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DOI
10.1016/j.futures.2025.103698

Publication date
2025

Document Version
Final published version

Published in
Futures

Citation (APA)
Nelson, R., Pearce, B. B., Warnier, M., & Verma, T. (2025). Constructing just mobility futures. *Futures*, *174*, Article 103698. https://doi.org/10.1016/j.futures.2025.103698

Futures 174 (2025) 103698

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

Constructing just mobility futures

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ARTICLE INFO

Dataset link: Summaries of interviews

Keywords:
Scenarios
Urban modelling
Stakeholder engagement
Accessibility
Justice

ABSTRACT

Scenario planning has become a common approach within transportation research to understand the varying impacts of transportation planning. By examining a range of uncertainties, scenarios can be developed that enable an exploration of alternative future visions of the world. Whilst there has been growing concern over the equity impacts of public transport investments, particularly in relation to accessibility of social and economic opportunities, equity of access considerations remain an underdeveloped area within transportation scenarios research. This has tremendous consequences for realising socially just mobility futures. Utilising the case study of Cape Town, in South Africa several transport scenarios are collectively developed through stakeholder engagement by analysing a number of parameters that have been identified as significant operational factors and policy levers. We develop representative urban network models for each scenario and evaluate equity of access to places of employment using a comparative equity framework. We find that a continuation of past trends leads to greater inequities, whereas alternative participatory future visions focused on the adoption of integrated transport and cycling indicate potential to decrease inequities. Overall the study highlights how the adoption of transportation solutions towards greater accessibility is not only an engineering problem, but a *human problem* related to institutional capacity, trust, coordination, community agency and political vision.

1. Introduction

The United Nations' Sustainable Development Goals (SDGs) call for planning that fosters a more equitable and socially inclusive urban future. Central to the United Nations' approach to human and sustainable development is Amartya Sen's Capabilities framework, which proposes that development should focus on expanding each person's capability to lead the life they choose by ensuring meaningful access to opportunities that improve their well-being (Sen, 1999). Empirical studies consistently show that barriers to accessibility can trap individuals in a cycle of poverty (Nijman & Wei, 2020). Consequently realising more socially inclusive and just development requires addressing the factors that will improve access to socio-economic opportunities such as employment (Zhu & Shi, 2022), healthcare (Pereira et al., 2016), and education (Troost et al., 2023).

Transportation and urban development takes place within a complex institutional context and thus can be considered a wicked problem as it is not only technical in nature, but also political (Machiels et al., 2023; Rittel & Webber, 1973). Multiple forces, ranging from private investment, policy decisions to climate change drive development in ways that are often difficult to predict leading to

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https://doi.org/10.1016/j.futures.2025.103698
Received 21 February 2025; Received in revised form 6 June 2025; Accepted 17 September 2025
Available online 23 September 2025

high degrees of uncertainty. This complexity poses a challenge when planning for a more just future, as traditional predictive data and modelling techniques struggle to account for uncertainty.

In this paper we employ scenario planning as a planning support tool, as it explicitly embraces un- certainties, with the intent of preparing organisations to adapt to multiple outcomes. Scenario planning has a long history of being applied across different sectors such as the military (Ringland, 1998), energy (Blondeel et al., 2024) and water management (Dong et al., 2013). It has become a common approach within transportation research to understand the varying impacts of transportation planning under different future conditions (Lyons et al., 2021). By focusing on the uncertainties which shape the future and how they could change, scenarios generate a representation of a system and are not an exact science (Paddeu & Lyons, 2024).

Although equity of access has been a concern for a long time in transportation accessibility research (Pereira et al., 2016), within transportation scenario planning it is an underdeveloped area (Pan et al., 2024). If equity is not considered within scenarios, it pre-supposes that the benefits and burdens associated with different future states are evenly distributed across a population and/or region. Empirical work from transportation accessibility literature has shown this not to be the case (Lucas, 2012; Lucas et al., 2016). Building on existing literature, we connect equity of accessibility and transport scenario planning research to explore how equity can be incorporated into scenario planning as a planning sup- port tool, utilising the City of Cape Town (CoCT), in South Africa as a case study. The CoCT is South Africa's second largest city characterised by vast spatial inequalities, with the wealthy residing around existing economic nodes and low-income settlements situated on the urban periphery (Cooke et al., 2019).

In this research, we present four transport scenarios for the CoCT in the form of coherent narratives based on participatory engagement through an interactive workshop and semi-structured interviews. To explore the equity impacts of each scenario, they are transformed into representative urban network models. Using the models, accessibility to places of employment is calculated for each neighbourhood and evaluated using the Mapping Accessibility for Ethically Informed Planning (MAP) comparative equity framework developed by Nelson et al. (2025). This framework operationalises three well established notions of equity drawn from moral and political philosophy. Ethical principles have historically been employed by philosophers to guide thinking about reshaping society towards more just outcomes. Rather than imposing a single ethical framework that may not account for local needs or preferences, we employ a comparative framework to highlight different issues, such as unequal access, lack of access by the socio-economically disadvantaged, or even by the majority of the population. In doing so, we showcase how different ethical frameworks can be operationalised to allow communities to identify their specific priorities and move in a direction that best aligns with their values. Our approach is situated within the broader notion of the *Right to the City*, as articulated by Harvey (2003), Lefebvre (1968), and others. This concept emphasises the collective power of communities to shape future urbanisation processes. Ultimately, communities and stakeholders must decide how they define justice, while our role is to provide tools that help them explore diverse pathways towards achieving the SDGs.

The remainder of this paper is structured as follows: through a literature review we connect transport scenario planning to equity of accessibility research, followed by a description of the Methodology, comprising of four stages. Subsequently the Results are presented, followed by a discussion of their implications both for research and the CoCT. We conclude by reflecting on areas for future research.

2. Linking scenario planning and equity accessibility research

2.1. Background to scenario planning

Contemporary scenario planning emerged as a strategic foresight tool developed by the think tank, the RAND Corporation, in the 1950's, to support the United States Military in investigating policy alternatives (Ringland, 1998). The technique focused on developing alternative "narratives" of the future, written from the perspectives of different people in the future, referred to as scenarios. In the 1970's, scenario planning gained popularity as a business strategy tool, when it was adopted by the company *Shell* to help senior management think about long-term, business challenges (Menzies & Middleton, 2020: 42). In the 1990's scenario planning began to emerge as a strategic urban planning tool to develop *desired* urban visions for the future (Avin & Goodspeed, 2020). More recently, the focus has shifted to create scenarios that stakeholders may not consider as desirable (Avin & Goodspeed, 2020). The purpose being to deepen an understanding of uncertainty within future development, such as changing levels of economic growth or the public's willingness to support policies towards carbon neutrality (Lyons et al., 2018).

2.2. Defining a scenario

Whilst many definitions for a scenario exist, it can broadly be understood as a representation of a potential future shaped by a specific set of driving forces, which does not align with any current or proposed policies (Shaheen et al., 2013). Contemporary scenario planning embraces uncertainty by accepting that the future is not a static and/or predictable outcome, but is shaped by a set of driving forces which could interact in complex ways. In some cases, a scenario is defined as a result of both driving forces and existing policies. However, in this paper, a scenario specifically refers to a "possible world" that does not take into account any current or proposed policies. Within urban and transportation studies, scenarios are either represented through qualitative descriptions that describe a certain state or, they are embedded in quantitative models (Pan et al., 2024: 87). In this study, we represent scenarios through both descriptive narratives and quantitative models.

2.3. Different types of scenarios

Avin (2016) distinguishes between three modes of scenario planning: predictive, normative and exploratory scenarios. A predictive scenario, sometimes called an expected, baseline or trend-line scenario, tends to reflect a singular situation, that is deduced by analysing past trends to determine what the most likely scenario will be. Whereas a normative scenario typically reflects a single *desired* state for the future. Normative approaches to scenario-based planning tend to assume a larger degree of control to realise the desired plan and often do not fully address uncertainties about how the future will unfold (Wiechmann, 2008). Whilst not formally referred to as a scenario, urban planners will typically design one singular urban or regional plan, based on a desired future by authorities and/or stakeholders. In contrast to the other categories, exploratory scenarios will embody a range of alternatives that weight the effect of various driving forces differently to explore avenues of development. Usually exploratory scenarios are developed through creative thinking and debate. Scenario development is ideally a participatory process that helps explore uncertainty about the future (Lyons et al., 2021). In developing scenarios, those participating will draw upon the mental models they have about the world based on their knowledge, experience and values (Paddeu & Lyons, 2024). Cognitive overload in scenario planning is a significant challenge and thus the recommended number of scenarios is between three to five scenarios (Amer et al., 2013; Lyons et al., 2021).

2.4. Equity of accessibility in scenario development

There is an extensive body of literature on accessibility research, developed over the last 60 years within transportation and urban planning-related fields (Batty, 2009). In planning, accessibility refers to the potential opportunities, both social and economic, that individuals or groups are able to reach within a specific time threshold, relating to transportation infrastructure, land use distribution and individual characteristics such as income and gender (Geurs & Van Wee, 2004). Researchers measure accessibility in many different ways, from cumulative measures that simply count the number of opportunities that are reachable to more complex measures which, for example, weight destinations by distance (gravity measures) and/or take into account aspects of competition (Floating Catchment Area Methods) (Demitiry et al., 2022).

Despite significant advancements in research, there is still a wide gap in the implementation of accessibil- ity measures in planning (Silva et al., 2017). Transport planning in practice tends to be forecast-led by expectations of future demand. Lyons et al. (2018) refer to this as the "predict and provide" approach, which focuses on optimising for a singular future, based on demand estimates. This approach overlooks both latent demand and conceals uncertainty about the future. Latent demand refers to the potential demand for travel that is not currently being realised due to various constraints (i.e. congestion, lack of infrastructure, pricing, or inconvenience) representing the unmet need for mobility that would materialise if conditions were improved (Clifton & Moura, 2017).

From a distributive justice perspective, equity of accessibility is concerned with the fairness of distribution of benefits and burdens across a city's population through access to urban resources (Pereira et al., 2016). From a procedural justice perspective, equity of access is concerned with the fairness of the processes which shape the way access to resources are distributed across a city (Harvey, 2003). Moving towards a more just future requires thinking about equity of access from both distributive and procedural perspectives. Strategic scenario planning is a useful methodology for identifying the factors which shape accessibility in a city to explore alternative future scenarios. However Pan et al. (2024) conduct a systematic literature review of equity in transport scenario planning finding that very few studies include quantitative evaluations of equity and involve community representatives. As a consequence many strategic scenarios are developed on the assumption that the benefits and burdens will be evenly distributed across regions and populations. This leads to the main concern of this paper, which focuses on how we can incorporate equity and justice considerations into scenario planning.

