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# Integrated Real-Time Information System for Public Commuting: Perspectives of Stakeholders in South Africa

Aphiwe Hlophe[1], Ayodeji Afolayan[1], Olawande Daramola[2*]

[1] Department of Information Technology, Cape Peninsula University of Technology, Cape Town 8000, South Africa
[2] Department of Informatics, University of Pretoria, Pretoria 0083, South Africa

Corresponding Author Email: wande.daramola@up.ac.za



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**ABSTRACT**

Decision-making while commuting in big cities is still challenging for many citizens in developing countries. The implementation of diverse transportation modes operating in silos combined with the inaccessibility of real-time travel information prevents commuters from these countries from making informed travel decisions. Commuters often have to choose the specific means of transport that will yield the highest value in terms of cost, safety, convenience, and timeliness among alternatives. This paper uses a case study of Cape Town in South Africa to explore stakeholders' perspectives on implementing an integrated real-time information system (IRIS) and the requirements that must be satisfied. We employed a qualitative methodology, utilising semi-structured interviews and co-design sessions as the means of data collection. Four categories of stakeholders associated with transportation, including taxis, trains, Bus Rapid Transit (BRT), and municipal buses, within the context of South Africa, participated in the study. The findings reveal that the commuters and the public transport operators agreed that challenges around socio-traffic incidents, infrastructure development, lack of technology resources and lack of real-time travel information are major concerns that must be addressed for successful IRIS implementation. Functional features, change management, data privacy, system integration and information sharing were the main priorities on the list of requirements. The study represents a first attempt at understanding the requirements of an IRIS from the stakeholders' perspective in the context of South Africa. It extends the discussion on using IRIS to support transportation in developing countries, which has received limited attention thus far in the literature. The study is relevant for developing futuristic policies, advanced infrastructure, and optimised service delivery in developing countries because it provides a good foundation for understanding the critical requirements for the design and development of IRIS.

## 1. INTRODUCTION

Cities are becoming more compact due to rapid urbanisation and changes to land-use policies. Increased pressure is placed on public transport systems worldwide due to increased urbanisation and motorisation. Efficient and sustainable urban mobility is the goal of many urban cities in the world. Recently, many transportation systems in developed countries have attempted to transform into integrated systems [1]. The possibilities for urban transport in these developed countries (e.g. Europe, North America, Japan) include trains (tram, light rail, subway, underground, metro), buses, ferries, water taxis, and smart transportation systems. As a developing country, the need for an integrated transportation system to boost urban mobility in South Africa has been identified [2].

According to the study [3], South Africa is experiencing population growth, necessitating increased infrastructure development. The population surged by 7 million from 2001 to 2011, underscoring the need for solutions that accommodate growth without compromising service quality and efficiency. The transportation sector is one critical aspect which requires attention to keep up with the demand and rapid growth of the population within urbanised areas. This situation has caused widespread issues such as traffic congestion, traffic-related deaths and injuries, pollution, and higher energy usage [4]. The high cost of fuel and traffic-related problems have also made using purely private commuting transportation undesirable [5]. Public transport systems, especially those that enable citizens to gain access to real-time information on available travel options at any given time, will significantly benefit commuters using the public transport system. Such a system will enable commuters always to make the best value-based decisions. A commuter can determine the best transportation option available for travel per time depending on critical factors such as estimated arrival time at the destination, cost, safety, and convenience. An integrated real-time information system (IRIS) can improve public transportation by providing commuters with real-time travel information to support decision-making on routes and available travel options. Real-time traffic data can help improve the commuters' experience by providing them with information on the status of a vehicle, including occupancy, speeds, and estimated arrival time. Commuters can also be provided insights into inconvenient traffic congestion so that motor vehicles are redirected to alternative routes [6]. Currently, the existing channels for accessing real-time information are mobile applications, display screens and websites. These are usually inaccessible during peak times or provide static information for commuters. Also, the data is not integrated, which makes it difficult for commuters to have a complete view of the transport system.

An IRIS can improve customer satisfaction by conveniently harnessing information sourced from multiple systems' sources into a unified platform where travel information on all transportation alternatives can be conveniently obtained by commuters at any given time [7]. Although multimodal trip planners are becoming more important in modern transport systems, real-time navigators and studying how they affect travel behaviour still need improvement. In France, a project called Optimod'Lyon pioneered developing a real-time travel navigator on a smartphone that integrated all modes of transportation (car, public transportation, bike, bike-sharing, foot, car sharing, and carpooling). The SMART-Way smartphone application created in 2010-2011 through an EU-funded project was the first for public transportation, allowing users to access travel information on the move within Europe. Other cities worldwide, such as Zurich, Vienna, London, and Kuwait City, have created projects similar to the Smart-Way smartphone application [8]. However, these digital projects are still very few and are limited to developed countries. Such concepts have yet to be replicated in developing countries even though many developing countries have big cities that require IRIS. Some solutions operate in silos and do not allow integrated multimodal-based trip planning.

Public transport is the backbone of the South African economy, as it plays a crucial role in transporting the workforce and providing access to economic hubs in line with other countries. According to the study [9], a significant distinction exists between mobility and accessibility planning. Mobility planning focuses on enhancing transportation network performance, while accessibility planning maximises individuals' access to various opportunities, such as employment, services, education, entertainment, and goods. However, South Africa's transportation system is inefficient due to the lack of mobility and accessibility planning. This paper reports an investigation of the stakeholders' perspective for IRIS in the context of South Africa to lay a good foundation for the design and development of an IRIS if such were to be created in the immediate future. Thus, the research questions of the study are:

1. What challenges affect the provision of real-time information for public commuting decision-making in South Africa?
2. What are the requirements for an IRIS for public commuting in South Africa?

The research questions seek to collect data at the operational level, focusing on internal stakeholders involved in the operation of the IRIS and the external stakeholders (the commuters will interact with its services).

Thus, the main objective of this study is to identify the challenges associated with implementing an IRIS for public commuting in South Africa and the specific expectations of such an IRIS after its implementation from the perspectives of critical stakeholders — commuters and transportation service providers.

As a contribution, this paper highlights the importance of understanding the requirements of an Integrated Real-Time Information System (IRIS) in the South African context from stakeholders' perspectives. By examining these requirements, the study aims to provide valuable insights into how an IRIS can be designed and implemented to address the specific needs and challenges of South Africa's transportation system. Our study also extends the discussion on integrated real-time transport information systems, a critical need in developing countries which has not received much attention thus far in the literature. Practically, the study provides a good foundation for the design and development of IRIS in South Africa and other developing countries in the immediate future. The limitation of this study is that the identified challenges of the IRIS are specific to Cape Town, and some observations may need to be more generalisable to public commuters in other cities in less developed provinces/areas of South Africa due to contextual differences. However, the observations will be relevant to other major cities in South Africa (Johannesburg, Durban) and big cities in other developing countries in Africa and beyond.

The rest of this paper is structured as follows. Section 2 presents the literature review, which provides the study's theoretical background and a review of related work. Section 3 describes the study's adopted methodology, while Section 4 outlines the study's findings. Section 5 presents the discussion of findings, while the study is concluded in Section 6 with a summary and an outlook of future work.

## 2. LITERATURE REVIEW

This section presents background on critical aspects relevant to this study and reviews related work.

### 2.1 Public transport in South Africa

The South African public transport system consists of three main modes: trains, taxis, and the subsidised and unsubsidised commuter bus industry [10]. These modes of transportation face numerous challenges, considering that nearly 70% of the population relies on public transport [11]. Metrorail trains are unreliable, often failing to adhere to schedules or failing to arrive at all [12]. Taxis, lacking set schedules or guides, can overwhelm first-time users and typically fill the gaps left by other non-punctual transport modes. However, the taxi industry in South Africa is volatile, prone to violence, and poses risks to commuter safety. The tensions within the industry can be attributed to the rise in unregistered operators [13]. Bus Rapid Transit (BRT) buses offer a safer alternative to other forms of transportation. However, they are scarce during off-peak hours, and BRT services do not cover certain routes, forcing commuters to seek alternative means to reach their destinations [14]. Navigating urban areas and major cities in South Africa remains a daunting challenge for commuters [2].

