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Electronic Fare Collection Systems in Public Transits: Issues, Challenges and Way-Forward

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***Abstract*—** With an estimated 174 million in 2013, Nigeria is faced with innumerable challenges. One of such challenges is ensuring that public transit systems within its metropolitan areas are fast and effective. Our system of interest is the Bus Rapid Transit (BRT) system. This paper looks at the present challenges in deploying Electronic Fare Collection Systems for the Bus Rapid Transit (BRT) system in Lagos state, Nigeria. The study sampled commuters with questionnaires administered using a simple random sampling technique. The study also interviewed a representative of the Electronic Fare Collection System Technology Provider (e-Purse). Findings revealed commuter's adoption of Electronic Fare Collection System remains low due to amongst other factors a lack of knowhow on the smart card usability. We propose an extended technical requirement for the Fare Collection system as well as modifications of the Lagos BRT policies that will ensure its effectiveness.
Keywords: Bus Rapid Transit, Commuter Electronic Fare Collection System, Architecture, Hardware, Software, Fare Estimation.

I. Introduction

Urban spaces and cities are characterized by multi-modal transit networks because of the growth in population within respective locations. Modes like Bus Rapid transit, Light rail transits, Ferry

services etc. serve millions worldwide within their cities. City authorities worldwide are in a search for every sustainable means to fend off congestion and manage mobility of people. Lagos Nigeria is not left out of the race. With a population of over 20 million, it's the largest urban enclave in Nigeria. In Lagos, the efforts to ensure seamless mobility are championed by the Lagos Metropolitan Area Transport Authority (LAMATA). LAMATA so far has deployed a number of solutions within a brief period of time. This includes the BRT lite (an abridged Bus rapid Transit scheme for ease of movement) and the soon to be on-stream Light rail Transit (LRT) scheme. The Lagos BRT has proven to be a success, currently serving an estimated 80 million passenger traffic yearly. Lagos state, often times referenced as a mini-Nigeria, is noted for its Urban-City-State nature. More so, the emergence of BRT makes available an alternative to curb the challenges posed by public transits in Lagos State. For a BRT system to be effective, the system must be able to provide efficient services and as well possess adequate institutional and regulatory framework. One of the ways in which effectiveness can be achieved is through the enhancement of its Electronic Fare Collection System which adopts the use of Smart Card technology for fare payment by commuters. Studies have revealed that the use of the Electronic Fare Collection system has been largely successful in other climes due to factors such as; pricing, convenience, accessibility of Tap-to-pay devices, publicity and marketing of smart cards, availability of top-up vendors, etc. However, the existing Electronic Fare Collection System in Lagos State still pales in comparison to other known systems worldwide (Osemwegie et al, 2016; Azeta et al, 2016; Nwoke et al 2017, Salawu et al 2018, Okokpujie et al 2017; Ezugwu et al 2016).

This study is structured as follows: Section 2 presents an overview of the Lagos BRT system which includes; its routes, interacting parties and players, smart card technology in use for its electronic fare system and the fare policies and structure used. The peculiarities of implementing and operating the Lagos BRT Electronic Fare Collection System are discussed. Some attention is paid to the system's hardware design, software or information system architecture. Section 3 discusses the methodology used in evaluating the BRT fare payment system. Section 4 Highlights findings and discusses the relevant data retrieved from the survey. Section 5 proposes recommendations based on the findings and concludes on the study.

II. Overview of the Lagos BRT

The Lagos BRT Lite system functions on a 22km corridor and about 65% of the route is physically isolated from the usual roadway with about 20% separated by road marking (Mobereola, 2009). Reforms beyond those in the infrastructure also play a crucial role in making this system a success, including a holistic approach with reorganization of the bus industry, financing new buses, creating a new institutional structure and regulatory framework to support the system, and training the personnel needed to drive, maintain, enforce, and manage the BRT-Lite system (Mobereola, 2009). BRT Lite is a

compromised BRT scheme that falls short of expected standards but still fills the gap. BRT consists of 7 elements which are: Running way, Stations, Vehicles, Services, Route Structure, Fare Collection and Intelligent Transport Systems (Levinson et al, 2002). This has been further expanded by the BRT Standard 2014 to include BRT Basics, Communication, Service Planning, Infrastructure, Stations and Access Integration. (See Table 1 for sub-elements, their description and a checklist of their presence in BRT lite).