To address this concern, requires answering the question, *how do we define justice*? Historically, philosophers have developed ethical theories to guide thinking about what justice means. Each ethical theory offers unique insights into how resources and opportunities can be distributed (refer to Table 1 in the Supplementary Material (SM)). Sen (2006) makes the distinction between transcendental and comparative approaches of justice. Transcendental theories of justice argue for a perfect ideal from which only then justice is achieved. In contrast, a comparative approach concentrates on ranking alternative societal arrangements by whether some arrangement is less or more just. For example, if a policy is introduced which improves society in some way, a comparative approach would argue that society has moved towards a more just condition, whereas from a transcendental approach, society would still be considered unjust. Whilst transcendental approaches are needed as they have long provided motivation for action towards social change, Sen (2006) asks us to consider the practical implications of them. Realistically no policy is going to create a perfectly just condition in a world where there is so much inequity, across human, environmental and planetary lines (Sen, 2006). A comparative approach allows us to rank different states by how *more* or *less* just they are. Harvey (2003: 939) enriches this argument, by advocating for citizens' right to the city, he states, "the right to the city is not merely a right of access to what already exists but a right to change it to our heart's desire". Central to this notion is that justice needs to be contextualised and citizens have a right to decide how they would like their cities to be shaped. This emphasises the importance of stakeholder and citizen engagement within scenario planning. Based on this discussion, there are two primary insights which inform this paper. Firstly, a comparative approach allows for a ranking of different states, which is more applicable to the reality of the world we live in. Secondly, people have a right to define how they would like their cities to develop and thus as an implication, should have a voice in how *justice* is defined.

This differs from typical approaches adopted in equity of access analysis. Although there are notable exceptions, many studies take a normative stance without referring to a particular ethical framework (Lewis et al., 2021: 2) or rely on indicators grounded in a single theory of justice, which may not account for wider socio-economic neighbourhood dynamics. For example, Bert Van Wee and Mouter (2021) conduct a systematic literature review, finding that the use of the Gini Index for equity of accessibility is by far the most applied

indicator, underpinned by egalitarian principles.

In contrast, we adopt a comparative approach to prevent any single theory from dominating the conversation, enabling a broader range of issues to emerge. By examining justice through multiple lenses, communities can deliberate on the trade-offs between maximising overall societal benefit, addressing the needs of the least advantaged, and ensuring equal opportunities for all. This flexibility is essential for navigating the complexities of accessibility and fostering more inclusive, equitable solutions that reflect the diverse needs of communities - placing them at the heart of urban development. To support this approach, we use the MAP comparative framework, which draws on Rawlsian, Equality-based, and Utilitarian theories (Nelson et al., 2025). MAP operationalises justice metrics in a way that allows for side-by-side comparison of how well different scenarios close the gap between current and ideal levels of access at the neighbourhood scale. These three theories are among the most widely applied in accessibility analysis, and MAP enables their comparative use without privileging one as inherently "most just." Instead, it highlights different dimensions of justice, empowering stakeholders to debate and determine which priorities matter most in their specific context.

2.5. Research question

There is a wide body of literature on scenario planning for strategic urban and transportation planning. Furthermore, agencies around the world are increasingly adopting it as an approach. Whilst accessibility indicators can be utilised to assess scenarios, there is still a wide implementation gap noted by Silva et al. (2017) and others. It is important to bridge that gap, with easy-to-understand measures and frameworks that can be translated to practice. Therefore, the primary research question of this work is: *How can we incorporate explicit comparative equity considerations into scenario planning to explore accessibility impacts of transportation alternatives?*.

3. Methods

This work aims to incorporate explicit comparative equity considerations into scenario planning to explore accessibility impacts of transportation alternatives in the CoCT. There are 4 stages, as depicted in Fig. 1:

- In the first stage, a stakeholder and institutional analysis of transportation governance is conducted. The intent is to identify the organisational actors involved in the operationalisation of transport and the policies used to govern them.
- The second stage focuses on stakeholder engagement to incorporate a diverse range of perspectives and views to inform the scenario creation.
- In the third stage, the transcripts are analysed through thematic analysis to identify themes which are organised into cohesive narratives representing scenarios. We validated both the drivers and scenarios through expert interviews.
- In the fourth stage, the accessibility conditions to places of employment in each scenario are evaluated using the MAP comparative equity framework.

3.1. Stage 1: stakeholder and institutional analysis

The purpose of institutional and stakeholder analysis is to provide insights into the broader visions and goals for development in the CoCT, identify relevant stakeholders, and gain insight into the operational- isation of transport. We adopt a multi-actor framework, which conceives the policy making as a social process enacted between stakeholders, rather than a purely rational endeavour to find the most optimal solution to a problem (Hermans & Thissen, 2009: 808). Through a revision of important policy documents (e.g. the Spatial Planning and Land use Management Act, 2013) the policy aims, characteristics of each public transport system (e.g., railway) and stakeholder entities (e.g., local government) are identified. Each entity is mapped as a block in Fig. 3 with the relations between them indicated through arrows and the main operating/policy levers.

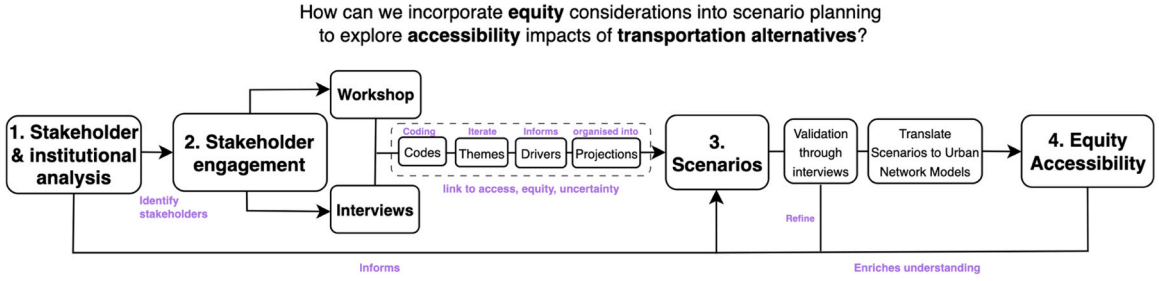

Fig. 1. This figure depicts the four stages of the methodology. A stakeholder and institutional analysis allows for the identification of stakeholders who are selected to participate in interviews and a workshop to inform the scenario creation. The transcripts are thematically analysed to identify key drivers of development and accessibility that are organised into cohesive narratives, which form the scenarios. The scenarios are transformed into representative urban network models. The accessibility conditions to places of employment in each scenario are evaluated through a comparative framework.

3.2. Stage 2: stakeholder engagement

Each of the main stakeholders is shown in Fig. 3. We contacted stakeholder representatives of each through email. In total, we had 7 respondents and conducted 7 semi-structured stakeholder representative interviews. In addition, we recruited a group of 30 citizens and professionals in the urban sector to conduct an interactive workshop. The purpose of the stakeholder engagement was to identify key drivers of development and accessibility to inform the scenarios.

Each interview was organised around particular themes to facilitate a deeper understanding of how each representative perceives the broader transport system, critical uncertainties, vision for future development and barriers related to their vision. Each interview was between 45 and 60 minutes and was digitally recorded. Section B.1.1 in the SM contains the list of questions used to guide the interviews.

The aim of the workshop was to facilitate a collaborative process to collectively consider barriers and drivers of accessibility within the CoCT. In collaboration with a local NGO, Young Urbanists South Africa, we recruited participants. In total, 30 participants signed up for the workshop with 55 %, who identified as women, and 45 %, who identified as men. The majority of participants were either working or studying in the sectors of Urbanism, Architecture, Research, Sustainability or Civil engineering. They were divided into five groups and given a series of questions to answer and discuss, as listed in the Section B.1.2 in the SM. After an hour, each group presented their ideas through posters, maps and diagrams for wider discussion. The workshop was documented through recordings,

