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Design of an Integrated Android Mobile Application and Web-Based System (IAMA-WBS) as a Solution to Concerns of Passengers Using Bus Rapid Transit System for Public Transportation in Dar Es Salaam

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***Abstract*—**The rapid population growth in Dar Es Salaam has prompted the demand of effective transport system in the city. This tremendous rise of population led to serious road traffic congestions, which brings a number of challenges into the city and other growing urban areas. City authorities attempted various solutions to control the traffic congestions such as construction of new roads, expansion of existing roads, installation of traffic lights and other transportation infrastructures such as re-establishment of commuter train to operate within the city but they couldn't effectively relieve the problem. Eventually, the Government of Tanzania (GoT) supported the city's effort by establishing the organ called Dar Es Salaam Rapid Transit (DART) to supervise the implementation and operation of Bus Rapid Transit (BRT) system. The BRT system provided direct benefits to passengers such as minimal travel time, improved reliability as compared to other public transport commonly known as daladala, and reduced accident as BRT buses travel in their dedicated lanes. Despite these benefits there still persist transportation challenges with the BRT, where passengers still suffer from waiting on very long queue during ticket booking, shortage of smart cards, they are unable to check balance direct from their mobile phones, as well as they fail to top-up onto their card's balance using their smart phones. This paper presents a software technology approach that would help passengers to check balance, send request specifying station to board a bus and check the bus arrival time at any station.

***Index Terms*—**Android Mobile Application, Web-based System, Bus Rapid Transit, Passengers, Public Transportation, Smart cards.

I. Introduction

Recently, BRT is being adapted as a means of cost effective transportation alternative in many cities worldwide. For instance, cities of Curitiba in Brazil, Cali in Columbia, Santiago and Lima in Chile and Peru respectively [1]. Additionally, since 2004, BRT has also been prominent in Asia in cities such as Jarkata in Indonesia, Seoul in South Korea, Pune in India and Beijing in China [2].

BRT delivers a good transport service in congested cities and provides reliable and comfortable, fast and cost-effective services direct to passengers [3,4]. Also, it improves the public transit services by reducing car congestion on roads, and carbonic compound emissions [4]. Many projects across the world have shown that BRT is a better and effective alternative for highly populated cities at a fairly little construction and operation cost.

In the recent past, the Government of the United Republic of Tanzania has also adapted the BRT system as a durable alternative to the traffic congestion in Dar Es Salaam by establishing the Dar Es Salaam Rapid Transit (DART), a government organ responsible to supervise the implementation and operation of BRT system in the city [5]. Dar Es Salaam city experiences a great rapid population growth and traffic congestion as well [6]. The population growth in Dar Es Salaam has led to insufficient public transport systems capacity within the city which has consequently caused a serious traffic congestion especially during peak hours [7]. This has prompted a need for improving the public transport system in the city [8]; the city authorities has attempted to mitigate the challenge by improving transit

infrastructures: road expansion, building new feeder roads, and fixation of traffic lights [9,10]. However, these efforts didn't annul the challenge; this perpetuated the adaption of BRT [3,11].

Furthermore, the operation of BRT activities such as bus fare collection and infrastructural maintenance, were commissioned to UDART, a private company under Simon Group companies that own the city's public transport company, Usafiri Dar Es Salaam (UDA) by 51% of shares. Additionally UDA is the big shareholder of UDART─ it's currently operating BRT system [11].

Since late 2016, the BRT system has been doing well such that it has been awarded the 2018 sustainable transit award and this has made Dar Es Salaam the first African city to win the award [11]. Despite the success of BRT, it's facing several operational challenges such as overcrowding at the bus stations and long queue during ticket booking [12]. Nevertheless it doesn't allow passengers to check and top-up their smart card balance using smart phones especially using mobile money services such as Tigopesa, M-Pesa, and AirTel Money. Eventually it's difficult for a passenger to predict bus arrival time at any station.