### 2.2 The challenges of public transport in South Africa

Public transport provides mobility for a large percentage of the population which cannot afford private car transport. This includes youth, elders and young professionals. The historical land use policies in South Africa made people live far away from central business districts where education and employment opportunities are accessible. Since most South African commuters live far from their places of employment, getting to work is expensive because it takes up between 15 and 30 per cent of their disposable income [15]. South Africa can learn from countries such as Japan, China, Germany, Singapore, Hong Kong, and others with well-developed public transport systems that facilitate seamless mobility for workers, students, residents, and tourists [16]. These countries have embraced advanced transportation infrastructure, including high-speed bullet trains and sophisticated systems aligned with the Fourth Industrial Revolution (4IR) concept. 4IR is critical in building modern smart transportation systems with autonomous vehicles embedded with sensors that connect and communicate through networks. The benefits realisable from smart transportation systems include electronic payment, automatic passenger counting, in-vehicle surveillance, and automated collision warning [17]. Integrating public transport in developing countries such as South Africa poses significant challenges, including fragmentation and the need for coordination among stakeholders. This fragmentation creates challenges for passengers who have to navigate multiple services and providers, leading to inefficiencies, increased costs, and reduced quality of service [18]. The passengers often fear falling due to poor road surfaces, crime, community unrest, inadequate infrastructure, and motor vehicles not honouring pedestrian crossings [19]. To address these challenges, involving stakeholders, including government agencies, private sector operators, and community groups, is essential. Stakeholder involvement in public transportation planning can help build consensus, promote coordination and cooperation, and ensure that the needs and perspectives of different actors are considered, leading to more inclusive, equitable and efficient transportation system [20].

Moreover, stakeholder involvement can help address social equity issues, a critical concern in a developing country like South Africa. Providing an integrated real-time information system (IRIS) for public commuting can positively impact different social groups, including low-income households, women, and people with disabilities [21]. However, some potential negative impacts of an IRIS in South Africa exist. First, resistance to change from commuters and stakeholders is possible, and the government must introduce proper change management to train and educate prospective users on IRIS. Second, from a regulatory and legal perspective, ensuring compliance with privacy laws, addressing liability issues, and establishing data usage guidelines may be challenging. Lastly, funding to provide adequate infrastructure could be a challenge. Hence, there will be a need to ensure adequate revenue generation from the IRIS to remain operational and effective.

### 2.3 Requirements elicitation

Requirements engineering is an important and foundational phase of any system development endeavour. It entails identifying, documenting, analysing, and managing the expectations (requirements) that a system or software application must meet from the perspective of relevant stakeholders. Thus, to fully understand the notion of an IRIS in the context of South Africa, a foundational activity like requirements elicitation is critical.

Requirements are the functions an automated system must perform to meet the user's needs. These functions can be classified into two main categories: non-functional requirements are the quality constraints of the information system (e.g. security, performance, maintainability), while the functional requirements are the functions and capabilities of the information system [22]. These two types of requirements are critical for the success of any system, which must be prioritised based on relevance since software projects are subject to budget, time and scope constraints [23].

Requirements elicitation is a crucial activity performed during the requirements engineering process because it allows system analysts to discover what the information system must do by understanding the functional needs of the various stakeholders [24]. It is usually the first phase in which work is done in software projects after the initiation and planning have been completed. Requirements elicitation is one of the five activities in the requirements engineering process, which includes 1. elicitation; 2. analysis; 3. documentation; 4. verification and validation; and 5. management [25]. The adverse effects of not understanding the stakeholder requirements are project delays, cancellations and deliveries of incomplete work [26]. The common techniques for gathering stakeholder requirements are interviews, questionnaires, observations, requirements workshops, and brainstorming [26]. Each technique has its strengths and weaknesses; the most widely used technique is the interview, as it allows for rich data collection through personal engagement with stakeholders. Questionnaires are also popular tools for gathering requirements as they can be distributed more conveniently, targeting a larger group of people [27]. Recently, co-design approaches with tools and methods that support broader user participation have been increasingly adopted [28-30]. Requirements elicitation activities are necessary before implementing the IRIS in South Africa because the IRIS will serve multiple stakeholders with unique expectations that the system must accommodate. For example, the taxis are very traditional in their operations and do not employ many technological tools in their day-to-day process, which contrasts with the BRT bus service. The variant and nuanced expectations of all stakeholders must be catered to in the design and development of the IRIS, which makes the elicitation of requirements necessary.

### 2.4 Real-time information systems for transportation

The real-time information systems used in the transportation domain can be in the form of websites, smartphone apps or display panels that provide commuters with information on the vehicle's location, estimated arrival time, occupancy rate and alternative routes [31]. Real-time transport information systems (RTIS) assist commuters in making more informed decisions and improve the overall travel experience. For example, in Jeju province of South Korea, real-time information accessed via mobile devices was used to detect over-crowdedness at tourist destinations; this allows tourists to make a guided decision on whether to visit the destination or not; the study confirms that overcrowding is a significant determinant of visit intention [32]. RTIS are particularly advantageous when passenger load fluctuations occur. When demand varies throughout the day, RTIS allow passengers to anticipate and respond to changing levels of crowding. RTIS can help prevent one service from becoming excessively crowded while others have available capacity. By balancing passenger loads across multiple services, RTIS contribute to a more efficient and effective public transport network operation [33]. A pilot study conducted in the Stockholm metro network evaluated the impact of RTIS on passenger behaviour. The study found that providing car-specific RTIS decreased the number of passengers choosing to board the most crowded metro cars [31].

Additionally, in the Netherlands, a smartphone application was utilised to provide train crowding information based on historical load observations [34]. This application allows passengers to access information about the level of crowding on trains based on previous observations. Similarly, RTIS real-time is applied in London to detect train occupancy [33].

### 2.5 Related work

A study conducted in Kuwait [35] presents an IoT-based public transport management system (TMS) to address the challenges of providing efficient and reliable public transportation services in cities. The authors designed and developed a smart TMS to enhance system capacity, passenger safety, and comfort while reducing costs and risks. The proposed system involves an electronic device powered by the Arduino kit. It was installed in public buses, capable of collecting data from various sensors and transmitting it immediately to a cloud server. By storing data in the cloud, the bus management staff can access and monitor the buses' status, which will help them to improve their services and make better decisions. The study presents a solution for bus commuting services. However, it provides features that enhance the overall passenger experience and help reduce wait times. It does not address the issue of a multimodal public transport system.

A real-time information system for public commuting called MOTUS — Mobility and Tourism in Urban Scenarios, was implemented in the Netherlands. The system is able to provide information on the best travel options to tourists and those who are travelling around the inner city [36]. The effectiveness of MOTUS can be measured based on four criteria: safety, mobility, revenue collection, and environmental impact.

The Expressway Management System (EMS) is a transport information system implemented in South Korea to guide commuters by collecting real-time traffic information. The EMS collect and stores data at South Korea's National Transport Information Center, which is distributed to commuters in real-time [37]. It also offers a platform for revenue generation for the government because users have to pay to access the EMS service. However, it needs to do more safety and environmental health. South Africa can improve on the South Korean system by incorporating features that focus on safety. Doing this may involve real-time reporting of incidents, accidents, and road disruptions to enhance passenger safety.

MIRA is a real-time system that is used in the United Kingdom to control complex transport situations. It is based on a robust military-grade architecture that guarantees its reliability and persistent uptime [37]. Learning from the UK model, South Africa can focus on building systems with persistent uptime. Doing this will involve investing in robust infrastructure to ensure continuous availability of services for commuters. In the case of South Africa, there is a lack of integrated real-time information systems. However, some transport information services are mobile apps that are downloadable onto smartphones and provide static route schedules. They operate in silos; there is no centralised real-time transport information system where all the modes of transport can share data to be disseminated to the public commuters.

Similarly, Google Services, such as the transit app, are available to South African commuters, but the system is limited to only road transport and provides fixed-route schedules [38]. This scenario makes the need for an IRIS for South Africa critical. An essential first step in realising this objective is to understand the stakeholders' requirements, which this study provides.

## 3. METHODOLOGY

### 3.1 Service design

A research strategy is a plan of how the researcher will achieve set goals and answer the research questions [39]. We adopted service design as a research strategy because it is suited to exploratory and inductive research. Service designers use the 'Double Diamond' model. The first diamond deals with understanding the problem, and the second diamond represents the creation of a solution [40]. As shown in Figure 1, the service design process is divided into four phases: Discover phase, Define phase, Develop phase and Deliver phase. The Discover phase aims to understand the problem by observing, reading, and engaging with stakeholders. The Define phase clarifies and focuses on the real problem to solve. Several possible solutions are designed and iteratively developed into prototypes in the development phase. In the Deliver phase, the developed solution is deployed, feedback is gathered, and the project is finalised [41].

