Towards Effective Bus Transit Service in South Africa: *automated passengers' authentication*

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ABSTRACT
Today, automation driven by information technology has overtaken the usual traditional manual operation in every key sector of human endeavor. It has greatly improved both productivity level and quality of service amongst other benefits. The existing bus transit system in South Africa (SA) is still characterized by inefficient manual operations among which are poor quality of service, non-user friendly and inefficient passenger identification. The pivotal economic and developmental role played by the bus transport sector in SA measures the weight of the need to fully incorporate advanced information and communication technology tools into its operations. This requires a system that automates all the bus transit services and has the capability to authenticate passengers electronically. Therefore, this paper proposes an automated bus transit system that offers e-subscription and real-time biometric passenger authentication as a solution to the challenges faced by the bus transit industry in SA. In addition, we have developed a novel system prototype with the technology required to fill the service gap.

Keywords
Transportation, Automated, Real-time, Bus

1. INTRODUCTION
Throughout human history, transportation has remain one of the most vital and indispensable organ of human activities. Ranging from the most ancient forms of transportation, using animals and wheel up to our modern day aircrafts, ships, speed trains, and buses or cars, the value of transportation still maintains its high significance to human and economic activities. In this case, societies cannot function without transportation. According to [1], the importance of transportation is described as "…*boarding a train or plane, or dispatching freight to the other side of the world are, for hundreds of millions of people, for hundreds of thousands of businesses, everyday acts which are both unremarkable and vital*".

Transportation is defined by [2] as "*the movement of people, animals and goods or services from one location to another*". The overall importance of transportation cannot be overemphasized because it facilitates the establishment of physical contact between people, goods, and services thereby promoting economic and social life. Like many economic activities that are intensive in infrastructures, the transport sector is an important component of the economy impacting on development and the welfare of populations. An efficient transport system has the potential to provide economic and social opportunities as well as benefits that result in positive multipliers effects such as better accessibility to markets, employment and additional investments [3]. By implication, an efficient system of transport is essential for a modern society with a competitive economy like South Africa (SA) for the purpose of rapid development. The current structure of SA transport system is divided into ports and shipping, roads, railways, airports and airlines. According to [5], available statistics indicate that 80 per cent of SA's population is totally dependent on public transport (bus, commuter rail and taxis) for its mobility needs. But unlike other means of transport, the bus transport system is yet to fully incorporate information and communication technology (ICT) tools into its services. These current bus transit companies still run all their operations ranging from ticket subscription to passenger authentication using the traditional manual approach.

Meanwhile automation plays an increasing important role in the world's economy and in daily activities. Transportation is not an exception as it is quite evident in modern day information technology (IT) enabled air ticket booking and reservation systems as well as rail and bus ticketing systems such as eFare 2010, MyWay smart card system, Gautrain etc. All these are already being implemented in several countries to help improve the quality of service in the transportation industry. Also running our mass transit systems manually would equally imply the absence of a central point of coordination. This is a situation where individual transport companies adopt isolated business and administrative policies. It is thus, not too healthy for both clients and the government since it introduces two important challenges:

1) Firstly, it makes it difficult for the government to monitor transport fares or implement a uniform transport fare system for equivalent distances across the country.

2) Secondly, there is the huge challenge of getting accurate data for appropriate budgeting, planning and forecasting in the transport sector.

In addition, other issues related to improving the quality of customer service and ensuring efficient passenger authentication to control fraud also remain a major problem. Therefore, in this research we propose an automated passenger authentication bus transit system that will be able to store passenger data in a central database and handle authentication of passengers in real-time mode using fingerprint technology. The goal is to ensure that the bus transit system operates effectively in SA cities and is beneficial to users and operators. As a proof of concept, we developed a system prototype called Automated Passengers Authenticated Bus Transit System (APABTS) to simulate the system's operations.

The rest of the paper is organized as follows: Section 2 is the current state of bus transit in SA, Section 3 is the design and analysis of the system, Section 4 is the prototype

implementation, Section 5 is APABTS' operation, Section 6 is the paper discussion and Section 7 is the conclusion.

