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Analysis of Digital Technological Applications in Public Transportation Systems Ticketing and Communications: Reviews of Singapore, Sydney, Cape Town and Lagos Experiences

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1 ABSTRACT

The world's urban population has seen an unprecedented growth in the last few years and will continue to soar rapidly in the coming years. Public transportation systems need to be equipped to handle this influx of people into cities. Digital technology applications have been adopted in public transportation systems by many cities around the world to help optimise trips. However, the various digital technology applications and experiences in developed and developing cities remain understudied.. The study uses qualitative data in the form of content analysis and case study analysis through the investigation of four cities, Singapore, Sydney, Cape Town and Lagos, and their implementations of digital technologies – ticketing and communication in public transportation systems. Through the analysis of two developing cities in Africa and two developed cities in Asia and Australia, the lessons of cities' peculiar experiences provide valuable insight around contactless payments such as mobile ticketing and smart cards and smart applications in the form of mobile applications which provide trip details. Finally, the study draws on each case by highlighting the uniqueness of lessons learnt when implementing digital technologies to improve public transportation systems. Future research into user experiences of digital technology applications in public transportation is necessary in providing deeper understanding of their effectiveness.

Keywords: digital technology, public transport, smart cards, ticketing, smart applications

2 INTRODUCTION

The world's urban population has seen an unprecedented growth in the last few years and will continue to soar rapidly in the coming years. By the year 2050, the world's urban population is expected to rise to 68%. This will further issues of traffic congestion, decreased parking availability and an increase in pollution. Therefore, there is a need for improved public transport systems which are equipped to handle this influx of people into cities (Bieler et al. 2022). Digital technology applications have become extremely popular in public transport systems, with smart cards and smartphones replacing the use of paper tickets as a method of payment (Durand et al. 2023). Information communication and technologies (ICT) have transformed public tranapsort systems. The most popular form of ICT is the smartphone. Majority of public transport users around the world have access to smartphones and public transport applications have proven to be very useful in disseminating public transport information through mobile applications and collecting user data through these very applications (Strenitzerova and Stalmachova 2021).

The paper starts by analysing literature on digital technology applications in public transportation systems, focusing on ticketing and communication, it then goes on to review the four different cases and finally concludes by drawing on the lessons learnt from each case.

3 LITERATURE REVIEW

3.1 Smart ticketing

Ticketing of public transport around the world are now dominated by Automated Fare Collection (AFC) systems (Li et al. 2018). These systems include contactless payments such as smart cards, smart watch payments, mobile payments (debit/credit cards), scanning QR codes and fare readers that read different methods of payment (Sydney.com 2023). Smart card data proves useful in determining different user trip characteristics, making it easier to improve on existing and new public transport plans. However, smart card data cannot provide other important details such as trip purpose, user satisfaction and so forth (Mohamed et al. 2016).

3.2 Communication

Mobile usage in public transport is becoming a popular option for not only paying fares and purchasing tickets via mobile apps but to also receive information pertinent to trips from these applications as well (Bieler et al. 2022). Information and Communication Technologies (ICT) provide useful information to users of public transport systems, in the form of trip planning, mode options and links between different modes to make effective and efficient decisions. However, there are limitations to having ICTs in public transport. Three key limitations are users access to the technologies, user's technological skill levels and just how pertinent and reliable the information provided by the technology is (Ryseck 2019).