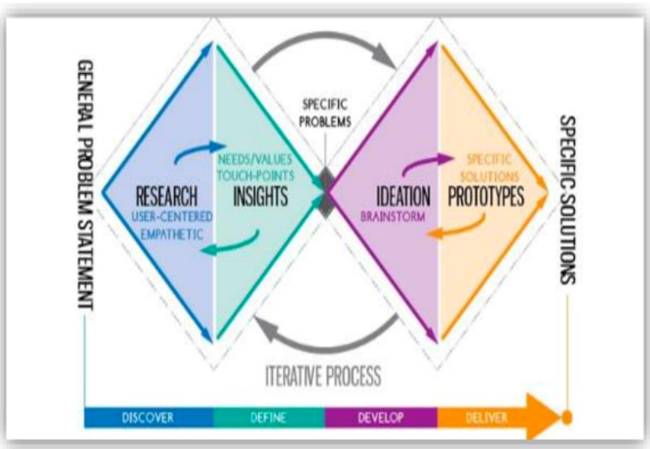


**Figure 1.** Service design process [41]

According to the study [42], the phases of service design can be applied individually or wholly in research, where the scope of the study drives the stages at which the service design process is applied. Thus, to explore stakeholders' perspectives on real-time information for public commuters in South Africa in this study, we covered the Discover and the Define phases of the first diamond and the ideation activity to identify requirements for the IRIS, which belong to the Develop phase of the second diamond. The rationale for using a service design strategy was to include public transport commuters in co-creating an IRIS to improve the delivery of public transport services in South Africa. Furthermore, public participation will increase commuter acceptance and support, which is essential for technology uptake.

### 3.2 Research design

Our research design for this study is based on service design. The Discover phase of our service design involved formulating research questions, generating interview questions, and interviewing selected stakeholders. The Define phase of the service design involved the analysis of the collected data (identifying themes and findings, and interpretation of findings). We achieved ideation, an activity of the Develop phase of service design, by conducting a co-design workshop involving commuters (see Table 1).

The research questions of this study are exploratory. Hence, a qualitative approach was adopted, focusing on understanding the requirements of an IRIS from the stakeholders' perspectives. The exploratory nature of qualitative research allows the reader to understand the experience, the distinct nature of the phenomenon or program and its impact on people. Therefore, this research is exploratory because it seeks knowledge concerning the stakeholder requirements for an IRIS.

We adopted a multiple case study research design that involves key transport operators in South Africa and a co-design workshop with public commuters. The authors used purposive sampling to select participants who were accessible and willing to participate in the co-design workshop. The sampling frame for the co-design workshops was working-class persons and students who commute using public transport. To ensure respondents' familiarity with integrated real-time information systems, we included participants who commute to the workplace or school through the public transport system (road, rail) in South Africa and are familiar with information technology. The participants of the co-design workshop were selected based on the following criteria: a balance between genders, active age groups, experienced and non-experienced commuters, techno-savvy commuters, and people who travel for different purposes, such as work, school, and other activities. The stakeholders interviewed are IT professionals and senior management employees at public transport operators (PTOs) in Cape Town (see Table 2 and Table 3).

A pilot study involving 3 participants assessed the quality of interview questions. We used the feedback obtained from the pilot study to revise the interview questions. The process workflow of the adopted research design is shown in Figure 2.

**Table 1.** The phases of service design and research activities

| Phase | Research Activities |
|---|---|
| Discover | • Formulate research questions<br>• Design interview questions<br>• Conduct semi-structured interviews of selected stakeholders |
| Define | • Identify themes from collected data<br>• Extract findings<br>• Interpret findings |
| Develop | • Ideation/brainstorming session with commuters to identify requirements<br>• Data collection from participants through an interactive Q&A session<br>• Compilation of affinity charts<br>• Discussion among the participants and researcher<br>• Develop design concept (prototype interface) |

**Table 2.** Profile of interviewed participants

| Participant | Title | Role | Stakeholder |
|---|---|---|---|
| R1 | Operations Manager | Management Role | Taxi Association |
| R2 | Communications | Co-ordinate route changes to taxi owners and other stakeholders | Taxi Association |
| R3 | IT Manager | IT department as a senior technician | Rail Transport |
| R4 | Operations Manager | Head of the department | Rail Transport |
| R5 | IT Manager | Managing IT infrastructure | Private Road Transport |
| R6 | Line Manager | Manage the operation of different routes | Private Road Transport |
| R7 | Manager | General Management and oversight of the organisation’s operations. | Public Road Transport |
| R8 | IT Administrator | Head IT infrastructure | Public Road Transport |

**Table 3.** Profile of co-design participants

| Participant | Age | Gender | Group | Occupation Status | Colour |
|---|---|---|---|---|---|
| P1 | 29 | Female | A | Employed | Green |
| P2 | 21 | Female | A | Student | Pink |
| P3 | 23 | Male | A | Student | Blue |
| P4 | 26 | Male | B | Work | Yellow |
| P5 | 19 | Female | B | Student | Pink |
| P6 | 25 | Female | B | Student | Blue |
| P7 | 46 | Male | C | Work | White |
| P8 | 43 | Male | C | Work | Yellow |
| P9 | 30 | Female | C | Work | Green |
| P10 | 29 | Male | C | Work | White |

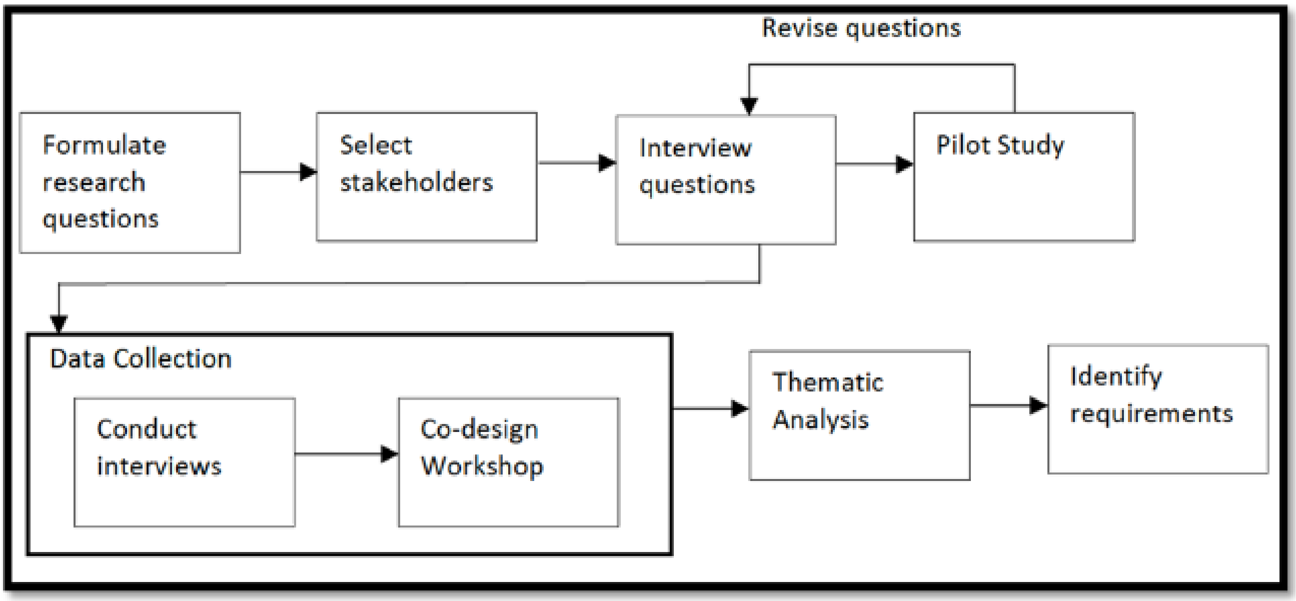


**Figure 2.** The process workflow of the study design

### 3.3 Data collection and analysis

The data were collected using semi-structured interviews with PTOs and co-design with public transport commuters. We interviewed a total of 8 participants who were the informants from the four major stakeholders' organisations (a public road transport operator, a rail transport operator, a private road transport operator, and a taxi association) in the public transport system within the City of Cape Town region of South Africa. Also, ten public transport commuters participated in the co-design sessions.

The interviews were recorded and stored on password-protected devices; the researcher then listened to the recordings to transcribe each interviewee's response. The transcription process involved transferring the interview responses onto Microsoft Word documents, with each interviewee's answers captured alongside a copy of the original question set. This approach facilitated a clear alignment between the provided questions and the corresponding responses, ensuring accurate representation and ease of reference during subsequent analysis; after that, the data was transferred to spreadsheets for analysis. The co-design participants were placed into groups A, B, and C. Groups A and B consisted of 3 participants each, while Group C had 4 participants. The co-design workshop was done in three phases. The first phase was collecting data from participants through an interactive Q&A session. Then, the participants were required to note their responses on a Post-it note, which was used to compile the affinity charts. The affinity charts assisted the groups to prioritise and categorise their ideas to ensure better collaboration for the second phase of the workshop. During the second phase of the workshop, the data was collated and discussed among the researcher and participants. Finally, the third phase required the groups to develop design concepts for how they envisioned the IRIS. The design of the IRIS by the participants' groups is shown in Figures 3, 4, and 5.


