A ‘World Class African City’? Exploring the usefulness of the Resilient Cities Index (RCI) through an investigation of urban resilience in Johannesburg

A vocational dissertation in collaboration with Marsh Advisory

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Executive summary

This research project was completed in collaboration with Marsh Advisory, a professional services firm which creates risk management strategies to help clients build resilience. This projects aims to evaluate the usefulness of the Resilient Cities Index (RCI) for informing resilience-building practice. The RCI, designed by Economist Impact and Tokio Marine Group in 2023 to measure the resilience of 25 cities globally, is underpinned by the following definition of urban resilience: ‘a city’s ability to avoid, withstand and recover from shocks, such as natural disasters; and from long-term stresses such as poverty, decrepit infrastructure or migration’ (Economist Impact, 2023a). The RCI is comprised of four pillars (critical infrastructure, environment, socio-institutional and economic), 19 indicators and 41 sub-indicators.

This research project utilises the case study of Johannesburg to evaluate the usefulness of the RCI. Firstly, the RCI was applied to Johannesburg, which allowed for an understanding about the kind of knowledge the RCI produces about urban resilience, as well as the simplicity and inexpensiveness of the RCI process. Secondly, the knowledge produced by the RCI was compared with local knowledge about urban resilience in Johannesburg. This facilitated the identification of key weaknesses of the RCI. These included the index’s failure to measure the resilience of key sub-systems operating within a city, as well it’s failure to assess how different sub-systems operating within an urban system impact the resilience of one another. Furthermore, this research finds that whilst the RCI does attempt to assess the adaptive and transformative potential of cities, it does not do so in sufficient detail to inform policymaking. As a result, it was necessary to conduct a GAP analysis of Johannesburg’s Climate Action Plan (CAP) to investigate a second line of enquiry - how could environmental resilience-building strategies be improved in Johannesburg? Recommendations for improvement ranged from the development of an urban fire management plan, to learning from the City of Cape Town (CoCT) to improve financial management, to fostering public-private-people partnerships to address air pollution caused by mine tailings storage facilities (MTSFs) in and around Johannesburg.

Acknowledgements

Firstly I would like to thank my dissertation supervisor, Dr. Andres Luque-Ayala, for his continued support and invaluable insight throughout this research process. I would also like to thank David Andrews and Callum Ellis at Marsh Advisory for their constant guidance and support throughout the vocational dissertation process. Further, I would like to thank all of the experts from Marsh's Johannesburg and London offices who provided vital insight into urban resilience in Johannesburg and resilience-building practices.

Finally, I would like to thank my Grandad who has been my biggest inspiration throughout my academic journey. Throughout his life, my Grandad had a constant eagerness to learn and a keen passion for education that I am very grateful to have been able to experience.

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1. Introduction

As rapid urbanisation, coupled with climate change, is making cities increasingly vulnerable to a variety of uncertain and unpredictable risks, academics and local authorities have become increasingly interested in building urban resilience (Ribeiro and Gonçalves, 2019). Despite this, there is no agreed method on how urban resilience should be measured, which has resulted in the creation of a range of urban resilience indexes (Zhang et al., 2020). One example of this is the Resilient Cities Index (RCI) originally developed by the Economist Impact and Tokio Marine Group in 2023 to assess the resilience of 25 global cities. The Economist Impact (2023a, p.5) defines urban resilience as ‘a city’s ability to avoid, withstand and recover from shocks, such as natural disasters; and from long-term stresses such as poverty, decrepit infrastructure or migration’. Furthermore, it states that a ‘resilient city’ must ‘plan ahead rather than react’ and be sustainable, ensuring that normal functioning does not contribute to any future potential problems. This definition emerges from an understanding of the city as a complex adaptive system and further highlights adaptive and transformative potential as two key qualities of a resilient city (Gotham and Campanella, 2010; Galderisi et al., 2020).

The purpose of this research project is to evaluate the usefulness of the RCI to policymakers and practitioners, who are looking to utilise urban resilience measurement tools to inform resilience-building practices and policies. More specifically, this research aims to produce knowledge about assessing urban resilience that can inform an upcoming project involving Marsh Advisory and the International Council for Local Environmental Initiatives (ICLEI). This project will involve assessing the resilience of 10 Latin American cities, as well as the development and implementation of resilience-building strategies. To do this, this dissertation evaluates the usefulness of the RCI by applying it to the City of Johannesburg (CoJ), whilst also exploring how the city could improve its environmental resilience-building strategies. Pursuing this second line of inquiry was imperative to understanding how well the RCI could measure the adaptive and transformative capacity of cities, as it encouraged a deeper analysis of the extent to which the RCI was able to inform resilience-building practice. Johannesburg was selected as a suitable case study, as the city has previously championed the concept of resilience, stating its aim to become a ‘world class African city by 2040’ through ‘development-driven resilience for all’, the provision of ‘a resilient, liveable, sustainable urban environment’ and the creation of ‘an inclusive, job-intensive, resilient and competitive economy’ (GDS, 2011, p.9). The city is situated in Gauteng Province and is the most populous city in South Africa (Okafor, 2023).

Furthermore, Johannesburg holds great regional importance, as it is considered the financial hub of Southern Africa (ARUP, 2023).

This dissertation begins with a literature review, exploring the academic debates around the concept of urban resilience, how best to measure it and its influence on South African policymaking. This is followed by an explanation and justification of the data collection and analysis methods utilised, as well as a chapter detailing the results of applying the RCI to Johannesburg. Next, the results are analysed in comparison to local knowledge on resilience in Johannesburg and then recommendations for how Johannesburg could improve its environmental resilience are provided. This involves a GAP analysis of Johannesburg's Climate Action Plan (2021), as this research project finds that the RCI does not enable sufficient analysis of a city's resilience-building strategies to extensively inform resilience-building practice. Finally, a summary of research findings and recommendations for future research concludes this dissertation.

The following research questions were used to achieve the overarching aim of assessing the usefulness of the RCI:

1. What is learnt about urban resilience in Johannesburg from applying the RCI?
2. How does a local understanding of urban resilience in Johannesburg differ from that gained through applying the RCI?
3. How could environmental resilience-building strategies be improved in Johannesburg?
    - To what extent did applying the RCI to Johannesburg facilitate answering this research question?

The third research question was shaped by Marsh Advisory's key interests in environmental and climate resilience.

2. Literature review

This chapter necessarily unpacks the key concept underpinning this research - urban resilience - before exploring the key academic debates surrounding urban resilience measurement and the operationalisation of the concept in South Africa.

2.1. Urban resilience

One of the key challenges of researching urban resilience is that there is no agreed definition of what it constitutes (de Bruijne et al., 2010; Grove, 2018). This has resulted in multiple understandings of the concept, which can be beneficial, as it has allowed policymakers to operationalise it in a variety of contexts to address specific local issues (Sanchez et al., 2018). On the other hand, these multiple understandings have proved problematic, as they have resulted in confusion about who should be responsible for implementing urban resilience and what exactly this implementation is aiming to achieve, thus preventing meaningful action (Washington, 2015; Knieling, 2016).

First introduced in scientific research in the context of ecological systems, resilience is defined by Holling (1973, p.17) as “the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist”. This definition is based on general systems theory and has gone on to inform more ‘conservative’ approaches to urban resilience, widespread in disaster studies, that focus on the capacity of a city to recover quickly when crises emerge (Manyena, 2006; Galderisi et al., 2020). These approaches have been criticised for being too reactive and focused on the short-term and thus failing to address chronic stress (Sutley et al., 2017; Goldbloom-Helzner et al., 2015). As a result, urban resilience scholars have developed an approach to urban resilience based in Complex Adaptive Systems (CAS) theory, which combines an adaptive perspective with a transformative one. This has allowed for a consideration of both a city’s ability to adjust to a constantly changing context, as well as its ability to radically change systems that are limiting its current or future adaptive capacity (Shaw, 2012; Meerow et al., 2016). This approach has been popularised in the global urban resilience discourse, informing the Economist Impact’s (2023a) definition and thus constituting the theoretical underpinning for this research project.

2.2. Measuring urban resilience

As the overarching aim of this research project is to assess the usefulness of the RCI for measuring the urban resilience of different cities globally, it is imperative to consider

why the development of an effective resilience measurement tool is so vital. Resilience measurement tools are key for attracting investment for resilience-building projects, for three key reasons. Firstly, diagnosing the current resilience of a city in comparison with the city's resilience potential provides a justification for why the investment is needed (Flax et al, 2019). Secondly, resilience measurement tools facilitate the identification of specific areas in which improvements are needed to increase a city's overall urban resilience. This knowledge allows for the creation of thorough investment plans and thus the calculation of benefits associated with the proposed resilience-building projects, alongside the expected return on investment (Ilmola, 2016). Finally, measurement tools allow for the impact of resilience-building efforts to be understood, which enables cities to highlight their progress and builds incentive for continued investment (Flax et al., 2019).

Recognising the importance of resilience measurement to the urban resilience-building effort globally, researchers and practitioners have worked to produce a variety of methods for assessing a city's resilience. Whilst, to date, there is no universally agreed upon method for measuring urban resilience, the City Resilience Index (CRI) is the most well-known method, promoted by the Rockefeller Foundation to inform the creation of a city Resilience Strategy as part of the 100 Resilient Cities initiative (2013- 2019) (Zhang et al., 2020). The CRI is made up of 312 questions (156 quantitative and 156 qualitative) across four key dimensions of a resilient city (health and well-being; economy and society; infrastructure and environment; leadership and strategy), which are each further broken down into three drivers and a variety of sub-drivers (Croese, 2020). Whilst designed to be a comprehensive assessment of a city's current resilience, the index has been criticised for being expensive, labour-intensive and too rigid, with local practitioners arguing that the 'one-size-fits-all model' of the CRI did not conform to their political reality (Naef, 2022). This criticism of the CRI has encouraged the development of other resilience measurement methods, such as the City Resilience Profiling Tool (CRPT) developed by UN-Habitat in 2018 (Zhang et al., 2020), as well as methods produced by private companies, such as Grosvenor and SwissRe (Ilmola, 2016). Furthermore, the response from the CRI highlights the need to be critical of resilience measurement tools to ensure their continued development, thus exemplifying the importance of this research project.

In order to understand whether the RCI is an effective urban resilience measurement, it is important to understand the key qualities an effective measurement tool should have. Briguglio (2014) argues that a good resilience measurement system should meet four key

criteria: simple to use and transparent; affordable; flexible in how certain features can be measured (in order to be inclusive of cities that are not included in certain indexes etc.); and facilitate the comparison of urban resilience between different time periods of different cities. Alternatively, Asadzadeh et al. (2017) argue that a good resilience measurement tool must be able to sufficiently evaluate the adaptive and transformative capacity of cities, utilising indicators that are able to assess the potential performance of an urban system in the long-term, as well as the current attributes of the system. Further, Dianat et al. (2022) highlight that the ideal urban resilience assessment tool should be able to provide information about how the different aspects of an urban system are working together and the potential impact of this, so the formation of any undesirable consequences can be quickly identified and eradicated. A strong method should also utilise both qualitative and quantitative measures to effectively assess the whole urban system holistically (ibid., 2022). These interpretations of what makes a good urban resilience measurement will be considered when analysing the effectiveness of the RCI.