This paper reports about a design and development of a software based prototype that can be used to mitigate challenges that passengers experience in commuting with BRT. The prototype is composed of two integrated systems which are Web based system developed using Hypertext Markup Language (HTML), Cascading Style Sheet (CSS), Bootstrap and Hypertext Preprocessor (PHP) Laravel framework and Android Mobile Application on the other hand was developed using eXtensive Markup Language (XML) and Java. The proposed prototype is composed of features that will help passengers to check balance online, check bus arrival time at any station and send request specifying station to board a bus. Furthermore, the system will help UDART administration to keep their records including passengers' information.

II. Related Works

In recent years, the use of smart cards has been growing in many places. It's replacing a traditional habit of carrying cash in hands or wallet. The smart cards have been adopted into many business activities such as in supermarkets, Petrol filling points, transportation systems, universities and so forth. They are being used in processing payments and they have been proved to effectively prevent money fraud.

The BRT system in Dar Es Salaam as well has introduced smart cards as an alternative to paper tickets due to its advantage over paper tickets as they are capable of storing balance information. However, the challenge has been how passengers can check the balance from their smart cards. To date, where the ICT is growing at a very high pace with its effects changing the life style of people, there is a need of integrating the smart cards' digital information into mobile applications. Therefore, several mobile applications have been developed to enable travelers to have real time transit information promptly. The proposed prototype in this paper resembles some transport mobile systems as follows.

A. Ride Systems GPS[3]

Ride Systems is a Company established in Morgan, a city in the U.S. state of Utah, which focuses in delivering a GPS tracking solution. One of the mobile applications developed by the company is Ride Systems GPS[3] which provides time to passengers about the next bus to arrive at any station. Another significant feature this mobile application offers is to explore bus stations [13]. This application can run in Android and iPhone operating systems. However, this mobile application lacks one important feature to be employed by BRT system in Dar Es Salaam which is the ability of passengers to check smart card balance.

B. OneBusAway (OBA)

It's a system developed in US for provision of transit real-time next bus countdown information for travelers of King County Metro through telephone, website, smart phone applications, and text-messaging [14]. The fundamental goal of OBA is to increase passengers' satisfaction in public transportation and transit ridership thereby providing the arrival time of the next bus at any stop. Similar to Ride Systems GPS[3], It also lacks the utility to check balance from the passengers' smart cards.

C. Robin Hood Network

It's based in Nottingham, UK which integrates most public transport services and made easily available to customers into their mobile phones. The Robin Hood Network application enables passengers to check their smart cards balance, plan their journey or sending request to specify boarding stations, exploring bus stop, online top-up of card balance and many more [15]. All these utilities are needed in our proposed prototype; however, they were developed purposefully to operate with public transport services within Nottingham, UK and therefore customization to fit the BRT system in our environment is a challenge.

Therefore, the proposed prototype has been developed based on features available in Ride Systems GPS[3], OBA and Robin Hood Network to best fit our BRT system environments with three core functions; these are check balance, bus arrival time and request to board a bus at any specified station.

III. Methodologies

The study has been conducted in Dar Es Salaam city, Tanzania, because is the city where the BRT system has been implemented and is already in operation. Moreover, Dar Es Salaam is the city that faces serious traffic congestion compared to any other region in the country.

The sample for data collection involves two groups which are, passengers found direct at the bus stations and others from two companies' offices which are Multichoice-Tanzania (DSTV) and Dar Es Salaam

University College of Education (DUCE) Employees who had experience in commuting with BRT buses. A Simple random sampling technique was used. In this case each respondent was selected wholly by chance and everyone was given an equal chance of being involved. Both, qualitative and quantitative data was collected using Questionnaire, Interviews, observations, website visit and review of several research papers. The development approach used to develop the proposed prototype is a Rapid Application Development (RAD) method. This has been opted due to the fact that RAD takes short time and fully involves client on most steps of product development and therefore helps in improving client satisfaction as several communication takes place and client is able to see the product progress. Table 1. below shows the comparison of RAD against other methodologies of software development.