**Figure 3.** Group (A) Participants' design of an IRIS

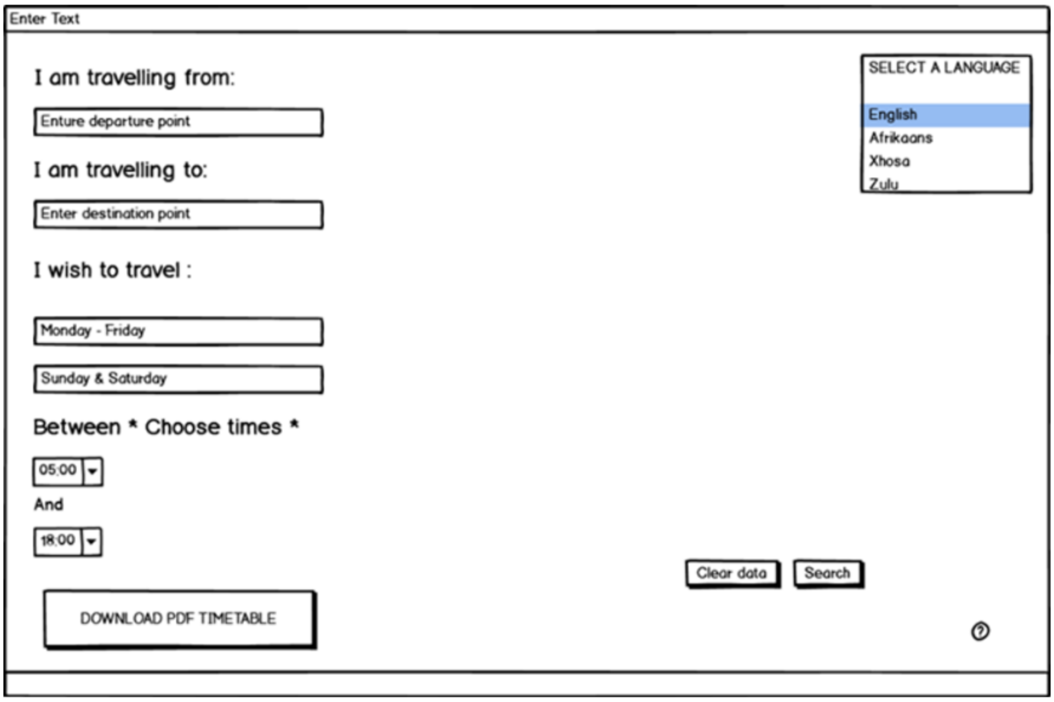


**Figure 4.** Group (B) participants' design of an IRIS.

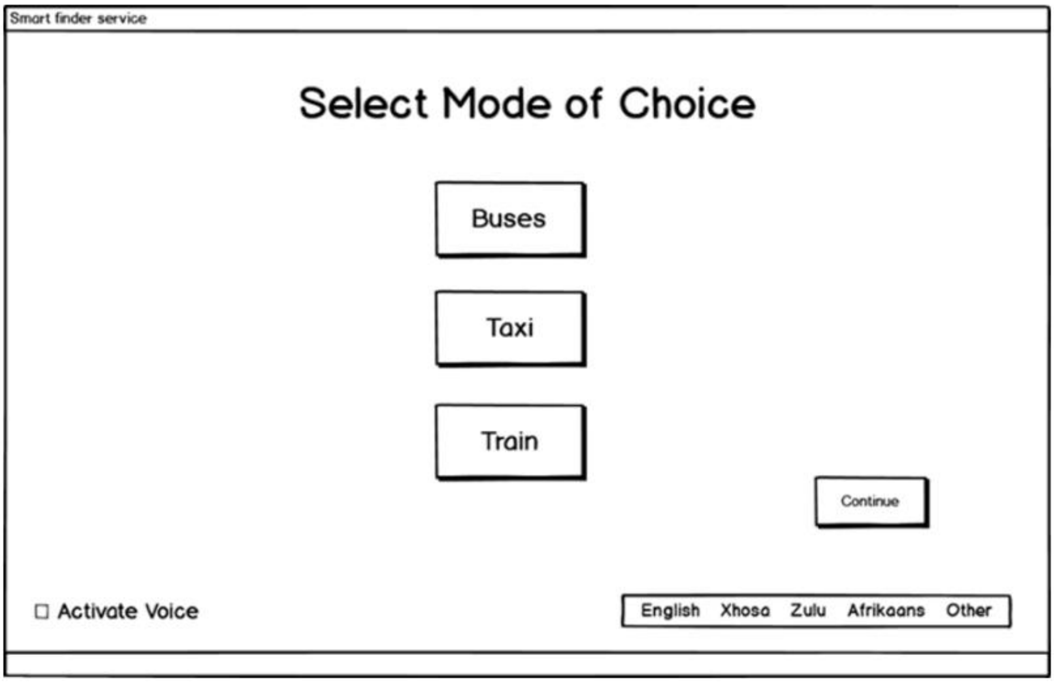


**Figure 5.** Group (C) participants' design of an IRIS

The illustrations of the conceptual designs above provided the researcher with some insights into the design requirements of an IRIS from the perspective of the commuters who would be the system's potential users.

We used thematic analysis to analyse the data collected from the interviews. Thematic analysis is usually applied to text-like interview transcripts, where researchers look for patterns and classify them into broader themes. For our thematic analysis, we used a six-step process: Step 1: Familiarisation with the data, Step 2: Generating initial codes, Step 3: Searching for themes, Step 4: Reviewing potential themes, Step 5: Defining and naming themes and Step 6: Producing the report. The primary tool used for organising and coding the data was Microsoft Excel. Initially, the responses from each participant to the questions posed during the interviews were transcribed. Then, through a systematic coding process, key patterns and categories were identified within the data. The procedure involved identifying recurring ideas, concepts, or statements and assigning them corresponding codes. Subsequently, these codes were organised and grouped into themes based on their similarity and relevance. The themes were developed iteratively by examining the relationships between the codes and refining their descriptions to represent the data accurately.

## 4. RESULTS

In this section, we present the findings of the study based on the two research questions after the analysis of data collected from co-design workshops with commuters and the interview sessions with informants from the public transport operators (PTOs). The research questions investigated are:

**RQ1:** What challenges affect the provision of real-time information for public commuting decision-making in South Africa?
**RQ2:** What are the requirements for an IRIS for public commuting in South Africa?

### 4.1 Challenges of public transport (RQ1)

There are several challenges faced by commuters with public transport in South Africa, as outlined in Table 4. The findings show that commuters are dissatisfied with the state of public transportation in South Africa. Their concerns relate to punctuality, lack of maintenance and poor service quality. There are instances when commuters feel let down by the public transport system, particularly those who travel to their places of work and students who are subject to unsavoury conditions of public commuting. Commuters are also often negatively affected by PTO trade union strikes, which cause violent conflicts between groups within the unions and jeopardise the safety of passengers. There is a perception amongst commuters that the ongoing problems around public transportation can be attributed to a lack of investment initiatives, lack of accountability, and neglect of socio-traffic issues like congestion, overcrowding, and accidents.

Table 5 shows that the PTOs highlighted similar sentiments regarding the nature of the public transport system in South Africa. The operators acknowledge the issues around safety, violence, degraded infrastructure, and other social traffic issues in the current public transport system. However, the participants also noted that the main reason public transport is still preferred is its affordability. The PTOs are aware of the role of real-time information as an innovative way of improving the current situation by aiding commuters' decision-making process. However, many issues surround providing such information to commuters, particularly around access to resources such as technology tools and reliable network connections.