Service Element	Sub elements	Presence in BRT lite
BRT Basics	Dedicated Right-of-Way	
	Busway Alignment	*
	Off-board Fare Collection	**
	Intersection Treatments	
	Platform-level Boarding	***
Communication	Branding	
	Passenger Information	****
Service Planning	Multiple Routes	
	Express, Limited, and Local Services	
	Control Center	
	Located in Top Ten Corridors	
	Demand Profile	
	Hours of Operations	*****
	Multi-corridor Network	
Infrastructure	Passing Lanes at Stations	
	Minimizing Bus Emissions	
	Stations Set Back from Intersections	******
	Centre Stations	
	Pavement Quality	
Stations	Distances Between Stations	
	Safe and Comfortable Stations	*******
	Number of Doors on Bus	
	Docking Bays and Sub-stops	
	Sliding Doors in BRT Stations	
Access Integration	Universal Access	
	Integration with Other Public Transport	********
	Pedestrian Access	*********

	Secure Bicycle Parking	
	Bicycle Lanes	
	Bicycle-sharing Integration	

* Busways that ****** 75% of ******* Some stations on ******** Integration ********* Good, safe pedestrian ********** Highlighted as the first BRT scheme in sub-Saharan Africa, the Lagos BRT route commenced operation on March 17, 2008, in Lagos, Nigeria (Mobereola, 2009). The first phase was the Mile12 to Tafawa Balewa Square (TBS) depicted in the figure 1 and figure 2.

** 60% of routes that touch the *** 100% of buses are **** Up-to-date static passenger ***** Late-night service. no

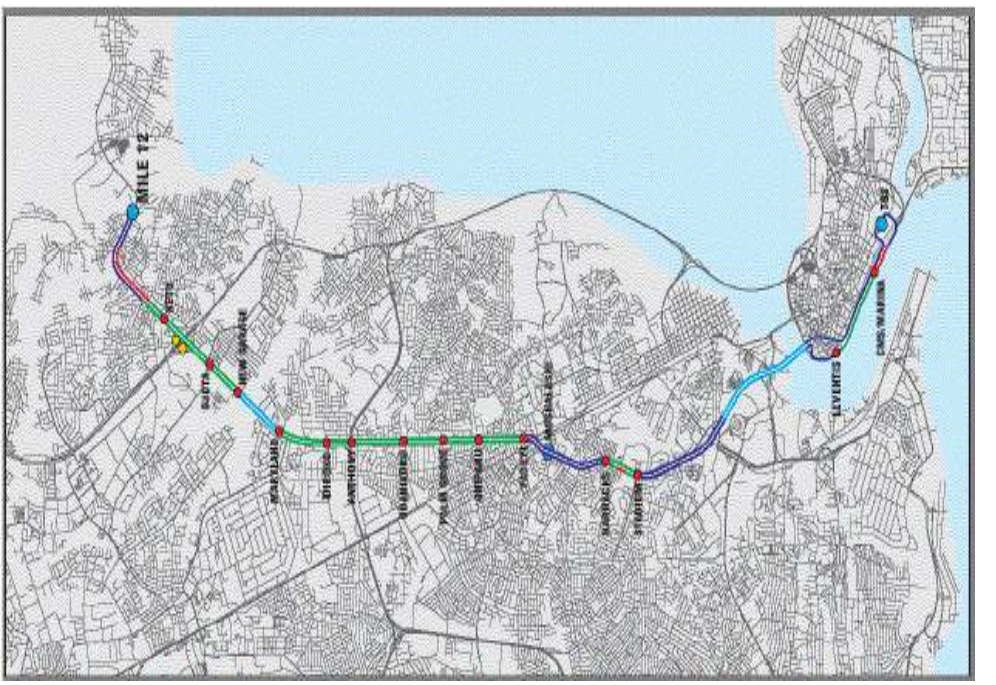

Figure: 1 The First Phase of BRT Route in Lagos
Source: Mobereola (2009)

This is a 22Km BRT corridor. A second Phase was completed in 2015 from Mile 12 to Ikorodu bringing the total mileage to 37 Kilometres. The Lagos BRT runs a 16-hour operation from 6.00 am to 10.00 pm while the bus has a maximum seating capacity of 47.

Figure 2: The BRT Corridor Source: *LEDS (2016)*

The Lagos BRT operates both a paper ticket and an Electronic fare collection system. Tickets and e-fares are sold using a zonal fare structure. A total of 460 buses as at March 2016, were in operation in the BRT corridor. However, daily operations may require fewer than this total number. The daily usage of the BRT corridor by commuters is estimated to rise to 400,000 (Guardian Newspaper online, 2015).