2.3. Urban resilience in South Africa

Urban governance has been of particular importance in South Africa since December 2000 and the establishment of the country's eight metropolitan governments (Cameron, 2005). This marked a new political era of democracy and local government authority in South Africa after 46 years of apartheid (1948-1994), with the municipalities inheriting issues associated with apartheid spatial planning, the economic and social exclusion of Black populations and the manifestation of poverty associated with a lack of access to basic services (Pieterse, 2019). The municipalities have continued to grapple with the challenges associated with the apartheid era, however as the concept of urban resilience gained traction in the global urban management discourse throughout the 2000s, it emerged as a potential solution to the issues faced in South African cities (Harrison et al., 2014; Kong, 2022). This became particularly evident in the 2010s, with the publication of The State of South Africa's Cities Report (SACN, 2011a) being themed around resilient cities, and the State of Cities Finance Report (SACN, 2011b) utilising ideas of financial resilience.

More specifically, the City of Johannesburg first championed urban resilience in its 'Joburg 2040: Growth and Development Strategy' (GDS, 2011, p.9), making it one of the key themes by mentioning it in three out of the four key desired outcomes: 'Improved quality of life and development-driven resilience for all'; 'Provide a resilient, liveable, sustainable

urban environment - underpinned by infrastructure supportive of low-carbon economy' and 'An inclusive, job-intensive, resilient and competitive economy that harnesses the potential of citizens'. These three desired outcomes reflect the multidisciplinary approach that the city has taken towards building urban resilience in the strategy, as the intention to build social, economic and environmental resilience is implied within them (Peyroux, 2015). Despite this, Jassat (2021) has highlighted that in the 2016-2021 Integrated Development Plan, which was designed to be complimentary to the GDS 2040, there was a decline in the extent to which the concept of resilience was utilised, perhaps suggesting that its use in the GDS was driven by the popularity of the concept in urban planning discourse at the time that it was published. Furthermore, although Johannesburg has engaged with the concept of urban resilience, it has had less impact on the global urban resilience discourse than other South African cities. For example, Durban has sought to actively contribute to the local and global urban resilience debate, viewing their involvement in the 100RC programme as 'an opportunity for social learning and academic partnership' (Roberts et al., 2020, p.565).

3. Methodology

This chapter discusses the research methods and approaches utilised for this dissertation. This includes the Resilient Cities Index (RCI), as well as, the collaborative and transdisciplinary approach taken to critically analyse the data produced by the RCI about resilience in Johannesburg. Finally, the decision to conduct a GAP analysis of Johannesburg's Climate Action Plan (CAP) to overcome the limitations of the RCI for informing resilience-building policy is discussed.

3.1. The Resilient Cities Index (RCI)

To answer the first research question, the Resilient Cities Index (RCI) was utilised to measure the resilience of Johannesburg. The RCI assesses the resilience of an urban system across four pillars, which are broken down into 19 indicators and 41 sub-indicators. The pillars represent four macro-level urban sub-systems (critical infrastructure, environmental, socio-institutional and economic), whilst the indicators and sub-indicators measure the resilience of meso-level subsystems (transposition, digital government, legal etc.), as well as certain socioeconomic factors and risks that shape a city's resilience (Johnson, 2012, Economist Impact, 2023b). Utilising the RCI to measure urban resilience in Johannesburg involved three steps: sub-indicator scoring; score normalisation and score weighting and aggregation.

Throughout this process, a research diary was kept, in order to assess the practical aspects of utilising the RCI. The RCI was relatively easy to use, as all sources could be accessed online, and inexpensive, as all sources were free to access, apart from the EIU Business Environment Rankings. Despite this, applying the RCI to a smaller city may come with additional challenges, as they may be less likely to be featured in some of the indexes and rankings utilised for sub-indicator scoring (e.g. the Tomtom traffic index).

3.1.1 Sub-indicator scoring

The RCI is comprised of 17 quantitative sub-indicators and 24 qualitative indicators. Scoring guidance for each of the individual sub-indicators is shown in Appendix A. The quantitative sub-indicators were scored utilising statistics from municipal, national or international sources and tended to assess the current state of Johannesburg's urban resilience. Examples of quantitative sub-indicators include electricity price, riverine flood risk and economic volatility. Conversely, a desk-based review of credible sources, such as the City of Johannesburg website, websites of international organisations (e.g. C40), news

articles and academic literature, was utilised to provide a score for each of the qualitative indicators based on a scale determined by Economist Impact (2023b). Examples of qualitative sub-indicators include public transport quality and net zero progress.

3.1.2. Score normalisation

Once all the sub-indicators were assigned a raw score, this data needed to be normalised on a common scale of 0-100 to allow for data aggregation. For the quantitative indicators this involved utilising the below formula:

xNORMALISED= 100 * (x – Min(x)) / (Max(x) – Min(x)), where Min(x) and Man(x) are respectively the lowest and highest values across the 25 cities that were assessed in original RCI Whitepaper plus Johannesburg. These values were obtained from the Resilient Cities Index workbook (Economist Impact, 2023c).

The qualitative indicators featured a built-in scale, therefore when normalising the qualitative data, the same equation was used, however, Min(x) is the lowest score on the built-in scale, whereas Max(x) is the highest, even if none of the 26 cities received these scores.

3.1.3 Score weighting and aggregation

The final step was to weight and aggregate the normalised scores. Firstly, sub-indicator scores were weighted and linearly aggregated to calculate the score of each individual indicator. Pillar scores were then calculated through the weighting and aggregation of their underlying indicators scores. Finally, the overall resilience of Johannesburg was calculated by weighting and aggregating the individual pillar scores. The sub-indicators, indicators and pillars were weighted utilising an expert-designed framework (Appendix B) produced by the Economist Impact (2023b) that reflects assumptions of their relative importance.

3.2. Transdisciplinary, collaborative knowledge production

To answer the second and third research questions a transdisciplinary and collaborative approach to knowledge production was taken, as Bandola-Gill et al. (2023) argue that it is the most effective way of producing knowledge that is useable and relevant to decision-makers. Transdisciplinarity involves crossing different institutional settings to extend knowledge production (Jahn et al., 2012; Brandt et al., 2013) and this was achieved through the relationship that was formed between myself, as an academic researcher, and

Marsh Advisory, as a vocational partner. Between April and August 2024, I engaged in weekly meetings with a key point of contact at Marsh and further conversed with two experts at Marsh's Johannesburg office. These conversations were recorded, transcribed and then coded thematically. Furthermore, in August 2024, I spent a week in Marsh's London office, learning from a range of experts from the Climate Resilience Team about resilience-building projects the company had engaged in, as well as about best practice approaches for building resilience at different scales (business, city, national etc.) This direct involvement with Marsh, as well as the continuous exchange of information, allowed for knowledge production to be 'extended' to produce data that could be useful to a wide variety of actors, either academic or non-academic (Pohl et al. 2010; Polk, 2015). As Marsh has stated their intention to utilise this research to inform a future urban resilience-building project, this approach was essential, as highlighted by Peck (2021), who argues the two-way exchange of ideas, data, experience and skills between the researcher and the research user is fundamental to the production of excellent research.

3.3. GAP Analysis

Additionally, a GAP analysis of Johannesburg's Climate Action Plan (CAP) (2021) was carried out to answer the final research question. This document was selected, as it is the primary document that sets out how the City of Johannesburg intends to achieve its long-term goal of creating a 'resilient, liveable, sustainable urban environment' (p.4). A GAP analysis can be utilised as a tool to aid in the improvement of plans and strategies, through comparing the current state of an organisation/city/nation with its desired state (Amir, 2009). This facilitates the identification of the key gaps which are slowing or preventing progress towards the desired state (Kim and Ji, 2018).

This GAP analysis was informed by conversations with Marsh experts about what a comprehensive environmental resilience-building plan should include, as well as first-hand knowledge from Marsh experts in Johannesburg. Furthermore, Johannesburg's environmental RCI scores partly informed the GAP analysis, as for example, the city's low renewable energy adoption score encouraged an investigation into what may be preventing/slowing the pace of renewable energy adoption. However, as the quantitative indicators measure the current state of urban resilience in a city, they did not provide much insight into the strength of resilience-building efforts. The final step of the GAP analysis was to suggest potential solutions to close the gaps in the CAP. These suggestions were made utilising knowledge gained from relevant academic literature, conversations with

Marsh experts and case study examples of resilience-building projects and plans produced by other organisations or cities (e.g. City of Cape Town (CoCT), C40, KLM Consulting).

4. Calculating the Resilient Cities Index (RCI) score of Johannesburg

This chapter presents the knowledge that was gained about urban resilience in Johannesburg from applying the Resilient Cities Index (RCI). As shown in Figure 1, Johannesburg scores 65.4 out of 100.0 for overall resilience, placing it as the 17th most resilient city out of 26. Furthermore, Johannesburg is the highest-ranking African city, with Cape Town, Cairo and Lagos scoring 62.1, 44.7 and 39.6 respectively (Economist Impact, 2023a). If judging the Resilient Cities Index as an accurate measure of urban resilience, this places Johannesburg favourably to become the 'World Class African City' that city officials envision it to be by 2040 (GDS, 2011). The following sections will show how this overall resilience score was calculated, presenting all of the data that was utilised to inform each sub-indicator score, as well as all the individual indicator scores. The expert-assigned weights for each pillar, indicator and sub-indicator are presented in Appendix B, whilst the scoring guidance and a list of sources for the data used to inform each individual sub-indicator score can be found in Appendix A.

	City	Overall Resilience Score
1	New York	84.9
2	Los Angeles	84.4
3	London	83.2
4	Singapore	82
5	Paris	81.3
6	Melbourne	80.9
7	Amsterdam	79.9
8	Tokyo	79.6
9	Barcelona	79
10	Munich	78.6
11	Hong Kong	77
12	Warsaw	75.4
13	Dubai	69.5
14	Shanghai	69.4
	AVERAGE	68.5
15	Santiago	66.1
16	Istanbul	65.9
17	**Johannesburg**	65.4
19	Mexico City	62.7
19	São Paulo	62.7
20	Cape Town	62.1
21	Bangkok	58
22	New Delhi	53.3
23	Jakarta	51.6
24	Cairo	44.7
25	Dhaka	43
26	Lagos	39.6

Figure 1: A ranking of the overall resilience scores of the 25 cities included in the original RCI Whitepaper, as well as Johannesburg

