17. Smart transport systems in SADC countries

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Abstract

African cities face many challenges related to transport. These include poor infrastructure, congestion, and lack of connections between different modes and providers. These challenges make traffic slow, unreliable and inefficient, impacting on the ability to do business and the quality of life of residents. Smart transport systems are being applied in many cities to ease traffic problems. Recent research seeks to benchmark levels of smart transport in cities. These benchmarks assume smart systems that are solely technological and operate without human intervention. They also rely on good infrastructure. In contrast, other researchers are investigating the use of Mobile Crowd Sensing and Computing systems that make use of people as elements in smart systems. This paper investigates the extent to which cities in SADC countries could make use of cellphone apps to provide such smart systems with low infrastructure needs. We examined transport-related apps that have been produced in SADC countries and the extent to which they exhibit the characteristics of smart systems. We propose a new framework for evaluating the smartness of such apps. The data suggest that there are such systems operating in SADC countries and that such smart transport systems could contribute to improving traffic in SADC countries.

Keywords

Transport, Smart systems, Smart transport systems, Mobile sensing, MCSC systems, SADC

1 Introduction

African cities face many challenges related to transport. These include poor infrastructure, congestion, and lack of connections between different modes and providers (Mutambara 2009, SADC 2012). These challenges make traffic slow, unreliable and inefficient, impacting on the ability to do business, hindering economic development, and negatively impacting the quality of life of residents (Njoh 2008).

Smart transport systems are being developed and installed in many cities to ease traffic problems. Smart systems are characterised as having sensors to collect data, the means to process data and make decisions as well as the means to act on those decisions (Akhras, 2000). Recent research seeks to benchmark levels of smart transport in cities (Debnath et al. 2014). These benchmarks assume smart systems that are solely technological and operate without human intervention, such as vehicle detection in parking facilities or at toll gates and electronic displays at public transport stations. Such solutions rely on infrastructure and so the benchmarks have been identified as only relevant to cities with such infrastructure (Debnath et al. 2014), effectively excluding cities in Africa.

Other research has recognised the role of people as sensors in smart systems (Guo et al. 2015, Rizzo et al. 2017, Tomasini et al. 2017). People sharing information through cellphones form sensor networks (Tomasini et al. 2017), or location-based social networks (Rizzo et al. 2017), that provide large amounts of data relating to perceptions of the city and linked to location. Such networks have the potential to create smart systems and are readily available in African cities.

So the potential exists for developing smart transport systems based on social networks to address transport challenges in African cities. This paper examines whether there are any such systems, and the extent to which they are smart, in countries within the Southern African Development Community (SADC).

2 Transport in SADC countries

The Southern African Development Community (SADC) includes large and small countries and economies, and a combination of low and middle income countries (SADC 2012). A number of the 16 SADC counties have inadequate transport and communication infrastructure, which limits their ability to participate effectively in global economic networks (Njoh, 2008). The World Economic Forum's Global Competitiveness Report identifies only seven countries in Africa with transportation matching international standards (WEF, 2016).

The growing population and urbanisation has caused a world-wide increase in the demand for transport services (Debnath et al. 2014). People and merchandise in SADC countries are transported primarily via road and rail and these transport links are also crucial for imports and exports (Mutambara, 2009). However problems in transportation in Africa extend across all modes of transport: road, rail, port and air. In cities a major challenge is congestion as city road infrastructure is often inadequate and the availability and quality of services does not yet meet the demand of growing populations and businesses (Njoh 2008, Khumalo and Chibira 2015). Lack of integration between transport systems is a weakness with systems often being uncoordinated due to poor relationships between stakeholders (Khumalo and Chibira 2015). Such lack of coordination makes for inefficiencies (Njoh 2008).

As many SADC countries are land-locked, transport networks are essential for mobility and to provide links to the major SADC ports in South Africa, Angola, Mozambique and Namibia (Mutambara, 2009). As a result, trans-regional transport has been identified as a major issue within SADC countries.

Countries in the SADC acknowledge the need for capital investment to develop transport and some efforts have been made in this regard (SADC 2012). Investments have been made into infrastructural upgrades; however outdated systems are still in use. In addition, the poor information and communication devices and weak telecommunication connections intensify problems and limit productivity in transport (Khumalo and Chibira 2015). In order to meet the transport needs in SADC countries, efforts have been directed towards increasing participation of the private sector entities in the provision of transport services. However, even with this contribution, there are gaps in funding and technical capabilities (SADC 2012).