2. CURRENT STATE OF BUS TRANSIT IN SA

SA land transport system presents a scenario that will be quite suitable for automation. This is because it is dominated by several privately run intra-city bus transit systems, offering monthly services on fixed routes to customers such as school children, students, civil servants, and others. To use these bus services, customers (passengers) have to pay a monthly fare or service subscription that covers their daily to-and-fro movement on a fixed bus route throughout the month subscribed for. But as mention earlier, the bus transit system is still being mired with series of challenges owing to its manual based operations. Interestingly, it has been revealed that a high proportion of average SA's students, businessmen, private, and government workers depend on the private bus mass transits for mobility [5]. Moreover, a significant amount of economic activities hinges on transportation service, making it obvious that an effective and efficient transportation system will no doubt have a direct positive economic impact or otherwise. In this case, transport is described as the heartbeat of SA's economic growth and social development [8]. Also, direct and indirect job creation in SA has been linked to transport and its related services, being a catalyst for economic growth [9].

The above fact in itself establishes the weight of the necessity to consider the option of an automated intra-city mass transit solution that will utilise the power of ICT to provide automated services. This paper will potentially address the concerns about the manual bus system through an automated passenger authentication bus transit system that will be web-based, support parallel ticketing, and use fingerprint to authenticate passenger in real-time mode. To show the effectiveness of the proposed system, Table 1 presents an evaluation of the system against the manual approach and other existing systems. As captured in Table 1, APABTS will be more secure, user-friendly, fault-tolerant and flexible if adopted for use.

3. PROPOSED SYSTEM ANALYSIS AND DESIGN

3.1 Functional requirements

For efficient and professional system development, there is need to first adequately elucidate the system requirements that will serve as blueprint for system design and development. This section then delineate the major system requirement namely – basic, general, passenger subscription, and passenger identification requirements.

3.1.1 Basic Functional Requirements

The requirements that form the core of the entire system are as follows:

R1-1: The system shall only allow a passenger to register only once on the subscription portal. **-** *Integrity*

R1-2: The system shall allow only VALID passengers to use the bus **–** *Authentication*

3.1.2 General Requirements

The general requirements take care of system usage and privileges. That is, who can use the system and at what level of allowable privilege. These include three kinds of system users – passenger, system administrator and support staff. It is here required that only authenticated persons are able to access or make use of the system and in accordance with their level assigned privileges. It includes the following two requirements:

R2-1 – Sign Up: This is the aspect of the system that enables certified system users to choose the platform of privileges to be associated with throughout the period of their system use by creating an account on the portal. This requirement ensures that only persons with certified credential are allowed to gain access to or use the system and that such a system user's tasks are only restricted within the boundaries defined by the associated privileges.

R2-2 – Sign In: With this feature, authenticated users are allowed to gain access to or use the system. It is meant to guarantee that only certified passengers, system administrator or support staff are enabled to use the system to perform tasks as defined by the associated privileges.

3.1.3 Passenger Subscriptions

Since the system makes use of an online portal and database that stores both passenger and administrative information for security, accounting, and support purposes, there has to be some features to support such functionalities as mentioned above. These are expressed in the following requirements:

R31 - Ticket Subscription: The ticket subscription feature enables a passenger to pay and subscript for a bus ticket through the online portal. With this, it becomes possible for passengers to subscribe for bus ticket individually and online, run separate subscription periods independent of others.

R3-2 - Data capture: This feature enables the system administrator or support staff to capture a passenger's fingerprint and other particulars. This is meant to create fingerprint authentication functionality in order to guarantee the one-passenger-one-subscription objective.

R3-3 – Renew Subscription: This feature allows users to renew their subscription after its expiration period. With this there will be no need for passengers to physically visit the bus ticket office for new subscription, making the system more user-friendly.

3.1.4 Passenger identification

The major challenge with the manual bus ticketing system is the difficulty in ascertaining the authenticity of passengers and the ease with which hard copy cards can be swapped. Passenger identification is handled differently with the requirement defined below:

R4-1 - Validation: This feature enables a passenger to gain access into the bus by authenticating his/her identity via a fingerprint device. It ensures only passengers with a matching finger print in the database are able to use the bus facility.

3.2 Use case analysis

As part of the requirements analysis and modeling, this section presents the representation of the system actors and their roles for effective comprehension and communication of the overall system processes.

3.2.1 Actors

Here three types of system users are identified as actors: the passengers, the support staff and system administrator. They constitute users who are going to interact with the system in order to achieve its objectives. This is captured in Figure 1.

