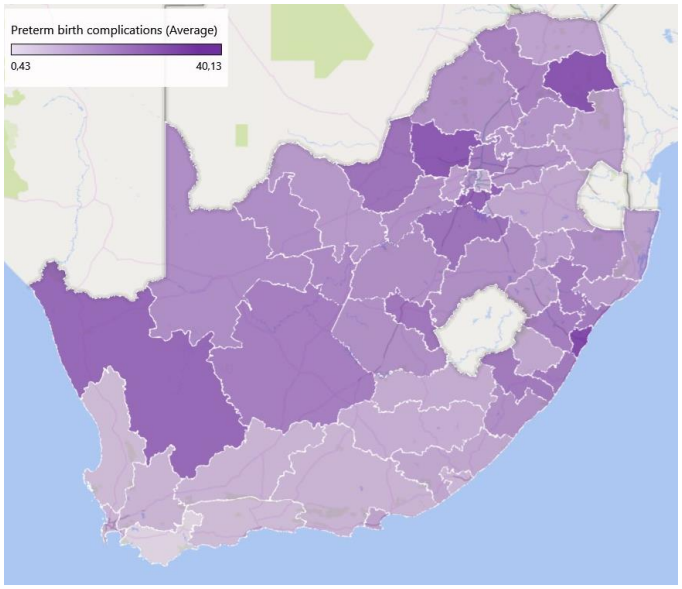
(Petrie et al, forthcoming)

Figure 30 Distribution of Risk of a Health Impact from Climate Change on Lower Respiratory Tract Infections



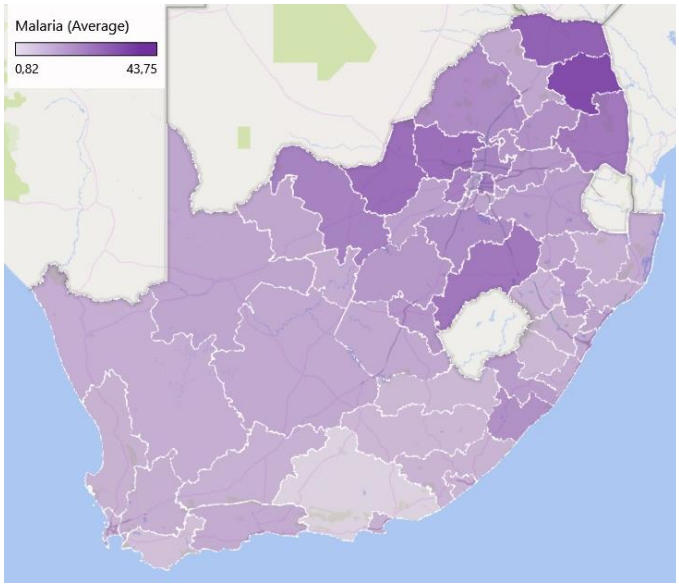
(Petrie et al, forthcoming)

Figure 31 Distribution of Risk of a Health Impact from Climate Change on Preterm Birth Complications



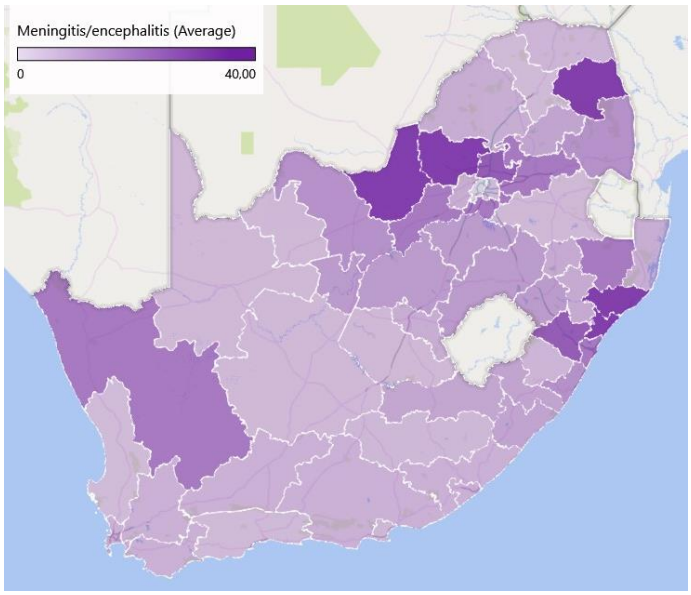
(Petrie et al, forthcoming)

Figure 32 Distribution of Risk of a Health Impact from Climate Change on Malaria ……



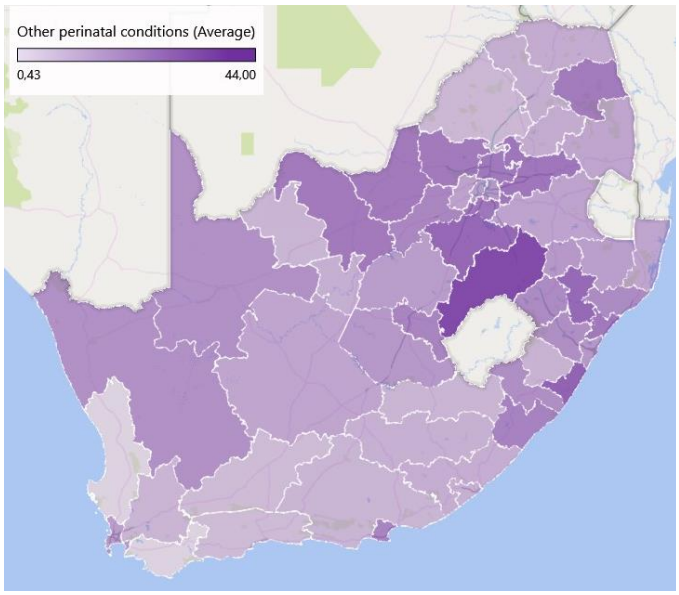
(Petrie et al, forthcoming)