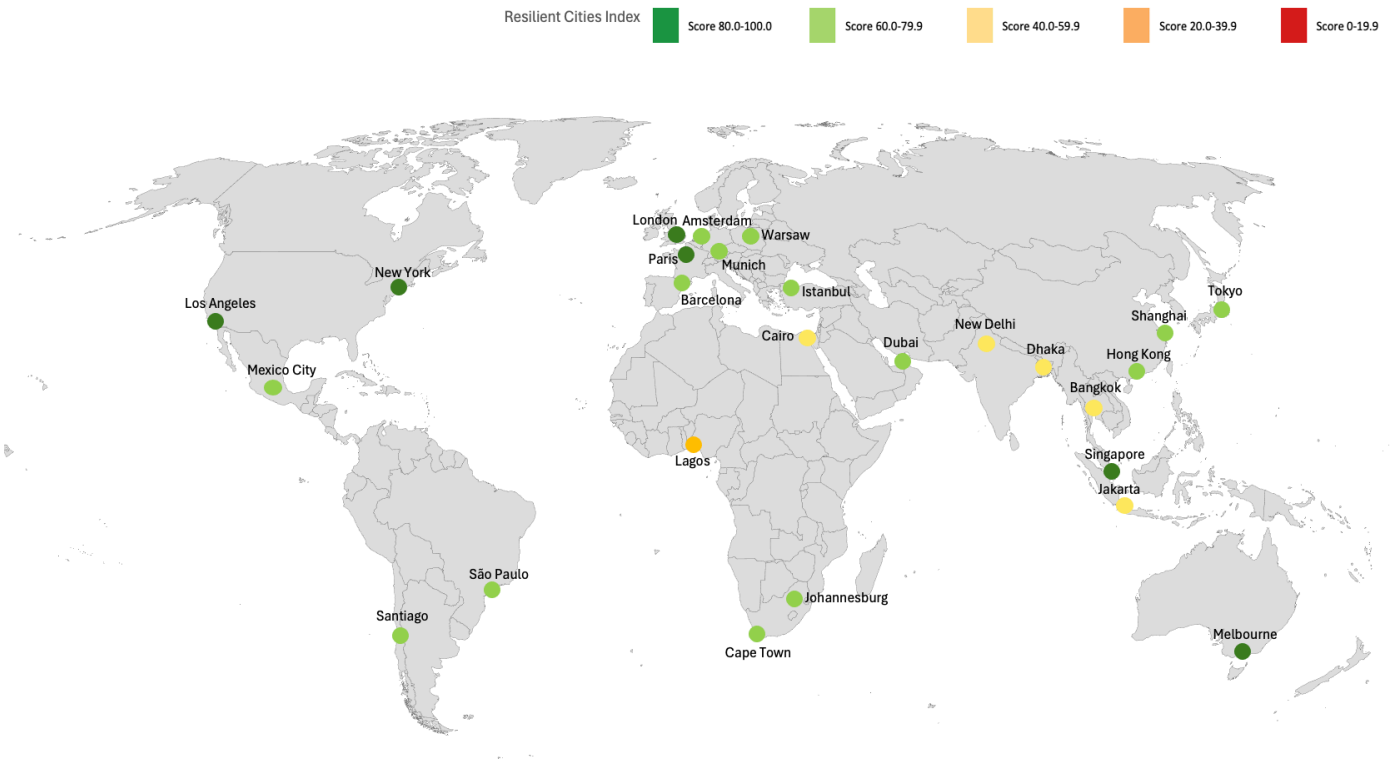

Figure 2: A map showing the location and overall resilience score of the 26 cities

4.1. Critical infrastructure

The RCI scores the resilience of Johannesburg's critical infrastructure 65.1/100.0, ranking it 18th out of the 26 cities and placing it 8 points below the average (Figure 3). This score suggests that the critical infrastructure of Johannesburg is the most resilient out of the four African cities analysed, with Cairo and Cape Town achieving scores of 56.3 and 51.3 respectively and Lagos achieving a significantly lower score of 31.1.

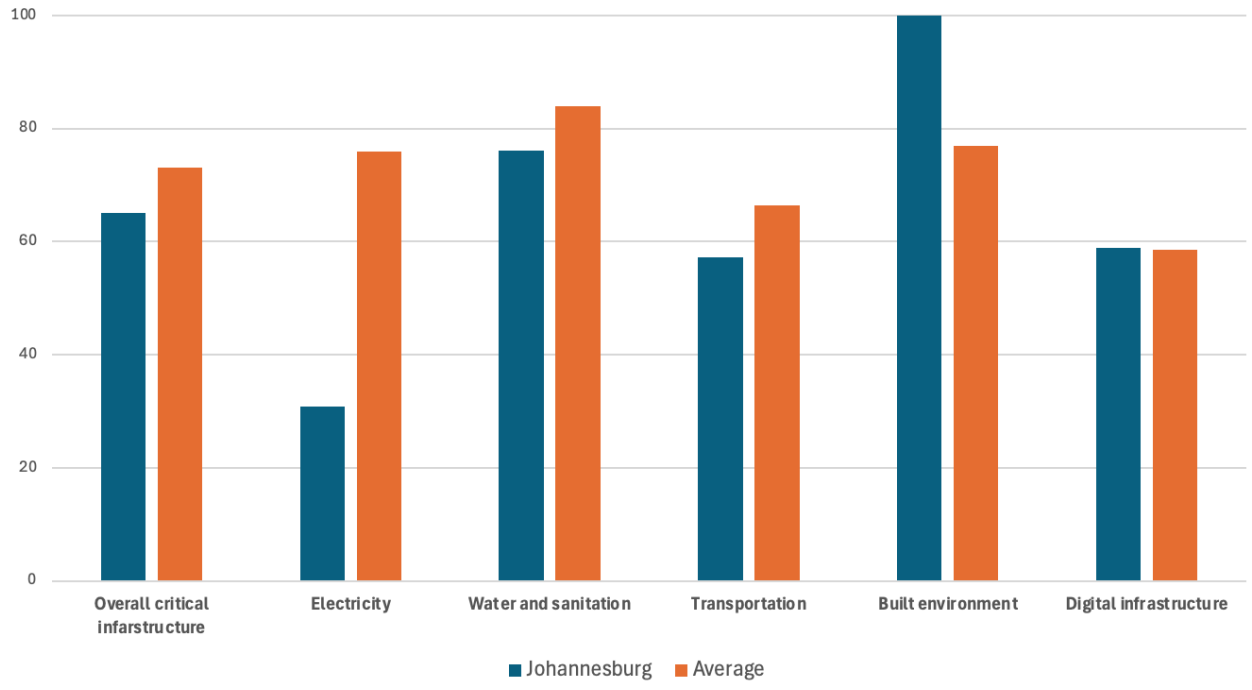

Figure 3: A bar graph showing the critical infrastructure score of Johannesburg, including the five critical infrastructure indicators, in comparison to the average scores across the 26 cities

Table 1 includes all the critical infrastructure indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

Indicator	**Score/100.0**				
Electricity					30.8
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Electricity price	• Petrol price in Johannesburg was $0.176/kWh on 14/5/24	0.176	0.614	0.027	74.6
Electricity quality	• Johannesburg has almost century-old electricity infrastructure, resulting in regular unplanned outages (Haffajee, 2021) • Load shedding occurs regularly (Trace, 2020) • Several incidences of electrical fires, for example, a fire in the city's eastern suburb in 2023 left people without electricity for months (Cox, 2024) • It has been estimated that it would cost ZAR 50 billion (US $2.6 billion) to repair the city's electricity infrastructure, however, City Power (the state-owned institution responsible for power in Johannesburg) only allocate ZAR 1 billion for capital expenditure per year (Kachkova, 2024)	0	0	4	0.0
Indicator	**Score/100.0**				
Water and sanitation					76.1
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Water provision quality	• Water infrastructure is affected intermittently by burst pipes, low pressure and interruptions caused by the unreliable energy supply (ARUP, 2022) • Johannesburg Water Management has reported that up to 44% of the volume of water it is supplied is lost to leaks and theft, resulting in periods where areas of the city are left without water (Sguazzin, 2024) • Despite this, Gauteng province has the highest volume of potable water in South Africa, with a Blue Drop Score of 98.1% in 2023 (DWS, 2022)	2	0	4	50.0

Wastewater treatment	• The average compliance of Johannesburg's six wastewater plants is 77%, ranging from 50% at the Goudkoppies plant to 100% at the Driefontein plant (DWS, 2022)	4	0	5	80.0
Water management	• City of Johannesburg's (COJ) Water Security Strategy (2022) includes information on water flows, the valuation of water in Gauteng and the wider region, financing and evidence of a system for water accounting	3	0	3	100.0
Indicator	**Score/100.0**				
Transportation					57.2
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Congestion	• Average travel time per 10km travelled in Johannesburg: 11 minutes and 10 seconds	11.2	23.0	9.5	87.4
Smart traffic management	• The Johannesburg Road Agency's (JRA) Intelligent Transport System (ITS) Strategy 2027 aims to utilise AI to 'predict movement patterns efficiently, ensuring smooth traffic flows and enhanced road safety' (CoJ, 2023) • Despite this, there is currently no smart traffic control systems in place	1	0	2	50.0
Public Transport Quality	• There is a public transport service including the Metrobus, the Metrorail, the Rea Vaya bus transit system, Minibus taxis and the Gautrain high-speed commuter train • Despite this, the reputation of public transport in the city is poor, as many of the transport systems are unreliable and have high crime rates (Deloitte City Mobility Index, 2019; WhereIsMyTransport, 2022) • Public transport in the province is expensive, with some spending up to 20% of their salary to utilise it (ibid., 2022)	1	0	4	25.0
Transport electrification	• The city has plans for electrification of transport • UK PACT South Africa announced the "Electric Vehicle Readiness Support Programme" in Johannesburg in 2021 providing financial support for the project (British High Commission Pretoria, 2021) • This includes plans for charging infrastructure, however operating systems are in the pilot stage (Malinga, 2021)	3	0	4	75.0

Indicator	Score/100.0				
Built environment					100.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Energy efficiency	• Energy building codes have been mandatory in South Africa since May 2012 (Tucker, 2017)	3	0	3	100.0
Future-proofing infrastructure	• CoJ has pioneered a municipal “Green Bond” to raise the capital to implement climate change mitigation and adaptation through the delivery of low-carbon infrastructure (C40, 2016)	1	0	1	100.0
Indicator	**Score/100.0**				
Digital infrastructure					58.9
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Internet quality	• In May 2024, Johannesburg median: - download speed was 59.29 Mbps - upload speed was 11.04 Mbps	2	0	5	40.0
Cybersecurity preparedness	• South Africa has a cybersecurity strategy - The National Cybersecurity Policy Framework (2015) - however, more work is needed to integrate the approach and ensure it is as effective as possible (Ncube, 2023)	3	0	4	75.0

Table 1: A table showing all the critical infrastructure indicator and sub-indicator scores, as well as all the relevant data used to calculate them

4.2. Environment

The RCI suggests Johannesburg is the 6th most environmentally resilient city out of the 26 analysed, scoring it 86.0/100.0 for environmental resilience. Again, Johannesburg was the highest-ranking African city, with Cape Town, Lagos and Cairo scoring 84.5, 60.7 and 47.3 respectively. As shown in Figure 4, Johannesburg scored higher than the average across all but two of the environment indicators, suggesting that the city could do more to improve its air quality and waste management.