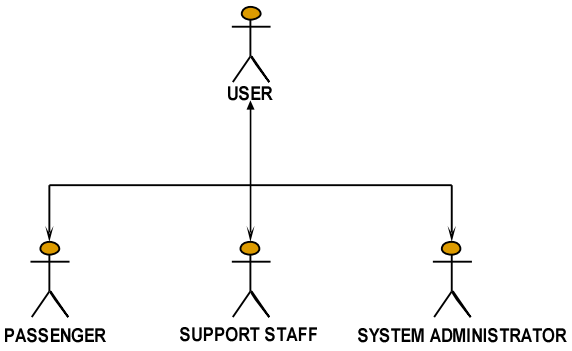

Fig 1: System Actors

3.2.2 Use case model

The roles of the three major system actors of APABTS (passengers, support staff, and system administrator) are clearly demonstrated here, showing interactions between system actors and system functionalities in a general use case model. See Figure 2.

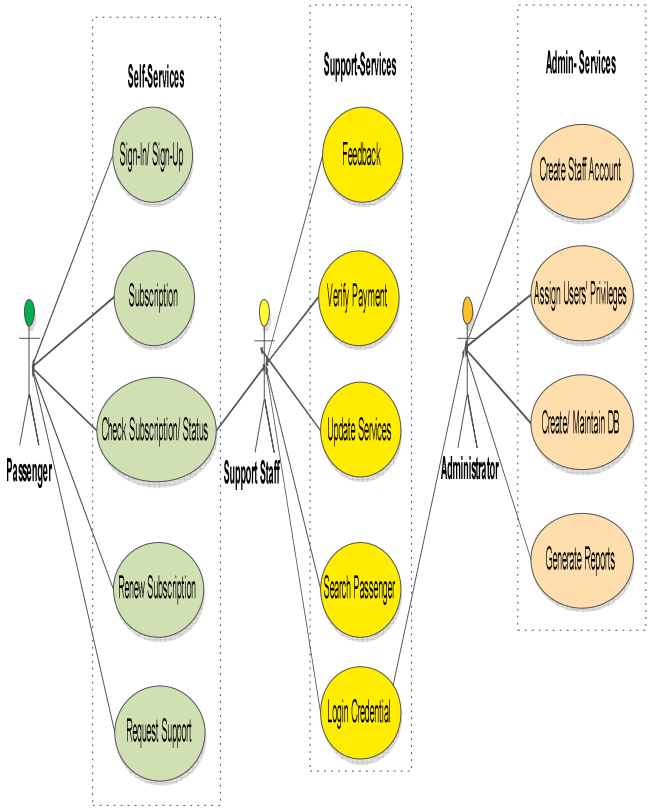

Fig 2: System use case model showing actors and interactions

3.3 System Structure and Components

The automated passenger authentication bus transit system requires a number of components to achieve its e-fare subscription and passenger authentication objectives as discussed Section 3.1. These components include the following:

3.3.1 Biometric sub-systems

The biometric sub-system is one of the most important components of this proposed system because it plays the central role in passenger's authentication. It consists of a fingerprint scanner/reader or sensor with an inbuilt database (made to interface with another database on a remote server) and can be set to either enrolment or authentication mode. A good example of such biometric system is the FingerTec technology, with 360° rotation of live capture for identification or verification, high identification speed, small memory requirement (where whole matching algorithm required just 350KB). It is an online biometric fuzzy inference system (OFIS) solution used for real-time verification and enrolment. The FingerTec OFIS runs on Browser/Server (B/S) Environment, where users can enrol their fingerprint through the FingerTec OFIS Scanner that is linked to a PC [10]. FingerTech biometric technology is strongly recommended for the implementation of this proposed system due to its compatibility and performance efficiency.

3.3.2 APABTS database

One of the key features of our proposed system is the use of a secure online data repository to hold passengers' information. Making use of a database is highly significant in the sense that the automated FIS references it in the process of searching for a match against individual passenger's fingerprint. Also, it helps to make transportation data handy for the purpose of forecasting and planning. The proposed structure is captured in Figure 3.