4 METHODOLOGY

The study collected qualitative data in the form of case study analysis. Four cities were selected based on digital technology applications within the public transport system. The four cities selected were Singapore, Sydney, Cape Town and Lagos, as the cities represent two developed cities in Asia and Australia and two developing cities in Africa respectively. Data was sourced from Google Scholar, Scopus, Web of Science as it allowed for more access to information pertinent to the study. The data was further broken down into digital technology applications implemented in the form of ticketing and communication for each city.
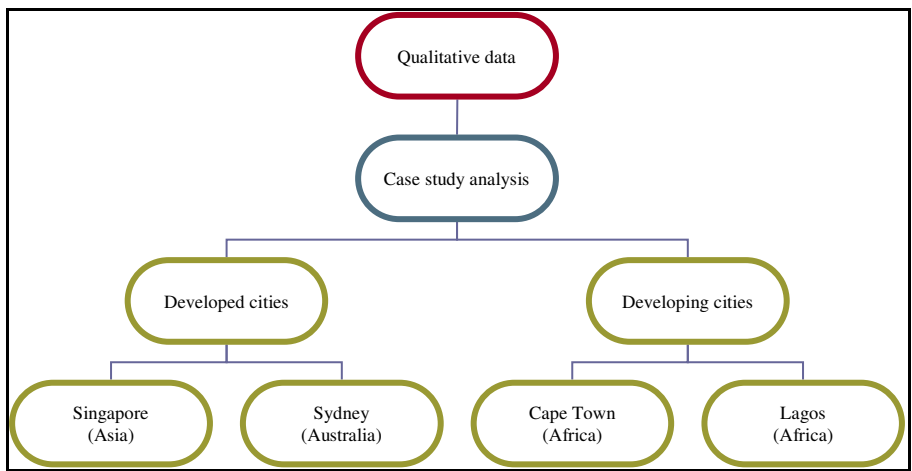

Figure 1: Breakdown of data collection and analysis (Source: Authors 2023)

The last stage of analysis was the creation of a table of the unique lessons learnt by each city's experiences of implementing digital technologies in public transport systems. Above (Figure 1) is a breakdown of the stages between data collection and analysis.

5 RESULTS AND DISCUSSION

The results below analyse four different cities, Singapore, Sydney, Cape Town and Lagos. Each city is broken down into the method of ticketing and communication used in the city's public transport system. The approach to the cities public transport planning is also explored to provide a context for the decisions made by the cities.

5.1 Singapore

Singapore occupies an area of 719,1km² and has an extremely high population density ratio, resulting in an increasing demand for public transport. Therefore, Singapore looks to mitigate the negative effects of this increased demand through the implementation of more sustainable public transport policies. The three core elements of Singapore's public transport policies lie with decreasing the use of private motor vehicles, increasing shared mobility and public transport and finally improving the integration of transport and land use planning. The policies further focus on smartness, inclusiveness and greenness. Singapore achieves sustainable public transport through efficient public transport systems that promote economic developments, strict private vehicle regulations coupled with environmentally friendly modes of transport which contribute to environmental sustainability and lastly, imposing high vehicles taxes and affordable public transport fares encourages social equity (Diao 2019; Haque et al. 2013 and Singapore Academy of Corporate Management 2024).

Users of public transport in Singapore can make use of two modes of payment, one in the form of a contactless smart card and the other is mobile payment approaches (Wolniak and Grebski 2023). Singapore's electronic ticketing system is the EZ-Link card (Zhu 2020). The EZ-Link card was first introduced in Singapore in April 2002. The card allows public transport users to pay for different modes of transport creating a more integrated system as well as an easy and efficient payment method (Wolniak and Grebski 2023). It is important to note that the EZ-Link card can also be used for other payments such as some retail purchases, tolls and parking. The fares of the card are dependent on the distance travelled, the age demographic of users giving a cheaper rate to seniors, students and children (Chakirov and Erath 2011).

Figure 2: EZ-Link card reader (Source: EZ-Link 2023)

The EZ-Link card is so widely used that it was found that between 1 August 2013 and 31 October 2013, 97% of public transport users had used the EZ-Link card for payment of trips and only 3% of users paid using cash (Liu et al. 2019). In 2022, EZ-Link card readers were able to read Mastercard and EZ-Link's collaboration called Pay by Wallet through loading the card on users' mobile devices which were able to make contactless payments for public transport trips and other e-commerce payments (Ang 2022). EZ-Link smart card data was found to be a useful source for research. A study found that data provided by the smart card combined with data from StarHub mobile geolocation would be able to determine and create popular feeder routes and main public transit lines and can explain the variables affecting route choice (Poonawala et al. 2016).