Figure 33 Distribution of Risk of a Health Impact from Climate Change on Meningitis/Encephalitis



(Petrie et al, forthcoming)

Figure 34 Distribution of Risk of a Health Impact from Climate Change on Other Perinatal Conditions



(Petrie et al, forthcoming)

6.4 NON-COMMUNICABLE DISEASES

Most of the impact from CCEs on Non-Communicable Diseases comes from very hot days, and relative humidity, and flooding to a lesser degree, however asthma is an outlier as it is also impacted by extreme precipitation days. This combination of impacts gives a wider range of risk across South Africa. Note that Figure 36 is a map of heart disease, and has had the averages of cardiovascular disease, hypertensive heart disease, and ischaemic heart disease combined as they all have similar impacts from CCEs which resulted in very similar risk distribution maps. It is important to note that as with tuberculosis, the sub-categories diabetes mellitus; endocrine, nutritional, blood and immune system; and prostate were all given no interactions with the CCEs by the project teams' health experts.

Following the trend established by previous categories of BoD, there is a band of elevated risk running from the west coast of South Africa across the north of the country through the Northern Cape, North West, Gauteng, Mpumalanga, and Limpopo. However, there are far higher risk values in the Western Cape than in the other disease categories, particularly for the heart diseases, chronic obstructive pulmonary disease, and asthma, however this is not expected for epilepsy and nephritis/nephrosis. It is interesting to note from Figure 38 that asthma has a far wider distribution than most other diseases, and is comparable to the distribution of diarrhoeal diseases (Figure 27) and road injuries (Figure 19), although the average risk level is lower than both these sub-categories. Epilepsy has the smallest distribution and is mainly driven by the extreme precipitation and drought values, and is concentrated in a band running from KwaZulu-Natal, through east-central South Africa through the Free State, Gauteng, and North West, with elevated levels in Mopani District Limpopo. It is interesting to note, that as with previous BoD categories, Limpopo remains one of the most at-risk provinces in the country.

From Figure 35, cardiovascular disease, hyper-tensive disease, and ischaemic heart disease are at the most significant risk of health impacts from climate change in almost all provinces. This concurs with the literature, as all these diseases are significantly worsened by very hot days, and relative humidity (Vogel et al, 2010; Wright et al, 2014; Kjellstrom et al, 2017). Heat stress, which is worsened by humidity decreasing the body's ability to cool itself, increases stress on the heart which increases the chances of a stroke. Further, dehydration increases stress on the heart, and can aggravate cerebral perfusion, and reduce cardiac output through venous pooling (Vogel et al, 2010; Wright et al, 2014; Kjellstrom et al, 2017).

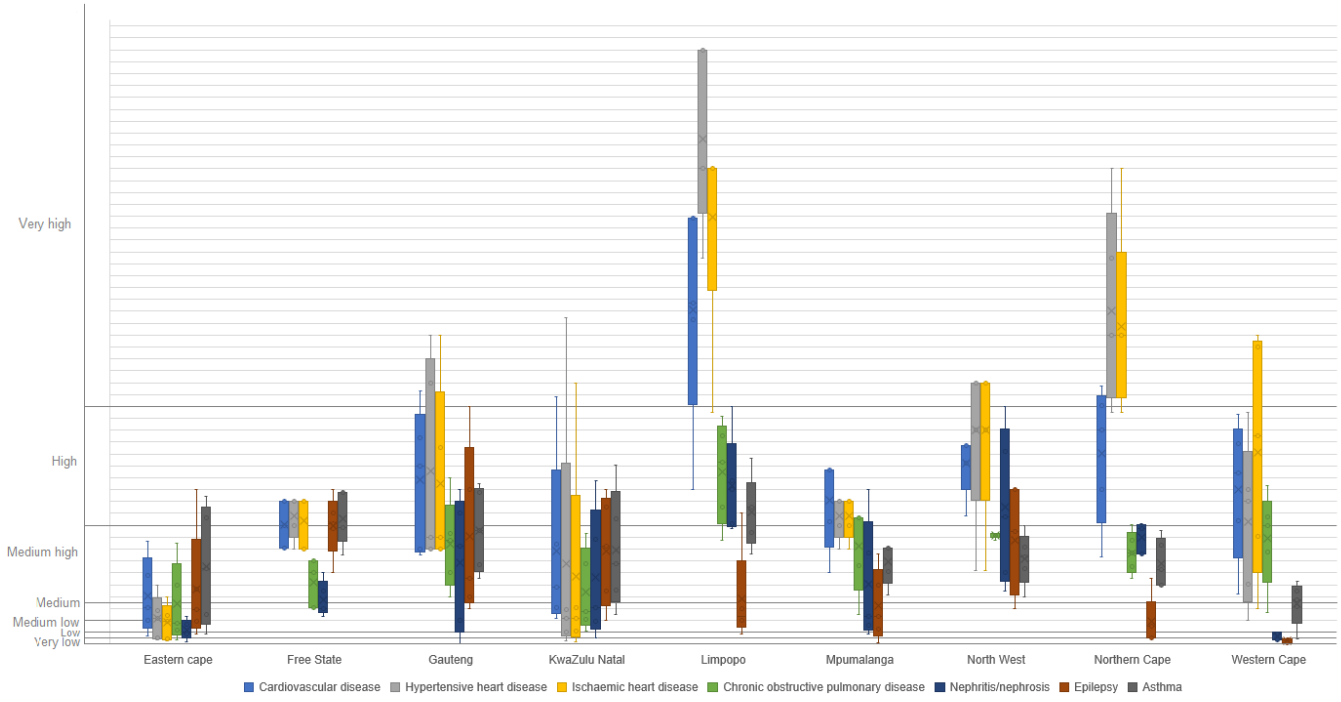
The Eastern Cape is expected to have a more significant risk from asthma and epilepsy, followed by cardiovascular disease, and chronic obstructive pulmonary disease. Very hot days, relative humidity and fires increase the severity of chronic obstructive pulmonary disease and asthma, while extreme precipitation significantly increases severity. As such in the Eastern Cape it is mainly the extreme precipitation and flooding values which are driving these values. Hot, humid, and damp conditions make it more difficult to breath, and increase the growth of mould and fungus indoors which release spores that aggravate these health conditions (Myers et al, 2011; Young et al, 2010; Department of Health, 2014). Outdoors, the possible increase in pollens and dust from very hot days aggravates these health conditions (Myers et al, 2011; Young et al, 2010; Department of Health, 2014). The Free State sees similarly elevated levels of risk to epilepsy and asthma, alongside cardiovascular disease, hyper-tensive disease, and ischaemic heart disease, although all at a higher risk level than the Eastern Cape, given the more significant very hot day's values.