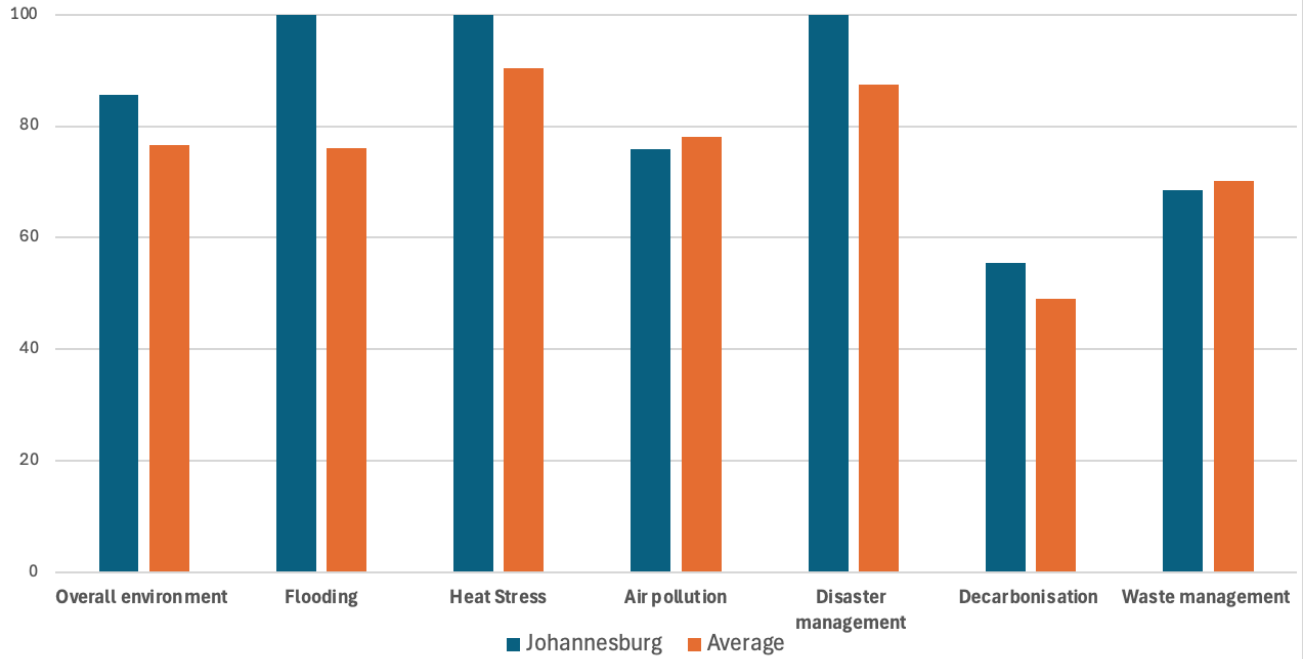

Figure 4: A bar graph showing the environmental resilience score of Johannesburg, including the six environmental indicators, in comparison to the average scores across the 26 cities

Table 2 includes all the environment indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

Indicator	**Score/100.0**				
Flooding					100.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Riverine flood risk	• 0 to 1 person in 1,000 is likely to be impacted by riverine flooding in Johannesburg	0	4	0	100.0
Coastal flood risk	• 0 to 1 person in 1,000 is likely to be impacted by riverine flooding in Johannesburg	0	4	0	100.0
Indicator	**Score/100.0**				
Heat stress					100.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Heat stress	• Heat stress is expected to be moderate by 2030 (average daily temperature projected to be 31.98°C in January 2030) • Plans to cope with heat stress are detailed in the CoJ CAP (2021), as well as 'The Heat Wave Response Plan'	2	0	2	100.0

Indicator	Score/100.0				
Air pollution					78.1
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Air quality	The average PM2.5 concentration in Johannesburg between 2019 and 2023 was 23.1µg/m³	23.1	89.1	4.8	78.1
Indicator	**Score/100.0**				
Disaster management					100.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Hazard monitoring	• South Africa has multi-hazard early warning system (EWS) coverage (UNDRR, 2023)	2	0	2	100.0
Hazard management	• CoJ published a comprehensive 61-page Disaster Management Plan in 2021. This includes details on disaster preparedness planning, education, training and public awareness and clearly defines responsibilities including but not limited to the CoJ Disaster Management Centre (CoJ, 2021)	2	0	2	100.0
Indicator	**Score/100.0**				
Decarbonisation					55.5
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Net zero progress	• Johannesburg has a target of net zero by 2050 • The CAP (2021) details how the city intends to meet this target	2	0	2	100.0
Carbon removal	• Johannesburg has no current plans for carbon capture and storage removal, however there are plans for nature-based removal through expanding green spaces e.g. Sub-action 4.2: “set a target percentage of urban tree canopy increase and expand tree planting programme” (CoJ, 2021)	1	0	2	50.0
Renewable energy adoption	• In 2023, South Africa generated 13% of its electricity from renewable sources	13.0	0	100	13.0
Indicator	**Score/100.0**				

Waste management					68.6
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Recycling and circular economy initiatives	• The CAP includes a variety of recycling strategies including: - 'Develop recycling facilities for building rubble and create partnerships to re-use building materials' (p.81) • Johannesburg has implemented the 'Sustainable Waste Management Project' as a circular economy initiative	2	0	2	100.0
Single-use plastic	• There is a plastic bag levy in South Africa, but no ban on them or other single-use items (CMS, 2024)	1	0	3	33.3

Table 2: A table showing all the environment indicator and sub-indicator scores, as well as all the relevant data used to calculate them

4.3. Socio-institutional

The RCI scores Johannesburg's socio-institutional resilience 53.8/100.0, exemplifying that it measures the city's socio-institutional system to be the least resilient macro-level sub-system out of the four assessed. Achieving a lower socio-institutional score was not uncommon across the 26 cities analysed, with only 14 cities having a score over 60. Despite this, as shown in Figure 5, Johannesburg scored lower than the average in three out of the four socio-institutional indicators, highlighting that the city may be restricted by its lack of willingness to effectively prioritise social issues. Further, the RCI ranks Johannesburg's socio-institutional system as the 17th most resilient out of 26. Johannesburg failed to be the highest-scoring African city in this category, with Cape Town gaining a higher score of 56.6. Despite this, Cairo and Lagos were the worst-scoring cities with 37.2 and 29.3 respectively.

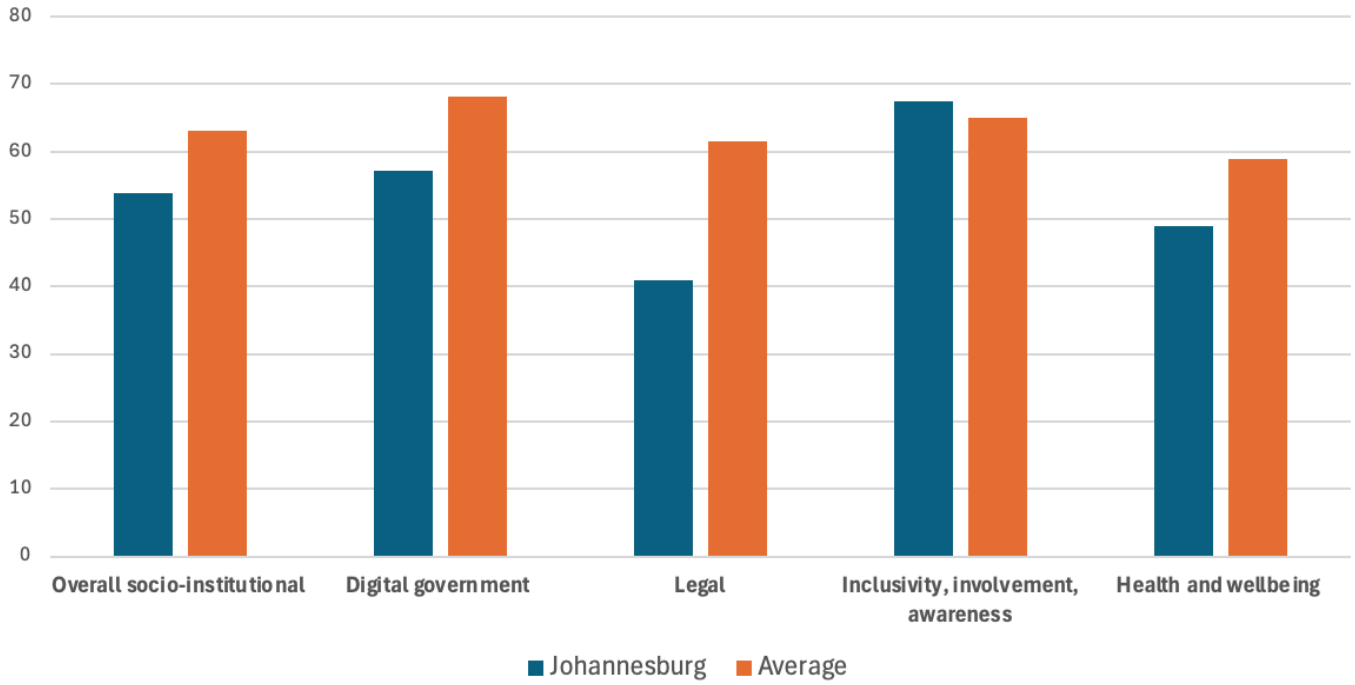

Figure 5: A bar graph showing the socio-institutional resilience score of Johannesburg, including the four socio-institutional indicators, in comparison to the average scores across the 26 cities

Table 3 includes all the socio-institutional indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

Indicator	**Score/100.0**				
Digital government					57.2
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
E-gov portal for residents	• Johannesburg receives a score of 0.6163 in the UN Online Services Index	0.6163	0	1	61.6
Open data availability and accessibility	• South Africa receives an Open Data Inventory score of 53	53	0	100	53.0
Indicator	**Score/100.0**				
Legal					41.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**

Crime and safety	• Johannesburg has the 3rd highest crime rate in Africa (South Africa Police Service, 2020) • Despite this, there is some evidence that crime rates are decreasing with recorded rates of assault with intent to inflict GBH decreasing by over 40% between 2008 and 2017, sexual offences decreasing by 60% in this time-period and non-violent property-related crime decreasing by 34% (CoJ, 2019)	1	0	4	25.0
Justice and law enforcement	• South Africa receives a score of 0.57 in the World Justice Project's Rule of Law Index	0.57	0	1	
Indicator	**Score/100.0**				
Inclusivity, involvement and awareness					67.4
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Income equality	Johannesburg's Gini coefficient score is 0.62 (CoJ, 2020)	0.62	0	1	62
Social protection benefits	63.4% of South Africa's population is covered by at least one social protection benefit.	63.4	0	100	63.4
Vulnerable group integration	• CoJ has shown a strong commitment to increasing the social inclusion of vulnerable groups through the City's Integrated Development Plan goals (CoJ, 2020) • This was reiterated by the city's budget for the 2024/25 year themed "An Inclusive Budget that Leaves No One Behind" (CoJ, 2024)	2	0	2	100.0
Culture of readiness	• The National Disaster Management Centre (NDMC) has carried out a number of projects to ensure DRR is incorporated in schools and to ensure that drills are adequate (Mpshane, 2022) • Awareness campaigns are evident e.g. 'Winter Safety Awareness Campaign 2023' (CoJ, 2023) • There is little evidence of comprehensive educational information sources	2	0	3	66.7
Indicator	**Score/100.0**				
Health and wellbeing					48.9

Sub-indicator	Data collected to inform scores	Score before normalisation	Min(x)	Max(x)	Normalised score/ 100.0
Health emergency response	• The current average response time for an ambulance in the Gauteng province ranges from 30 to 60 minutes (Cloete, 2022)	1	0	2	50.0
Longevity	• Evidence of the city partaking in campaigns for World Obesity Day and World Diabetes Day - involved raising awareness about preventative measures through exercise classes, nutritional guidance etc. (Rabid, 2023; ibid., 2024) • No evidence of mental health campaigns	1	0	2	50.0
Work-life balance	The average hours worked per week in South Africa is 42.6.	42.6	53.0	30.1	45.4

Table 3: A table showing all the socio-institutional indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

4.4 Economic

The RCI scores Johannesburg 54.5/100.0 for economic resilience, ranking it 17th out of the 26 cities, and below Cape Town, despite being considered the financial capital of Southern Africa. Figure 6 shows that Johannesburg scored higher than average for the 'exposure and risk' and 'human capital' indicators, however lower than average for the 'economic robustness' and 'innovation and entrepreneurship' indicators.