**Table 4.** Challenges of public transport: Findings from co-design sessions with commuters

| **Co-design Question 1:** *How would you describe the state of public transportation in South Africa today?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • Well, I would say the state of the transport system is good at some times and terrible at others simply because the operators fight themselves for stupid things, causing passengers to be late. (P1)<br>• The public transport system has positive and negative sides; drivers treat people with respect, but not all. The negative side is that it is not safe for passengers in taxis and buses. (P2)<br>• Fully functional, it works for me (P3)<br>• Not Safe (P4)<br>• Public transport is very unreliable at times; for example, a taxi does not take you to your destination at your desired time. (P5)<br>• Using public transport in South Africa is a struggle as it is little maintained. (P6)<br>• Can be unfeasible (P7)<br>• Bad customer service (P8)<br>• Lacks security to keep us safe during peak (P9)<br>• Sometimes, it can let you down when you are in a hurry (P10) | • There is an overwhelming dissatisfaction among commuters about the safety and unreliability of the current public transport system in SA, with concerns such as punctuality, lack of maintenance, and poor services also voiced. |
| **Co-design Question 2:** *In what situation or encounter can you recall where you most needed travel information on public transport service?* | |
| **Stakeholder Comments** | **Findings** |
| • There was a time when taxis were on strike, and I needed to know if I should request an Uber. (P1)<br>• When I was going to write an exam but the taxi took too long to get to the taxi rank whereas I woke up on time. (P2)<br>• When I got lost trying to get to the Cape Town campus at Bellville. (P3)<br>• The time My CITI buses were unavailable as it's my primary mode of transport. (P4)<br>• There was a time when I had to wait 30 minutes for a bus as I did not make it in time for the previous one that had already left, and this made me late for class. Therefore, I had to end up taking a taxi. (P5)<br>• When I was leaving campus late, the taxis to my area were finished. (P6)<br>• I woke up late for work and needed the fastest mode of transport to work. (P7)<br>• Leaving work after hours and not knowing which public transport is still available. (P8)<br>• When a private car would not start in the morning. (P9)<br>• When I got to the taxi rank and the loading was full, I had to queue and wait for the next one to finish loading. (P10) | • It revealed the need for real-time information on alternative modes during peak travel periods to school/work and the return, often marred by delays and long queues.<br><br>• A significant issue raised was trade union strikes, which have become a growing trend of disruptions in SA's public transport systems. |
| **Co-design Question 3:** *In your opinion, why do these challenges faced by public commuters persist?* | |
| **Stakeholder Comments** | **Findings** |

| | |
|---|---|
| • This is because the owners are selfish and think for themselves only; trains, whoever is in charge, do not want to upgrade nor fix them, and the buses it is because they are not familiar with technology to improve the situation. (P1)<br>• Still exist because taxi managers and other translation managers do not listen to their passengers; even when there are complaints about certain things, they just don't listen. (P2)<br>• No challenges faced (P3)<br>• The transport system in South Africa is plagued with too many challenges; trains have poor service and delays a lot, and buses are always affected by road accidents. (P4)<br>• No Money (P5)<br>• It still exists because people don't do anything about it; people in charge or responsible for challenges aren't taking matters seriously enough or aren't finding solutions to prevent these challenges from happening. (P6)<br>• There is a lack of will from the government to fix the problems. (P7)<br>• No accountability. (P8)<br>• The operators need to invest in their infrastructure. (P9)<br>• The owners do not listen to the customers (P10) | • Participants indicated varying concerns relating to the state of public commuting in SA, including lack of investment, engagement and accountability, in addition to the neglect of socio-traffic issues, which have further exacerbated the state of the public transport system in South Africa. |

**Table 5.** Challenges of public transport: Findings from interviews with public transport operators (PTOs)

| **Interview Question 1:** *Can you provide an overview of the public transportation system in Cape Town?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • The public transport system in Cape Town faces a few challenges since it combines government transport and privately owned transport like taxis; government-owned transport is given an advantage over taxis. (R1)<br>• I wouldn't say it is at its best; there is room for improvement. (R2)<br>• It's decreasing in terms of effectiveness and becoming less preferred. The public transport system infrastructure is also a mess. (R3)<br>• The transport system in Cape Town is dysfunctional, with a lot of overcrowding, and also lacks safety. (R4)<br>• The Cape Town public transport system needs a plan to help address the traffic situation during peak hours. (R5)<br>• Public transport in the City of Cape Town plays a crucial role in transporting people without private vehicles; it is also an alternative for those who are saving costs and don't want to walk. (R6)<br>• The public transport system is experiencing a lot of challenges, including violence and traffic-related issues about parking. (R6)<br>• The public transport system is experiencing a lot of challenges, including violence and traffic-related issues. (R7)<br>• The public transport system mainly caters for low to middle-income users but can sometimes be unreliable, especially during strikes. (R8) | • Cape Town's public transport system has challenges such as safety concerns, violence, degraded infrastructure, and other social traffic issues. However, it is cost-effective for public commuters, making it preferable to private commuting for most commuters. |
| **Interview Question 2:** *What is your knowledge of real-time information?* | |
| **Stakeholder Comments** | **Findings** |
| • Real-time information can be used; however, a study needs to be conducted on how we can reduce the number of vehicles that gonna be on the road. (R1)<br>• Not full knowledge. (R2)<br>• I understand that its information is received with fewer delays. It can help to better communicate with passengers promptly, especially regarding a delay. (R3)<br>• I don't know what real-time information is.<br>• I know its information is sent out in a faster manner and periodically than normal information. (R4)<br>• Not aware. (R5)<br>• Real-time information is useful for supporting commuters when making decisions. (R6)<br>• It is information that is used when travelling. (R7) | • Many respondents have a basic understanding of real-time information, with some mentioning that it can improve decision-making within public transportation. |
| **Interview Question 3:** *What do you think are the challenges of providing real-time information for commuters?* | |
| **Stakeholder Comments** | **Findings** |

| | |
|---|---|
| • There is a need for more resources and how the information will be sourced since each association has its financing model. (R1)<br>• Most of our customers don't have access to the technology to get the information; at the moment, we are doing it the best we know. (R2)<br>• The lack of human intervention has caused the system to be outdated in terms of information updates. (R3)<br>• The system sometimes goes down, so network problems must be fixed. (R4)<br>• The passengers must also have the proper devices to consume such information; otherwise, the system will be of no value. (R5)<br>• In general, we have challenges providing information as passengers wanna access it in different ways. (R6)<br>• Taking into the different backgrounds of commuters in order to make diverse measures. (R7)<br>• The data needs to be constantly kept up to date for all to access the information. (R8) | • Transport operators' provision of up-to-date travel information is hampered by a lack of resources, such as the technology tools required by commuters to receive real-time updates and stable network connectivity.<br>• The provision of up-to-date travel information is affected by a lack of uniformity of standards as operators have unique business processes, and commuters also expect tailored solutions.<br>• Challenges of ineffective administrative processes and inadequate human resources are cited as inhibitors to providing up-to-date real-time information in the South African public transport system. |

### 4.2 The requirements for an IRIS (RQ2)

The co-design workshop yielded rich qualitative data extracted from the affinity charts created by the participants as a series of questions were asked by the researcher. The questions asked are as follows:

- What is your understanding of integrated real-time information systems for public commuting? How do you think this will benefit commuters?
- What type of information about each mode of transport system would you specifically want to be made available to commuters?
- In what format would you like to receive this information? What type of features would you want to see on such a system?

During the co-creation phase of the workshop, the participants were allowed to conceptualise their responses to the questions asked by producing a series of design concepts. The design concepts created by participants were subsequently analysed to extract additional requirements. Similarly, to achieve the objective of understanding the requirements from the perspective of the PTOs, a series of questions are asked during a semi-structured interview process:

- Do you think there is merit in sharing real-time travel information with other transport agencies?
- How would you describe the benefits of an integrated traveller information system for commuters?
- Considering the current transportation system in CT, how well would an integrated real-time system work?
- What desirable features should an integrated real-time information system provide for commuters and operators?
- What are the challenges such a system might encounter in the current climate?

The need for an Independent Contractor (IC) as a mediator between several PTOs emerged from the concerns raised by both the commuters and PTOs around the issue of trust, security, transparency and fairness of the operations of an IRIS. All the stakeholders expressed the need for a neutral body to administer the IRIS. Thus, the third stakeholder of the IRIS is the IC organisation, which would be appointed as a neutral body that would maintain the IRIS and mediate disputes between the other stakeholders, particularly relating to revenue sharing. The commuters also require training and technical support on how to use the IRIS, which would be the role of the IC organisation. The roles of the stakeholders of the IRIS are shown in Figure 6.

4.2.1 Use case of the IRIS

A use case model reveals the different functions a new system is expected to perform and the role of various actors in the system. Based on interaction with participants in the study, we were able to derive a use case model for the IRIS. Figure 7 presents a use case diagram showing the various tasks the stakeholders would perform in the system. These functions correspond to the expected behaviour of the IRIS based on the inputs from each type of stakeholder. These define the functional requirements that the IRIS must satisfy in response to inputs/activities of each specific stakeholder. We used interviews to elicit requirements from the PTOs who would be the internal stakeholders of the IRIS. Also, the commuters participated in co-design sessions, which involved the ideation and co-creation of conceptual designs that outlined their desired features from an IRIS.