In 1996, the SADC introduced the Protocol on Transport, Communication and Meteorology to address multiple issues and regulate the transport sector (SADC 2012). The protocol mandated countries within the SADC to "facilitate the unimpeded flow of goods and passengers between and across their respective territories by promoting the development of a strong and competitive commercial road transport industry which provides effective transport services to consumers" (SADC 1996, p17). It is anticipated that the full implementation of the Protocol will have long term benefits for the region (Khumalo and Chibira 2015).

3 Smart transport systems

Smart transport systems offer the physical infrastructure of traditional transport systems with added informational capabilities. Smart transport systems sense the location and behaviour of transport vehicles and vessels, make assessments and decisions, and communicate information about the system to users and controllers (Debnath et al. 2014). So, for example a smart transport system might detect where buses are on a route and how full they are, identify the need for more buses and deploy another bus, and inform passengers of the additional service.

A smart transport system has been characterised as one based on smart technologies (Debnath et al. 2014, Goldman and Gorham 2006, Santos, Behrendt and Teytelboym 2010). A smart technology is defined as a “self-operative and corrective” technology which “requires little or no human intervention” (Debnath et al. 2014, p48). The basic capabilities of smart systems have been identified as having (1) sensors that collect data, (2) a processing capacity to analyse the data and make decisions, (3) actuators that enable the system to act on those decisions and (4) the capacity to communicate (Akhras 2000, Debnath et al. 2014). In addition, advances in data science enable smart systems with expanded higher-order characteristics: the ability to predict, heal and prevent (Debnath et al. 2014).

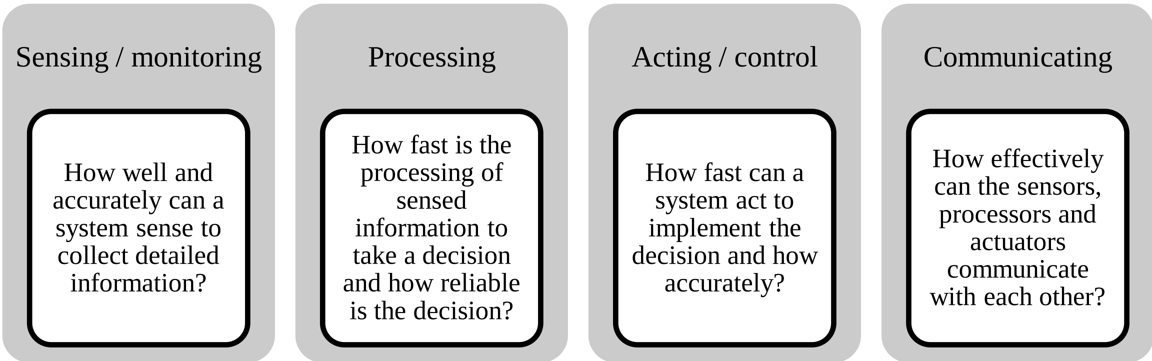

Figure 1: Basic capabilities of a smart system (Debnath et al. 2014)

Debnath, et al. (2014) developed a generic matrix of smartness indicators for smart transport systems that can be used as the basis for developing indicators for benchmarking the smartness of transport in cities. The matrix identifies the kinds of infrastructure and technologies that can be provided for private, public and emergency traffic in terms of each characteristic of smart transport systems. So, for example, the matrix includes the use of occupancy detectors as sensors for private transport and the display of arrival information as a communication capacity in public transport.

In illustrating their proposed benchmarking, Debnath et al. select 26 cities based on their level of infrastructure and size of population. They argue that cities with good infrastructure have “the potential to deploy smart technologies” (Debnath et al., 2014, p51) and many of the items proposed in the matrix of smartness indicators do indeed assume costly infrastructure. The implication of this benchmarking exercise is that cities cannot take advantage of smart systems to improve transport without deploying costly infrastructure.

However there is increasing awareness that smart systems, far from excluding humans, may make use of humans as sensors. With the advent of cellphones, people share information about their location and activities either passively or actively as they move around the city. This data collection has been characterised as forming sensor networks (Tomasini et al. 2017), or location-based social networks (Rizzo et al. 2017). Since transport systems are so closely concerned with the location and movement of people, such sensor networks could provide effective inputs to smart transport systems, without the need for complex and costly infrastructure.

In addition to acting as sensors, people can also act as actuators in smart transport systems by making choices about which transport to use when. Some researchers have suggested that people can even provide the capacity to analyse data and make decisions through crowd data processing in Mobile Crowd Sensing and Computing (MCSC) systems (Guo et al. 2015).