Turning to KwaZulu-Natal, asthma, cardiovascular disease and epilepsy are similarly of the most significant concern for the districts when considering the risk rankings, with all three mainly falling between the first and third sub-categories at the most risk. There is a much wider distribution of risk ranks for the heart diseases generally, as while there are districts with very high risk values, the majority of cardiovascular diseases are at medium (45%), and medium high (45%), while both hypertensive heart disease, and ischaemic heart disease have the following risk distribution: 27% very low, 9% medium low, 45% medium, 9% medium high, and 9% very high. This suggests a lower risk to the heart diseases than other provinces, however cardiovascular disease still mainly falls between the first to third most at risk sub-category among the districts in KwaZulu-Natal. Both hypertensive heart disease, and ischaemic heart disease are mainly situated in the fourth to eighth most at-risk sub-categories except in King Cetshwayo and uMkanyakude districts where hypertensive heart disease and ischaemic heart disease rank first and second as the most at-risk sub-categories, which is due to the higher relative humidity values in these districts.

The heart diseases are the most at-risk sub-categories in Gauteng, Limpopo, Mpumalanga, North West, the Northern Cape, and the Western Cape. Gauteng does have elevated risk in chronic obstructive pulmonary with 20% high, and 60% medium high; nephritis/nephrosis with 20% medium high and 40% high; and epilepsy with 20% medium high and 40% high. In Mpumalanga chronic obstructive pulmonary has elevated risk with 67% of districts having a high risk ranking, and 33% of districts have a high risk rank for nephritis/nephrosis. This indicates an elevated risk level for these diseases; however, they are of comparably less concern than the heart diseases. Turning to the North West, nephritis/nephrosis and epilepsy have the same distribution of risk ranks in its districts, with 25% medium, 25% medium high and 50% high. The elevated levels of nephritis/nephrosis are driven by the very hot days, and drought conditions which increase the likelihood of a health impact on nephritis/nephrosis, as this increases the stress on the kidneys, and increases the likelihood of dehydration which can further compromise the kidneys (Myers et al, 2011; Wright et al, 2014). Finally, it is important to note that beyond the impact of the heart diseases in the Western Cape, there is elevated risk to chronic obstructive pulmonary disease. This has a risk distribution of 17% medium, 50% medium high, and 33% high.

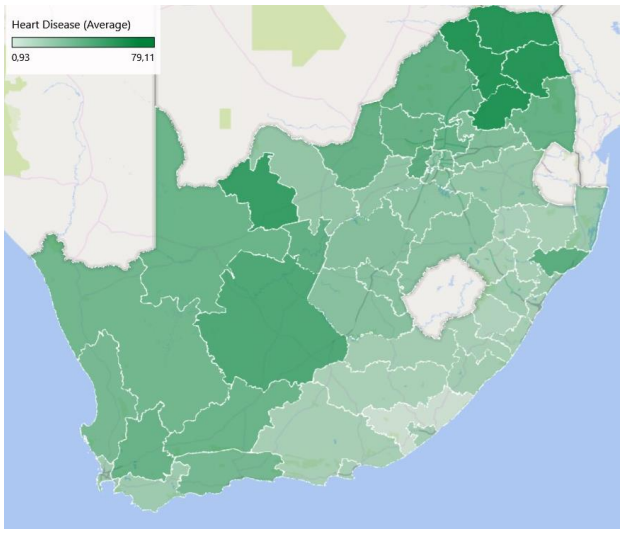
From these results there is generally an elevated risk from climate change to the Non-Communicable Diseases, which is most significant in the heart diseases. This is of particular concern for individuals over 50 (Rodgers et al, 2019) and those living in poverty (Oldewage-Theron & Grobler, 2021) who already experience elevated risk of heart diseases, and thus exemplifies the disproportional impact which climate change will have on the poor and elderly. It is interesting to note that out of the four BoD categories, Non-Communicable Diseases had the most similarity between the provinces' most at-risk diseases.

Figure 35 Box and Whisker Graph of the Non-Communicable Diseases Category



(Petrie et al, forthcoming)

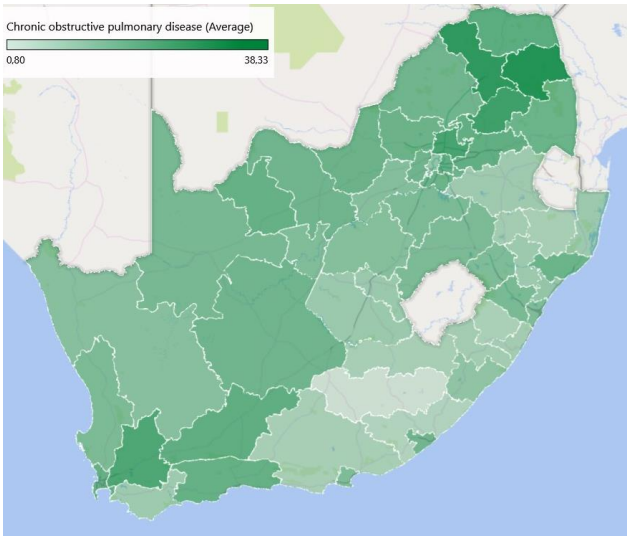
Figure 36 Distribution of Risk of a Health Impact from Climate Change on Heart Disease (Cardiovascular Disease, Hypertensive Heart Disease, and Ischaemic Heart Disease)