4.2.2 Functional requirements of external stakeholders

Figure 7 shows a use case diagram derived from the data collected from interviews and the co-design workshop in response to the research question, "What are the requirements for an IRIS for public commuting in South Africa?". The collected data was analysed (as described in the previous sections) to identify the key themes and perspectives shared by the participants from which the requirements emerged. In Figure 7, Commuters and IC staff are categorised as external stakeholders because they are external to the organisations that generate the travel information.

However, there is an overlap between some of the functions triggered by the external and internal stakeholders; this is mainly because the IC staff provide maintenance and administrative duties with escalated permissions while the staff of PTOs would also require administrative functions; however, at lower levels of permissions. This is to maintain system integrity by ensuring that an independent organisation is responsible for performing high-level admin functions instead of granting the powers to all the PTOs.

4.2.3 Functional requirements of internal stakeholders

The PTO staff are the only internal stakeholders in the IRIS because they are involved with the processes, infrastructure and subsystems that would be integrated to build a new proposed system. Thus, they are directly and financially involved in the operational process and categorised as internal stakeholders. Table 6 presents the use case of the PTO staff with transaction management overlapping from Table 7.

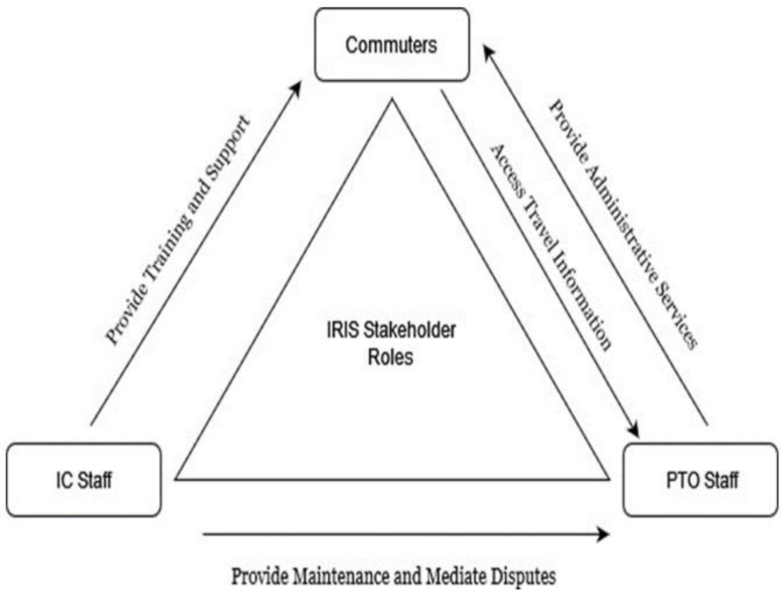


**Figure 6.** Diagram showing stakeholder roles

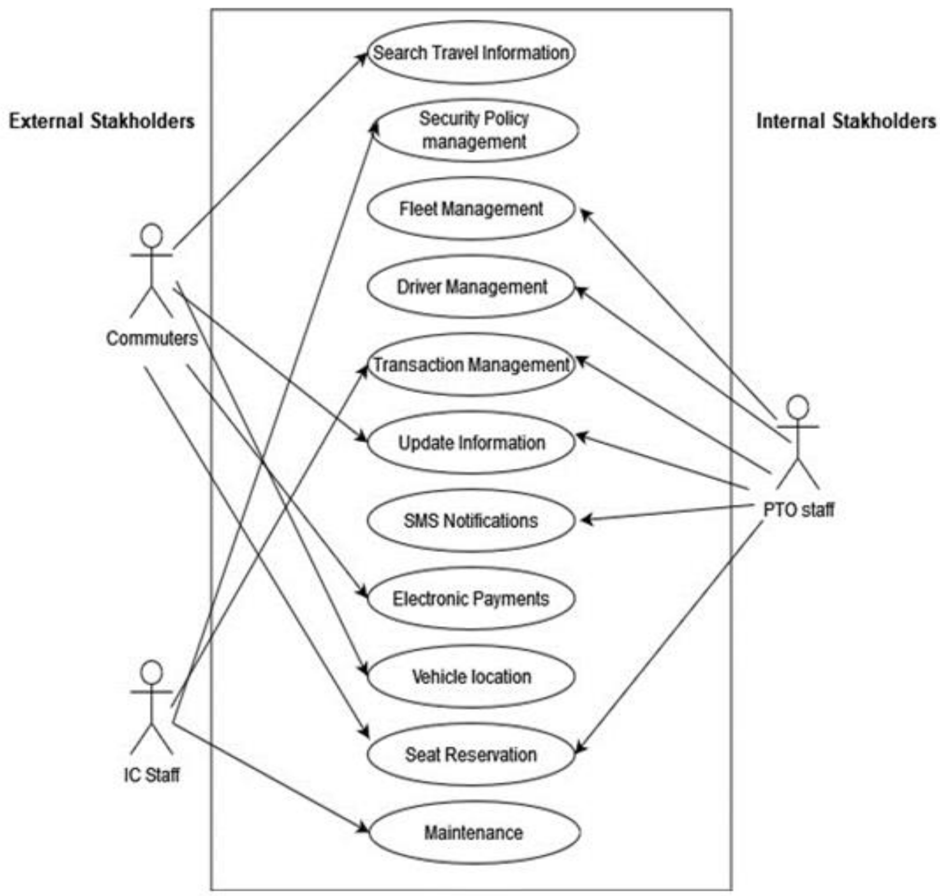


**Figure 7.** Use case diagram of stakeholder requirements

**Table 6.** Description of internal stakeholder use cases

| Use Case | Description |
|---|---|
| Fleet Management | This use case involves the geolocation of vehicles on live maps. |
| Driver Management | This use case relates to how Human Resource Departments can monitor drivers' habits and rate performance. |
| Transaction Management | This use case only allows PTOs to trace or view the status of a transaction; however, they cannot withdraw any money from the system without the permission of the IC. |
| Update Information | Being able to update certain components of travel information, for example, changes in fare amounts |
| Seat Reservation | The PTOs should be able to reserve or limit the number of seats available for passengers on a vehicle. |

**Table 7.** Description of commuter and IC use cases

| Use Case | Description |
|---|---|
| Search Travel Information | This is triggered by the commuters who are the main users of the IRIS; the use case allows them to filter travel information about fare amounts, number of passengers on board, alternative routes or modes, departure and arrival time, delays, accidents, strikes, and traffic congestion. |
| Update Information | Commuters must be able to update their personal information on the system, for example, by adding billing information for electronic payments. |
| Electronic Payments | Commuters must be able to use digital payment methods as an alternative to carrying cash. |
| Vehicle Location | The commuters must be able to track vehicles on interactive maps. |
| Seat Reservation | Commuters should have the ability to reserve seats on an approaching vehicle. |
| Security Policy Management | The IC must have top-level permission to assign access rights to users who are either commuters or PTO staff. |
| Transaction Management | The IC will have access to financial records and mediate when there are disputes between the system's stakeholders. |
| Maintenance | The system must have scheduled backups, security patches and fixes for bugs or errors. This is placed on the IC, who must be able to put the system in an isolated state during off-peak hours. |

**Table 8.** Description of non-functional requirements of an IRIS

| Non-functional Requirements | Description |
|---|---|
| Functionality | As outlined in the functional requirements, working feature sets also include security, which is very important in the IRIS and was a concern for the interviews and co-design session participants. |
| Usability | The commuters who participated in the co-design sessions require travel information from different channels such as display screens, mobile applications, USSD and other IoT devices. The user interface must allow multiple devices to render the system, and a consistent look and feel must be maintained. |
| Reliability | The IRIS must be robust and have backup mechanisms that reduce the impact of failures. |
| Performance | The real-time aspect of this system requires the processing speeds to be kept at optimum levels, so performance is an important attribute. |
| Supportability | The end-users must be able to give feedback on the system and be provided with support in the event of a system glitch. Maintenance must be done at regular intervals to minimise these errors. |

#### 4.2.4 Non-functional requirements

The non-functional requirements were ascertained through the guidance of the FURPS+ model [43], which classifies Functionality, Usability, Reliability, Performance and Supportability as the main qualitative measures of a system. The non-functional requirements were also extracted from the responses of the commuters and the PTOs to the questions that were posed. Non-functional requirements are often overlooked and not considered as important as functional requirements. However, they are a qualitative measure of the system's capabilities.