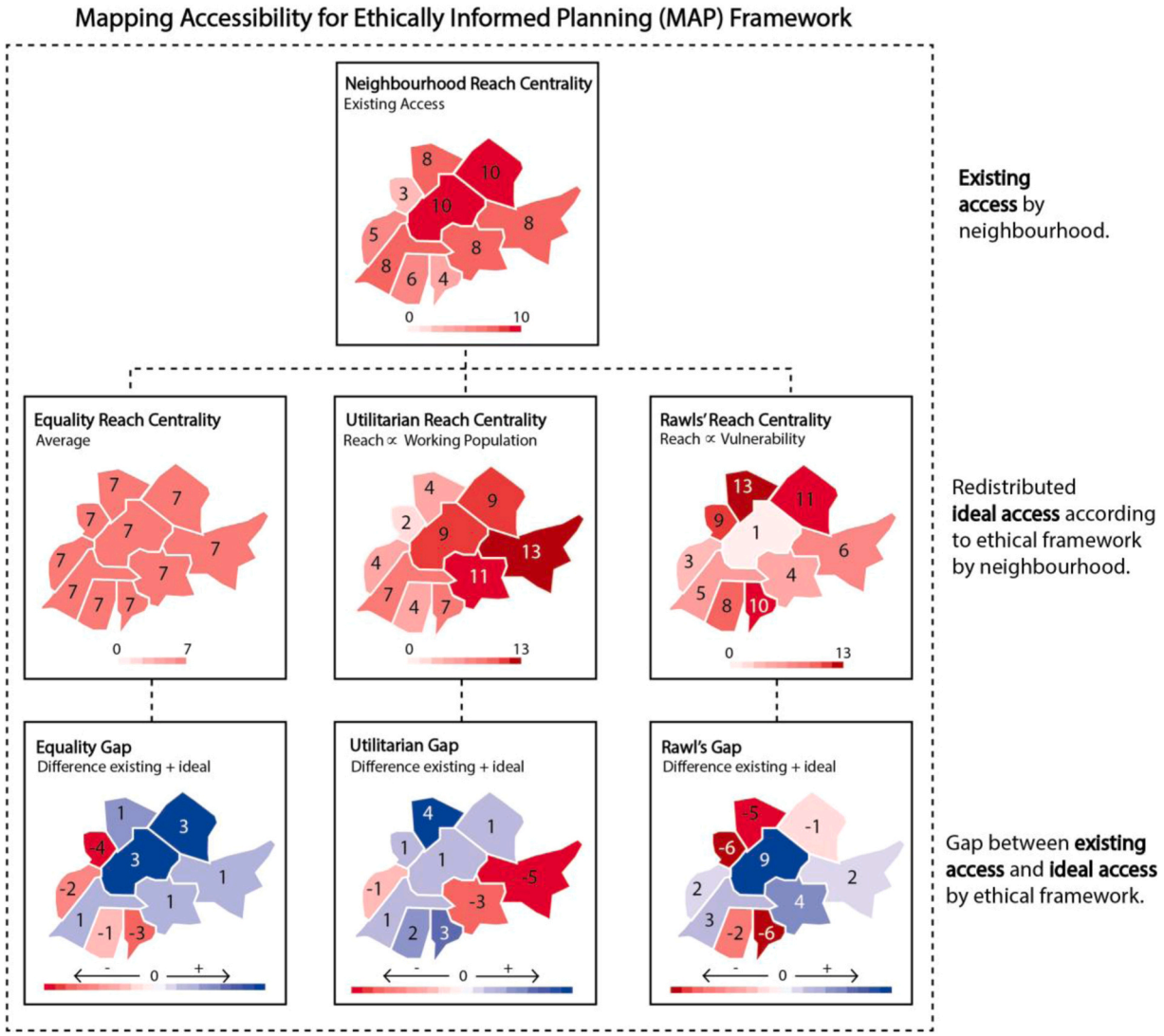

Fig. 2. This figure illustrates the MAP framework. The first row illustrates a map of existing cumulative access for an urban area by neighbourhood. The second row illustrates the ideal access level for each neighbourhood in the urban area by ethical framework. The third row illustrates the difference between ideal and existing access, when a neighbourhood's gap is below 0 it does not meet the requirement for justice from that particular perspective.

photographs, videos, and expert note taking.

3.3. Stage 3: scenario development

The interview and workshop transcriptions were analysed using thematic analysis to identify the core themes related to accessibility and drivers of future development. Thematic analysis is a method used to analyse qualitative data, involving the identification of patterns in a data set, which are then interpreted for their inherent meaning (Braun & Clarke, 2006). The first step involves highlighting a segment of text - a few words, or longer excerpt - which is given a label. Each label communicates a summary of what is present in the highlighted text, such as "institutional capacity". This is referred to as the coding process; it is conducted iteratively until a coherent set of codes is applied across all transcripts. The codes are organised into meaningful themes, to identify patterns and relationships, refer to Table 2 in the SM for examples. The themes go beyond merely being recurring elements as they embody meanings that link the ideas discussed to equity, accessibility and future development. These themes are based on our own underlying theoretical knowledge and main research question.

The thematic analysis informed an enriched definition of accessibility and identification of 10 main drivers of change in Cape Town - refer to Figs. 6 and 7 for corresponding summaries respectively. Each driver is weighted to project various states that it could exist within, reflecting uncertainty in the way it could develop over time, refer to Table 3 in the SM for a summary of each driver and state. For example, one of the drivers is, "community agency", which could be high, low or somewhere in between. The 10 main drivers, as shown in Fig. 7, were clustered together and organised to develop coherent scenario storylines. Each scenario is given a specific name which defines the overarching characteristics of that scenario (refer to Fig. 8 for a visual representation of each scenario). In creating each scenario, we ensure that the combination of drivers which inform them can reasonably coexist. For example, it is not reasonable to believe that different transport modes will be integrated if institutional relations are low, as integrated planning requires strong institutional mobilisation. This ensures that the final scenarios are consistent. As cognitive overload is a challenge, the advised number of scenarios is between 3 and 5 (Amer et al., 2013). We thus develop 4 scenarios. The scenarios were presented to three policy and transportation experts, who work in the CoCT, where they were asked to validate the drivers and scenarios for relevancy, consistency and coherence.

3.4. Stage 4: measuring equity of access through MAP

This section outlines the implementation of the Mapping Accessibility for Ethically Informed Urban Planning (MAP) framework, developed from the work of Nelson et al. (2025). The framework consists of three main components, illustrated in Fig. 2. First, MAP enables the calculation of network accessibility by assessing the actual cumulative access of each neighbourhood, within each scenario, to places of interest, in this case places of employment. This is termed *Neighbourhood Reach Centrality* (NRC). Second, MAP supports the computation of ideal accessibility scores using three frameworks:

- Equality Reach Centrality (ERC), based on principles of equality;
- Utilitarian Reach Centrality (URC), aligned with utilitarian goals;
- Rawls' Reach Centrality (RRC), grounded in Rawls' egalitarianism

Finally, MAP allows for spatial comparison between actual and ideal access of each scenario by mapping the gap between them. In all three frameworks, a gap value of zero or greater indicates that a neigh- bourhood meets or exceeds the respective justice criterion. While excessive access (positive gaps) may raise concerns of fairness, our analysis primarily focuses on under-access, highlighting areas for potential intervention by urban planners and policymakers.

Access to employment opportunities has long been a central theme in accessibility research (Levinson, 1998), with the jobs-housing balance frequently shaping local and regional planning efforts (Cervero, 1996). Recent trends indicate rising commute times as workers relocate further from job centres in search of affordable housing (Blumenberg & King, 2021). Increasingly, access to employment is recognised as critical to improving livelihoods (Lucas, 2012), reinforcing its importance as the focal point of this study.

The implementation of MAP involves a series of steps, which are summarised below.

3.4.1. Creation of urban network models

The first stage in applying the MAP Framework requires the creation of urban network models for each scenario. An Urban Network Model (UNM) is a representative model of the transportation and land use system within each scenario. We create one or more UNM for each scenario, where specific parameters such as walking and transfer time between modes are adjusted. For an explanation of each parameter, refer to "Parameters of the Urban Network Models" in Section B.3.1 of the SM. Each UNM is constructed by connecting land use with the street and transportation networks (Bus Rapid Transit, Minibus taxi, Railway and Bus). Refer to Section B.3.1 for a technical description of a UNM and each data source in Table 4 of the SM.

3.4.2. Measuring accessibility

Network centrality measures are commonly employed to evaluate the importance of nodes in a graph, based on their spatial or topological position within the network (e.g., Sevtsuk & Mekonnen 2012). Building on this concept, to measure accessibility, we apply a cumulative metric called *Neighbourhood Reach Centrality* (NRC). This calculates the number of places of employment that can be reached from each neighbourhood using Dijkstra's shortest path algorithm. Following this formalisation neighbourhoods are

composed of agglomerations of vertices which fall within the official administrative boundary of each neighbourhood. We apply different time thresholds in our analysis: 15, 30, 45 and 60 min, meaning the total travel time for each trip cannot be more than the specified time. For a detailed description of NRC and associated equations, refer to the Methods section of Nelson et al. (2025).

It is important to acknowledge that measured accessibility serves as a proxy for actual perceived accessibility. Perceived accessibility is defined as the perceived potential to participate in spatially dispersed opportunities (Pot et al., 2021), in this case, places of employment. There is a mismatch between how accessibility is perceived and measured, as there is a range of barriers to accessibility which may not be fully represented through spatial models, as perceptions and individual capabilities differ from the measured built environment. Although we have captured some perceptions through changing variables in each of the models by scenario, such as walking time, we acknowledge that they are limited in capturing the diversity of perceptions which could and would exist across populations and neighbourhoods, serving only as a proxy.

3.4.3. Measuring equity

Once accessibility has been calculated for each neighbourhood within each scenario, we apply three metrics which operationalise three alternative ethical principles to redistribute access based on each principle. They are *Equality Reach Centrality* (ERC), *Rawls' Reach Centrality* (RRC) and *Utilitarian Reach Centrality* (URC). For a technical explanation of the associated equations and calculations under- lying these metrics, refer to the Methods section of Nelson et al. (2025).

ERC is rooted in the principle of egalitarianism and thus assumes that all neighbourhoods should ideally possess equal access to available opportunities. Following this formalisation, for each scenario, the *Neighbourhood Reach Centrality* (NRC) is redistributed so that each neighbourhood is given an ideal access level equivalent to the average. As an illustration, if the total NRC of all the neighbourhoods for a particular scenario is 100 and there are 2 neighbourhoods in the system (A and B), each neighbourhood would be given 50 (100 divided by 2) as the ideal access. To assess deviations from this ideal and actual calculated access, *Equality Reach Gap* (ERG) is applied to each scenario which quantifies the difference between the actual reach centrality (NRC) and its corresponding egalitarian benchmark (ERC).

URC, inspired by utilitarian philosophy, which emphasises maximising benefit for the largest number of people (Bentham, 1907) assumes that a neighbourhood's access should be proportional to the ratio of working population that reside in that neighbourhood. Following this formalisation, for each scenario, the NRC is redistributed so that each neighbourhood is given an ideal access proportional to its working population (between 18 and 65). As an illustration, if the total NRC of all the neighbourhoods for a particular scenario is 100 and there are 2 neighbourhoods in the system (A and B) and Neighbourhood A has a working population of 150 and B of 50, Neighbourhood A would be given 75 and Neighbourhood B 25 as the ideal access. To assess deviations from this ideal and actual calculated access, *Utilitarian Reach Gap* (URG) is applied to each scenario which quantifies the difference between the actual reach centrality (NRC) and its corresponding Utilitarian benchmark (URC).

RRC draws from Rawlsian justice theory, which prioritises the well-being of the most disadvantaged groups (Fainstein, 2016: 263). In operational terms, this perspective assumes that accessibility should be allocated in proportion to a neighbourhood's vulnerability level (Nelson et al., 2025). Following this formalisation, for each scenario, the NRC is redistributed to be proportional to a neighbourhood's calculated vulnerability score. To quantify vulnerability, we calculate a composite Vulnerability Score for each neighbourhood, based on the relative levels of the neighbourhood population's income, employment and education, derived from the South African National Census 2011 (Nelson et al., 2025). *Rawls' Reach Centrality* (RRC) is then obtained by adjusting each neighbourhood's reach (NRC) in proportion to its vulnerability score (Nelson et al., 2025). As an illustration, if the total NRC of all the neighbourhoods for a particular scenario is 100 and there are 2 neighbourhoods in the system (A and B), and Neighbourhood A has a vulnerability score of 0.6 and Neighbourhood B has 0.4, Neighbourhood A would be given 60 and Neighbourhood B 40 for ideal access. To assess deviations from this ideal and actual calculated access, *Rawls' Reach Gap* (RRG) is applied to each scenario to quantify the difference between the actual reach centrality (NRC) and its corresponding Rawlsian benchmark (RRC).