Lagos BRT Electronic Fare Collection System

The Lagos BRT Electronic Fare Collection System first started operation in July 2013, however this was discontinued two years later after a disagreement between the Bus Operators (NURTW BFS) and the technology providers (e-Purse). The technology providers attribute this to a breakdown in relationship between them and the erstwhile bus operators. However, Electronic Fare Collection System was reintroduced in November 2015 after the old bus operators were replaced and the right to use the BRT routes transferred to new bus operators. The new operators promptly reintroduced the electronic fare collection system and approved vendors for paper tickets tied to the smart card technology.

The electronic fare collection system uses contactless smart cards with tap-to-pay devices. In the contactless smart card, the chip can be completely embedded within plastic, but is usually visible. A small antenna is also installed in the contactless card, which makes smart card technology similar to radio frequency identification (RFID) technology (Pelletier et al, 2011). Smart cards usually don't contain passenger details and thus are limited in use to payment transaction. This makes them susceptible to theft and other security concerns. The electronic fare collection system operates as an on-board fare collection system using the zonal fare structure. With zonal based system, prices depend upon the number and type of zones, for which the ticket is valid (Urbanek, 2015). Electronic fare collection operators (e-Purse) noted that security and power supply concerns as the determining factor for

its choice of an on-board fare collection system. Tap-to-pay devices are Liquid Crystal Display (LCD)-equipped, Personal Computer (PC)-Linked, Near Field Communication (NFC) Contactless Reader with USB as its host interface. It is developed based on the 13.56 MHz RFID technology and the ISO/IEC 18092 standard (Advanced Card Systems Holdings, 2016, Okokpujie et al, 2016, Okokpujie et al, 2017, Obiazi et al, 2009). These devices are not insured and thus Technology operators incur losses when devices are damaged, stolen or destroyed.

Interacting Parties

The Lagos BRT fare collection system has a number of parties in close interaction which participate in fare price modelling and policy making. This consists of the Regulator (LAMATA), the bus operators (Primero or BFS), Funding Bank (Sterling Bank Plc), Technology providers/operators (e-Purse) and ticketing and card sales vendors and dealers.

Fare tables are decided upon by the close interaction between the Regulator and the Bus Company. This fare tables are the guiding template for the technology operators in setting the pricing policy in operation on BRT routes. Unlike its past operations, all fare is paid using either technology operator terminals or smart cards. Charge units that are retailed to commuters using pay terminals and smart cards. In the case of paper tickets, a token is printed indicating charge units purchased. Funding banks are also interacting parties (or elements) within the Lagos BRT fare collection system. Funding banks provide a means of remission of funds from approved vendors. Approved vendors are entitled to pre-negotiated fees, technology operators are also paid via funds remitted.

III. Methods

This study was conducted in Lagos metropolis, in Lagos State Nigeria. Lagos is the sixth largest and fastest growing city in Nigeria and the Lagos metropolitan area has a population estimated at between 15 and 18 million. It is projected to go beyond 25 million by 2025, making Lagos the third largest agglomeration in the world, after Tokyo and Mumbai. The Lagos metropolis is made up of 16 local government areas which includes both the Islands of the former municipality of Lagos and the Mainland suburbs with a land area of about 999.6 km2 (Somuyiwa and Adebayo, 2009). In Lagos, road transport dominates more than 90% of all intra-urban movement (Oni, 2004). The Lagos BRT Lite System which is Africa's first Bus Rapid Transit Scheme in sub-Saharan Africa has proved a most effective public transit scheme as it conveys about 800, 000 commuters daily and about 20 million passengers annually. The Lagos BRT is based on existing BRT models such as the one in Bogota and Colombia (Mobereola, 2009).

The primary sources of data for this study included the use of questionnaire and guided oral interview. The study sampled about 55 BRT commuters which cuts across passengers going to Fadeyi-Ikorodu route, Fadeyi-Mile12 route and Ojota-Fadeyi route using a simple random sampling technique. The questionnaire was divided into three sections in which the first section elicits information on the socio-economic characteristics of the

respondents while the second section elicits information on commuter awareness of the BRT system and adoption of the electronic fare collection system (i.e. the e-Purse ticketing system). The third part of the questionnaire elicits information on commuters' perception of the e-Purse card payment system. A comparison of commuters' adoption of electronic ticketing system on commuters' satisfaction with the services provided by the electronic fare collection provider (e-Purse) in Lagos BRT system was done; using a five point Likert Scale ranging from 'very satisfied' to 'very dissatisfied'. Data generated was analyzed using Special Package for Social Sciences (SPSS). The study also interviews an Electronic Fare Collection Technology Provider (e-Purse) to obtain information on the technological capacity, innovation and challenges since the implementation of the Electronic Fare Collection System. Data was also obtained from secondary sources such as; the sub-Sahara Africa Policy Program report, journals, and other relevant publications.