During the interviews and co-design sessions, the participants focused more on the system's functional requirements, assuming that non-functional attributes such as functionality, usability, reliability, performance and supportability are expected to be part of the system by default. However, they were specifically prompted to give their views on the non-functional requirements that they consider important for the IRIS. The participants opined that the IRIS must have internal controls to protect the integrity of its data; just like any other information system, internal and external threats must be mitigated. This will require knowledge of the role of each stakeholder so that they are assigned the appropriate access permissions on the system. The primary users are the commuters who will consume travel information from the IRIS.

In contrast, the PTOs are tasked with keeping the information up to date when changes at the organisational level occur, representing another category of stakeholders. For example, fare changes would necessitate an update to the system, which must be the function of PTOs. The elicited non-functional requirements are shown in Table 8.

4.2.5 Perceived benefits and concerns of the IRIS

This section presents the findings on the perceived benefits and concerns of the IRIS amongst the different transport operators and commuters. Most stakeholders' comments indicated that sharing information between operators would benefit the public transport system. However, privacy issues were also raised, and extra security measures must be implemented to protect confidential customer data. Table 9 presents the perceived benefits from the perspective of the commuters, and Table 10 shows the views of the PTOs

The stakeholders also expressed several concerns regarding the IRIS (see Table 11 ), which focussed on issues of i) low digital literacy among commuters and lack of access to high-end digital devices to consume the services of IRIS; ii) late arrival of buses due to delays; iii) government interference in the operations of PTOs; iv) unfavourable fare increases; v) accuracy of the IRIS regarding specific stations and estimated wait times; vi) revenue sharing amongst PTOs; vii) ability of the IRIS to tackle the difficulty of finding taxis after regular working hours; viii) poor state of infrastructure; ix) unhealthy competition amongst PTOs; x) the impact of enforced standardization and accountability; xii) currency of information in the IRIS; xiii) how to source information from different PTOs; and xiv) system downtimes due to regular power failure (load shedding).

**Table 9.** Benefits of IRIS for commuters

| **Co-design Question 4:** *What is your understanding of IRIS for public commuting? How do you think this will benefit commuters?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • There are integrated sources of information for common decisions that would work for passengers (P1)<br>• They can work together to create a better transport system (P2)<br>• Coming from different sources (P3)<br>• The integration is good for people to work in teams (P4)<br>• Integrated is basically subsystems brought together into one whole system like buses, trains, and taxis for various ways to travel (P5)<br>• No, I don't understand the system that they use. (P6)<br>• Integration is things that work together. (P7)<br>• Merging things into one system like a train, bus and taxi. (P8)<br>• I don't understand fully (P9)<br>• The transport system will operate better as one (P10) | • Commuters generally understand the concept of an IRIS for public commuting.<br>• Responses suggest that an IRIS will provide collaborative information sharing from multiple sources accessible for public commuting in SA. |

**Table 10.** Benefits of IRIS from PTOs

| **Interview Question 4:** *How would you describe the benefits of an integrated traveller information system for commuters?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • The commuters will gain from having multiple options to choose from. (R1)<br>• It can bring a lot of safety and make things much faster. For example, if it were an app, they could find most routes and make decisions. (R2)<br>• People will be better informed about alternative modes of transport. (R3)<br>• The public transport system will be more efficient and reliable (R4)<br>• It can help reduce the number of private cars in the city as more people will have confidence in an efficient modernised system (R5)<br>• Commuters will be able to decide early where to take transport and when a vehicle will be arriving late. (R6)<br>• This will assist with traffic congestion as commuters will have diverse options. (R7)<br>• improved security and safety for passengers and drivers. (R8) | • The consensus is that commuters will benefit from an integrated system because it will improve the public transport system's decision-making, safety, and reliability. |

**Table 11.** Concerns of stakeholders regarding the IRIS

| **Interview Question 1:** *What are the challenges that such a system (IRIS) might encounter in the current climate?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • The system may cause government interference in operations and place the taxi industry at a disadvantage through increased laws and regulations. Roads and other infrastructure will need to be upgraded first, and new routers must be created. (R1)<br>• Vehicle information and driver information in the event that there are problems can be reported swiftly. (R2)<br>• Delays and Time schedules. (R3)<br>• Incidents and delays; Fare changes; Delay durations. (R4)<br>• Commuters would generally want to know if the bus will arrive on time and when the next one is coming. (R5)<br>• The commuters are generally concerned with time and delay issues and are occasionally notified when fare increases. (R6)<br>• The commuters expect a regular feed of information relating to the next scheduled bus. (R7)<br>• Being able to find stations and calculate estimated wait times (R8) | • The commuters are generally concerned with time and delay issues and are not sure if the IRIS can solve the problems of disruptive incidents (like riots and labour union strikes) that cause delays in the arrival times of buses.<br>• The IRIS may promote government interference in the operations of public transport organisations (PTOs) through increased laws and regulations, which may not augur well for the taxi industry.<br>• Commuters are concerned that the IRIS may lead to fare increases<br>• The commuters are unsure if the IRIS will enable them to find stations and determine estimated wait times. |

| Interview Question 2: *What do you think are the preferred travel information needs of commuters?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • Commuters have different working hours, so most of the questions are: will the taxis be available after hours? (R1)<br>• The most important challenge is infrastructure, there need to be improvements to the roads first. (R2)<br>• People will need training; Accountability needs to be improved. (R3)<br>• There might be violence due to increased competition with other agencies, and they may feel an unfair advantage is given to others. (R4)<br>• There could be tension between the different operators, particularly in the taxi industry. (R5)<br>• it will require the stakeholders involved to standardise their process. (R6)<br>• The training may need to be provided to users and administrators to use the system efficiently. (R7)<br>• There needs to be an equal revenue-sharing strategy between the different agencies. (R8) | • There is concern about how revenue will be shared among different transport agencies.<br>• Commuters desire that taxis be available at varying hours, including after working hours. They are unsure if the advent of IRIS will help meet this need.<br>• There is concern that the poor state of infrastructure and quality of roads will hamper the benefits derivable from the IRIS initiative.<br>• The IRIS can stimulate unhealthy competition among PTOs, which may not create problems and increase tension.<br>• There is generally a low level of digital literacy among stakeholders, which can hamper the success of the IRIS. Thus, training will be necessary.<br>• The IRIS will force stakeholders to standardise their processes and embrace accountability. |

| Interview Question 3: *What do you think are the challenges of providing real-time information for commuters?* | |
|---|---|
| **Stakeholder Comments** | **Findings** |
| • There needs to be more resources and a method of sourcing the information since each association has its own financing model. (R1)<br>• Most of our customers don't have access to the technology to get the information, at the moment we are doing it the best we know. (R2)<br>• Lack of human intervention has caused the system to be outdated in terms of information updates. (R3)<br>• The system sometimes goes down, so network problems must be fixed. (R4)<br>• The passengers must also have the proper devices to consume such information; otherwise, the system will be of no value. (R5)<br>• In general, we have challenges providing information as passengers wanna access it in different ways. (R6)<br>• Taking into the different backgrounds of commuters in order to make diverse measures for all to access the information. (R7)<br>• The data needs to be constantly kept up to date. (R8) | • There is concern about how information will be kept current and up to date.<br>• There is concern about how information will be sourced from the different PTOs since they have different financial models.<br>• Most commuters lack sufficient digital literacy and have low-end digital devices, which may not enable them to consume the services of the IRIS.<br>• There are concerns about system downtimes due to the problem of load shedding (power failure), which occurs regularly. |

## 5. DISCUSSION

### 5.1 Interpretation of findings

**i. What challenges affect the provision of real-time information for public commuting decision-making in South Africa?**

The findings in this study show an overlap between the views of commuters and PTOs regarding the nature of public commuting in South Africa. The prevalent view is that the public transport system faces challenges that disadvantage commuters. These include discomfort, overcrowding, waiting time, and breakdowns. Other challenges are poor infrastructure [44], traffic issues, overcrowding, and safety. Shange and Harmáček [45] state that public transport is prone to accidents caused by reckless driving, unroadworthy vehicles, and poor road conditions. According to the study [46], a lot has to be done before a shift toward an efficient public transport system; the fundamental is to address the dysfunctional rail network and improve the quality of the roads. However, as indicated by this study's participants, the main benefit of using the current public transport system is its affordability. Hence, the users are tolerant in light of the challenges they experience daily.

Similarly, Luke and Heyns [47] posit that the current perception of public transport in South Africa is so low that most public transport users aim to buy a private vehicle as soon as they can afford it. The development of public transport requires investment towards technology solutions at facilities, which is lacking in the South African context. The lack of funds and resources is one of the things which is hindering transport development in most countries [48, 49]. The government is at the core of sourcing funds to modernise the public transport system through private-public partnerships. This can help alleviate the problem of degrading infrastructure and facilities through increased investment projects. Providing quality infrastructure creates the foundation for an IRIS, which will resolve traffic-related challenges.