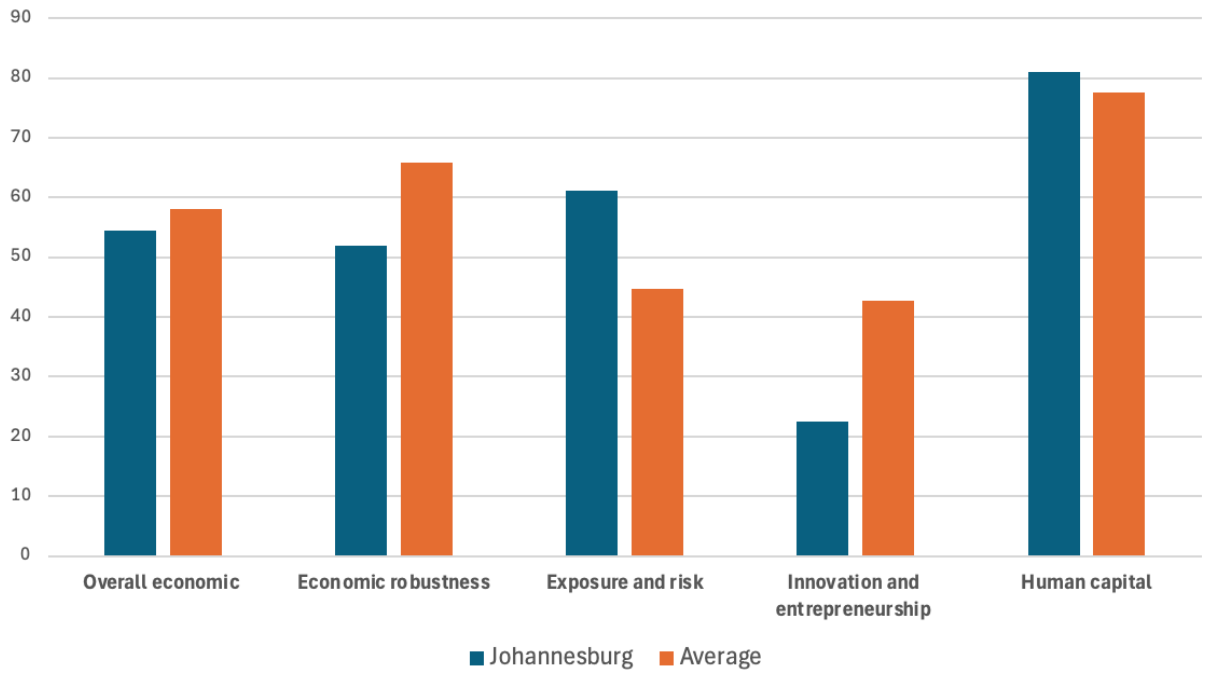

Figure 6: A bar graph showing the economic resilience score of Johannesburg, including the four economic indicators, in comparison to the average scores across the 26 cities

Table 4 includes all the economic indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

Indicator	**Score/100.0**				
Economic robustness					52.0
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Business environment	South Africa receives an average score of 3.08 across 13 sub-indicators included in the EIU Business Environment Rankings	3.08	1	5	52.0
Indicator	**Score/100.0**				
Exposure and risk					61.1
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
Economic volatility	• The coefficient of variation for South Africa's 2016-2020 GDP values is 0.073	0.073	0.159	0.02	61.9
Insurance penetration	• Insurance penetration in South Africa is 12.56%	12.56	0.5	20.511	60.3
Indicator	**Score/100.0**				
Innovation and entrepreneurship					22.5
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
AI readiness	• South Africa receives of 47.28 in the Government AI Readiness Index 2023	47.28	0	100	47.3
Innovation ecosystem	• Johannesburg receives a Startup Ecosystem score of 5.011	5.011	2.5	223.4	1.1
Indicator	**Score/100.0**				
Human capital					
Sub-indicator	**Data collected to inform scores**	**Score before normalisation**	**Min(x)**	**Max(x)**	**Normalised score/ 100.0**
High-skilled workforce	• 81% of South Africa's working-age population has advanced education	81	0	100	81.0

Table 4: A table showing all the economic indicator and sub-indicator scores, as well as all the relevant data used to calculate them.

5. Looking at the index through local knowledge

This chapter compares the knowledge produced about urban resilience in Johannesburg from applying the RCI to local knowledge provided by experts from the Marsh office in Johannesburg. This comparison allowed for the identification of some key weaknesses that restrict the usefulness of the RCI, such as its failure to be comprehensive or specific enough and its failure to sufficiently assess adaptive and transformative capacity.

5.1. Assessing indicator appropriateness and contesting the 'perfect' score

Due to the complexity and multi-dimensionality of the urban resilience concept, one of the fundamental steps to operationalising it is answering the questions 'to what should resilience be built against?' and 'resilience of what?' (Cutter, 2016). By selecting certain aspects of urban resilience to be measured, the creators of the RCI implicitly answer these questions, highlighting the risks they perceive to pose the greatest threat to the urban system (e.g. flooding, heat stress, economic volatility etc.), as well as defining the different levels of the urban system and their sub-systems that most critically need to build resilience (Asadzadeh et al., 2017). For example, the chosen pillars define four key levels of the urban system (critical infrastructure, environment, socio-institutional, economic), as well as the different sub-systems that operate within them (transportation, waste management etc.) to be measured. Whilst the consideration of many of the various layers of the urban system and its sub-systems is regarded as a quality of a good urban resilience measurement tool (Dianat et al., 2022), the RCI fails to consider some of the key sub-systems, as well as some of the key risks facing currently facing cities globally.

For example, the RCI fails to measure the resilience of food systems operating within cities. Considering this, the RCI is less likely to be able to accurately communicate the extent of resilience within urban systems. This was highlighted by one of the experts, who stated '*more inconsistent rainfall and more extreme temperatures could pose a serious threat to agricultural systems in and around Johannesburg which could disrupt health systems, economic systems etc. and seriously impact the city's resilience'* (Expert A) . Interestingly, Expert A discusses food systems '*in*' and '*around'* Johannesburg, which raises important questions about where the spatial boundaries of the urban system lay and potentially explains why food systems were not included in the RCI (Meerow and Newell, 2019). Furthermore, the expert recognises the interconnectedness of different sub-systems and system levels within an urban system by recognising how threats to one sub-system (food) would impact other sub-systems (health) and system levels (economic), as

well as the overall resilience of the urban system. The RCI fails to sufficiently assess how the system components work together or how they impact one another, exemplifying a weakness of it as a resilience assessment tool (Johnson, 2012; Dianat et al., 2022).

Moreover, the RCI fails to sufficiently measure cities' vulnerability to a variety of natural disasters, such as drought, famine, flash flooding etc. For example, whilst the RCI considers resilience to flooding, this is assessed on the basis of riverine flood risk and coastal flood risk, however flash flood risk is not considered. This resulted in Johannesburg being awarded a 'perfect' score of 100.0/100.0 for flood resilience, which is misleading, as highlighted by a local expert:

'Whilst Johannesburg is the largest city in the world that is not located on the coast or a major river, flashing flooding still causes significant problems, especially for informal settlements' (Expert A)

Further, the expert specifically mentioned the lack of flood resilience in Alexandra, a township in Johannesburg which sits on the banks of the Jukskei River and its three tributaries. The township experiences a plethora of locational environmental hazards, such as industrial-scale illegal dumping, which narrows the riverbed, unequally elevating the riverbank. This results in the potential retention area being reduced on one side of the river, consequently diverting floodwater to the settlement and exacerbating the township's vulnerability to flash flooding (Danielak, 2022). In November 2016, this vulnerability was realised, as heavy rainfall led to flash flooding, washing away parts of the Setswetla community (Mvulane, 2020). The RCI's failure to recognise Johannesburg's lack of resilience to flash flooding highlights that the index is not comprehensive enough. This could be rectified by including a broader range of sub-indicators, such as one that specifically addresses flash flood risk, alongside riverine flood risk and coastal flood risk. Alternatively, the index could integrate a consideration of flash flood risk by including (sub-)indicators that assess the factors that impact the likelihood of flash flooding, such as the quality of stormwater drainage systems, land use and average precipitation (Adegun, 2015). Furthermore, the RCI's failure to recognise specifically Alexandra's lack of resilience to flash flooding exemplifies another weakness of the index - it does not consider spatial variations in urban resilience across a city (Dianat et al., 2022). This could result in important questions, such as 'for who and where does resilience-building need to be prioritised?' being overlooked (Vale, 2014).

Additionally, it must be recognised that awarding a city a perfect score for an aspect of its urban resilience could be potentially detrimental to future resilience-building efforts, as it could result in the formation of 'resilience resistance'. Resilience resistance emerges when urban governance systems develop organisational and psychological barriers to achieving urban resilience through everyday operations (Shamsuddin, 2020). By awarding Johannesburg a perfect score for certain aspects of its resilience, the index could encourage complacency, reducing the extent to which city officials are concerned about potential threats that urban resilience strategies are designed to address (ibid., 2020). This could be particularly detrimental when considering environmental issues in Johannesburg, as city officials remain governed by the obligation to address the consequences of Apartheid, and therefore issues of inadequate infrastructure and resources take precedence (Arapostathis and Pearson, 2019; Grin, 2020).

5.2. 'Green aspiration, grey realities'?