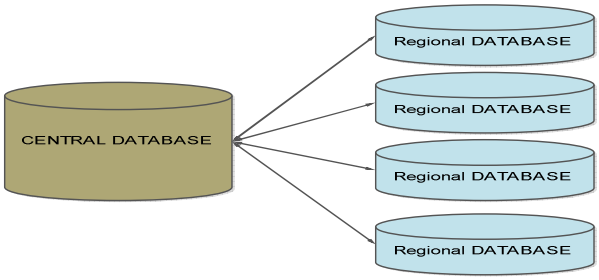

Fig 3: Proposed database structure

Since the proposed system will be used by different bus transit companies, the database system will be structured to consist of a central database (holding data from all bus transit companies) and regional databases that will store data from each bus transit company. With this database architecture, system administrators will only have access to their bus transit database alone, whereas all the regional databases are linked up to the central database that will be only accessed by government or authorized government agencies for the purpose of monitoring, forecasting, and planning.

The database will hold passenger information such as *name, fingerprint, gender, passenger ID, e-mail, phone number*, and *city of residence*. In addition to these passenger personal data, the subscription portal generates transaction data for each passenger as he or she interacts with the e-portal. The

transaction information that will be generated for each passenger includes the following:

1) Subscription status
2) Subscription date
3) Expiration date, and
4) Payment status.

In the database, information will be organized into three tables, namely ***personal data table*** (for passenger information including fingerprint data), ***payment table*** (to contain passenger payment details), and ***subscription table*** (for data fields which are generated as passengers interact with the portal). Information from these tables is to be used by the system administrator for support purposes and informed decision making.

3.3.3 Supportive devices

Apart from the core system components as explained above, other devices are also needed to complement the running of the system such as the Internet facility. The processes of e-subscription and automated passenger authentication functionalities of the proposed system are both web-based and therefore require a fast and reliable internet access point wired or wireless. For the purpose of mobility, any mobile ultra-broadband Internet access device such as wireless 4G LTE mobile hotspot MiFi 4510L is recommend in the buses for the real-time passenger authentication.

In addition, laptop computer or desktop PCs constitute another important supportive device. For the bus transit companies to fully utilize the system for administrative purposes and also effectively provide the required services to their clients, it is highly recommended that the various bus service offices be equipped with these devices. Such computer systems should be up-to-date in terms their capability to support wireless internet facilities.

The conceptual model that defines the system structure and interaction between system components we have discussed in this section is captured in Figure 4.

4. APABTS IMPLEMENTATION

The core functionalities of APABTS partition the entire system into two interfaces: *admin* and *client interface*, each with a set of functionalities. The prototype implementation explain here is thus, based on these two aspects of the proposed system.

4.1 Admin interface

The admin interface offers two types of login classification – *supper admin* and *support staff*. The supper admin account is configured once at during system deployment then the supper admin can subsequently create support staff account. In compliance with the standard security principles of verification, validation, authentication, and authorization, APABTS provides this interface constrained for only clients with valid login credentials.

4.1.1 Supper admin functionalities

With supper admin credentials, an administrator performs the following tasks - add administrators, view subscription requests, assign privileges, treat client's enquiries, update bus fares.

4.2 Clients' interface

The admin interface offers two types of login classification – *supper admin* and *support staff*. The supper admin account is configured once during system deployment then it can subsequently create support staff account. In compliance with the standard security principles of verification, validation, authentication, and authorization, APABTS provides this interface constrained for only clients with valid login credentials

4.2.1 Client's interface functionalities

The client interface offers a variety of functionalities through which the bus transit services are accessed. These include: Sign Up, Login, view personal Details, order for subscription, read feedbacks, check bus Fares, and so on.

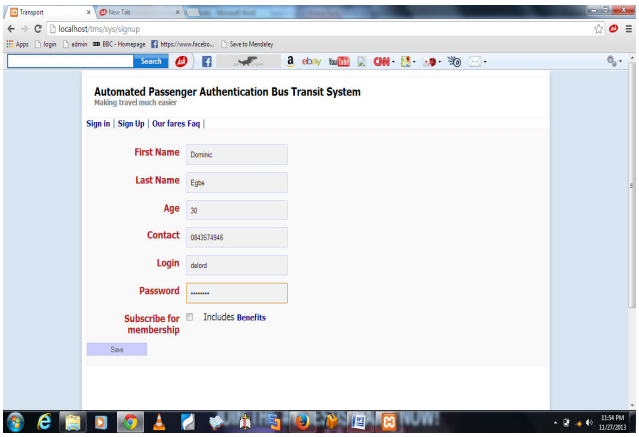

Fig 5. APABTS sign-up/sign-in page

4.3 APABTS operations

This section presents a step by step explanation of the operation of APABTS system. These are presented as follows:

4.3.1 Sign up/sign in

The user can creates account in the subscription portal by supplying user name/password and other personal data required to maintain the client's profile on the database. (See Figure 5)With the chosen username and password the user can login if account creation is successful.