Mobile Crowd Sensing and Computing (MCSC) is defined as "a new sensing paradigm that empowers ordinary citizens to contribute data sensed or generated from their mobile devices, aggregates and fuses the data in the cloud for crowd intelligence extraction and human-centric service delivery" (Guo et al. 2015). Examples of MCSC applications that have been developed for transport include applications that report on traffic dynamics (Calabrese et al. 2011, Liu et al. 2009, Wen et al. 2008), public transport (Chen et al. 2013, Morency et al. 2007, Zhou et al. 2012), aid individual travel planning (Thiagarajan et al. 2009, Wolfson et al. 2013, Costa et al. 2011, Koukoumidis et al. 2011) and report on road conditions (Mohan et al. 2008, Eriksson et al. 2008).

4 Research questions

In African cities, where budgets are stretched and more pressing needs exist, investments in infrastructure to support smart transport systems are unlikely. However African cities enjoy large populations and high penetration of cellphones and so the potential exists for using cellphone apps to create location-based social networks that can form the basis of smart transport systems that have low infrastructure needs. This begs the question:

To what extent can cellphone apps be used to develop smart transport systems for African cities?

In trying to understand this potential, we investigated the following questions:

1. What transport-related cellphone apps have been developed in SADC countries?
2. Do these apps display the characteristics of smart systems, and to what extent?
3. What insights do any existing examples of smart transport systems based on cellphone apps provide as to the potential for other such systems?

5 Data collection and analysis

We collected data from the Google Play Store and Apple iStore. Our search took place in October 2016 and we searched using the keyword "transport" and the name of each of the 16 countries in SADC. We eliminated apps, like Uber, that were not developed in SADC countries because we were interested in local solutions.

The description (in the online store) of each app was examined for an initial assessment of smartness, looking for evidence of the four basic characteristics of smart transport systems. Apps that showed signs of being smart were downloaded and used in order to increase our understanding of their functioning. The analysis of the smartness of each app is described below.

In conducting this analysis the basic capabilities of smart systems identified by Debnath et al. (2014) as well as the characterisations by Guo et al. (2015) of sensors as active or passive and processing of information as human and machine were combined to create a new framework for evaluating the smartness of apps. This framework is applicable to smart systems that lack a human component as well as to MCSC apps, making it more versatile and relevant to the African context than existing frameworks.

6 What transport-related apps have been developed in SADC countries?

Seventeen (17) transport-related apps were identified, of which 14 were developed in South Africa and one each in the Seychelles, Tanzania and Zimbabwe. Thirteen of the identified apps were developed by private companies, three were developed by government bodies and one was developed by a public-private partnership (PPP).

The apps provided information about transport by road, rail, air and water. Thirteen of the apps were concerned with road transport, eight with rail, five with air and one with travel on water. Eight of the apps provided information for more than one mode of transport, indicating that there are companies trying to tackle the problem of disjointed transport systems.

Seven of the apps give information about private transport, although that includes SAA, the South African national airline which is a state-owned enterprise. Computicket supports both public and private transport operators. The remainder are all focussed on improving public transport, perhaps indicating a greater need for information in that sector.

Name of app	**Country**	**Transport Mode**	**Type of provider**	**Description**	**Transport sector**
CompuTicket	South Africa	Air, rail and road	Private company	Flight, bus and train bookings	Private and public
FindMyWay	South Africa	Road, rail and sea	Private company	Schedules.	Public bus, rail and ferry
Flapp (Travelstart)	South Africa	Air	Private company	Flight bookings	Private airlines
GauTimes	South Africa	Rail and road	Private company	Train schedules	Public train and buses
Gautrain	South Africa	Rail and road	PPP	Bus tracking, train and bus schedules	Public train and buses
GauRider	South Africa	Rail and road	Private company	Train schedules	Public train and buses
GoMetro	South Africa	Rail and road	Private company	Train and bus schedules	Public train and buses
GTAXI	Zimbabwe	Road	Private company	Cab bookings	Private taxis
GTBuddy	South Africa	Rail and road	Private company	Train schedules	Public train and buses
Mango Airlines	South Africa	Air	Private company	Flight bookings	Private airline
MovingGauteng	South Africa	Road and rail	Private company	Bus and train schedules	Public bus and train
MyCiti	South Africa	Road	Government	Bus schedules	Public busses
SAA	South Africa	Air	Government	Flight bookings	National air carrier
Vaya Moja	South Africa	Road	Government	Bus schedules	Public busses
Volo Cab	Tanzania	Road	Private company	Cab bookings	Private taxis
ZebraCabs	South Africa	Road	Private company	Cab booking	Private taxis

Name of app	Country	Transport Mode	Type of provider	Description	Transport sector
Zil Air	Seychelles	Air	Private company	Flight bookings	Private airline

Table 1: Transport apps developed in SADC countries

The number of apps developed in the region is really small and there are no apps being provided in many countries in SADC, indicating that there is space for more apps in the transport space. Four apps were all focused on providing information about the Gautrain train and bus service in Gauteng in South Africa. This suggests that the apps are developed in response to the demand for information by commuters.