The EZ-Link card is linked to an EZ-Link mobile application which allows users to real-time top-up their EZ-Link cards, making tracking funds and rewards easier and reducing queues at ticketing machines (EZ-Link 2023).
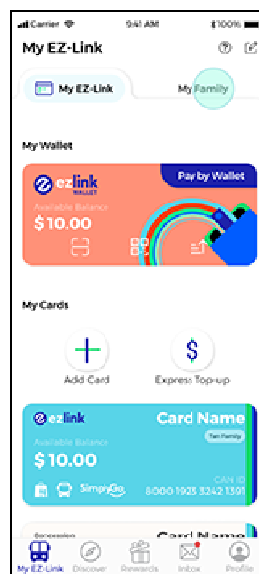

Figure 3: EZ-Link Mobile app (Source: EZ-Link 2024)

Singapore has another mobile application called 'SG bike' that allows you to locate bicycles real-time through the application or physically, once located at a docking station, scan the QR code on the bicycle with the application and it automatically unlocks the bicycle for use. Bicycles can also be unlocked with a membership card (Wolniak and Grebski 2023).

5.2 Sydney

Covering 12368,7km² of land, Australian public transport planning has been centred around land use planning which is a facet of metropolitan-based strategic plans. However, in the last two decades, public input around the processes and policies which govern the city have taken the forefront in planning and is referred to as 'consensus-based planning'. Australian cities, specifically Sydney, seek to integrate land use and transport planning to allow for the improvement in accessibility of residents. The financing and urgency of transport plans are not discussed with the public which tends to lead to financing and first preference going to high-profile road projects and not to public transport projects (Legacy, Curtis and Scheurer 2017 and City of Sydney 2023).

Sydney has adopted an electronic ticketing system in the form of a smartcard for public transport. The smartcard is called the Opal card, which replaced the previously used paper tickets. The Opal card was introduced between 2013 and 2014 in a step-by-step method (Ellison et al. 2017). The Opal card provides an integrated transport system as the card can be used on different public transport modes, which are; bus, train, light rail and ferry (Qu 2022). Though the Opal card itself provides contactless payments, Opal card readers also allow contactless payments from Visa debit and credit cards, Mastercards and American Express cards (Sydney.com 2023). There are six different Opal cards; adult, child/youth, gold, concession, school and free opal cards. Each card has a different has a different fare with the adult Opal card paying the highest fares.

Figure 4: Sydney's Opal card for public transport payments (Source: Poposki 2019)

A study conducted on the travel behaviour of public transport users based on the introduction of the Opal card system found that the new system was much simpler in terms of fare structures than the previous paper ticketing system and encouraged more car to train switches. Users of the Opal card were also more likely to use public transport on weekends as the new fare structure allows for unlimited trips capped at $50 a week for adults (Ellison et al. 2017). The Opal card itself is useful in collecting data on travel behaviour as it was able to track the patterns of seniors in order to analyse their preferences of public transport use (Harada, Birtchnell and Du 2023).

In 2015, it was recorded that 79% of Australians were using smartphones (Tompson 2015). Sydney has two mobile applications available to public transport users. The first application is called 'TripView' and provides timetables for different public transport modes.

A study conducted in Sydney found that the TripView app is popular among those with intellectual disabilities and therefore helps improve social inclusion in public transport (Danker 2023). The second application is called 'Next Station' and not only provides timetables of different public transport modes but also includes real-time vehicle position as well as service notifications that can be set to various languages (Sydney.com 2023).

Figure 5: TripView App summary of trip view (Source: TripView 2024)

5.3 Cape Town

The population of Cape Town was at an estimated 3.78 million in 2018 with an area of 2455km². Cape Town is the most traffic-congested city in South Africa, having both low- and high-income areas (Smith 2021 and New World Encyclopedia 2024). The history of Apartheid planning has greatly influenced the city of Cape Town and its spatial characteristics. Cape Town has a growing issue of urban sprawl which has since worsened by public-led investments. This means that residents have to travel further distances (to and from work, education, entertainment, and so forth), having major implications on the cost of trips increasing. The planning of public transport in Cape Town is handled by the Transport and urban Development Authority (TDA) agency. The TDA aims to achieve the implementation of a high quality and inexpensive public transport services. The city is guided by policy in the form of the National Land Transport Act from 2009 which requires Cape Town to have a Comprehensive Integrated Transport Plan (CITP) to guide public transport planning (Allansson and Kajander 2017).