(Petrie et al, forthcoming)

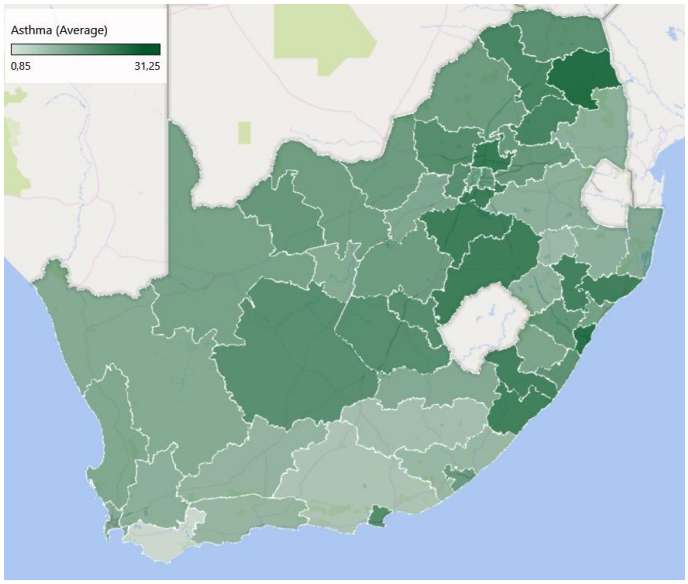
Figure 37 Distribution of the Risk of a Health Impact from Climate Change on Chronic Obstructive Pulmonary Disease

……



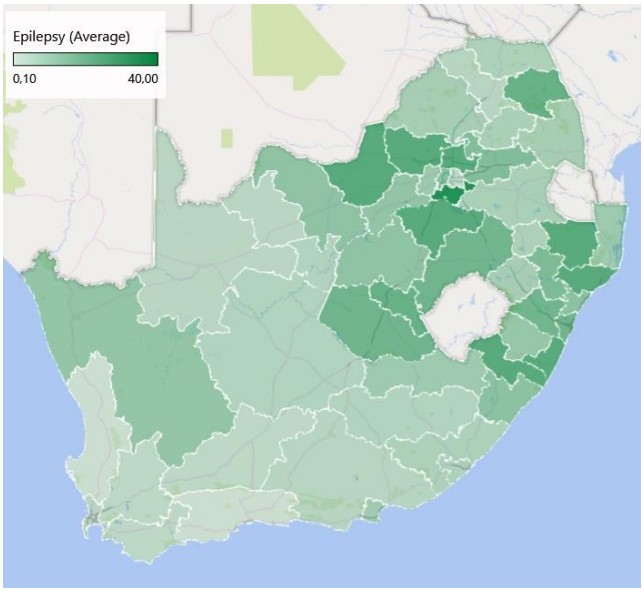
(Petrie et al, forthcoming)

Figure 38 Distribution of the Risk of a Health Impact from Climate Change on Asthma



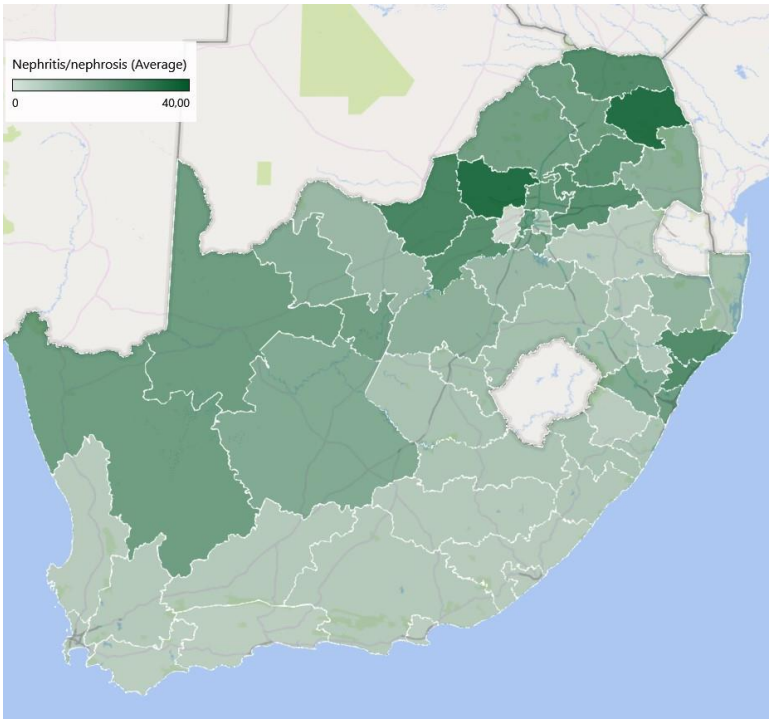
(Petrie et al, forthcoming)

Figure 39 Distribution of the Risk of a Health Impact from Climate Change on Epilepsy



(Petrie et al, forthcoming)

Figure 40 Distribution of the Risk of a Health Impact from Climate Change on nephritis/nephrosis



(Petrie et al, forthcoming)

7 CONCLUSION

This paper sought to detail the development and application of the HVRA Tool developed for the NDoH to examine if it was successful in building climate change capacity of the DHOs utilising it, such that they could give estimates of future BoD and health services, which could be used to model the risk of climate change to the South African health sector and displayed in a manner which DHOs can interpret and integrate into their work.

The feedback from the workshops and feedback surveys, outlined in Chapter 5 Applying the Tool, demonstrate that the capacity development was successful in conveying complex climate change data in a means which was understandable. In particular, the CCE maps, and the 1st-to-4th Order Impact Assessment were found to be of particular use. The recommendations listed in Chapter 5 will help to improve the capacity building process, which should be continued and expanded for a long-term, meaningful impact to be realised.