Table 1. Comparison of Methodologies and its Criteria

Methodology	*Budget*	*Time*	*Functionality*
Waterfall	High	Long term	Static
Incremental	High	Short term	Static
	Low	Long term	Static
Evolutionary	Low	Long term	Dynamic
Spiral	High	Long term	Dynamic
RAD	High	Short term	Dynamic
Extreme /Agile Development	Low	Short term	Dynamic/Static

Source: Dillma, 2003(as cited in [16])

IV. Proposed System (IAMA-WBS)

The study indicated that, the passengers are willing to use alternative methods by which they will be able to check their balance and bus arrival time. We therefore proposed a solution that involves an Integration of an Android Mobile Application and Web Based System. There are two groups of users in the proposed system; one group includes Passengers who interact with the system using Android Mobile Application and on the other hand involves UDART administration (System Administrator and Data Entry Personnel) who uses a Web-Based system to interact with the central database. The choice to use Android technology is based on the fact that, in the year 2011, Android systems were 52.5% of global Smartphones sales to end users, while Symbian were 16.9% and iOS were 15.0%. Therefore developing an Android based application ensures maximum user reach and also it integrates the easiness and usability for which the Android platforms have to provide [8].

Furthermore, the penetration of internet in Tanzania has been rapidly growing in the past six years increasing from 17% in 2012 to 45% in 2017, and the number of internet clients has been also growing from 7.52 in 2012 to 23 million people in 2017 most living in urban areas [5].

A. Requirement analysis

We considered both, functional and non-functional requirements specifications in developing IAMA-WBS system. Functional requirement defines specific function that a system has to perform such as login, register, logout etc. whilst Non-functional requirement describes any quality which a system will have [17]. Tables 1 and 2 bellow presents functional and non-functional requirements of the IAMA-WBS system respectively

Table 2. Functional Requirements

Requirement	Description
Add Staff, Add Departments, Add Vehicles, Add Routes, Add Stations, and Add Users	The System Administrator will register staff, departments, vehicles, routes, stations and users into the system.
Register Passenger	The data entry personnel will register passengers into the system together with their card numbers.
Assign user to a User Group	The registered user has to be assigned to any goup of users so that he/she can login as Data entry or Administrator
Enter into Android Mobile Application(Login)	The passenger is granted a functionality to enter into mobile application using his/her card number
Check balance	The functionality that enable a passenger to check his/her balance using mobile device
Choose boarding station	The functionality that enable a passenger to send request to the central system specifying a station at which he/she expect to board a BRT bus
View bus arrival time	The functionality that enable a passenger to view the bus arrival time at any station

Table 3. Non-Functional Requirements

Requirement	Description
Performance	➢ Updating and saving records shall be fast ➢ Login and logout operation shall respond quickly
Safety and security	➢ The user's login details are secured enough so that no one will be able to by-pass the system ➢ The system is secure enough to protect against Denial-Of-Service Attacks (DOS)
Usability	➢ The system shall be easy to learn so that users know how to use the system on the first use

B. System Design

Functional and Non-functional requirements obtained from requirement analysis above led to a design of system that is integrating two systems which are Android Mobile Application and Web-Based system. The Fig.1 below is a Use Case Diagram showing all Actors and their relationship to Use Cases. A Use Case Diagram depicts the interaction of users and the system. It describes what actions or processes a user can perform in the system. In Use Case Diagrams, Actions are called Use Cases and Users or External Entities are called Actors [18]. Actors of our proposed system are Data entry personnel, Passenger, and System Administrator. Use Cases are Check Balance, Check Bus Arrival Time, Select Route, Choose Station, Top-Up Balance, Register Passenger, Add User,

Add Station, Add User Group, Register Route, Register Department, and Register Staff.