Overall the MAP framework allows for each of the ethical frameworks to be applied to each scenario and compared through maps. We normalise the results of each gap metric between −1 and 1, which allows for direct comparison between them. The normalisation process is as follows: $x^{(T)}$ represents the original reach value for neighbourhood a at a time threshold $T \in \{15, 30, 45, 60\}$. The $x^{\min}$ and $x^{\max}$ denote the minimum and maximum values across all selected columns and observations, defining the scaling factor as:

$$M = \max x^{\min}, |x^{\max}| \tag{1}$$

The normalised reach value $\tilde{x}^{(T)}$ is then calculated as:

$$\tilde{x}_a^{(T)} = \frac{x_a^{(T)}}{M} \tag{2}$$

This normalisation preserves the sign of the original values and ensures that zero remains unchanged, with all normalised values falling within the range $[-1, 1]$. The advantage of employing multiple ethical theories within one comparative framework, is it allows different issues to be highlighted at the neigh- bourhood scale. This could relate to deficiencies in access based on population size or vulnerability, with the overarching intention of stakeholders being able to engage and debate these issues further.

4. Results

The results are divided into five distinct, but interconnected sections. The first section presents the findings of our investigation into

the transport policy landscape in the CoCT. The second and third sections enrich this understanding by shedding light on characteristics of accessibility and drivers of transportation development based on the thematic analysis of the transcripts. Building on the first three sections, the fourth section presents a description of four scenarios. The final section evaluates each scenario revealing based on different notions of equity.

4.1. *Stakeholder and institutional analysis: misalignment between policy and operation of transport*

The development and maintenance of transportation systems is shaped through mechanisms of institu- tional governance and policy (Jacobs, 2022). Understanding these mechanisms shines light on historical, as well as current factors which contribute to inequities in accessibility. Our analysis shows that spatial and transportation planning in South Africa sits within a wide policy landscape, enacted by all three levels of government (National, Provincial and Municipal), as shown in Fig. 3. In reviewing key policy documents enacted across the three levels, clear visions of integrated transport and land use planning are espoused. According to the national Spatial Planning and Land Use Management Act (SPLUMA) *spatial justice* is one of the primary principles upon which all spatial planning in South Africa should be based, through "redressing past spatial imbalances through improved access to and use of land" (SPLUMA, 2013: 19). Whereas local policy documents, such as the Comprehensive Integrated Transport Plan (CITP, 2023) outline a detailed vision for a fully multi-modal, integrated transport system to provide "all people with efficient access to a range of opportunities in a sustainable and dignified manner" (CITP, 2023: 3).

Our analysis of the organisation of the transportation system reveals many structural and operational barriers. Each of the four

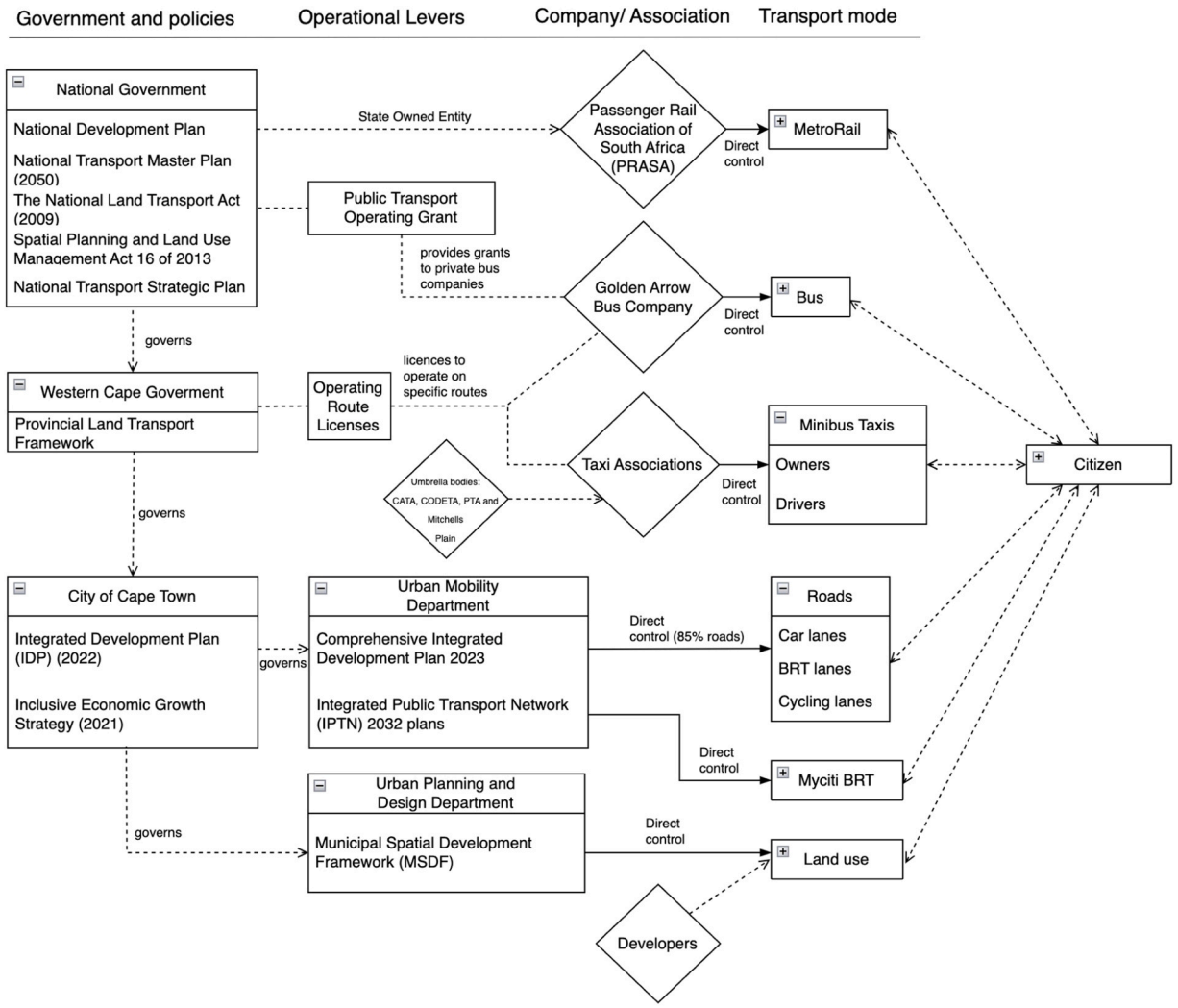

Fig. 3. This figure showcases a diagrammatic representation of the urban and transport planning landscape in the CoCT. It emphasises the fragmented nature of the transportation governance landscape, with each transport mode governed by a different level of government, private company or association/s.

main modes of public transport are operated by different stakeholders and subject to different levels of government influence (refer to Fig. 3). The train system is managed and owned by the Passenger Rail Association of South Africa (PRASA), a state owned entity with the National Department of Transport being the main shareholder and source of funding. Whereas, the majority of public bus services

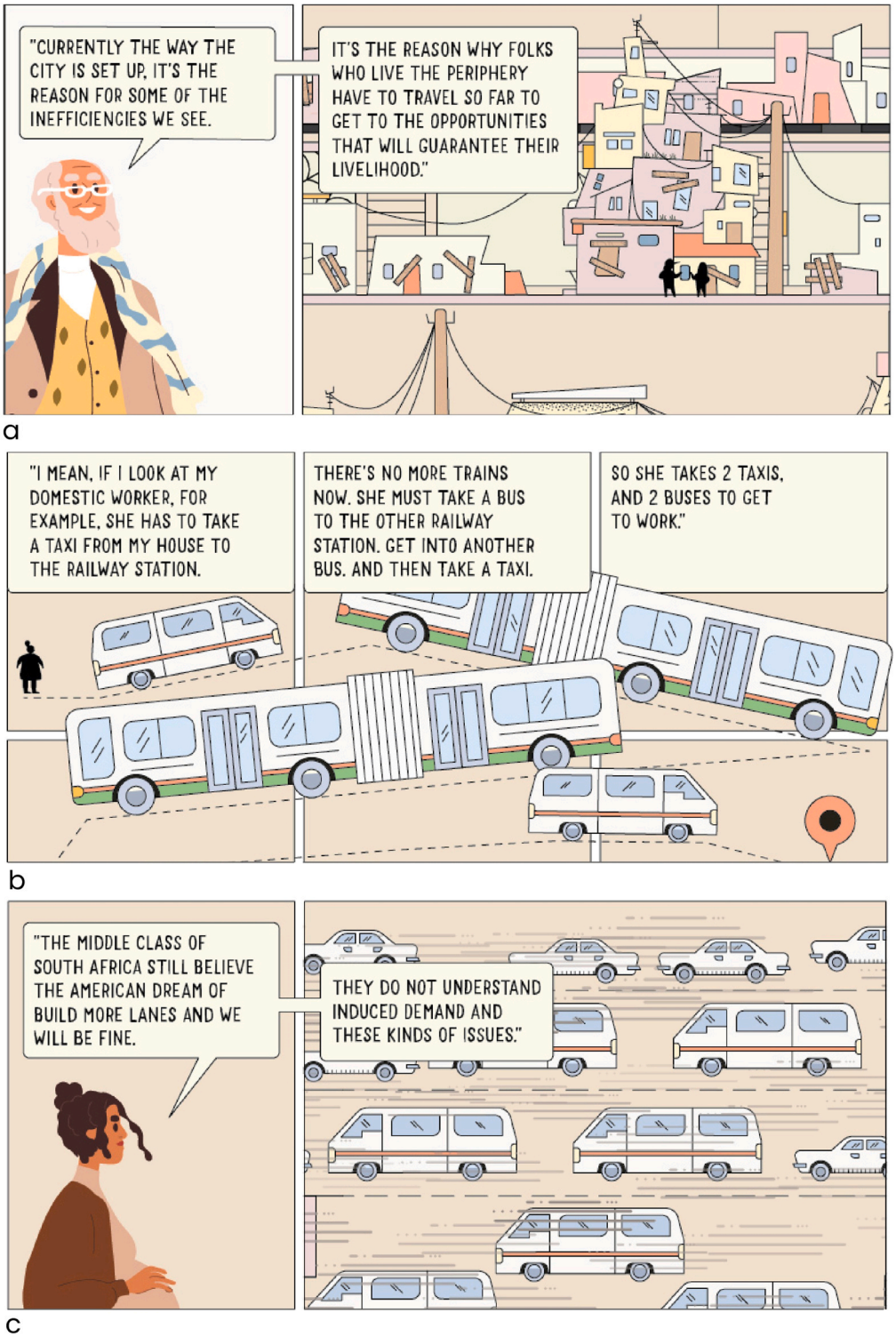

Fig. 4. This figure presents direct quotes from workshop participants illustrating different concerns, such as *safety*, *community agency* and *information*. Illustration by Agata Smok.