IV. Results and Discussion

Socio-Economic Characteristics of Respondents:

The survey revealed that more male commuters (63.6%) use the Lagos BRT as compared to female commuters (36.4%). This is in agreement with the findings of Okagbue et al. (2015). Majority (65.4%) of the commuters are about 30years of age, which implies that younger individuals make more use of the Lagos BRT services than the older ones. BRT operators can redesign its policies and make available features that will attract or increase the older populations' patronage. More so, most (70.4%) of the Lagos BRT commuters are low income earners as their monthly income is far below N100,000. The reason for this is not far-fetched as most of the commuters are young individuals who might just be at the very early stage of their career and therefore may not have enough money to own a car. Policies relating to fare structure to accommodate more low-income earners should continue to be in the forefront of the thinking of Regulatory authorities.

Lagos BRT System Awareness and Usage:

All respondents surveyed demonstrated high level awareness of the existence of Lagos BRT system. Most (74%) of them became aware of the Lagos BRT system not less than four years ago and only a few (26%) became aware of the Lagos BRT system within the last three years. Thus, implying that majority of the Lagos dwellers are aware of the existence of Lagos BRT system. Despite the level of awareness, about 43% of the respondents use the BRT services not more than ten times monthly. This implies that most commuters are yet to deploy the services of the Lagos BRT as a major means of transportation daily. About 31.5% of commuters surveyed uses the BRT services at most once daily and about 22.2% of the respondents use the BRT services at most twice daily. This result shows the intensity of usage of the BRT could still be considerably improved upon, with only about 43% of the commuters using the services of the Lagos BRT not more than ten times monthly. This therefore implies that most commuters still use other transport

mediums such as Danfo (mini-buses deployed for transportation in Lagos), Molue (old express-buses deployed for transportation in Lagos), taxi or individual's own car which is the reason for the high-traffic congestion and environmental pollution emanating from the exhaust pipes of this fleet of automobiles presently experienced in the Lagos metropolis.

Interestingly, most (50%) of these commuters use the services of the Lagos BRT as a means to get to their workplace and only about 7.4% of them still uses the Lagos BRT to get back home after work. This implies that commuters prefer to board the BRT to their workplace as it is timely and faster than other public transit vehicles. This may be connected to the dedicated right of way feature of the BRT that makes it easy to avoid traffic congestions and to convey passengers faster and these findings is in accordance with Okagbue et al. (2015) findings. Most of the commuters indicated their use of the BRT services between the hours of 6:00am and 9:00am. The main reason is that this is usually the period that most office workers leave home for their workplace.

Adoption and Perception of the Electronic Card Payment System (e-Purse)

On the adoption of the electronic card payment system (i.e. e-Purse card); only about 16.3 % of the respondent indicated their ownership of an e-Purse card. Of this few that possesses an e-Purse card, majority of them indicated that hey last used their card two years ago and some couldn't even remember when their e-Purse card was last used. However, about 83.7% of the respondents do not own an e-Purse card. A major reason for this is their lack of understanding of how electronic card payment system works and their lack of knowledge of where e-Purse card can be purchased. Only a few of the commuters indicated their unawareness of the existence of an e-Purse card payment system. This implies that majority of the BRT commuters are aware of the e-Purse card payment system yet the level of adoption is still very low due lack of adequate enlightenment campaign to educate the commuters on the usability and accessibility of the e-Purse card by the technology providers (i.e. the BRT operators and e-Purse). This implies that there is an urgent need for the technology providers (e-Purse) to effectively enlighten the BRT commuters on the usage, accessibility and benefits of e-Purse card payment system so as to encourage increased adoption of the electronic card payment system.