4.3.2 Subscription request

In order to perform subscription request, the user clicks on "My subscription" (after successful login), selects subscription plan, supplies payment details and sends a subscription request to the system administrator by clicking "Subscribe" button as captured in Figure 6.

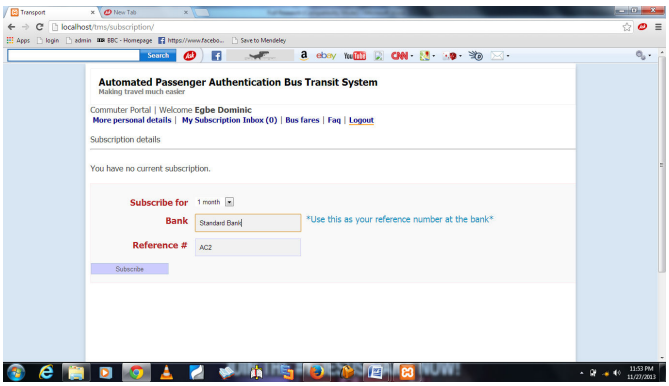

Fig 6: APABTS subscription request page

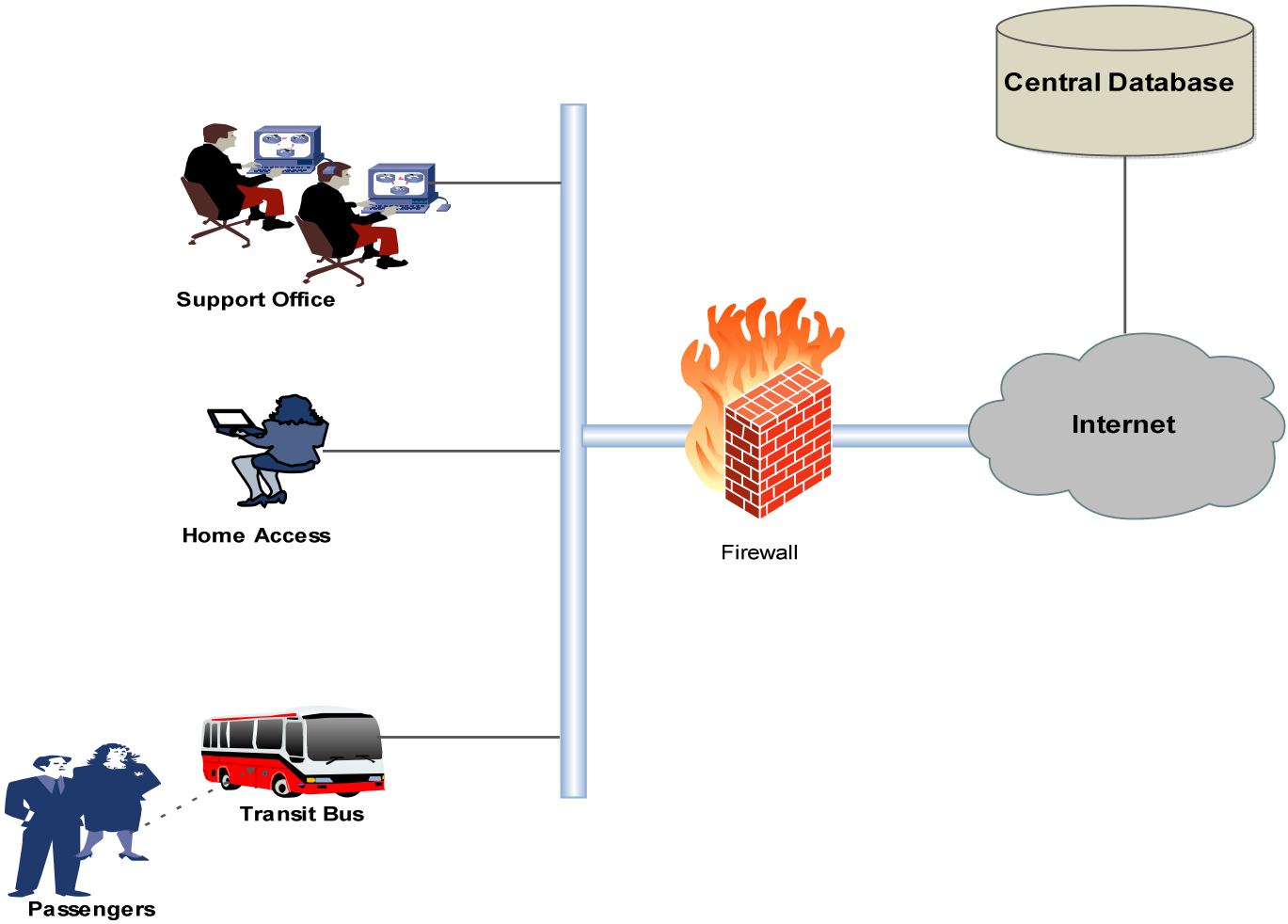

Fig 4: Proposed APABTS model

Table 1. System evaluation

System	Authentication	Security	Fault-tolerance	User-friendliness	Complexity and Cost	Flexibility
Manual	No	No	NA	Not user friendly	NA	NA
RFID/CSC	Smart card	Secured but difficult to maintain (cards can be stolen, misplaced or cloned	Faulty circuitry or mishandling can lead to card damage	User friendly	Uses a combination of expensive technologies with complex equipment	Not too flexible
APABTS	Fingerprint	Secured guaranteed – fingerprints cannot be copied, swapped, or stolen	Cannot be easily damaged as in the case of smart cards	More user-friendly	Requires less expensive technology and equipment	More flexible

4.3.3 Subscription approval

It is the duty of the supper admin or support staff (depending on the privilege level granted) to approve client's subscriptions from the admin system interface. To view all clients' subscription requests, the system administrator clicks on "Subscription requests" and selects on "Full details" option to activate individual client request as captured in Figure 7.