fall under the auspices of the private company, Golden Arrow Bus services (GABs). Their operations are fully independent, but they receive national subsidisation. The MyCiti Bus Rapid Transit (BRT) is directly operated and funded by the CoCT. Whereas the minibus taxi industry is composed of thousands of private operators, governed by regional taxi associations who receive operating route

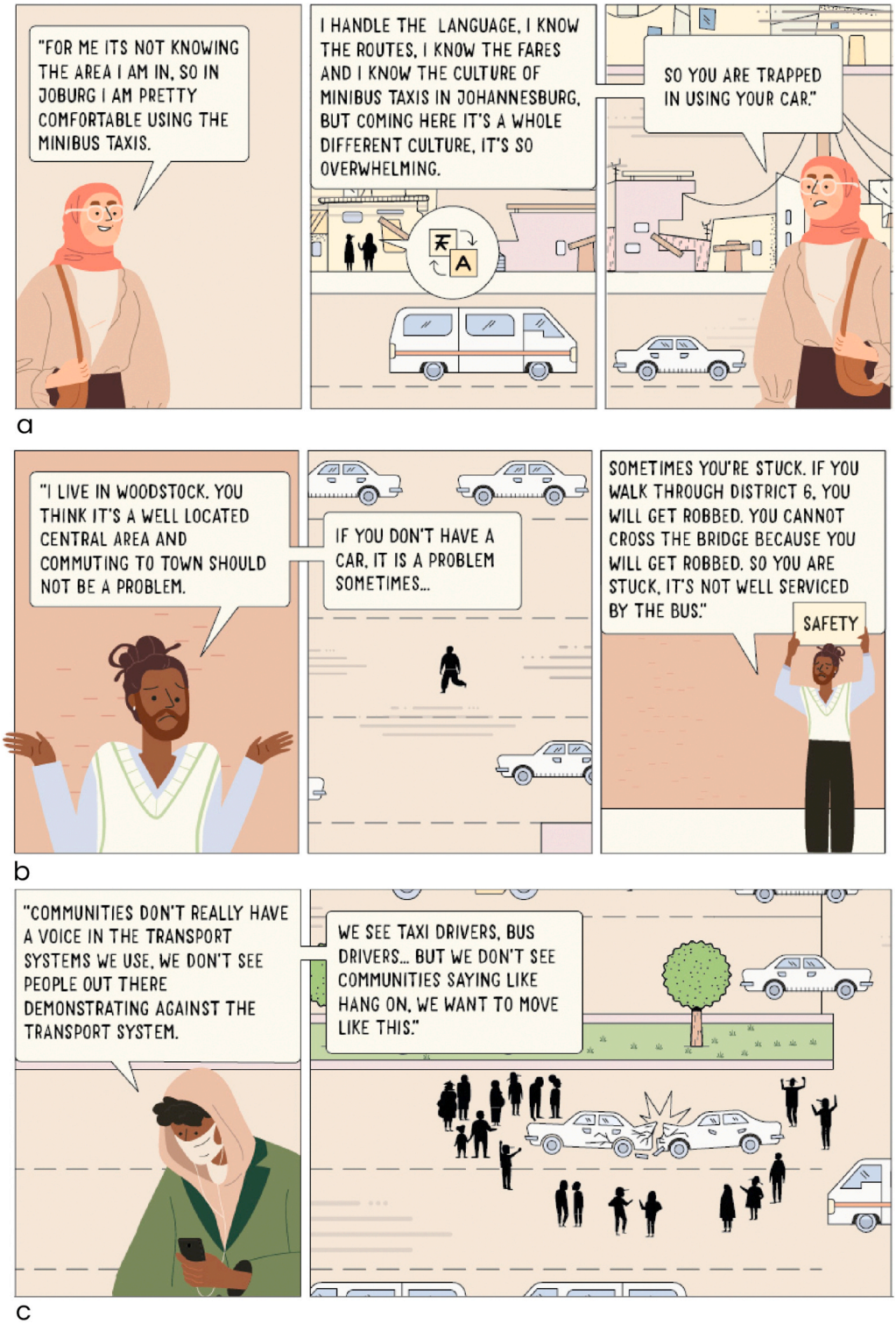

Fig. 5. This figure presents direct quotes from the stakeholder interviews illustrating different concerns, such as *spatial organisation* and *education*. Illustration by Agata Smok.

licences (ORL) from the provincial government granting them permission to operate on specific routes. Minibus taxis (taxis) initially developed informally as an illegal industry during Apartheid, when people of colour were not permitted to own businesses in urban areas. They arose to serve the real needs of the marginalised and under-serviced non-White urban population. Whilst they are legalised now, they are loosely regulated. As a result, the taxis are the only form of public transport that are not subsidised. As a counter balance, it is well known that they predominantly operate without paying tax and that the taxi associations charge fees to each operator for every ORL, which has led to a system of rivalry (Tosh-Mlambo, 2024: 17). Furthermore, there is not only competition between individual operators, but also between the taxi industry and alternative modes, when at its height has led to acts of violence (Duba, 2023).

Whilst both national and local policy advocates for an integrated and fully multi-modal transporta- tion system with the aim of providing accessibility to all citizens and redressing past spatial imbalances, there is high operational fragmentation. The decline in modal share of the railway signifies inefficient resource allocation and governance of this system (down 10 % from 2013 according to the CITP, 2023). The Central Line, which is the line that serves the most disadvantaged areas, has not been fully opera- tional since 2020. Whereas the rise of minibus taxi modal share reflects its resilience and capability in being able to respond to the needs of a rapidly growing population (up 10 % from 2013 according to the CITP, 2023). Refer to Table 6 in the SM for a summary of key characteristics of each transport mode. Our analysis highlights a clear disconnect between visions for integrated transport espoused in

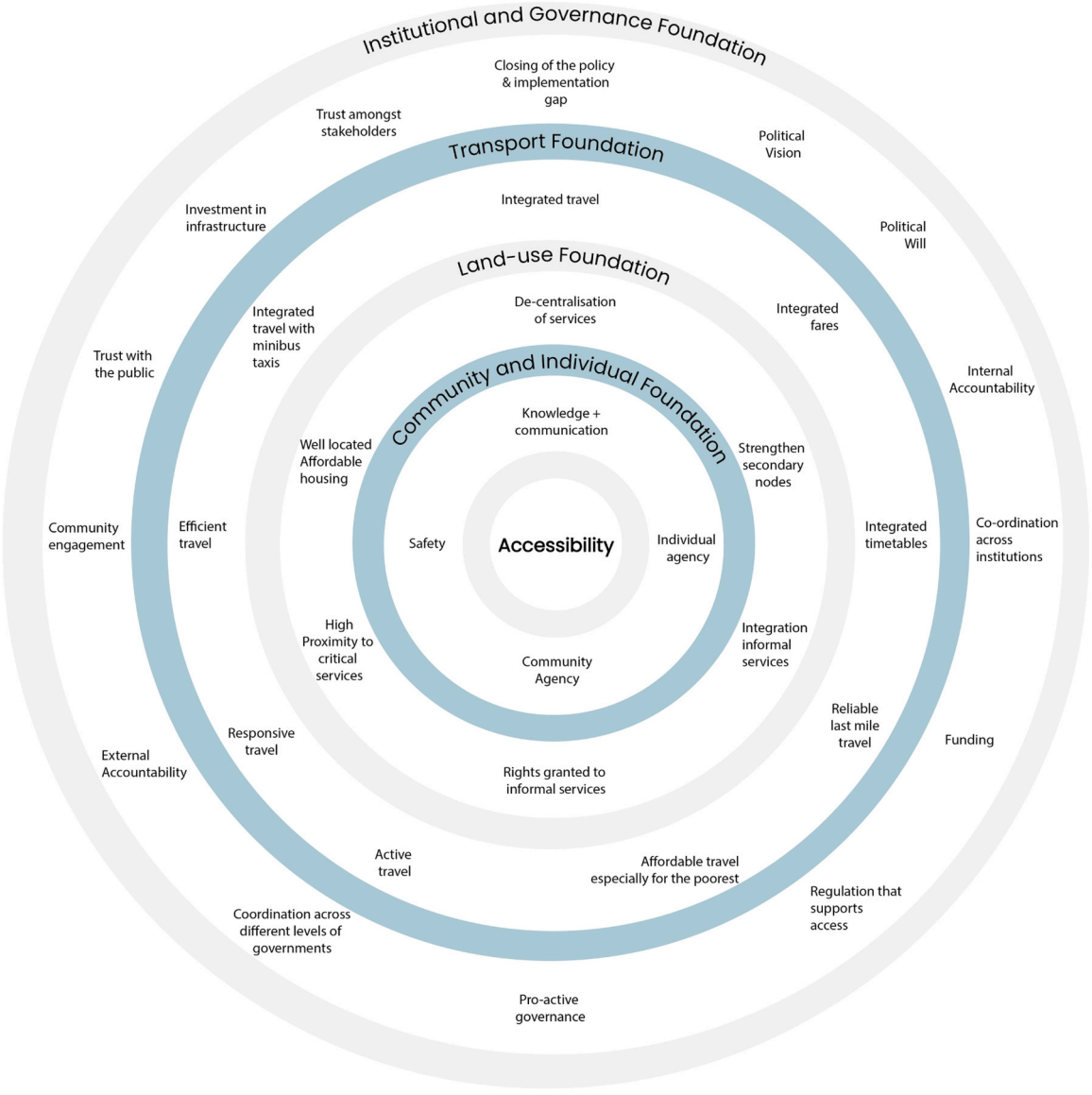

Fig. 6. This figure presents an enriched formalisation for accessibility within the CoCT. This formal- isation is underpinned by four foundational rings and also emphasises issues which are unique to a city in a global majority context, such as the integration of "informal" services.