**ii. What are the requirements for an IRIS for public commuting in South Africa?**

The functional requirements in this study can be classified into two types: end-user requirements and administrator requirements. End-user requirements are features that commuters use. These include searching for travel information, updating information, e-payments and vehicle location services. The administrator requirements are those used by PTOs to automate their business processes. These features include fleet management, driver management, transaction management, updated travel information, and seat reservations. Integrated systems are complex since they connect and harmonise multiple systems, and therefore, standards must be followed to ensure that these integrated applications are compatible [50]. Non-functional requirements are characteristics that have been standardised as system performance measures; this study identified functionality, usability, reliability, performance and supportability as critical attributes. Interoperability is one such characteristic that is, by default, required in an integrated system as multiple varying subsystems are merged into a larger system. Regarding the IRIS, three types of interoperability assessment will be critical.

These are potentiality/maturity, compatibility, and performance assessments [51].

The maturity assessment of the IRIS will evaluate how well it can adapt and respond dynamically to overcome possible barriers when interacting with a potential partner. This evaluation uses a qualitative measures-based rating scale composed of linguistic variables focusing on aspects such as competency, capability, and level of sophistication. The IRIS's compatibility assessment will evaluate the interoperability level between different subsystems that make up the IRIS before or after any instance of interoperation. This evaluation aims to determine the current state of various subsystems to be integrated to identify the conflicts that may cause problems. Quantitative measures such as maximal potential interoperability measure (MPIM) and minimal effective interoperability measure (MEIM) [52] can be used. Lastly, the performance interoperability assessment of the IRIS will focus on the quality of interaction between component subsystems of the IRIS at run-time. This evaluation will require quantitative metrics such as the costs of implementing interoperable applications, the interval between an information request and response between systems, the quality of the information exchange, the quality of use, and the quality of conformity [51].

The above features bring about efficiency and convenience for the commuter and public transport operator. They improve many of the manual processes and outdated applications being used currently. For example, commuters would no longer be required to carry around cash as IRIS would have e-payment options; this is efficient and improves their safety at transport facilities. The PTOs also believe that commuters will benefit from an integrated system because it will enhance the public transport system's decision-making, safety, and reliability. Although the stakeholders ascertained the requirements above, there is a great need to provide training to users post-implementation to ensure a smooth transition from operating in silos to a new integrated system [53]. The other apparent concern was the need to put in measures to protect customer data in a shared environment. The Protection of Personal Information Act (POPI) is government legislation protecting the public from being victims of data misuse [54]. Therefore, this regulation needs to be enforced in the IRIS.

### 5.2 Managerial and societal implications

The findings of this study can have significant managerial and societal implications that can contribute to improving public transport services and the well-being of commuters. From a managerial perspective, the findings can help stakeholders in the transport sector better understand commuters' needs and preferences, which can inform decision-making and resource allocation. For example, the rollout of free WiFi connections at passenger stations to make the IRIS equally accessible. Additionally, the findings on the stakeholder requirements for an IRIS may have significant societal implications. For example, the system can promote public transportation over private vehicles by giving commuters accurate and up-to-date information on available options, reducing traffic congestion and its associated environmental effects. Additionally, the IRIS can enhance passengers' overall travel experiences by lowering the stress and inconvenience associated with public transportation in underdeveloped nations like South Africa.

Also, the IRIS will have a significant socio-economic impact on stakeholders (PTOs and commuters). Some of these include the possibility of job displacements for non-technology-savvy employees of PTOs due to automation. On the positive side, it will also facilitate the recruitment of many technology-skilled personnel by PTOs. According to Mccrocklin [55], based on data from Worldometer and Statista, in 2019, "South Africa had a population of 58.56 million and 101.9 million mobile subscribers spread across five main mobile network operators". Also, according to Mccrocklin [55], South Africa has over 95% mobile phone penetration. Additionally, 91% of all phones in the country are smartphones, a relatively high percentage compared to most countries in sub-Saharan Africa. Hence, it is expected that many commuters can immediately consume the services of the IRIS. However, for the significant few that remain, PTOs and government authorities can initiate special smartphone ownership schemes in collaboration with the major telecommunication providers to ensure that more persons can acquire smart digital devices at an affordable cost and cheap internet data rates.

### 5.3 Recommendations

Based on the findings from this study, we present some recommendations to address the challenges of IRIS and to ensure that the requirements of the IRIS identified by stakeholders are satisfied.

**i. Challenges of public transport (RQ1)**

A substantial investment is required to enhance and maintain the transportation infrastructure, along with integrating Public Transport Operators' (PTOs) systems into the improved infrastructure. This investment is crucial to accommodate the anticipated population growth and unlock the complete benefits of an IRIS. Also, the government needs to implement policy reforms that incentivise and support improvements in the public transportation sector. This may include regulatory changes, subsidies, or other policy instruments encouraging better service delivery. The other recommendation is to create awareness and education programs to make commuters and PTO staff realise the benefits of an IRIS, which could reduce the concerns and resistance regarding implementing the IRIS.

**ii. The requirements for an IRIS (RQ2)**

There is a need to invest in state-of-the-art technology initiatives such as Vehicular Internet of Things (Vehicular IoT), Artificial intelligence (AI) and Fourth Industrial Revolution (4IR) technologies to enhance the efficiency and reliability of public transportation. These modern technology initiatives will play a crucial role in addressing congestion, delays, and communication issues. Commuters also expect to consume real-time information from devices such as mobile phones, display screens, and other digital platforms. Therefore, the IRIS must be interoperable and responsive for different screen types. Apart from the functionality, the non-functional aspects of the IRIS, such as security, must be attended to because users are concerned about how their data will be stored and protected.

## 6. CONCLUSION

This study explored the various challenges affecting the provision of real-time information for public commuting in South Africa to understand the stakeholder requirements for an IRIS for public commuting in a developing country such as South Africa. We undertook a qualitative study where data was collected through interviews with PTOs (public road transport, rail transport, private road transport, taxi association) and co-design sessions with commuters within the Western Cape province of South Africa.

The findings suggest that the growth and improvement of the public transportation system in developing countries like South Africa have long been plagued by several challenges. These include unreliability, safety, and socio-traffic problems like accidents, crowding, and congestion. At the same time, infrastructure is deteriorating due to insufficient investment projects and neglect. From the commuter perspective, we found that the critical requirements for an IRIS in the South African context are capabilities for searching information, multiple payment methods, support for multiple languages, and identifying the live location of vehicles on interactive maps. In addition, private transport operators (PTOs) require features such as managing drivers and fleet and customer reviews, which aid them in their administrative duties.

The findings also suggest that implementing an IRIS can benefit commuters by providing real-time information to support decision-making on modes and routes. However, to get the best experience from such a system, the features need to be well understood from all stakeholders' perspectives. The stakeholders also expressed several concerns regarding the IRIS, which include low digital literacy of commuters, lack of access to high-end digital devices, delay in the arrival times of buses, undue interference in the operations of PTOs by government, unfavourable fare increases; accuracy and currency of information from the IRIS; revenue sharing amongst PTOs; availability of taxi after regular working hours; poor state of infrastructure; unhealthy competition amongst PTOs; the impact of enforced standardisation and accountability on operations of PTOs; complexity of sourcing from different PTOs; and system downtimes due to regular power failure (load shedding).

This study makes an academic contribution by providing insights into the nature of public transport in South Africa and the critical requirements for designing and developing an integrated real-time information system (IRIS). The practical contribution of this study is that its findings offer significant insight into enhancing South Africa's transportation landscape. Also, the recommendations of this study will contribute to the formulation of policies that will advance infrastructure development and improve public transport service delivery standards for the benefit of commuters in South Africa and other developing countries.

In future work, the identified requirements will be used for prototype development and implementation of an IRIS. We will also conduct exploratory studies on the potential for its adoption and uptake by South African PTOs, commuters and government agencies. As a future research direction, we shall explore how emerging technologies such as Artificial Intelligence (AI), machine learning, and blockchain could enhance the IRIS's functionality and effectiveness and elicit stakeholder requirements for the IRIS. Further investigations will focus on evaluation studies involving commuters, public transport organisations (PTOs), and government agencies in South Africa. Specific focus will include assessing the impact of IRIS on commuters' behaviour and traffic congestion management. We will also conduct evaluation studies regarding the usability of the IRIS, interoperability assessment (INAS) of PTOs based on the IRIS, and the influence of the IRIS on public transport efficiency, safety and effectiveness.

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