The RCI could be considered a dynamic tool for measuring resilience, as it does not just assess the current state of a city's resilience, but also the potential for a city to develop its resilience, by scoring some (sub-)indicators on the presence of specific resilience-building plans (Asadzadeh et al., 2017). This could be considered a strength of the RCI, as this partially process-oriented approach exemplifies an attempt to recognise the long term adaptive and transformative potential of cities (Chelleri and Olazabal, 2012). For example, the RCI awards Johannesburg a score of 100.0 for 'net-zero progress', as it has a net-zero target and plan in place. Whilst Expert B highlighted that they didn't believe Johannesburg would necessarily meet their net-zero by 2050 target, they recognised the value of measuring resilience in this way, as the city still has transformative potential, despite facing socioeconomic constraints that slowed the resilience-building process:

'*As a country close to 90% of our energy is sourced from coal.. so it's a dirty fuel and does not help with your net zero pledges whatsoever… If we were to say 'let's rapidly ramp up renewable power and rapidly downscale our current energy mix'.., we would leave a lot of people who have jobs in this industry without jobs and only exacerbate our huge unemployment problem. So the pace of our net-zero journey in South Africa is going to be a lot slower than it would be in European countries and North America, but I think this will make the city more resilient in the long-term*' (Expert B)

As highlighted above, this partially process-oriented approach could be considered a strength of the RCI, however, it could also be considered a weakness. This is because the index fails to be critical of the robustness of many of the resilience-building plans a city has in place, therefore painting a potentially inaccurate picture of the city's adaptive and transformative capacity. In the case of Johannesburg, this could be particularly detrimental, as the city has a tendency to produce plans that align with its global city branding, rather than its technical or financial capacity to deliver them (Pieterse, 2006; Mulligan et al., 2020). This sentiment was corroborated by practitioners tasked with making Johannesburg 'water-sensitive' who stated they felt as if they were 'trying to force a very First world concept into a situation where we've got bigger challenges than that' (Mguni et al., 2022, p.150). The impact of this on the city's overall resilience score can be recognised. For example, Johannesburg achieves a high score of 75.0 for 'transport electrification', as the city has plans for developing EV charging infrastructure, as well as some sources of investment to finance the electrification of transport. Despite this, the city's poor electricity infrastructure presents a huge barrier to transport electrification, which Kachkova (2024) highlighted is an issue that is unlikely to be resolved in the short term. The impact of this is not reflected in the 'transport electrification' score, suggesting that Johannesburg's ability to implement transformative plans has been overstated.

5.3. The implications of utilising national statistics to assess urban resilience

A final weakness of the RCI that was identified was the use of national statistics or policies to measure 11 out of the 41 sub-indicators, including 5 out of the 6 economic sub-indicators. This restricts the usefulness of the indicator for comparing the resilience of different cities within the same country and in some instances results in an inaccurate picture of a city's resilience being painted. For example, Johannesburg and Cape Town are likely to have different levels of economic resilience, as the cities' key industries differ, with Cape Town's being tourism and technology, whilst Johannesburg is considered the financial hub of the country (Jackson, 2015). Different economic sectors face varying threats to their resilience, therefore assessing the two cities economic resilience utilising primarily national statistics is not sufficient (Hallegatte, 2016). Furthermore, the limitation of utilising national statistics to measure urban resilience was highlighted by expert A when comparing Cape Town and Johannesburg:

"*The two cities are very different .. they're 1000 miles apart geographically .. there are climate risks more abundantly in Cape Town than there are in Johannesburg. Cape Town*

is within the only province that is governed by the Democratic Alliance rather than the ANC and the general feeling is [the Western Cape] has done better than other provinces… Cape Town is also a lot further on in terms of renewable power" - (expert A)

The RCI consider 'renewable energy adoption' as a factor contributing to a city's overall resilience, however it is measured utilising a national statistic. Whilst this may be for practical reasons, as reports on a nation's energy mix tend to be more readily available than reports on a city's energy mix, both Johannesburg and Cape Town have stated their intention to invest in decentralised renewable energy, resulting in variable degrees of renewable energy adoption (CoJ, 2021; CoCT, 2021). For example, The City of Cape Town's Climate Action Plan highlights that the city aims to 'generate its own renewable electricity', as decarbonisation of the national grid 'may not happen fast enough for Cape Town to achieve its goal of carbon neutrality' (CoCT, 2021). Considering this, the RCI's use of a national statistic to measure renewable energy adoption cannot be judged as sufficient, as it creates a narrative that the two cities are making equal progress towards transitioning to renewable energy.

6. Looking to the future: how can Johannesburg improve its environmental resilience-building strategies?

This chapter will provide recommendations for how the City of Johannesburg (CoJ) can improve its environmental resilience-building strategies, which are summarised in its 2021 Climate Action Plan (CAP). Cardoso et al. (2020) argue that the regular review of resilience-building plans is imperative to identify any gaps and ensure continuous improvement in the resilience process. Whilst the RCI identified some key areas of weakness in Johannesburg's current environmental resilience, such as renewable energy adoption, carbon removal and the use of single-use plastic, the previous chapter highlighted that the RCI fails to be sufficiently critical of Johannesburg's resilience-building plans. Considering this, a GAP analysis of the CAP was conducted to identify any key weaknesses in the plan. The key findings are presented below in Table 5.

	Current state	**Desired State**	**Gap in CAP**
Financing the CAP	• The CoJ's Sustainable Services cluster is primarily responsible for implementing climate action • This cluster has a total annual budget of R7.5 billion (CAP, 2021, p.129). This fails to cover the operational costs for mitigation actions alone.	• R1.3 billion in capital investment made available for prioritised adaptation actions until 2050 (CAP, 2021, p.4) • R650 million per annum made available for the operational costs associated with these adaptation actions (ibid.) • R10 billion in capital investment made available for prioritised mitigation action until 2050 (p.5) • R25 billion per annum made available for the operational costs associated with these mitigation actions (ibid.)	• There is a lack of a detailed and structured plan for how CoJ will finance the implementation of the CAP and close the city's climate finance gap • External financing is discussed in the CAP, however, not in sufficient detail • The plan fails to address how the city will overcome its history of institutional incapacity and poor financial management to effectively implement the strategy (Bega, 2021; Mazzacuto et al., 2013)
Renewable energy adoption	• Johannesburg receives a low score of 13.0 for renewable energy adoption in the RCI • The CoJ meets 94% of its energy needs with coal-based electricity (CAP, 2021, p.60)	• The CoJ aims to obtain 35% of grid electricity from renewable sources by 2050 (CAP, 2021, p.37) • Alternatively, the CAP highlights an ambitious scenario of the CoJ obtaining 71% of grid electricity from renewable sources by 2050 (ibid., p.39)	• The plan lists methane gas, alongside solar, thermal and wind, as a renewable energy source that should be developed (p.61). Whilst methane is a renewable resource, an expert from the African Climate Reality Project highlights that methane is 'a false bridge to clean energy'. (Bega, 2021)

Air quality	• In 2023, the city's annual average PM2.5 concentration was 18.7µg/m³, more than 3x the WHO recommended level (IQ Air, 2023)	• The CoJ aim for compliance with the National Ambient Air Quality Standards by 2030 • The city 'aspires towards compliance with WHO [air quality] guidelines' (CAP, 2021, p.114)	• The CAP fails to suggest solutions for some of the major causes of air pollution in the city, as highlighted by Expert B: - '*We have lots of mine tailings facilities that predate legislation requiring mine companies to return the land to what it was after the mine has closed. They contain a variety of harmful pollutants and they create a lot of dust as well, which doesn't help our air quality. The management of these will be a huge environmental topic to reduce the risk there but currently, there are few policies in place*' - (expert B) • There is a lack of responsibility for the uneven effects of air pollution across Johannesburg
Urban growth	• Between 2011 and 2020, there was an increase of approximately 1122% in cleared land area in Johannesburg (Nhamo et al., 2021) • Development is occurring in areas that are particularly vulnerable to flooding/ ecologically sensitive, despite land-use regulations (Hetz, 2015)	• The development and effective enforcement of regulations that: - Restrict infrastructure construction on land that is particularly vulnerable to climate hazards (CAP, 2021, p.104) - Restrict land use and development within the 100-year flood lines (CAP, 2021, p.108)	• The CAP fails to address one of the root causes of uncontrolled/illegal urban development: high rates of rural-urban migration.

Resilience to climate-related events/ disasters	• The CAP (2021) includes plans to build Johannesburg's resilience against inconsistent rainfall, heat stress, drought and flash flooding	• Urban resilience is built against all possible climate-related events that could affect Johannesburg	• ThinkHazard!, an open-source tool that identifies natural hazards in specified areas, judges the risk of urban/ wildfires in Johannesburg to be 'high', stating there is a 'greater than 50% chance encountering weather that could support a significant wildfire' (GFDRR, 2024) • Whilst the CAP recognises the potential for climate change to cause extreme heat in Johannesburg, with temperatures predicted to rise by as much as 6ºC by 2100 and further exacerbated by the urban heat island effect (p.46), the plan fails to acknowledge the potential for this be a contributing factor to urban fire.

Table 5: A table showing the current and desired state of environmental resilience in Johannesburg, as well as keys gaps in Johannesburg's Climate Action Plan

Furthermore, Table 6 recommends potential solutions to address the identified gaps in Johannesburg's CAP. These recommendations are based on principles of inclusive development, enhanced multi-stakeholder collaboration, government transparency and environmental justice.

	Potential solutions
Financing the CAP	• Financial management could be improved by increasing government transparency and allowing residents to monitor public spending. This could be achieved by combining e-tools, such as PEFA, with geo-mapping, which would allow residents to see how public funding is being spent in their area (Wright, 2023). PEFA or Public Expenditure and Financial Accountability is an e-tool developed by the World Bank to assess a city's public expenditure. • The CoCT include a detailed financial plan in its Climate Action Plan, which explores innovative insurance mechanisms, options for accessing national and international climate change funding and the potential of special rating areas for financing environmental resilience-building projects. Special rating areas can be defined as geographic areas in which property owners agree to pay additional rates to fund certain services (CoCT, 2021, p.105). The CoJ should aim to learn from this, as well as seek to leverage private sector expertise to strengthen the city's plan for financing its CAP. There is some evidence that the city has already begun this process, as C40 has recently published a request for a proposal from consultants interested in collaborating with the CoJ to strengthen the city's climate financial planning (C40, 2024).

Renewable energy adoption	• The CAP should be revised, either removing methane from the list of renewable energy sources or highlighting the city's preference for solar and wind energy. Whilst this may appear to be a minor problem, the CAP discusses the particular importance of ensuring carbon lock-in and maladaptation is avoided (p.129). Organisational discourse on climate change adaptation and mitigation is by nature highly politicised (Wang, 2024), therefore making the city's intention to prioritise the development of South Africa's abundant solar and wind resources is imperative.
Air quality	• Public-private-people (PPP) partnerships could be utilised to more effectively address the key sources of air pollution in Johannesburg. In the context of urban resilience-building, PPP partnerships can be defined as purposeful, strategic relationships between public entities, private enterprises and citizens that are established with the aim of achieving a set of common objectives (Marana et al., 2018). • KLM Consulting Services has highlighted the potential of PPP partnerships to bring about environmental justice by addressing pollution caused by mine tailings storage facilities (MTSFs) in the WIN-WIN solution for mine waste clean up project proposal. This proposal highlights that the 270 MTSFs situated in and around Johannesburg still contain valuable mine residue, which can be collected and reprocessed to sell. Despite this, private companies have yet to explore the potential of this mine residue, due to the labour-intensive processes required to collect it. Considering this, the City of Johannesburg could collaborate with a private company interested in purchasing the mine residue to train and provide appropriate personal protection equipment to citizens, who would be employed to clean up the MTSFs (Morton, 2020). It is estimated that this could produce up to 5,000 jobs per year for those living in informal settlements, whilst reducing the harmful impacts of air pollution and generating profit, which could be re-invested to either clean up less profitable sites or to fund other resilience-building efforts (Morton et al., 2020).
Urban growth	• Nhamo et al. (2018) suggest that urban resilience in Johannesburg could be improved through increased inter-regional cooperation to slow rural-urban migration, whilst addressing some of the other goals in the CAP, such as increasing water and energy security in Johannesburg. • CoJ should seek to identify the primary regions from which people are migrating and survey these areas for potential water/energy development projects. The implementation of these projects could result in job creation in the identified regions, slowing the rate of urban-rural migration, whilst strengthening critical infrastructure resilience.
Resilience related to climate-related events/ disasters	• A risk assessment should be conducted of fire risk in Johannesburg and a management plan should be developed. This should be recognised as an area of key concern, as the city already struggles with incidents of electrical fires, due to the poor state of the city's electricity infrastructure. Furthermore, this should be recognised as an issue of climate justice, as informal settlements may be more vulnerable to fires, as fire-prone building materials, such as untreated wood, are more common in informal settlements (Murray, 2009; CoCT, 2021). • To facilitate the creation of an urban fire management plan, the CoJ should utilise the "Fire Engineering Guidelines for Informal Settlements", which were created by the Western Cape government and Stellenboche University utilising funding provided by Lloyd's Register Foundation. These guidelines have been lauded as a 'world-first' and exemplify the importance of public-private partnerships in resilience-building efforts (Walls et al., 2020). • Furthermore, the CoJ could explore the possibility of partnering with social enterprises, such as Lumkani, which has previously aimed to provide affordable early warning systems, as well as low-cost inclusive insurance products, to citizens in urban informal settlements in Cape Town (GSMA and UKaid, 2020).