Many of the apps are supported by web sites and a separate search for transport-related web sites found 54 sites across thirteen of the sixteen SADC countries. So more transport information is available on web sites and these sites might be accessible through cellphones as well.

7 Are these apps part of smart transport systems?

In assessing how smart such apps are we considered whether they displayed the four basic characteristics of smart systems: sensing, processing, acting and communicating.

Guo et al. (2015) distinguish between participatory sensing in the form of data automatically sent from mobile devices, often without the knowledge of the user (passive or implicit) and data that users actively and intentionally contribute through apps or other services (active or explicit) and so we distinguished between how the apps were using people as sensors to collecting data.

Hybrid Mobile Crowd Sensing Computing systems make use of both human intelligence (often embedded in the data that people contribute) as well as machine intelligence (Guo et al. 2015). The sophistication of the machine intelligence in use can range from basic computing functions to the use of sophisticated statistical and data science techniques. We categorised the processing ability of the systems in terms of whether or not they used human intelligence or machine intelligence. We also tried to discern the level of machine intelligence in use based on the functionality of the app. Almost all the apps made use of basic machine intelligence with only a few taking advantage of human intelligence. It was not possible to detect the use of advanced machine intelligence in any of the apps, although the web site supporting the FindMyWay app showed that the developers were aware of and possibly used or were intending to use more advanced algorithms.

The apps act primarily by feeding information back to the user, although some carry out a transaction and some act by initiating additional communication. As a result the user is the primary actuator in these systems, making the decision whether or not to take the transport or route. Taxi apps typically inform the driver of the vehicle and the controller, making them both actuators in the system as well.

The mode of communicating was in most cases through information displayed in the app although some (particularly those that processed transactions like Computicket and Flapp) also sent confirmatory emails. We found two apps that offered other forms of communication with the user: MyCiti offered a widget for more immediate communication without having to open the app, and MovingGauteng made some use of interactive displays. Some of the apps also communicated with other parties like a taxi driver, and in the case of GoMetro, with the user's employer.

Name of service	Description	Sense	Process	Act	Communicate
Compu-Ticket	Flight, bus and train bookings	User provides information (active)	Uses static information to identify booking options (basic machine)	User acts to initiate a transaction	Communicates with the user through the app and by email
FindMy-Way	Schedules.	User provides information (active), detects location of vehicles (passive)	uses schedules, route info, current vehicle info (basic machine, possibly advanced machine)	User acts to use transport or not	Communicates with the user through the app
GauRider	Train schedules, calculates length of trip, fares, stores Smartcard balance	User provides information, reads Smartcard (active)	uses schedules and route information, and current train information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app
Gau-Times	Train schedules	User provides information (active)	uses schedules and route information, and current train information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app
Gautrain	Bus tracking, train and bus schedules	user provides information (active), may be using sensors on the trains to detect locations (passive)	uses schedules and route information, and current train information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app
GoMetro	Train and bus schedules	Detects location of buses and user (passive). Allows feedback from commuters about delays (active).	Uses timetables, announcements, updates, route maps and press releases to compute next train or bus (basic machine and human)	User acts to use transport or not	Communicates with the user through the app. Informs employer by email of transport delays
GTAXI	Cab bookings	Detects user and vehicle location, tracks location during ride (passive), users rate drivers (active)	Identifies nearest vehicle, tracks ride, keeps rating information (basic machine and human)	Assigns a driver, processes transaction, alerts controller	Communicates with the user through the app and to controller
GTBuddy	Train schedules	Detects location of buses and user (passive), user gives destination information (active)	Computes information from schedules and route information (basic machine)	User acts to use transport or not	Communicates with the user through the app
Mango Airlines	Flight bookings	User provides information (active)	Uses static information to provide flight options (basic machine)	User acts to initiate transaction	Communicates with the user through the app