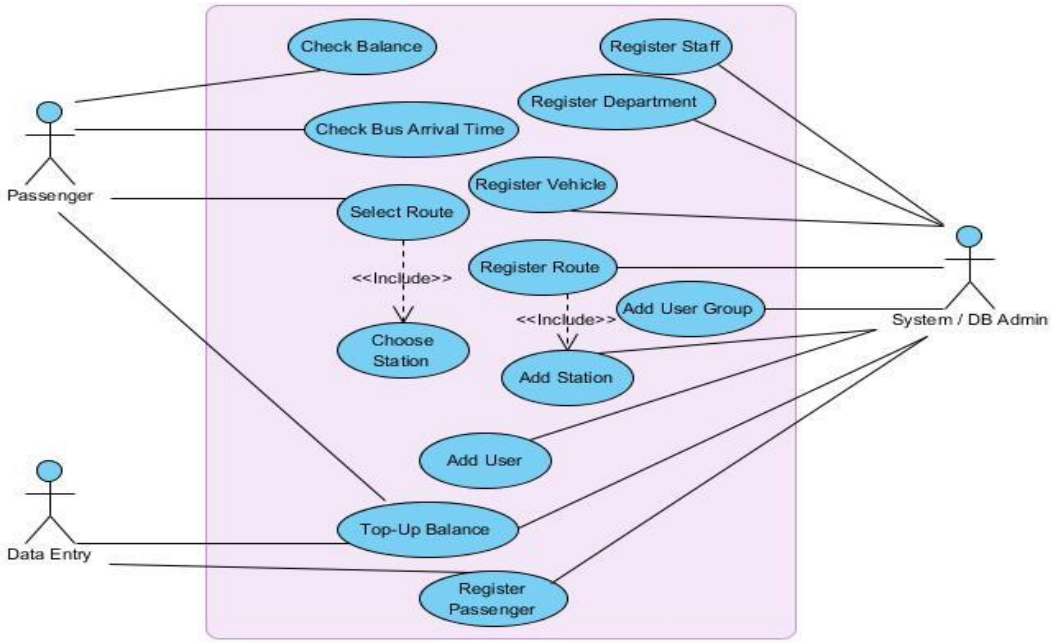

Fig.1. Use Case Diagram for the Proposed System

C. Database Design

The database design involves the identification of entities, relationship of entities and attributes of each entity. Entity-Relationship (ER) diagram was used to model the relationship of system's entities. ER Diagram is a method used to document the entities and relationships during database design [19]. The identified entities are Person, Passenger, Staff, Department, User, Role, Menu, Vehicle, Account, Transaction, Point, Station, and Route. The relationships are; ISA or IS-A, Contain, Board_At, Works_In, Log_As, Via, Owns, Drivers, Has, Makes, and Access.

The following are relational schemas of the ER Diagram (Fig.2);

1) Person(pid, pname, sex, DOB)
2) Passenger(pid, contact)
3) Staff(sid)
4) Department(dname)
5) User(username, password)
6) Role(rid, rtitle)
7) Menu(mname)
8) Vehicle(plateNo, type, capacity)
9) Account(cardNo, balance)
10) Transaction(tid, amount)
11) Point(longitude, latitude)
12) Station(sname)
13) Route(rname)

D. System development

The selection of technologies to use in developing the proposed system depends on time, cost and complexity of the system. For this reason, most of the technologies used in developing the system were open sources tools. Open source tool is a tool or software having its source code public accessible and therefore anyone can edit, modify and inspect [20].

1) Database

The system developed using My Structured Query Language (MySQL) for the back-end data storage i.e. database. MySQL is compatible with many different operating systems (OS) platforms, such as SCO OpenServer, SCO UnixWare, Symbian, eComStation, OpenBSD, AIX, IRIX, Microsoft Windows, OpenSolaris, Linux, HP-UX, FreeBSD, i5/OS, BSDi, Solaris, Sanos NetBSD, OS/2 Warp, Mac OS X, Tru64, SunOS, QNX, and Novell NetWare [20]. For this reason, MySQL became our choice in developing the systems' database with assurance that the system will run into many different OS platforms.