Table 6: A table of recommendations for how Johannesburg could improve its environmental resilience-building strategies

7. Conclusion

The overarching aim of this research project was to evaluate the usefulness of the Resilient Cities Index (RCI) to policymakers and practitioners who are looking to utilise urban resilience measurement tools to inform resilience-building practices and policies. This was achieved by applying the RCI to Johannesburg and then comparing the knowledge it produced about urban resilience in Johannesburg to local knowledge. Furthermore, a second line of enquiry was followed, as this dissertation explored how environmental resilience-building strategies could be improved in Johannesburg. The purpose of pursuing this second line of enquiry was to evaluate whether applying the RCI to Johannesburg allowed for an assessment of urban resilience in the city which could usefully inform resilience-building strategies.

The findings exemplify that whilst the RCI was relatively simple and inexpensive to apply, its usefulness for measuring urban resilience in Johannesburg was limited in a plethora of ways. Firstly, not only does the RCI fail to measure the resilience of some of the key sub-systems operating within a city, such as food systems, but it also fails to measure how efficiently the different components within an urban system are working together. This prevents the RCI from facilitating an understanding of any undesirable consequences that are emerging from sub-system interaction and thus the identification of any systems traps. Additionally, this research finds that whilst the RCI is somewhat useful for comparing the resilience of cities in different countries, the use of national statistics for many of the indicators prevents it from being as useful for comparing the resilience of cities within the same country. The use of national statistics and the use of seemingly perfect scores of 100.0/100.0 can result in the RCI presenting the resilience of a city in a misleading light, as was highlighted by experts from Johannesburg.

Furthermore, the RCI does assess the adaptive and transformative potential of a city to an extent, by scoring a variety of city plans and strategies. Despite this, in many cases, this qualitative assessment does not encourage a deep enough analysis of a city's resilience-building strategies to inform recommendations to improve them. As a result of this, it was necessary to conduct a GAP analysis of Johannesburg's Climate Action Plan (2021) to answer the third research question and identify ways in which environmental resilience-building strategies in Johannesburg could be improved. Recommendations for improvement ranged from the development of an urban fire management plan, to learning from the City of Cape Town (CoCT) to improve financial management, to fostering public-

private-people partnerships to address air pollution caused by mine tailings storage facilities (MTSFs) in and around Johannesburg.

Further research should be conducted to explore whether the RCI would be more useful for assessing the resilience of cities that are less engaged with the concept than Johannesburg and the 25 cities included in the original RCI Whitepaper. Additionally, further research could investigate whether the RCI is simple and inexpensive to apply for a city less frequently included in global rankings and indexes.

8. Bibliography

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9. Appendices

Appendix A: a table that includes the scoring guidance produced by the Economist Impact (2023b) for the 41 sub-indicators included in the RCI, as well as the data sources used to score each sub-indicator.

Sub-indicator	Unit	Scoring guidance	Source
Electricity price	**USD per kWh** Lower = better	**What is the price of one kilowatt hour (kWh) of electricity?** USD	Global Petrol Prices 2024
Electricity quality	**Score (0-4)** Higher = better	**What is the quality of electricity provision?** 0- Supply is completely inadequate, delivered by an out of date and potentially dangerous network. Disruptions such as surges or outages are commonplace and maintenance is extremely poor and very slow. An alternative source of supply such as a generator is considered to be an essential part of life. 1- Interruptions are regular and an alternative source of supply such as a generator may be required during these times. However, a largely uninterrupted supply is maintained. Maintenance is poor but does seek to resolve problems as they occur usually within a few days. 2- Supply is generally good but interruptions do occur at a frequency of every month or two, even for short amounts of time. Sustained outages take place far less frequently but can leave homes without supply for hours and delays for essential maintenance in restoring specific supply issues can take days. 3- A good and modern network that delivers a relatively consistent supply but suffers from very occasional power outages or surges (perhaps a few times per year maximum), or where maintenance can sometimes be delayed. 4- A very good, extensive and modern network with very few disruptions. Speedy and regular maintenance is available.	Desk-based research (city website, city plans/ strategies, news articles etc.)

Water provision quality	**Score (0-4)** Higher = better	**What is the quality of water provision?** 0- Supply is completely inadequate and delivered by an out-of-date pipe network that makes drinking water potentially dangerous. Shortages in water are commonplace and maintenance is extremely poor and very slow. Bottled drinking water has to be delivered regularly and tap water is not consumed by a substantial part of the population. 1- Interruptions are regular. Alternative water supplies such as storage tanks are often kept in reserve to tide-supply over during these times. Maintenance is poor and concerns over the quality mean that most people favour bottled drinking water, which is delivered regularly by private services. 2- Supply is generally good but interruptions do occur at a frequency of every month or two. Sustained shortages take place far less frequently but can leave homes without water for hours and delays for essential maintenance can take days. Water is ok to drink but many prefer to opt for bottled water. 3- A good and modern network that delivers a relatively consistent water supply but suffers from very occasional shortages (perhaps a few times per year maximum), or where maintenance can sometimes be delayed. Water quality is considered fine for residents but some visitors may prefer bottled water. 4- A very good, extensive and modern network with few disruptions. Speedy and regular maintenance is available. Quality of water is drinkable and often preferred to bottled water	Desk-based research (city website, city plans/ strategies, news articles etc.)
Wastewater treatment	**Score (0-5)** Higher = better	**What percentage of wastewater is treated before discharge?** 0- 0-10% 1- 11-30% 2- 31-50% 3- 51-70% 4- 71-90% 5- 91-100%	Desk-based research (city website, city plans/ strategies, news articles etc.)
Water management	**Score (0-3)** Higher = better	**Does the city have an ongoing programme(s) to protect existing natural water sources from overuse and depletion?** 0- No plans to protect water resources. 1- There are plans to protect water resources but the budget/funding/responsible agency has not been outlined. 2- There are plans to protect water resources and the budget/funding/responsible agency has been outlined. +1 if the city has a system for water accounting	Desk-based research (city website, city plans/ strategies, news articles etc.)
Congestion	Average travel time per 10 km in minutes Lower = better	**What is the average travel time?** Average travel time per 10 km in minutes	Tomtom traffic index 2023

Smart traffic management	**Score (0-2)** Higher = better	**Does the city have smart traffic management systems that leverage AI, IoT and data analytics?** 0- No 1- In planning/pilot stage 2- There are smart traffic control systems in place	Desk-based research (city website, city plans/ strategies, news articles etc.)
Public transport quality	**Score (0-4)** Higher = better	**What is the quality of public transport considering efficiency and level of maintenance?** 0- There is little or no public transport network to speak of. Any routes that are on offer are antiquated, dirty, overcrowded, and can be unsafe. There is little regard for the regularity and punctuality of routes and a number of private services such as private bus or taxi services mean that public transport is only considered by many to be a last resort. 1- Public transport is extremely limited and alternatives are regularly used. Networks may be limited to just bus or rail routes with few options available to undertake journeys. Concerns over safety, cleanliness and crowding act as a disincentive for many routes. 2- The city has a public transport system that is inefficient. Although there are a number of networks, some may be antiquated and an irregularity of service or delays means regular overcrowding, even outside peak travel hours. Travel options on some routes are limited and may be avoided due to concerns over crowding, safety or cleanliness. 3- The city has a public transport system that is large and incorporates a number of different networks. Service is regular but is not always punctual and overcrowding can occur, especially during peak travel times, with occasional delays or a lack of choice sometimes limiting options. 4- The city has an excellent public transport system that uses a range of different options such as buses, rail, underground and tram networks. It is regular, punctual, and clean or modern. The system is not overcrowded with multiple routes available for most journeys	Desk-based research (city website, city plans/ strategies, news articles etc.)
Transport electrification	**Score (0-4)** Higher = better	**Does the city have a plan/policies to encourage the electrification of public transport and/or private cars?** 0- The city doesn't have a plan/policies. 1- The city has a basic plan/policy to promote the electrification of its transport. Cities get an additional score for each of the below: +1 The plan/policy includes measures to develop EV charging infrastructure. +1 The plan/policy includes financial support for electrification of transport. +1 There is electric public transport operating in the city (not pilot).	Desk-based research (city website, city plans/ strategies, news articles etc.)

Energy efficiency	**Score (0-3)** Higher = better	**Does the city have energy building codes?** 0- No known code 1- In development 2- Voluntary 3- Mandatory	Desk-based research (city website, city plans/ strategies, news articles etc.)
Future-proofing structures	**Score (0-1)** Higher = better	**Are there regulatory frameworks/ policies/strategies that legislate/ support (in the form of financial incentives) innovative solutions for future-proofing (these include adopting flexible/adaptable design approaches, using durable/renewable materials and building green roofs against heat) infrastructure projects apart from energy efficiency?** 0- No 1- Yes	Desk-based research (city website, city plans/ strategies, news articles etc.)
Internet quality	**Score** Higher = better	**What is the downloading speed?** 0- 0-20 Mbps 1- 20-40 Mbps 2- 40-80 Mbps 3- 80-120 Mbps 4- 120-160 Mbps 5- >160 Mbps **What is the uploading speed?** 0- 0-5 Mbps 1- 6-10 Mbps 2- 10-15 Mbps 3- 15-20 Mbps 4- 20-25 Mbps 5- 25-30 Mbps **Average of scores for uploading and downloading speeds**	Ookla Speedtest Intelligence Global Index 2024
Cybersecurity preparedness	**Score (0-4)** Higher = better	**How prepared is the city/country to withstand cyberattacks?** 0- Very low preparedness, reflecting an absence of a national cybersecurity strategy and near absence of barriers in place to defend key infrastructure. 1- Low preparedness, reflecting low awareness within both the government and corporate sector, and intermittent implementation of policy. 2- Moderate preparedness, reflecting a lack of coordination over cybersecurity, and gaps in awareness and technical capacity at the corporate and government level. 3- High preparedness, with uniform cybersecurity awareness, but co-ordination and capacity gaps exist. 4- Very high preparedness, with uniform cybersecurity awareness, and advanced technical barriers in place to defend key infrastructure.	Desk-based research (city website, city plans/ strategies, news articles etc.)