DHOs reported that the data collection process in the Tool was easy to use and understand once they had some hands-on experience with it, as illustrated in Chapter 5 section 5.3. The standardised layout of the data collection sheets was found to aid this, and DHOs found the severity rankings an effective medium for estimating future BoD and health services. The resulting data was found to reflect the interactions identified in the literature in most cases. However, the true robustness of the data will only be established once the results have been validated by a wider cohort of health officials, and once the project is repeated and subsequent data compared to the current dataset.

The display of the risk results was found to be understandable and approachable by DHOs during the workshops, with Chapter 6 Discussion of Findings demonstrating how risk data can be conveyed in an approachable manner. Given the responses to the CCE maps, the BoD distribution maps displayed in Chapter 6 are likely to be of significant use, and given the design of the Tool, can easily be generated from the Tool itself. A more extensive report on health officials' responses to the data is unfortunately outside of this paper's reach, as it will only be received in late 2022, and thus after its submission. These will aid in further developing the set of recommendations made on improving the Tool in Chapter 5.

Given these findings, it can be concluded that the HVRA Tool was successful in achieving the goals set for it under this paper's research question and has aided in further developing knowledge of the impact of climate change on the South African health sector. It is important to note that while the primary goal of the Tool was to gather severity ranking data from all 52 districts to inform the NDoH's climate change adaptation planning, an almost as significant outcome will be the capacity built on the impact of climate change among DHOs. The training of a cohort of DHOs across South Africa on the Tool's use, and the impact of climate change on the health sector, will be critical for future implementation of the health sector's climate change policy, and gathering of further primary data.

As noted in the literature review, understanding the impact of climate change on a given sector, and the implementation of that knowledge in planning processes, can be highly complex, and often is not approachable to professionals who deal with already complex systems (IPCC, 2021; WHO 2021). Understanding how temperature, precipitation, and relative humidity changes will cascade through, and impact on, the systems which professionals work in is incredibly complex. This creates a barrier between climate scientists and data, and the integration of their findings into these systems. As such, having individuals who can bridge the gap between climate change knowledge and health professionals is critical for the successful implementation of adaptation and mitigation plans. This further will enable the health sector to engage in the cross flow of data, knowledge, and experience between different sectors of the economy and society to better enable holistic mitigation and adaptation plans that target multiple sectors - which is the most successful means for mitigating and adapting to climate change (WHO, 2021; IPCC, 2021). This will further allow South Africa to better contribute to the international body of knowledge and discussions on the impact of climate change on health, further improving our own knowledge, and access to international cooperation.

Thus, in the long term it is likely that the most important outcome of this project is beginning the development of a South African cohort of health officials who are informed about climate change and its impact on the South African health sector, and who can facilitate future iterations of the project. It is interesting to note that this was already being recognised by DHOs in the workshops. Several DHOs in different workshops stated that they not only felt they had

a much better understanding of climate change but also had a sense of urgency to share this knowledge with their colleagues, and the communities which they serve. This cohort will serve to make future iterations of this project far more robust, as these individuals will be able to train their colleagues and facilitate discussions on identifying areas of vulnerability to climate change. Considering the literature on CoPs, this will be a critical component in driving more robust, fruitful, and engaging discussions among DHOs, and allow far more health officials to be reached by the training, as this cohort will be the equivalent of a core group in CoPs. This will result in better and more representative data being gathered, which in turn will be better implemented into decision and planning processes.

8 REFERENCE LIST

- Abayomi, A. and Cowan, M. 2014. The HIV/AIDS epidemic in South Africa: Convergence with Tuberculosis, Socioecological Vulnerability, and Climate Change Patterns. *South African Medical Journal*. 104(8): 583. DOI: 10.7196/SAMJ.8645.
- Amis, A., Jalloh, A., & Hachigonta, S. (2014) Review of Research and Policies for Climate Change Adaptation in the Health Sector in Southern Africa. *Future Agricultures*. DOI: 10.13140/2.1.2462.6566.
- Barrett, M. S., Ballantyne, J., Harrison, S., & Temmerman, N. 2009. On Building a Community of Practice: Reflective Narratives of Academic Learning and Growth. Reflective Practice 10(4): 403–16. Accessible: http://www.tandfonline.com/doi/full/10.1080/14623940903138233
- Berry, P., Enright, P., Shumake-Guillemot, J., Villalobos Prats, E., Campbell-Lendrum, D. (2018). Assessing Health Vulnerabilities and Adaptation to Climate Change: A Review of International Progress. *International Journal of Environmental Research and Public Health.* 15: 2626. https://doi.org/10.3390/ijerph15122626
- Britt, V., & Paulus, T. (2016). Beyond the Four Walls of My Building: A Case Study of #Edchat as a Community of Practice. *American Journal of Distance Education*. 30(1). 48-59. DOI: 10.1080/08923647.2016.1119609
- Campbell-Lendrum, D., Patz, J., Corvalan, C., and Horwitz, P. (2012). Our Planet, Our Health, Our Future. *World Health Organisation*. Geneva: Switzerland. Accessible: https://discovery.ucl.ac.uk/id/eprint/1477192/1/Patz_Our_planet_our_health.pdf
- Casimiro, E., Calheiros, J., Santos, F.D., Kovats, S. (2006). National Assessment of Human Health Effects of Climate Change in Portugal: Approach and Key Findings. *Environmental Health Perspectives.* 114: 1950–1956. https://doi.org/10.1289/ehp.8431
- Chersich, M., Wright, C., Venter, F., Rees, H., Scorgie, F., Erasmus, B. (2018). Impacts of Climate Change on Health and Wellbeing in South Africa. *International Journal of Environmental Research and Public Health*. 15(9): 1884. https://DOI.org/10.3390/ijerph15091884
- Chersich, M.F., Swift, C.P., Edelstein, I., Breetzke, G., Scorgie, F., Schutte, F., & Wright, C.Y. (2019). Violence in hot weather: Will climate change exacerbate rates of violence in South Africa? *South African Medical Journal.* 109: 447–449. https://DOI.org/10.7196/SAMJ.2019.v109i7.14134
- Cil, G., & Cameron, A. (2017). Potential Climate Change Health Risks from Increases in Heat Waves: Abnormal Birth Outcomes and Adverse Maternal Health Conditions. *Risk Analysis*. 37(11). DOI: 10.1111/risa.12767
- Council for Scientific and Industrial Research. (2019). About the Greenbook. Accessed: 2021, 1 August. Available: https://greenbook.co.za/about-the-green-book.html
- Council for Scientific and Industrial Research. (2019). Greenbook – Municipal Risk Profiles. Accessed: 2021, 1 August. Available: https://riskprofiles.greenbook.co.za/
- Council for Scientific and Industrial Research. (2020). *Climate Change and Health RVA Framework* [Computer Software]. Pretoria: CSIR. (Unpublished).