Name of service	Description	Sense	Process	Act	Communicate
Moving-Gauteng	Bus and train schedules for all public buses and trains in Gauteng	Alerts input by passengers, chat with other commuters (active)	Uses schedules and route information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app and interactive boards at some locations
MyCiti	Bus schedules, routes and fares as well as transaction information	Uses android wear for location information (passive), scans cards and uses user input (active)	Uses schedules and route information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app and onscreen widget
SAA	Flight bookings	User provides information (active)	Uses flight and booking information as well as weather data (basic machine)	User acts to initiate transaction or to check in	Communicates with the user through the app
Flapp (Travel-start)	Flight bookings	User provides information (active)	Identifies cheapest available flights based on static information (basic machine)	User acts to initiate transaction	Communicates with the user through the app and by email
Vaya Moja	Gives bus routes, maps and timetable information for buses in Johannesburg	User provides information (active)	Uses schedules and route information to identify relevant information (basic machine)	User acts to use transport or not	Communicates with the user through the app
Volo Cab	Cab bookings	Detects location (passive), user supplies information about destination (active)	identifies free drivers based on location and availability (basic machine)	Informs driver, controller, processes transaction	Informs user of cab and driver, transaction details, tracks movement of cabs
Zebra-Cabs	Cab booking	Detects location (passive), user supplies information about destination (active)	identifies free drivers based on location and availability (basic machine)	Informs driver, controller, processes transaction	Informs user of cab and driver, transaction details, tracks movement of cabs
Zil Air	Flight bookings	User provides information (active)	Uses flight and booking information (basic machine)	User acts to initiate transaction	Communicates with the user through the app

Table 2: Smart characteristics of transport apps

Table 2 summarises our assessment of the smartness of the transport apps. From this we conclude that these apps do display the characteristics of smart transport systems, when viewed as MCSC systems. However the majority are unsophisticated and do not make use of the full potential of the technologies and people available to them.

The taxi apps are the smartest in that they make use of passive sensor information (user and taxi location) as well as active sensor information (user destination), they communicate to three actuators (users, drivers and controllers) and they use human intelligence (in the evaluation of drivers by users). Other apps that appear more “smart” are GoMetro, Moving Gauteng and MyCiti which are discussed in the next section.

8 Insights from examples

GoMetro appears to make use of sensors on buses to determine the location of buses and allows feedback from commuters about service delays. So it is using human intelligence to supplement information about routes and timetables. This app also offers the option of having a message sent to the user's employer informing them of transport delays, thus including an additional actuator in the system.

Similarly, Moving Gauteng allows passengers to raise alerts about the bus and train services, although it is not clear to what extent these alerts are used by the app. This app also facilitates communication between passengers, presumably so that other passengers can confirm service quality or delays. The app makes use of some interactive boards to communicate information to commuters who are not using the app.

MyCiti allows the user to communicate location information through an android wear device and also scans the card that is used for payment to give information about the cost of trips and the card balance. This app makes use of an onscreen widget to display information to the user without having to open the app.

None of the apps showed signs of the higher-order smart system characteristics: to predict, heal and prevent, however at least one plans to move in that direction. FindMyWay is developed by WhereIsMyTransport, a Cape Town-based company which wants to address the problem of lack of connectedness of public transport in cities. They have built an open data repository for collecting information about public transport which they use in the app to give users information about different routes they can take around the city (whereismytransport.com). WhereIsMyTransport are aware of the potential for using data science to introduce higher level smart system capacities as their web site explains that "over time, we can use what we've learned from the data to help cities optimise their transit networks".

9 Conclusions

African cities face challenges in transport that may be eased by the implementation of smart transport systems. Systems requiring large investments in infrastructure are expensive, but Mobile Crowd Sensing and Computing offers the means to build smart systems that make use of people with cellphones as sensors.

This research found 17 transport related cellphone apps that have been developed in SADC countries. These apps display the basic characteristics of smart systems, using people as sensors, to compute and as actuators. The apps address transport concerns across all modes of transport both public and private. While the apps are relatively unsophisticated, there is scope for the further development of such apps.

This paper constructed a framework for analysing the smartness of smart transport apps that combined the basic capabilities of smart systems identified by Debnath et al. (2014) as well as the characterisations by Guo et al. (2015) of sensors as active or passive and processing of information as human and machine. We further distinguished between basic machine computing and the use of advanced statistical and data science techniques. This framework is useful in assessing the smartness of systems whether or not they include a human component. The intention is to broaden the understanding of smartness making it more relevant to developing country contexts.

Further research is needed into the conditions necessary for the development and deployment of smart transport systems that make use of Mobile Crowd Sensing and Computing as a means to ease traffic problems. In particular more apps that address trans-regional transport would be of interest to the SADC region.

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