The MyCiti bus rapid transit (BRT) uses a smart card payment method called the MyConnect card. The MyConnect card was made available free of charge to South African users in 2013, however, a R30 fee to pre-load Mover points was required to attain the card (MyCiti 2013). In order to use the BRT, users are required to possess a MyConnect card. There are no other payment methods available other than the MyConnect card on the BRT. However, the MyConnect card is only available for payment on MyCiti BRTs and no other form of public transport in Cape Town. The MyConnect can now be purchased for R35 from MyCiti booths or from retailers that sell the card. One use cards can also be purchased for R30 and airport route cards for R100. All MyConnect cards require a pre-load Mover points before travelling. The fares of the MyConnect card are dependent on the distance and whether the trip is peak or off-peak. The smartcard comes with different fare packages available for regular and occasional users, with regular users attaining discounts. Users are able to tell when their cards need to be topped up by the validator turning yellow and beeping twice (less than R20 available) and red beeping five times when payment is unsuccessful (no funds available). Users are charged a penalty for unsuccessful payments (Smith 2021).

The MyConnect card has been a useful tool in research projects which analyse travel data that include routes of users through the process of route node insertion to generate various network scenarios to optimise MyCiti BRT routes as there have been financial losses incurred by the service and a lack of funding to help solve these issues (Mzengereza 2021).

Figure 6: MyConnect card being tapped aboard MyCiti BRT (Source: MyCiti 2024)

Cape Town has three active ICT mobile applications that provide public transport users with schedules which are essential to trip planning. The three apps are 'GoMetro app', 'TCT app' and the 'iOSMyCiti app' which is not an official one.

Figure 7: Transport for Cape Town (TCT) app (Source: Sustainable Energy Africa 2017)

The city had two other apps called 'Transport Hero' and 'Public Transport App' to provide a similar service, however, due to little marketing and a low number of downloads, both applications were removed from the Android and iOS app stores (Ryseck 2019 and Ryseck 2022).

5.4 Lagos

Lagos has an area of 3345km² and is the highest populated city in Africa, with projections for 2100 being between 61 and 100 million inhabitants. Therefore, the city experiences the most traffic congestion in Africa. This increase in population means that there will be an increased demand for transportation (Paul and McSharry 2021 and Britannica 2024). In 1999, in conjunction with the newly appointed government, the World Bank introduced the Lagos Urban Transport Project which aimed at introducing a BRT, water transport, cable car and rail services. The Lagos Area Metropolitan Transport Authority (LAMATA) was then established through the Lagos State Ministry of Transport. Lagos has over 100 agencies of local, state and federal government which all would act in their own powers in making transport planning decisions, therefore, the introduction of LAMATA provided strategic goals that assisted agencies of government to work towards to (Klopp, Harber and Quarshie 2019).

Lagos has had two methods of paying for public transport, the Lagos connect card and Cowry. In 2015, Lagos launched their first BRT service called the Metro Bus. Along with the launch of the Metro Bus was the installation of a Card Validator and a Lagos Connect Card. The Lagos Connect Card could be tapped when entering and exiting the bus in order to get a 20 naira discount on any trip. At the time of the launch, it

was reported that not all buses had active card validators, many of the terminal points did not have card recharging services, passengers were being overcharged on trips and validators being switched off by drivers as paper tickets made more money (Popoola 2015).

Figure 9: BRT Lagos app (Source: AppAdvice 2024)

Within the Cowry payment system, there are two forms of payment. First is the Cowry card which can be tapped (using NFC technology) upon entering and exiting the public transport mode. The Cowry card can be used on all transport modes such as ferry, BRT buses, and the First Mile and Last Mile (FMLM) Scheme, however, the BlueLine railway is still in the integration process. The Cowry app is the second form of payment, users can scan the app generated QR code at the readers. Users can top up their Cowry cards through the Cowry app wallet by a service agent or self-service validator at the relevant terminals (Cowry 2024). Use of the Cowry Card commenced in February 2021. A Cowry Card costs 200 naira (for a paper card) and 400 naira (for a plastic card). Card balances are displayed on the validator post payment to alert users on their balances (Joshua 2021). It seems that the current Cowry payment system has replaced the Lagos Connect Card system. Another mobile app would be the Lagos BRT app which provides real-time locations of BRT buses which are sent to central intelligence and transforms the GPS details to bus arrival and departure times for users. The app also provides users with other buses available close to their BRT stops (Amiegbebhor and Popoola 2021).