- Cowan, J. (2012). Strategies for Developing a Community of Practice: Nine Years of Lessons Learned in a Hybrid Technology Education Master's Program. *TechTrends: Linking Research & Practice to Improve Learning*: 56(1): 12–18. Doi: 10.1007/s11528-011-0549-x
- Craig, M., Kleinshcmidt, I., Nawn, J., Le Sueur, D., and Sharp, B. (2004). Exploring 30 Years of Malaria Case Data in KwaZulu-Natal, South Africa: Part I. The Impact of Climatic Factors. *Tropical Medicine & International Health*. 12: 1247-1257. DOI: 10.1111/j.1365-3156.2004.01340.x
- Cuthell, J. (2005). What does it take to be active? Teacher participation in online communities. *International Journal of Web Based Communities*. 1(3): 320-332. Doi: 10.1504/IJWBC.2005.006930
- Davis-Reddy, C., & Vincent, K. (2017). Climate Risk and Vulnerability: A Handbook for Southern Africa (Second Edition). *CSIR*. Pretoria: South Africa.
- Department of Health. (2014). National Climate Change & Health Adaptation Plan 2014-2019. *National Department of Health.* South Africa.
- Dinku, T. (2019). Challenges with Availability and Quality of Climate Data in Africa. In *Extreme Hydrology and Climate Variability*. A. Melesse, W. Abtew, & G. Senay Eds. Amsterdam: Elsevier. DOI: https://doi.org/10.1016/C2017-0-04193-9
- Drimie, S. and Casale, M. (2009). Multiple Stressors in Southern Africa: the Link between HIV/AIDS, Food Insecurity, Poverty and Children's Vulnerability Now and in the Future. *AIDS care.* 21 Suppl 1(August): 28–33. doi: 10.1080/09540120902942931.
- Fields, S. (2005). Continental divide: Why Africa's climate change burden is greater. *Environmental Health Perspectives.* 113(8): A534–A537.
- Gao, J., Kovats, S., Vardoulakis, S., Wilkinson, P., Woodward, A., Li, J., Gu, S., Liu, X., Wu, H., Wang, J., Song, X., Zhai, Y., Zhao, J., Liu, Q. (2018). Public health co-benefits of greenhouse gas emissions reduction: A systematic review. *Science of The Total Environment.* 627: 388–402. doi: https://doi.org/10.1016/j.scitotenv.2018.01.193
- Garland, R., Matooane, M., Engelbrecht, F., Bopape, M.J., Landman, W., Naidoo, M., Van der Merwe, J., & Wright, C. (2015). Regional projections of extreme apparent temperature days in Africa and the related potential risk to human health. *International Journal of Environmental Research and Public Health*. 12(10):12577–12604. doi: 10.3390/ijerph121012577.
- Government of Canada. (2021). Health of Canadians in a Changing Climate. *Government of Canada*. Retrieved 12 November, 2021, from [URL] https://www.nrcan.gc.ca/maps-tools-and-publications/publications/climate-change-publications/canada-changing-climate-reports/health-canadians/21189
- Harris, I. (2021). High-Resolution Gridded Datasets (and Derived Products). Accessed: 2021, 1 August. Available: https://crudata.uea.ac.uk/cru/data/hrg/
- Health Systems Trust. (2020). District Health Barometer. *Health Systems Trust.* Accessed: https://www.hst.org.za/publications/Pages/HSTDistrictHealthBarometer.aspx
- Health Professionals Council of South Africa. (2017). Continuing Professional Development Guidelines for the Health Practitioners. *Health Professionals Council of South Africa*. Accessed: 2021, 5 December. Available: https://www.hpcsa.co.za/Uploads/Professional_Practice/CPD/CPD%20Guidelines%20Sept%202017.pdf