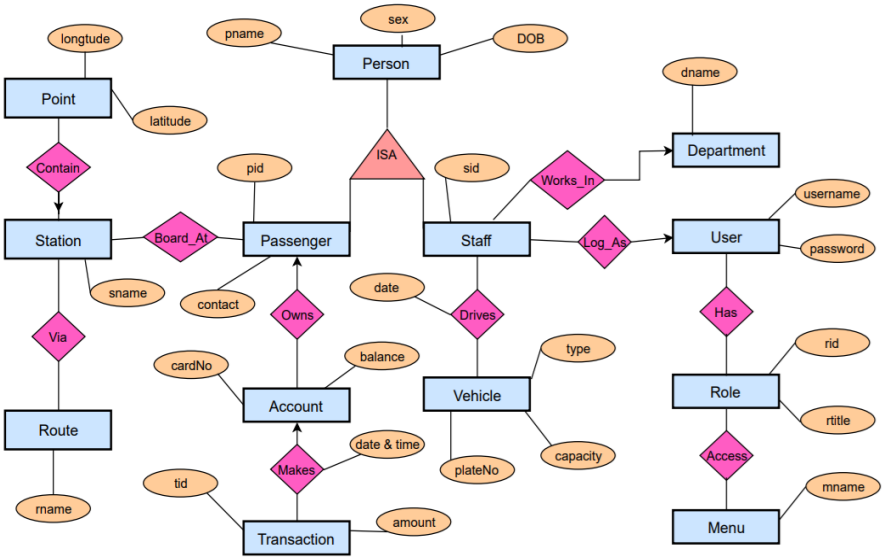

Fig.2. Entity-Relationship(ER) Diagram.

2) Interface

The Interface or front-end of the system was designed by using the following technologies; JavaScript, Bootstrap, HTML, XML, and CSS. They are commonly known as client-side scripting languages. Table 4 below show client side languages used in development and their brief descriptions.

Table 4. Client-Side Scripting Technologies with their Description

Language	Description
Javascript	The dynamic language that executes within a browser
Bootstrap	A toolkit for developing with Javascript, CSS, and HTML framework for responsive, mobile-first websites
HTML	Hypertext Markup Language for developing websites' pages. Used for formatting and displaying data
XML	eXtensible Markup Language for storing and transporting data
CSS	Cascading Style Sheet used to describe how HTML element can be displayed.

3) Server-Side Technology

It is a web technology whereby users fulfil their requests by executing a source code direct from the web server in order to provide dynamic website pages. They are used to develop interactive web-sites which provide dynamic web contents from databases or other data stores to users and vice-versa. Nowadays a lot of scripting languages exists for server-side and each has its strengths and weaknesses. To mention few; Nodes.js, PHP, Ruby on Rails, Django, ASP.NET, and Java. This results into difficultness for programmers to choose a right server-side language for developing a dynamic website projects [21]. PHP with Laravel framework and Java were used in development of the proposed system. PHP was used in development of dynamic web system contents while Java was used to develop dynamic Android Mobile Application contents.

PHP is one of the mostly used server-side scripting language used to implement web based systems. A number of web based systems are using PHP and therefore easily to get support of its developers worldwide.

Table 5. Comparison of Server–Side Scripting Languages(source: [21])

Language	**Creation Date**	**Popularity (%) of entire internet use**
Nodes.js	May 27, 2009	0.24
Ruby on Rails	December 18, 2005	0.3
Django	July 21, 2005	0.1
PHP	June, 1995	11.7

Due to the PHP popularity among other languages, the PHP based framework, Laravel was used to implement IAMA-WBS; it supported the development of the system interfaces such as the illustration in Fig. 3. It is a passenger registration interface which allows data entry personnel to interact with IAMA-WBS and be able to register passengers' details: smart card number, balance, passenger name, gender, photo and mobile number.