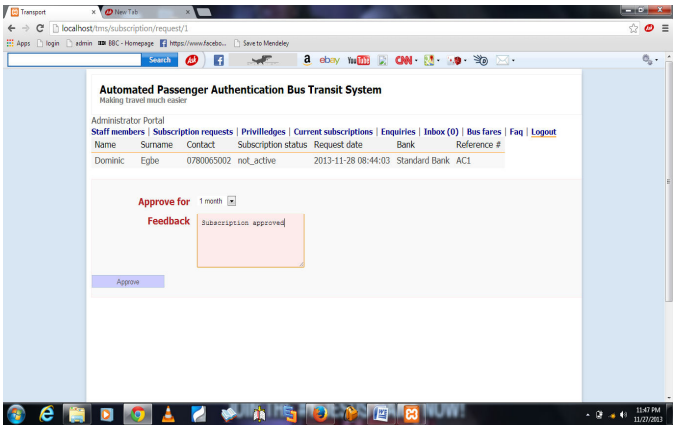

Fig 7: APABTS subscription status page

4.3.4 View subscription status

Subsequently after submitting a request for subscription, the status of the request can be checked by users. To do so, users can login and click on "My subscription". If it has been approved, the system displays the duration of the subscription otherwise, the message "Your subscription is awaiting approval" will be displayed. (see Figure 7)

5. PASSENGER IDENTIFICATION

One of the major requirements of the proposed system is to ensure one-client-one-subscription. To achieve this, the APABTS employs a biometric system using fingerprint to authenticate clients in a real-time mode. The whole process of passenger authentication is divided into two phases as explained below:

5.1 Enrolment

Enrolment process occurs when passenger's fingerprint data is extracted and stored in the APABTS database using a biometric scanner. When clients create user account or login or send subscription request to the system administrator for the first time, they are prompted by the system to visit any of the support offices for biometric data capture. At the bus support office, the system administrator scans client's fingerprint and uploads it to the biometric database on a real-time basis. On the biometric database, each client's fingerprint data is link to their unique ID number on the subscription table and personal data table.