- Hew, K.F., & Hara, N. (2006). Identifying Factors That Encourage and Hinder Knowledge Sharing in a Longstanding Online Community of Practice.
- Intergovernmental Panel on Climate Change. (2014). Climate Change 2014: Synthesis Report. *Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Core Writing Team, R. Pachauri, & L. Meyers Eds. IPCC. Geneva, Switzerland. Available: https://ar5-syr.ipcc.ch/ipcc/ipcc/resources/pdf/IPCC_SynthesisReport.pdf
- Intergovernmental Panel on Climate Change (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou Eds. Cambridge University Press: United Kingdom. In Press.
- Iyalomhe, F., Jensen, A., Critto, A., & Marcomini, A. (2013). The Science–Policy Interface for Climate Change Adaptation: The Contribution of Communities of Practice Theory. *Environmental Policy and Governance*: 23(6): 368–80.
- Kendrovski, V., Spasenovska, M., Menne, B. (2014). The Public Health Impacts of Climate Change in the former Yugoslav Republic of Macedonia. *International Journal of Environmental Research and Public Health.* 11: 5975–5988. https://doi.org/10.3390/ijerph110605975
- Kjellstrom, T., Lemke, B., & Otto, M. (2017) Climate conditions, workplace heat and occupational health in South-East Asia in the context of climate change. *WHO South-East Asia Journal of Public Health*. 6(September): 15–21. Available: https://www.ncbi.nlm.nih.gov/pubmed/28857058.
- Kuehn, L., & McCormick, S., (2017). Heat Exposure and Maternal Health in the Face of Climate Change. *International Journal of Environmental Research and Public Health*. 14(8):853. https://DOI.org/10.3390/ijerph14080853
- Lave, J. & Wenger, E. 1991. Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511815355 (May 25, 2021).
- Manangan, A., Uejio, C., Saha, S., Schramm, P., Marinucci, G., Brown, C., Hess, J., & Luber, G. (2014). Assessing Health Vulnerability to Climate Change: A Guide for Health Departments. Georgia: *Centre for Disease Control.* Available: https://www.cdc.gov/climateandhealth/pubs/assessinghealthvulnerabilitytoclimatechange.pdf
- Massyn, N., Day, C., Ndlovu, N., & Padayachee, T. 2020. District Health Barometer 2019/2020. *Health Systems Trust*. Durban: South Africa. Available: https://www.hst.org.za/publications/Pages/DHB2019-20.aspx
- McMichael, A. (2009) Climate change and human health. *Commonwealth Secretariat editor*. *Commonwealth Health Minister's Update*. Woodbridge: United Kingdom
- Myers, J., Young, T., Galloway, M., Manyike, P., Tucker, T. (2011). A public health approach to the impact of climate change on health in southern Africa - identifying priority modifiable risks. *South African Medical Journal.* 101: 817–820.
- Myers, J., & Rother, H. (2012). Public health impact of and response to climate change in South Africa: social and environmental determinants of health. *South African Health Review*. May: 127–138.
- Nordling, L. (2019). Scientists Struggle to Access Africa's Historical Climate Data. *Nature*. 24 October. Available: https://www.nature.com/articles/d41586-019-03202-2

- Oldewage-Theron, W., Grobler, C. (2021). Double Burden of Poverty and Cardiovascular Disease Risk among Low-Resource Communities in South Africa, Lifestyle and Epidemiology - The Double Burden of Poverty and Cardiovascular Diseases in African Populations. In *Lifestyle and Epidemiology*. K. Monyeki, & H. Kemper. London: IntechOpen. DOI: https://doi.org/10.5772/intechopen.95992
- OneWorld Sustainable Investments. (2020). *What we do*. Accessed: 2022, 10 August. Available: https://oneworldgroup.co.za/about-oneworld/
- Petrie B., Petrik, D., Martin, L., Chapman, A., Davies, R., Blignaut, J.N. (2016). Strengthening Climate Resilience in the Kafue sub-Basin (SCRiKA) Project: Training Manual. OneWorld Sustainable Investments. Cape Town, South Africa
- Petrie, B., Le Quesne, F., Beukman, R., Lucas, B. & Gerhard, M. (2018). PPCR Learning & Knowledge Networking Strategy. Oxford Policy Management. Pretoria, South Africa.
- Petrie, B., Tsilik, P., Weaver, Z., and Price, H. (2021a). Inclusive Budgeting and Financing for Climate Change in Africa (IBFCCA): Component A – Peer learning and Exchange and Knowledge Management Cadre and Knowledge Portal Research Report. *OneWorld Sustainable Investments.* Cape Town: South Africa.
- Petrie, B., Steenkamp, T., Weaver, Z., and Wewege, S., (2021b). Scoping Report: Capacity building on risk and vulnerability assessment tool and development of National Climate RVA for Health. For the GIZ. OneWorld Sustainable Investments, Cape Town, South Africa. In Press. 2021.
- Petrie, B., Steenkamp, T., and Weaver, Z. (2021c). Facilitation Plan: Capacity building on risk and vulnerability assessment tool and development of National Climate RVA for Health. For the GIZ. OneWorld Sustainable Investments, Cape Town, South Africa. In Press. 2021.
- Petrie, B., Chapman, A., Kinghorn, A., and Weaver, Z. (Forthcoming). *Capacity Building on Risk and Vulnerability Assessment Tool and Development of National Climate Risk and Vulnerability Assessments for the Health Sector – Synthesis Report*. Department of Fisheries, Forestry and Environment, and Department of Health, South Africa. OneWorld Sustainable Investments, Cape Town.
- Riverin, S, & Stacey, E. (2008). Sustaining an Online Community of Practice: A Case Study. *Journal of Distandce* Education. 22(2): 43-58. Available: https://dro.deakin.edu.au/eserv/DU%3A30017596/stacey-sustaininganonline-2008.pdf
- Rodgers, J., Jones, J., Bolleddu, S., Vanthenapalli, S., Rodgers, L., Shah, K., Karia, K., Panguluri, S. (2019). Cardiovascular Risks Associated with Gender and Aging. *Journal of Cardiovascular Development and Disease.* 6:19. https://doi.org/10.3390/jcdd6020019
- Rylander, C., Odland, J., & Sandanger, T. (2013). Climate change and the potential effects on maternal and pregnancy outcomes: an assessment of the most vulnerable – the mother, fetus, and newborn child. *Global Health Action*. 6(1). DOI: https://DOI.org/10.3402/gha.v6i0.19538
- Schnitter, R., Verret, M., Berry, P., Chung Tiam Fook, T., Hales, S., Lal, A., Edwards, S. (2019). An Assessment of Climate Change and Health Vulnerability and Adaptation in Dominica. *International Journal of Environmental Research and Public* Health. 16(1): 70. Doi: https://doi.org/10.3390/ijerph16010070
- Schwen, T. M., & Hara, N. (2003). Community of Practice: A Metaphor for Online Design? *The Information Society*: 19(3): 257–70. Doi: https://doi.org/10.1080/01972240309462
- Sweijd, N., Wright, N., Westwood, A., Rouault, M., Landman, W., MacKenzie, M., Nuttall, J., Mahomed, H., Cousins, T., Winter, K., Berhoozi, F., Kalule, B., Kruger, P., Govender, T., & Minakawa, N. (2014). Climate Change is Catchy – but when Will it Really Hurt? *South African Medical Journal*. 105(12):1018-