Riverine flood risk	**Score (0-4)** Lower = better	**What is the proportion of people expected to be impacted by riverine flooding?** 0- Low (0 to 1 person in 1,000) 1- Low-medium (1 person in 1,000 to 2 people in 1,000) 2- Medium-high (2 people in 1,000 to 6 people in 1,000) 3- High (6 people in 1,000 to 1 person in 100) 4- Extremely high (more than 1 in 100)	Aqueduct Water Risk Atlas 2024
Coastal flood risk	**Score (0-4)** Higher = better	**What is the proportion of people expected to be impacted by coastal flooding?** 0- Low (0 to 9 people in 1,000,000) 1- Low-medium (9 people in 1,000,000 to 7 people in 100,000) 2- Medium-high (7 people in 100,000 to 3 people in 10,000) 3- High (3 people in 10,000 to 2 people in 1,000) 4- Extremely high (more than 2 people in 1,000)	Aqueduct Water Risk Atlas 2024
Heat stress	**Score (0-2)** Higher = better	**How prepared is the city to mitigate heat stress (current mitigation plans vs 2030 heat stress projections)?** 0- No heat mitigation plan but is expected to have medium-high heat stress. 1- Has a vague heat plan and is expected to have a medium-high heat stress. 2- Is expected to have a low heat stress or has a detailed heat plan and is expected to have a medium-high heat stress.	Copernicus Interactive Climate Atlas and desk-based research (city website, city plans/ strategies, news articles etc.)
Air quality	**µg/m³** Higher = worse	**What is the city's annual average PM2.5 concentration (µg/m³) between 2019 and 2023?** Average of PM2.5 concentration (µg/m³)	IQAir 2023
Hazard monitoring	**Score (0-3)** Higher = better	**Does the city have a comprehensive early warning system?** 0- No early warning system. 1- Early warning system exists but it doesn't capture a multi-hazard approach. 2- Early warning system exists with a multi-hazard approach.	Desk-based research (city website, city plans/ strategies, news articles etc.)

Hazard management	**Score (0-2)** Higher = better	**Does the city have a disaster management plan?** 0- The city doesn't have a disaster management plan in place. 1- The city has a disaster management plan but it's not comprehensive. It doesn't include details such as disaster preparedness plan (ie, evacuation routes) and clearly defined responsibilities, emergency response team, emergency facilities and emergency communication. 2- The city has a comprehensive disaster management plan. It includes details such as a disaster preparedness plan (i.e. evacuation routes) and clearly defined responsibilities, emergency response team, emergency facilities and emergency communication.	Desk-based research (city website, city plans/ strategies, news articles etc.)
Net zero progress	**Score (0-2)** Higher = better	**What is the status of the city's net zero target?** 0- No target 1- Target exists + **What is the status of the city's net zero plan?** 0- No plan 1- Plan exists	Desk-based research (city website, city plans/ strategies, news articles etc.)
Carbon removal	**Score (0-2)** Higher = better	**Does the city mention carbon removal in its net zero target plan?** 0- The city doesn't have any plans. 1- The city has either nature-based removal, or carbon capture and storage removal plans. 2- The city has both nature-based removal, and carbon capture and storage removal plans.	Desk-based research (city website, city plans/ strategies, news articles etc.)
Renewable energy adoption	**% of total electricity generated** Higher = better	**What is the percentage of electricity generated from renewable sources?** % of total electricity generated	Our World in Data 2023
Recycling and circular economy initiatives	**Score (0-2)** Higher = better	**Does the city have any comprehensive longterm policies/initiatives/strategies to encourage recycling and/or the circular economy?** 0- The city doesn't have any recycling or circular economy strategies/plans. 1- The city has recycling strategies/ plans but not circular economy. 2- The city has both recycling and circular economy strategies/plans.	Desk-based research (city website, city plans/ strategies, news articles etc.)
Single-use plastic	**Score (0-3)** Higher = better	**Does the city/country enforce a ban on plastic bags or single-use plastic? (Eg, plastic bags, single-use cutlery, straws)** 0- No ban. 1- There is a fee charged on plastic bags or single use plastics or a limited ban on plastic bags. 2- There is a full scale ban on plastic bags. 3- There is a full-scale ban on single-use items (more than just plastic bags)	Desk-based research (city website, city plans/ strategies, news articles etc.)

E-gov portal for residents	**Index Score (0-1)** Higher = better	**What is the scope and quality of online government services?** The UN online services index assesses government websites to assess their ease and accessibility for an average citizen, and scope and quality of online services. The composite value of the index is normalised between the range of 0 to 1.	United Nations Division for Public Institutions and Digital Government 2022
Open data availability and accessibility	**Index Score (0-100)** Higher = better	**What is the level of accessibility and availability of open data on government websites?**	Open Data Watch rankings 2022
Crime and safety	**Score (0-4)** Higher = better	**What is the level of crime rate in the city?** Petty crime: this refers to minor crimes such as theft and trespassing, where no physical harm is inflicted on the victim. Violent crime: this refers to armed robbery, mugging or assault as well as more serious acts of violence such as rape and murder. 0- Very high level of petty crime and violent crime. 1- High level of pretty crime and violent crime. 2- Moderate level of pretty crime and violent crime. 3- Low level of petty crime and violent crime. 4- Very low level of petty crime and violent crime.	Desk-based research (city website, city plans/ strategies, news articles etc.)
Justice and law enforcement	**Index Score (0-1)** Higher = better	**What is the capacity of the city's law enforcement and justice system?** The World Justice Project's Rule of Law Index considers an effective criminal justice system as a key aspect of the rule of law. Scores for criminal justice are calculated from data collected from academics, practitioners and community leaders via questionnaires. Scores are normalised to a range between 0 to 1.	World Justice Project 2022
Income inequality	**Gini coefficient (0-100)** Lower = better	**What is the extent of income inequality in the city?** Gini score	Desk-based research (city website, city plans/ strategies, news articles etc.)
Social protection benefits	**% of population** Higher = better	**What is the percentage of population covered by at least one social protection benefit (excluding health)?**	ILO's World Social Protection Data 2022

Vulnerable group integration	**Score (0-2)** Higher = better	**Is there any evidence to support the vulnerable groups in the city?** This includes existing schemes or plans aimed to ensure their social integration and inclusion in society. 0- No evidence of any schemes/plans 1- Evidence of several individual schemes/ plans provided by the government for at least two vulnerable groups (these could be provided in collaboration with other stakeholders or civil society, etc) 2- Evidence of a single comprehensive and detailed scheme/plan	Desk-based research (city website, city plans/ strategies, news articles etc.)
Culture of readiness	**Score (0-3)** Higher = better	**What is the level of societal disruption readiness in a society to act decisively amid major shocks and stresses?** 1. Educational programmes (evidence of either of the two below) - Does the school curriculum involve subjects such as disaster/disruption management and preparedness? - Any evidence of conducting training programmes such as drills at a school level? 2. Information sources (evidence of either of the two below) - Does the city provide comprehensive and detailed information to make citizens “aware” of disaster/disruption preparedness? - Is there evidence of the availability of disaster preparedness educational materials? 3. Awareness campaigns - Is there evidence/examples of awareness campaigns undertaken by the government on various kinds of threats/disasters/disruptions in the preceding year? 0- No evidence of educational programmes, information sources and awareness campaigns 1- Evidence of only one of the three categories 2- Evidence of only two of the three categories 3- Evidence of all the three categories	Desk-based research (city website, city plans/ strategies, news articles etc.)
Health emergency response	**Score (0-2)** Higher = better	**What is the average response time for an ambulance in the city?** 0- No emergency service, or more than one hour response time. 1- Emergency response time is 10 minutes to 1 hour 2- Emergency response time is less than 10 minutes	Desk-based research (city website, city plans/ strategies, news articles etc.)
Longevity	**Score (0-2)** Higher = better	**Is there any evidence of public information awareness campaigns/ campaigns on preventive measures on non-communicable diseases (NCDs) in the city in the past five years?** 0- No evidence of campaigns or initiatives on NCDs. +1: Evidence of information campaigns for preventative measures including exercise, healthy eating and/or screening. +1: Evidence of a mental health campaign.	Desk-based research (city website, city plans/ strategies, news articles etc.)

Work-life balance	**Average weekly working hours** Lower = better	**What are the average working hours per week in the city?**	ILO 2024
Business environment	**Average score on a scale of 1 to 5, where 5 = most favourable business environment** Higher = better	**How favourable is the business environment in the city?** The indicator is a composite of 13 sub-indicators from two pillars from the EIU Business Environment Rankings. The two pillars are: -Private enterprise policy, which covers aspects like the protection of private property, government regulation, freedom to compete, competition policy, price controls, lobbying, state control and minority shareholders. Protection of intellectual property is not included. -Foreign investment policy, which covers policies around foreign investors, openness of national culture, expropriation risk, investor protection and government favouritism.	EIU Business Environment Rankings 2022
Economic volatility	**Coefficient of variation for GDP values** Lower = better	**What is the variance in the economic output for the city?**	EIU 2020
Insurance penetration	**% of GDP** Higher = better	**What is the level of total insurance penetration (direct gross premiums/ GDP) in the city?** Percent	Desk-based research (city website, city plans/ strategies, news articles etc.)
AI readiness	**Index Score (0-100)** Higher = better	**What is the government's AI readiness score?**	Oxford Insights - Government AI Readiness Index 2022
Innovation ecosystem	**Score** Higher = better	**What is the level of innovation for businesses in the city?** This indicator uses the Startup Ecosystem score, which assesses a broad range of elements within a city such as: performance, funding, market reach, connectedness, talent and experience, and knowledge. In addition, the Startup Ecosystem score considers a critical mass of activity in each city, which partially explains score differentials between cities in the same country.	
High-skilled workforce	**% of working-age population** Higher = better	**What is the percentage of the total working age population with advanced education?**	World Bank 2022

Appendix B: Expert-assigned weights for each of the pillars, indicators and sub-indicators included in the RCI (Source: Economist Impact, 2023b)

Pillar	Weights, %
1) Critical infrastructure	27.38%
2) Environment	26.19%
3) Socio-institutional	27.38%
4) Economic	19.05%

Table A1.2: Indicator weights

1) CRITICAL INFRASTRUCTURE	
1.1) Electricity	21.00%
1.2) Water and sanitation	22.00%
1.3) Transportation	19.00%
1.4) Built environment	21.00%
1.5) Digital infrastructure	17.00%
2) ENVIRONMENT	
2.1) Flooding	19.20%
2.2) Heat stress	18.40%
2.3) Air pollution	15.20%
2.4) Disaster management	18.40%
2.5) Decarbonisation	12.80%
2.6) Waste management	16.00%

3) SOCIO-INSTITUTIONAL	
3.1) Digital government	19.28%
3.2) Legal	25.30%
3.3) Inclusivity, involvement and awareness	28.92%
3.4) Health and well-being	26.51%
4) ECONOMIC	
4.1) Economic robustness	25.71%
4.2) Exposure and risk	24.29%
4.3) Innovation and entrepreneurship	24.29%
4.4) Human capital	25.71%