6 LESSONS LEARNT

Each city has had unique experiences with smart ticketing and communication. Fig. 10 shows the lessons learnt by each city. The lessons can be noted by other cities looking to implement such services.

7 CONCLUSION

The world's urban population continues to grow, making the need for efficient public transport systems extremely important. Both African cities, though both being some of the most developed developing cities in Africa faced challenges with smart ticketing and smart communication systems. However, these two African cities implemented alternative systems in response to previous challenges which proved that implementing such technologies in Africa requires a trial and error process which allows for tailor-made solutions that may not be applicable in developed cities. All cities allow for the use of smart card payments across different modes of transport except Cape Town which leaves room for creating a more integrated public transport system, thereby increasing mobility. However, Cape Town has spatial expansion restrictions in terms of the mountains and waterfront, Sydney has a large harbour, a series of waterways and challenging topography in some parts. Lagos has a similar situation being located on a strip of land between the Atlantic Ocean and a lagoon. Singapore also has spatial restrictions being an island, this means that public transport needs to be implemented strategically in all of these cities as they each have unqiue spatial challenges. One instance

where the African cities proved more user friendly would be the balance warnings promting users to top up which are not seen in the Singapore and Sydney systems. The implementation of the two systems improves convenience, optimisation, efficiency, accessibility and user experiences. The study found that the introduction of digital technology applications was not without its challenges but overall positively improved public transport systems not only for users but for transportation planning as well.

City	Lessons learnt
Singapore	The strict private vehicle regulations and high vehicle taxes coupled with environmentally friendly modes of transport and low fare public transport reduces private vehicle use.
	Two modes of payment (smart card and mobile) makes it easier for users to pay.
	EZ-Link card can be used to pay for various modes of transport and other small retail payments aiding in public transport integration.
	Fare structures generated on distance travelled coupled with other factors helps users attain fare discounts.
	EZ-Link data was able to determine and provide popular feeder routes for users.
	EZ-Link app made for easier EZ-Link top-ups reducing ticketing queues.
	'SG bike' provides non-motorised transport to users at anytime through the scanning of a QR code or membership card.
Sydney	Financing of public transport projects not being discussed with the public leads to finances being used rather on high-profile road projects.
	Opal card readers not only allow Opal card payments but other mobile and credit and debit card payments, which creates efficiency during payments.
	Opal cards can be used to pay for multiple modes of public transport creating an integrated public transport system.
	Studies show that the new card system fare structure was easier for user to understand and increased car to train switches.
	Fare capping encouraged more weekend trips.
	TripView app provides timetables of different public transport modes.
	TripView aids in social inclusion.
	'Next Station' app also provides timetables, real-time vehicle positioning and service notifications making it convenient for users.
Cape Town	The spatial form of Cape Town (urban sprawl) makes public transport planning difficult.
	The MyConnect Card can only be used for payments on MyCiti buses which does not promote public transport integration.
	No other methods of payment are accepted on the MyCiti BRT making it inconvenient for users.
	Regular users get higher discounts making public transport more affordable for everyday use.
	Warnings for low balances alerts users to top up before next trip and penalties for unsuccessful payments encourages top ups.
	MyConnect card data assisted in route optimisation of the BRT.
	Three different mobile apps for public transport schedules helps user communication.
	Low marketing on public transport apps leads to low use and eventual discontinuation of the apps.
Lagos	The creation of LAMATA helped effectively plan public transport systems.
	Use of the Lagos Connect Card ensured a discount encouraging smart card use.
	Various issues around inactive card validators, lack of recharging services and overcharging trips with the Lagos Connect Card led to the introduction of a new system called Cowry.
	Cowry can be used to pay for different transport modes promoting public transport integration.
	Cowry card and Cowry app serves as payment methods for public transport which is convenient for users.
	Balance alerts make it easier for users to know when to top up cards.
	Lagos BRT app provides real-time location information which makes bus arrival and departure times readily available to users.
	Lagos BRT app furthers convenience through providing users with other buses available close to their BRT stops.

Figure 10: Lessons learnt from Singapore, Sydney, Cape Town and Lagos (Source: Authors 2024)

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