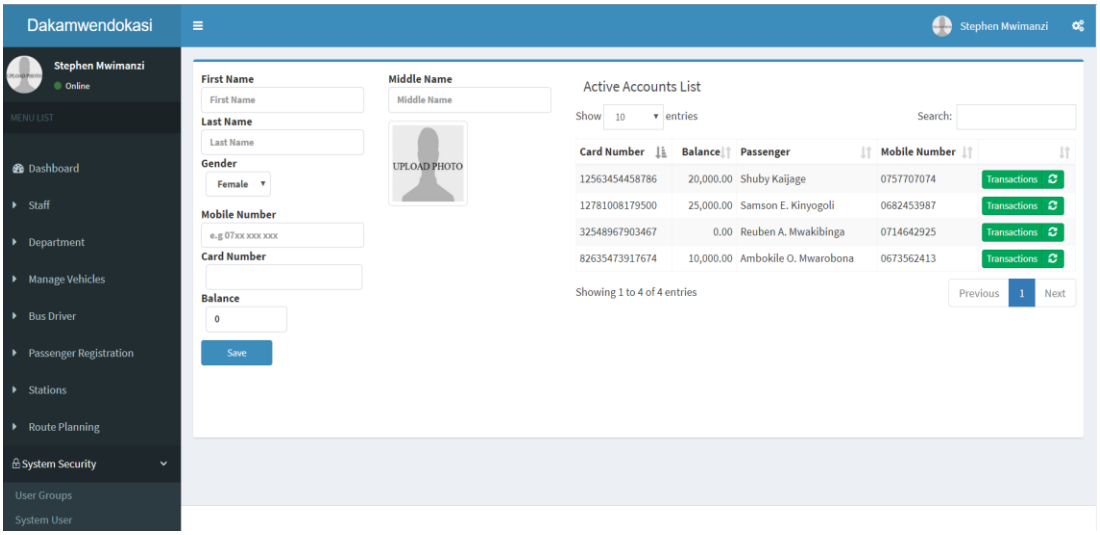

Fig.3. Web Page prototype Interface Showing Registered Passengers' Account Details

Moreover, the other side of the system i.e. Android Mobile application was developed by using Java as the Server-Side language and XML as a Markup language. Java came to be among the most popular high level programming language soon following its release, particularly in web-based and distributed systems [22]. The fast rising in Java interest for computing is mainly due to its important characteristics of portability and object orientation. Its portability is due to its capability to run in many operating systems, PDAs, and on mobile phones [23]. That is why the official language for Android systems development is Java because major parts of Android has been written using Java and its APIs are intended to be called using Java.

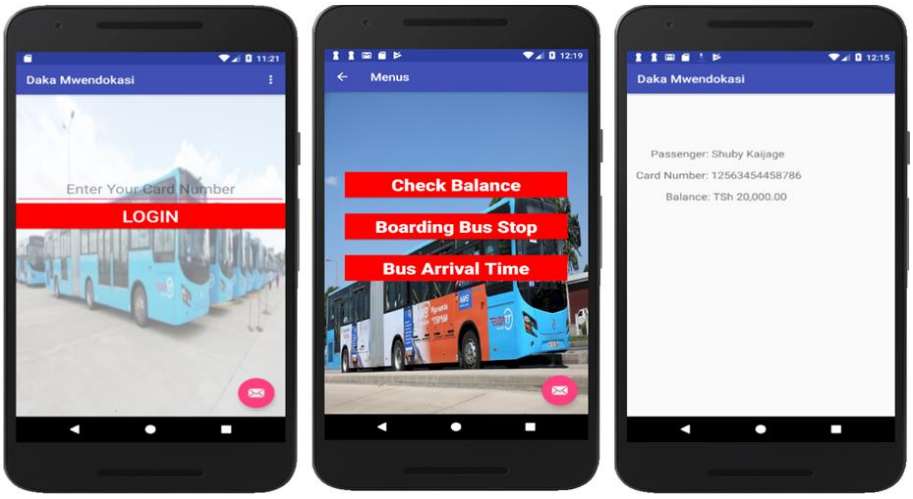

Fig.4. Prototypes for Android Mobile Application Interfaces

Fig.4. illustrates three mobile application Interfaces; from left, the First interface is a Login interface, Second interface displays three core application menus where passenger can check balance, select and send request about boarding station and check bus arrival time, and the third interface indicates a signed in passenger's details which are Passenger's name, Smart card number and Balance.

V. Conclusion and Future Works

The proposed areas to improve discussed in this paper require software technology approach rather than physical infrastructure. Therefore, the study provided a solution by designing and developing a software prototype system which has two parts i.e. Android Mobile application and Web-based system integrated together and able to interact with a central database. In this system, passengers will be able to check their balance using their mobile phones, send request specifying boarding bus station and get approximate bus arrival time at any station as requested by passenger.

In addition, the system will help UDART (BRT operator) to keep records about staff, vehicles, number of station's passenger request, passengers. By keeping track of number of passengers' request on every station, it will enable the allocation of bus into different routes based on a number of passengers' request being easy. This means that more buses will be allocated into routes having more requests.

However, the system has some limitations as it currently lack some useful features such as ability to top-up balance using mobile phones via mobile money platforms such as m-pesa, airtel money, tigopesa etc, and getting vehicle's real time transit information such as location and speed. Therefore, another study can be done to improve the proposed system thereby adding that feature.

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