5.2 Authentication

Here passengers are identified in real-time mode at bus stations by APABTS as they place their finger on the scanner device installed beside the door of the bus as the walk in. During this process, the system verifies a match between their fingerprint and the fingerprint stored in the database. The biometric scanner to be used for example FingerTech has a programmable interface that can be programmed in the implementation language to light the green indicator light if there is a valid match otherwise the red indicator light.

6. DISCUSSIONS

For any competitive economy, the need to have an effective and efficient transportation system cannot be over emphasized. The emerging SA economy that also plays a leading role in Africa is not an exception. Having a well efficient air and rail systems, SA bus transit system is yet to braze up with the IT demands of the 21st century. The fact remains that the transport sector just like several other economic activities that are intensive in infrastructures, is an economic catalyst, impacting on development and the welfare of populations. Therefore, having an efficient transport system in place has the potential to provide economic and social opportunities as well as benefits such as better accessibility to markets, employment and additional investments [3]. It must be noted that any transport system is service oriented in nature and the core parameter with which to define its efficiency is the quality of service rendered.

But opposed to this background, we still run a bus transit system in SA characterized by poor quality of service and fraud. These elements of inefficiency in the bus transit system, to a large extent stems from the lack of ICT-driven operations in the system unlike what is obtainable in other systems of transportation – air, rail. It is against this backdrop that we are proposing APABTS, an IT-driven bus transit system for fixed route buses. The design of APABTS is aimed at eliminating the traditional manual card transaction system, replacing it with an e-subscription portal with biometric capability to perform passenger authentication. This approach will bring several benefits in addition to minimizing fraud and improving the quality of services. Firstly, it will bring about increased revenue generation for bus transit companies. Secondly, improving the quality of service and boosting revenue generation in the bus transit system will attract more investors thereby raising job creation opportunities. Finally, the architecture of APABTS makes provision for a central, secured remote database that can serve as a dependable data repository for SA department of transport for the purpose of budgeting and planning.

7. CONCLUSION

Transportation is a key component of any competitive economy apart from being an agent of job creation and a catalyst to social development. And the world is fast incorporating essential ICT to every facet of human endeavor to improve productivity and quality of service amongst a host of other benefits – the transport sector is one of such major benefactors. The state of affairs of bus transport system in SA places a demand for the full incorporation of IT in order to boost its operations and deliver quality of service to its huge consumers. In this paper, a background is provided that justifies the need for automation in SA bus transit sector, and present the system requirements, design and implementation of a novel bus transit system, APABTS for commercial bus companies with fixed routes. The system consists of an e-portal with which passengers are able to subscribe for bus service online and a biometric component with which passengers are authenticated at bus stations real-time using fingerprint. Based on the components incorporated into this system, it is believed that if implemented for use, APABTS will be more user-friendly, flexible, secured and fault tolerant than its counter parts – manual and other existing systems.

8. REFERENCES

[1] E. Commission, "World report on road traffic injury prevention," *World Rep. Road Trafic*, 2012.

[2] N. Encyclopedia, "Transport - New World Encyclopedia," 2010. [Online]. Available: http://www.newworldencyclopedia.org/entry/transport. [Accessed: 10-Aug-2013].

[3] Rodrigue and T. Notteboom, "Transportation and economic development," 2012.

[4] "The state of South Africa's public transport system | earthworks magazine." [Online]. Available: http://earthworksmagazine.co.za/features/1452-2/. [Accessed: 19-Aug-2013].

[5] "SABOA, Industry Profile, Southern African Bus Operators Association, Public Bus Transport." [Online]. Available: http://www.saboa.co.za/industry_profile.htm.

[6] A. Systems and O. Platform, "Automation Systems the Optimisation Platform," 2013.

[7] Ouellette, R. *Automation Impacts on Industry*. Ann Arbor, MI, USA: Ann Arbor Science Publishers, 1983.

[8] "Department of Transport - South Africa > Home." [Online]. Available: http://www.transport.gov.za/. [Accessed: 15-Aug-2013].

[9] "South Africa Government Online." [Online]. Available: http://www.gov.za/.

[10] B. Solutions, C. Fingerprint, P. Free, E. Integration, M. Y. Own, A. Securely, P. Recognition, and I. Programming, "FingerTec ' s Online Fingerprint Identification System or OFIS is a biometric solution for online verification and enrollment . The FingerTec."