1023. DOI: 10.7196/SAMJ.2015.v105i12.10332

- Thompson, A., Matamale, L., & Kharidza, S. (2012). Impact of climate change on children's health in Limpopo province, South Africa. *International Journal of Environmental Research and Public Health.* 9(3): 831–854. DOI: 10.3390/ijerph9030831.
- Young, T., Tucker, T., Galloway, M., Manyike, P., Chapman, A., & Myers, J. (2010). Climate change and health in SADC region: Review of the current state of knowledge. *Centre for Occupational and Environmental Health Research.* Cape Town: South Africa
- Vogel, C. (2010). Climate Change and Health in South Africa. in State of the Nation, South Africa 2012-2013 – Addressing Inequality and Poverty. Eds Pillay, U., Hagg, G., Nyamnjoh, F., Jansen, J. ISBN: 978-07969-2422-3
- Wenger, E. (2006). Communities of Practice: A Brief Introduction. *National Science Foundation.* 5. Accessed: https://www.ohr.wisc.edu/cop/articles/communities_practice_intro_wenger.pdf
- World Bank. (2018). Building Community: A Primer. 2018 Update. *World Bank Group.* Accessed: https://documents1.worldbank.org/curated/en/188671504682900121/pdf/119411-REVISED-PUBLIC-Community-Primer-2018-Final-2-21-2018.pdf
- World Health Organisation. (2009). Climate Change and Health. *World Health Organisation.* Geneva: Switzerland. Accessed: https://www.who.int/globalchange/A62_11_en.pdf?ua=1
- World Health Organisation. (2013). Protecting Health from Climate Change Vulnerability and Adaptation Assessment. Accessed: https://www.who.int/publications/i/item/protecting-health-from-climate-change-vulnerability-and-adaptation-assessment
- World Health Organisation. (2015). Climate and Health Country Profile – 2015 Uganda. *World Health Organisation*. Retrieved 13 August, 2021 from https://www.who.int/publications/i/item/health-and-climate-change-country-profile-2015-uganda
- World Health Organisation. (2021). Climate change and health: vulnerability and adaptation assessment. Accessed: https://www.who.int/publications/i/item/9789240036383
- World Health Organisation. (2021). COP26 special report on climate change and health: the health argument for climate action. *World Health Organisation*. Geneva: Switserland. Accessed: https://apps.who.int/iris/handle/10665/346168
- Wright, C.Y., Garland, R.M., Norval, M., Vogel, C., (2014). Human health impacts in a changing South African climate. *South African Medical Journal.* 104: 579–582. https://DOI.org/10.7196/SAMJ.8603
- Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J., & Warburton, M. (2014). Climate change impacts and adaptation in South Africa. *WIREs Climate Change.* 5: 605–620. https://DOI.org/10.1002/wcc.295

9 APPENDIX 1: LIST OF PROVINCES, DISTRICTS, AND WORKSHOPS

This appendix provides a table of the provinces, and their constituent districts, as well as the types of workshops conducted in each province, and how many attendees the workshops had.

Province	Districts	Workshops
Eastern Cape	Alfred Nzo District	Half day Capacity Building Workshop. Number of Attendees: 17 Three half day HVRA Workshop. Total Number of Attendees: 68
	Amathole District	
	Buffalo City Metro District	
	Chris Hani District	
	Joe Gqabi District	
	Nelson Mandela Bay Metro District	
	OR Tambo District	
	Sarah Baartman District	
Free State	Fezile Dabi District	Combined Capacity Building and HVRA. Number of Attendees: 33
	Lejweleputswa District	
	Mangaung Metro District	
	Thabo Mofutsanyane District	
	Xhariep District	
Gauteng	City of Ekurhuleni Metro District	Half day Capacity Building Workshop. Number of attendees: 29 One half day HVRA Workshop. Total number of attendees: 28
	City of Johannesburg Metro District	
	City of Tshwane Metro District	
	Sedibeng District	
	West Rand District	
KwaZulu-Natal	Amajuba District	Half day Capacity Building Workshop. Number of Attendees: 11 Three half day HVRA Workshop. Total Number of Attendees: 77
	eThekwini Metro District	
	Harry Gwala District	
	Ilembe District	
	King Cetshwayo District	
	Ugu District	
	uMgungundlovu District	
	uMkhanyakude District	
	uMzinyathi District	
	Uthukela District	
	Zululand District	
Limpopo	Capricorn District	Combined Capacity Building and HVRA. Number of Attendees: 29
	Mopani District	
	Vhembe District	
	Waterberg District	
	Sekhukhune District	

Province	Districts	Workshops
Mpumalanga	Ehlanzeni District	Combined Capacity Building and HVRA.
	Gert Sibande District	
	Nkangala District	Number of Attendees: 15
Northern Cape	Frances Baard District	Combined Capacity Building and HVRA.
	John Taolo Gaetsewe District	
	Namakwa District	Number of Attendees: 9
	Pixley Ka Seme District	
	ZF Mgcawu District	
North West	Bojanala Platinum District	Combined Capacity Building and HVRA.
	Dr. Kenneth Kaunda District	
	Dr. Ruth Segomotsi Mompati District	Number of Attendees: 41
	Ngaka Modiri Molema District	
Western Cape	Cape Winelands District	Combined Capacity Building and HVRA.
	Central Karoo District	
	City of Cape Town Metro District	Number of Attendees: 53
	Garden Route District	
	Overberg District	
	West Coast District	

10 APPENDIX 2: EXAMPLE HVRA TOOL

The link below to the embedded Excel workbook will open the Example HVRA Tool

Example HRVA Tool.xlsx