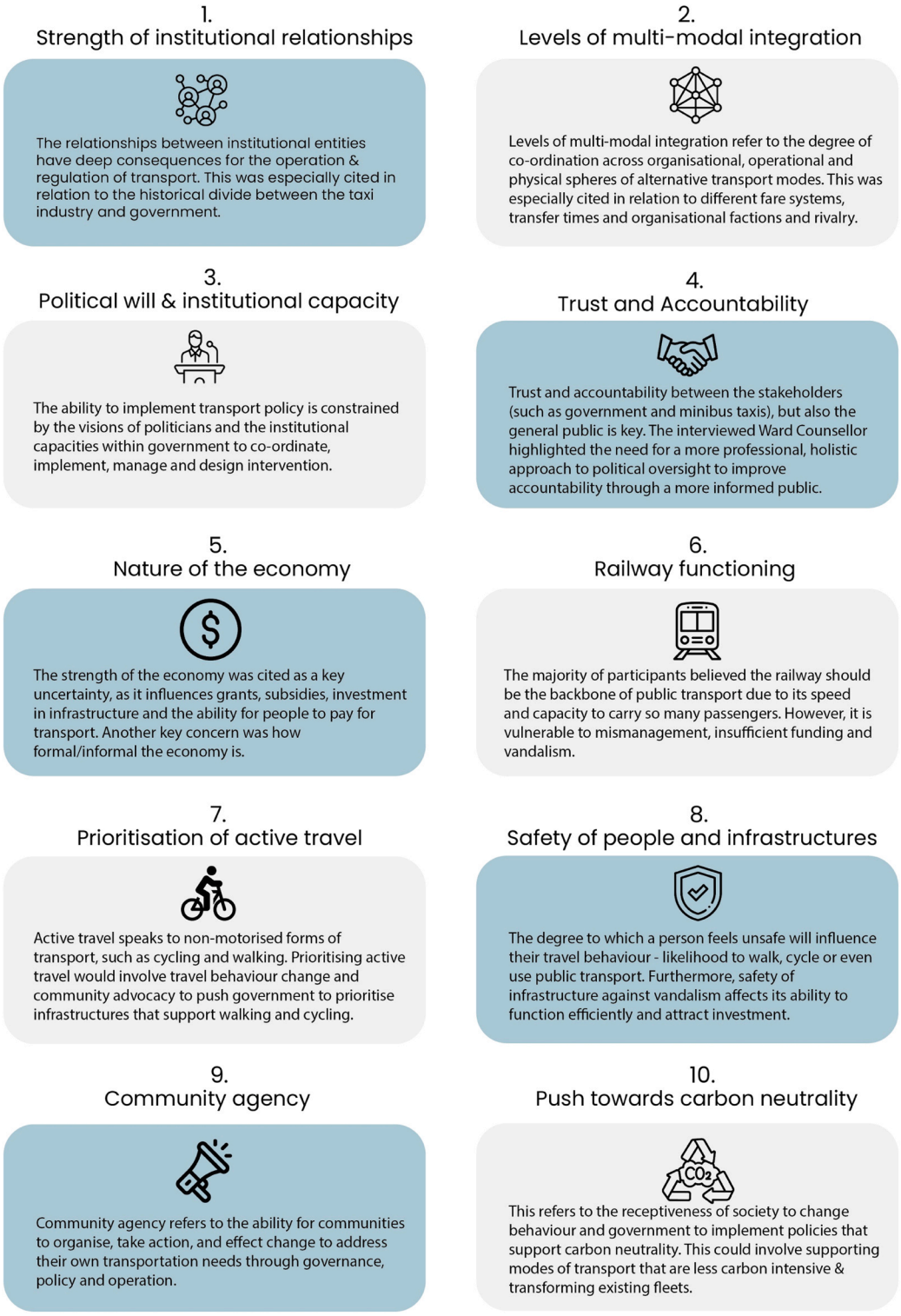

Fig. 7. This figure presents the 10 main driving forces of urban and transportation development identified through the thematic analysis of the stakeholder interview transcripts.

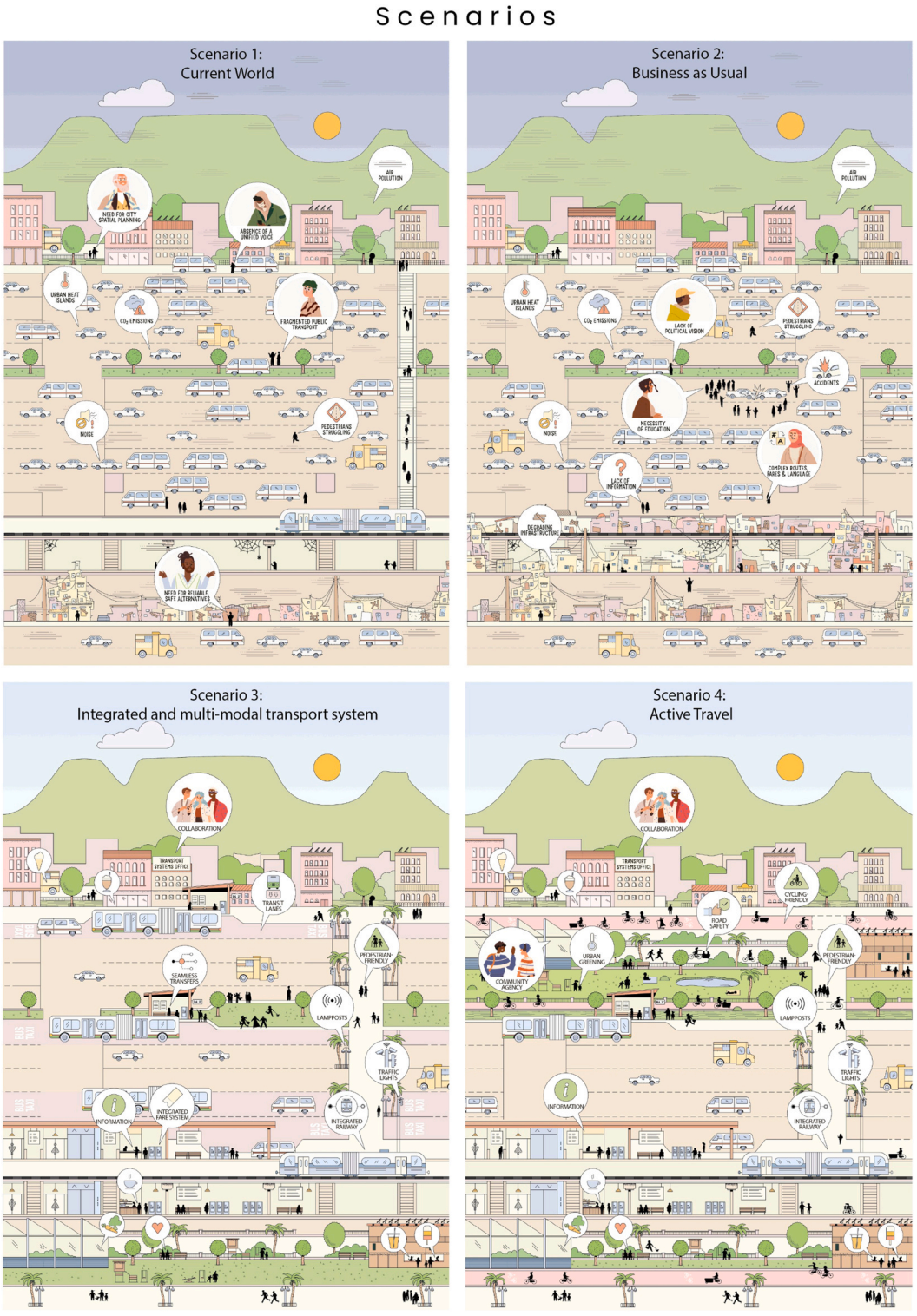

Fig. 8. This figure illustrates visual depictions of the four scenarios: the *Current world*, *Business as Usual*, *Integration* and *Active Travel*. Illustration by Agata Smok.

policy and the fragmented operational functioning of transport.

4.2. Contextualising accessibility in Cape Town

The insights drawn from the stakeholder and institutional analysis serve as a foundation for the stake- holder engagement. One of the main prerequisites to developing the scenarios involved establishing perceptions of accessibility within the context of Cape Town based on the stakeholder engagement.

In reviewing the transcripts, one of the defining contextual characteristics which emerged in relation to perceptions of accessibility is the high level of socio-economic and spatial inequalities which exist across communities and regions in the CoCT, as illustrated by the quote in Fig. 3a. This confirms that the vision of spatial justice, as envisioned in SPLUMA (2013), is far from being achieved. Certain operational factors, such as differences in levels of transportation services and economic opportunities, were highlighted. Private car ownership is associated with those of high socio-economic status and public transport, especially the taxis, reserved for the urban poor. For example, Fig. 3b describes the complex and long journey the domestic worker (cleaner) of one of the stakeholders has to take in order to get to work.

Important social characteristics were emphasised in the interviews, such as inequalities in knowledge dissemination on the transportation systems. Fig. 3c illustrates how perceptions of car ownership as being the predominant and preferred mode of transport shape the belief that accessibility issues can be directly addressed through expanding car lanes. Language barriers are another issue that emphasise people's perceptions of accessibility. For example, a taxi driver may speak one of South Africa's 12 official languages and a user, a different language (illustrated by the quote in Fig. 4a) which represents a barrier to making use of this system. There was general consensus that safety is a primary concern, especially when walking and cycling. A workshop participant told us that even though they live in a

neighbourhood which is considered to be quite central, it is not well serviced by the bus and they are unable to walk into the City due to safety concerns (refer to Fig. 4b). Community agency to effect change was also a central issue. Another participant highlighted how operators might strike, garnering media attention, but communities rarely have a platform to voice their concerns (refer to Fig. 4c).

Many of the participants' concerns were underscored by the high levels of social segregation in the city. A third participant, spoke about long commuting times, suggesting that "15 minute city ideas" (see, Moreno et al., 2021) need to be adopted to support better access to opportunity. Another recur- ring theme, which differs significantly from a typical city in the global North, is the disconnect between so-called, "formal" and "informal" services. A fourth participant, pointed out, that of all the forms of public transport, the taxis are the only system which operate without subsidy. They suggested that if perhaps the taxis were subsidised this could incentivise more respect for the rules of the road, improving safety levels.

To structure the multitude of factors which influence perceptions of accessibility, as discussed in the previous two paragraphs, we summarise them in the conceptual framework shown in Fig. 6. It shows that accessibility in the CoCT is underpinned by four foundational rings. The innermost ring being the *Social and community foundation* which refers to perceptions of safety, collective knowledge of the city and transport systems and a community's agency to influence the development of transportation systems. The second ring is the *Land-use foundation*, which focuses on the decentralisation and distribution of land use, the availability of affordable housing in proximity to services and the integration of informal services into the broader economy. The third ring is the *Transport foundation*, which consists of integrated travel (the degree to which transport modes are integrated, transportation networks, timetables, transfer times and fare systems, notably including the minibus taxis), efficient travel (how responsive, fast, viable it is to travel) and affordable travel (the monetary cost associated with travel, which is very high for the urban poor). The final ring is the *institutional and governance foundation* which refers to the level of institutional coordination between different entities, trust and ability to cohesively plan, develop and implement transport services. Concepts of accessibility have been developed over many years, the framework developed here builds on this long body of research. It adds to it by shedding light on the specific challenges related to accessibility facing a city in the global South by incorporating perceptions from stakeholder engagement in Cape Town.

4.3. Driving forces of urban development

The conceptual framework shown in Fig. 6 sheds light on the contextual factors that would be required to achieve access in the CoCT. In order to establish the scenarios, it is necessary to build on these insights to determine key drivers of urban development. Through the thematic analysis of the transcripts, we identified 10 key drivers which are visualised and explained in Fig. 7.

4.4. Scenarios

We organise the systemic understanding of accessibility developed through the analysis of institutional policy landscape, factors which influence accessibility and the driving forces to develop coherent scenarios. Each of the driving forces, in each scenario exist within a specific state (low to high) and come together in a specific way to form a coherent narrative (refer to Table 3 in the SM). This was based on the understandings of potential scenarios derived from the transcripts and subsequent thematic analysis. Each scenario was checked for consistency through interviews. For a visual depiction of each scenario, refer to Fig. 8.

4.4.1. Current scenario

The current transportation landscape is characterised by a lack of integration between different modes of transport, with parts of

the railway system being non-operational, as can be seen in the Current scenario depiction in Fig. 8. The institutional framework is fragmented, marked by a lack of political will and vision to implement effective policies. There is low trust between stakeholders, including local and na- tional governments, which have differing objectives. This is especially evident in the strained relationship between the government and the minibus taxi industry, which has historically been marginalised and operates under a complex, competitive system. Operating route licences are sold at high prices within the industry, benefitting a select few and creating internal conflict. Despite being a critical mode of transport for many, the taxi industry remains under-supported and the poorest in society spend the largest share of their income on public transport (roughly 40 % according to the CITP, 2023). Public transport is not particularly safe, both from the perceptions of users and security of infrastructure perspectives. Political leaders are hesitant to prioritise public transport, partly to avoid alienating influential groups like the middle class who may not be fully informed when it comes to issues such as induced demand, which refers to a phenomenon where car usage is induced through road infrastructure. There is a disconnect between political decision-making and community needs, with politicians focused more on maintaining power than addressing transportation issues. Local governments are forced to plan independently due to a lack of coordination from the national government, leading to inconsistent oversight and poor maintenance of services. While there is an integrated transport plan, it has not been effectively translated into actions that the public or politicians can rally behind, resulting in a reactive political landscape and under performance of the transport system.

4.4.2. Business as usual scenario

A "Business as Usual" scenario represents a continuation of the existing trends without significant intervention or reform. In this situation, the fragmentation between different modes of transport persists, with no integrated system in place, making it difficult for commuters to transition seamlessly between transport modes, as can be seen in the Business as usual depiction in Fig. 8. The decline of the railway system continues, with no efforts to restore or expand services, leaving many areas under-serviced and placing more pressure on other forms of transport, particularly the minibus taxi industry. Political will to address these issues diminishes further, with even less attention given to public transport reform. Trust between stakeholders, including government bodies and the taxi industry, remains low, with competing objectives and a lack of meaningful collaboration. Non-motorised transport, such as walking and cycling, continues to be neglected in urban planning and infrastructure development, further entrenching car de- pendency and exacerbating traffic congestion. Funding remains inadequate, with subsidies for public transport falling further behind inflation, leaving systems underfunded and unable to meet the growing demand. Without sufficient financial support, both the public transport network and the infrastructure needed to support it, such as roads, stations, and pedestrian walkways, deteriorate. The continuation of these trends results in a deepening crisis, where mobility options for the city's residents, particularly the most vulnerable, become increasingly limited, inefficient and unsafe.

4.4.3. Integrated scenario

An "Integration" scenario would require a socio-technical transformation of Cape Town's transporta- tion system from a fragmented to a fully multi-modal network that seamlessly connects all modes of travel, as can be seen in the Integration depiction in Fig. 8. This involves not only technical and operational changes but also a more collaborative approach across different levels of government and greater inclusion of community voices in decision-making. An integrated fare system using a single payment method and synchronised timetables make transfers between different modes more predictable, with reduced waiting times and smoother connections. The result is a more user-friendly and efficient experience for commuters. There is a high level of trust and coordination between transport operators, including the taxi industry, GABs, and the Metrorail which ensures that all modes work optimally together. Priority lanes and traffic signalling would be implemented for key transport services, like taxis and GABs, enabling them to bypass congestion and offer faster, more reliable travel times. Crucially, different levels of government, from local to national, would adopt an institutionally integrated approach, working together under a unified vision for urban mobility. This coordinated governance ensures consistency in policies, planning, and funding, resulting in a more coherent and well-maintained transportation network. Moreover, community agency is woven into decision-making processes, ensuring that transport solutions reflect the needs and priorities of local residents. By involving communities in planning and oversight, the system is more responsive to the real-world challenges people face daily. Overall, this integration enables a transportation system that is efficient, reliable, and accessible, encouraging more people to opt for public transport over private cars.

4.4.4. Active travel scenario

An "Active Travel" scenario would require a shift in focus towards promoting active modes of transportation, such as walking and cycling, as central components of the urban mobility system. The emphasis is on sustainable, low-carbon transportation that prioritises health, safety, and environmental responsibility, as can be seen in the Active Travel depiction in Fig. 8. The City invests heavily in the walkability and cyclability of its streets, redesigning urban spaces to make walking and cycling not only viable but highly attractive options. Streets are widened for pedestrians, dedicated cycling lanes are created, and infrastructure such as safe crossings, bike-sharing stations, and well-lit walkways is developed to support these modes. The emphasis on active travel aligns with Cape Town's push towards carbon neutrality, reducing reliance on motor vehicles and decreasing overall emissions. Safety is paramount with streets and public spaces being designed to ensure the safety of cyclists and pedestrians, with traffic calming measures, secure bike parking and policing. Community agency plays a significant role in this vision, local communities are actively involved in decision-making processes around the design and use of urban spaces. This approach ensures that transportation solutions are responsive to the specific needs of neighbourhoods, creating a sense of ownership and trust among residents. While active travel is at the forefront, rail is also given preference as the backbone of the public transport system. Investment in the rail network is prioritised, with improvements in

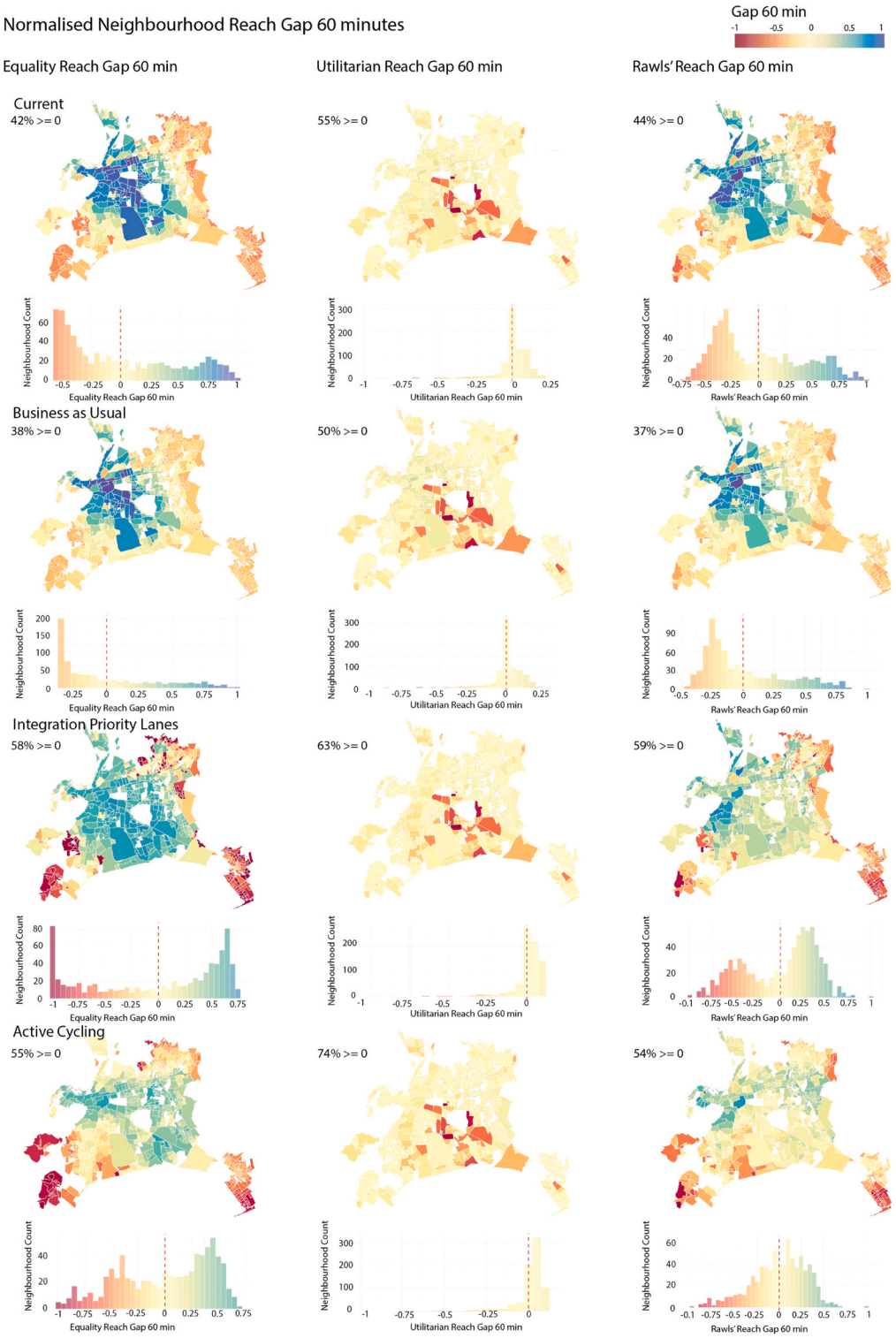

Fig. 9. This figure shows choropleth maps and histograms of the distribution of the gap metrics from each ethical perspective at 60 min for the Current, Business as Usual, Integration Priority Lanes and Active Cycling Scenarios. The distributions are normalised to be between −1 and 1. If a neighbourhood has a positive gap or gap equal to 0, it meets the requirement for justice from a particular ethical perspective, if it is below 0 it does not meet that requirement.

service frequency, reliability, and safety. Rail becomes a key part of the low-carbon transportation strategy, serving as a complementary option to walking and cycling for longer distances. There are high levels of trust and accountability among stakeholders. Government institutions, transport operators, and local communities work closely together, with transparent policies and clear lines of responsibility. The system is designed to be inclusive, safe, and efficient, creating a more resilient urban mobility network that supports environmental goals, enhances community well-being, and provides viable alternatives to car dependency.

4.5. Equity of accessibility

An Urban Network Model (UNM) is created for each scenario. This results in one UNM for the Current Scenario and one UNM for the Business as Usual Scenario. For each of the Active Travel and Integration Scenarios we created two UNMs. This first UNM of the Active Travel Scenario prioritses walking, re- ferred to as *Active Walking*. The second UNM prioritises cycling, referred to as *Active Cycling*. The first UNM of the Integration Scenario integrates all the travel modes with minimal transfer times, referred to as *Integration*. The second UNM of the Integration Scenario, represents a situation where all the modes are integrated, but gives the buses and taxis priority lanes thus reducing their overall trip time, referred to as *Integration Priority Lanes*. Each scenario represents a different combination of factors, such as operating railway infrastructure, transfer times between modes, average walking/cycling time allowed per trip. Each model allows us to compare potential outcomes, offering insights into how the conditions of each scenario might improve or hinder access to jobs. For a summary of the UNM parameters of each scenario, refer to Table 5 in the SM.

From an *Equality perspective* at 15 min the scenario which possesses the highest percentage of neighbourhoods which meet the requirement for justice is the *Active Cycling* scenario at 39 % followed by the *Current* scenario at 32 %. Whereas at 60 min the highest percentage of neighbourhoods which meet the requirement for justice is the *Integration Priority Lanes* scenario with 58 %, followed by the *Active Cycling* scenario at 55 % of neighbourhoods (refer to the first column of Fig. 9).

From a *Utilitarian perspective* at 15 min the 'scenario which possesses the highest percentage of neighbourhoods which meet the requirement for justice is the *Active Cycling* scenario at 69 % followed by *Integration Priority Lanes* at 63 %. At 60 min the *Active Cycling* scenario possesses the highest percentage of neighbourhoods which meet the requirement for justice at 74 %, followed by *Active Walking* at 69 % (refer to the second column of Figure in 9).

From a *Rawlsian perspective* at 15 min the possible world which possesses the highest percentage of neighbourhoods which meet the requirement for justice is the *Active Cycling* scenario at 43 % followed by the *Current* scenario at 31 %. At 60 min the *Integration Priority Lanes* scenario possesses the highest percentage of neighbourhoods which meet the requirements for justice at 59 % followed by *Active Cycling* at 54 %, refer to the third column of Fig. 9.

The implications of these results will be explored further within the Discussion.

5. Discussion

5.1. Accessibility based planning

Transportation and urban planning is a complex subsystem of society which has traditionally been based on a "predict and provide planning approach" (Lyons et al., 2018; Cooke et al., 2019). In practice, trans- portation planning has relied on optimisation engineering techniques to find the optimal solution for predicted future demand. Critically this approach ignores uncertainties and effects of latent demand, which represent the travel needs or desires that people have but are unable to fulfil due to constraints such as traffic congestion, lack of public transportation, or poor connectivity.

In contrast, accessibility-based planning emphasises people's ability to reach essential destinations, such as employment opportunities, which is the focus of this study. While this approach has gained traction in academic research and in assessing the impacts of existing transport infrastructure (Silva et al., 2017), it has been less commonly applied in forward-looking planning processes. This work bridges scenario-based planning with accessibility-focused transport research. Shifting planning practice toward accessibility involves a wide range of changes across multiple levels - technological, institutional, and cultural. While much attention is often given to the effect of new technologies and infrastructure in changing planning practice (Geels, 2018; Cooke et al., 2019), this study highlights that many drivers of accessibility are embedded in institutional capacities, urban governance, quality of relationships, funding, political vi- sion and will. Furthermore, particularly in this setting, the strength of relations between the so-called "formal" and "informal" sectors of the economy is an important factor. A move towards accessibility would require a revision of the current regulations, policy instruments and relationships which mediate the interaction between these sectors, particularly in relation to the minibus taxis.

5.2. Equity of access scenario insights

According to the equity evaluations, the *Business as Usual* scenario suggests that if existing trends continue, inequities will widen. Market-based strategies for urban development prioritise profit-making over social good and thus the development path with the least risk, leading to the reinforcement of old patterns of urban development. Moving away from current trends of development, would require coordinated and proactive governance to drive change. According to the analysis, from both Equality and Rawlsian perspectives, the ideal scenarios would include a combination of the *Active Cycling* and the *Integration Priority Lanes* scenarios. From a Utilitarian perspective, implementing only the *Active Cycling* scenario would be sufficient as it reveals the best results across all time thresholds. An important finding is that even if the transfer times were reduced to a minimum between all modes, the *Active Cycling*

would still lead to more equitable outcomes from all ethical perspectives. The primary factor, thus, which placed the *Integration Priority Lanes* scenario as the most equitable outcome, from certain scales and perspectives, was the reduction in taxi and bus travel times. This suggests that providing priority lanes and signalling to reduce travel times on these modes could have a real impact. The quantitative evaluation is a useful tool to visualise and explore the varying impacts of accessibility for equity, but if applied in practice would need to be debated amongst the stakeholders. From all the perspectives, but particularly from a Utilitarian perspective, land use deficiencies are emphasised. This is most salient in historically disadvantaged neighbourhoods in the South-east regions of Cape Town, refer to the second column in Fig. 9. This highlights an important point: transport is not the only solution, but land use and affordable housing close to places of employment also have a role to play.

5.3. Equity of future development

Equity of access is based on the idea that justice should be concerned with equality of opportunity. In our work, equality of opportunity translates to seeking justice through providing a job opportunity mediated by the provision of a transport system. The institutional analysis revealed that there is a disconnect between policy and operation. Every stakeholder has a different viewpoint, and thus it is imperative to involve less historically represented actors, such as those who attended the in-person workshop. As shown by the different quantitative equity evaluations, there are physical improvements which can be made. However, in order to achieve these, the underlying social and institutional issues, such as trust, institutional coordination, education and community knowledge need to be addressed.

The evidence suggests that a focus on cycling has significant potential to reduce inequities. In real- ity this would involve a number of changes. Firstly, in relation to infrastructure, cycling lanes and bike parking would need to be developed. Secondly, behavioural change in travel patterns, would need to be encouraged through advertising campaigns, education and regulation. For example, in Mexico City, car usage is regulated through only certain car number plates being allowed to drive on highways on certain days of the week and certain roads being completely closed for cycling only on a Sunday. Thirdly, open governance and relationship building across all sectors of transportation would be necessary. Cycling would be beneficial for all as it could be used for first and last mile commuting, making public transport ultimately more attractive. Finally, there would be opportunities for new businesses to emerge from bike sharing, to renting, parking and storage - the private sector has a role to play.

6. Conclusion

This study has drawn on both accessibility and transport scenario literature to incorporate explicit equity concerns within scenario planning for future development. Equity is a contested notion, and that is a primary motivation for involving diverse stakeholders and community organisations to support collective decision-making. The equity insights presented here are not meant to be deterministic, but can be used in a generative way to facilitate decision-making and coordination processes. The results also highlight the complexity of moving from a market-oriented, demand-driven mode of planning to co-creation and accessibility focused transportation planning. Future research could focus on qualitative assessments of the scenarios with perceptions of accessibility, in addition to the quantitative insights presented. Furthermore, we advocate for a research agenda that focuses on bridging the gap between research and practice, so that these insights are applied for wider societal benefit.

CRediT authorship contribution statement

Ruth Nelson: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **BinBin Pearce:** Writing – review & editing, Conceptualization. **Martijn Warnier:** Writing – review & editing, Supervision, Conceptualization. **Trivik Verma:** Writing – review & editing, Supervision, Conceptualization.

Declaration of Competing Interest

The author(s) have no relevant financial or non-financial interests to disclose.

Acknowledgements

This article would not have been possible without the support of many different organisations and people. Firstly we acknowledge and thank the TU Delft Global Initiative for the funding to conduct stakeholder engagement in Cape Town, South Africa. We thank Mark Zuidgeest at the University of Cape Town for sharing the GTFS transportation data used in this study. We thank Young Urbanists South Africa and, particularly Roland Postma, for supporting the workshop and stakeholder engagement in Cape Town. We thank Agata Smok for her role in designing the images used in this research. Finally, this study would not have been possible without the time given by the participants in the workshop and interviews – it is co-created with your visions and concerns at its heart.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2025.103698.

Data availability

Summaries of interviews (4TU.Research Data)

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