On commuters' perception of e-Purse card payment system; of the few commuters that possesses the e-Purse card, about 57.1% indicated having problems using the card. The major challenges faced by the commuters in using the e-Purse is that only few Lagos BRT had the e-Purse card machine installed in them and commuter's inability to access where recharging their e-Purse card could be done easily. Other challenges include; cash loaded on e-Purse card is less than amount credited to the card, cash deducted from the card more than the actual bus fare, and the fact that e-Purse card machines are usually turned off in most BRT buses that has this facility. Despite these array of challenges, most (65%) of the commuters still indicated their preference for the e-Purse card

payment system to the paper ticketing system if the e-Purse card payment system is adequately improved upon by the technology provider. Quite a number of the respondents (56%) indicated their satisfaction with the services of the Lagos BRT (in terms of Ticket sales, ticket inspectors and drivers). This implies that most Lagos BRT commuters are satisfied with the BRT services provided to them and this was also affirmed by Okagbue et al. (2015).

Relationship between Smartcard (e-Purse Card) Usage and Commuters' BRT Travel Frequency /BRT Service Satisfaction

The study examined the relationship between commuters' Smartcard usage and the frequency with which commuter's travel using BRT. This was done to know if Smartcard usage is associated with BRT travel frequency. The study shows a weak positive association between Smartcard usage and BRT travel frequency (r = 0.091). This implies that increase in BRT travel frequency is not likely to bring about a significant increase in Smartcard usage. From the table 2 below, this is not statistically significant (P > 0.05), hence there is no real evidence that increase or decrease in Smartcard usage relates to increase or decrease in BRT travel frequency. Also, the study examined the relationship between e-Purse card usage and commuter's satisfaction with Lagos BRT services. The study reveals a strong positive relationship between Smartcard usage and BRT service satisfaction (r = 0.620) and this is statistically significant as P < 0.05. Hence, there are real evidences that Smartcard usage is associated with commuters' BRT service satisfaction. This implies that an increase in Smartcard usage is more likely to bring about an increase in commuters' BRT service satisfaction.

The study further examined the relationship between Smartcard usage and two control variables; 'age' and 'income'. The study revealed a negative relationship between Smartcard usage and commuters' age (r = -0.236) (see Table 2). This implies that with increase in commuter's age, the usage of Smartcard decreases, therefore younger commuters are more likely to use Smartcards more. However, this is not statistically significant (P >0.05), hence increase or decrease in Smartcards usage does not significantly relate to increase or decrease in BRT commuters' age. The study also revealed that no relationship exists between Smartcard usage and commuters' income level (r = 0.000) (see Table 2). Again, this is not statistically significant (P > 0.05), hence, there are no real evidences that Smartcard usage is not associated with commuters' income level.

Regression Analysis:

The study further conducted a regression analysis to reveal how much of a total variation in BRT service satisfaction (BRT-SS) can be explained as regards variation in Smartcard usage (ScU). Table 3 shows that R2 = 0.384, hence 38.4% variation in BRT service satisfaction can be explained by Smartcard usage. The ANOVA table (table 4) shows how well the regression model predicts BRT service satisfaction. In this case, the regression model

predicts BRT service satisfaction well since P<0.05.

The coefficients table (table 5) provides information that predicts BRT service satisfaction from Smartcard usage as well as determines if Smartcard usage contributes statistically significantly to the model. Hence the regression equation is given as: BRT-SS = 1.583 + 0.275 (ScU).

Table 2: Correlations

		1	2	3	4	5
Electronic Smart Card Usage	Pearson Correlation	1				
	Sig. (2-tailed)					
BRT Usage Frequency	Pearson Correlation	.091	1		.	
	Sig. (2-tailed)	.791				
BRT Service Satisfaction	Pearson Correlation	.620*	.020	1		
	Sig. (2-tailed)	.042	.902			
Age	Pearson Correlation	-.236	.083	-.152	1	.
	Sig. (2-tailed)	.485	.549	.330		
Commuters Income Level	Pearson Correlation	.000	-.119	.187	.342*	1
	Sig. (2-tailed)	1.000	.436	.275	.020	

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3: Model Summary[b]

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.620[a]	.384	.316	1.010

Predictors: (Constant), Smart Card Usage

Table 4: ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	5.730	1	5.730	5.618	.042a
	Residual	9.179	9	1.020		
	Total	14.909	10			

Table 5: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.583	.637		2.485	.035
	Smart Card Usage	.275	.116	.620	2.370	.042

*a. dependent variable: BRT Service Satisfaction

III. Conclusion

This study shows that most Lagos commuters are aware of the BRT system and the Lagos BRT services are deployed mostly by younger commuters than the older ones. Significantly, the survey demonstrated a good relationship between Service satisfaction and Smart card usage. Also, the adoption of the electronic card payment system (e-Purse) by commuter is still very low due to commuters' lack of know-how on the e-Purse card usability and accessibility. Of the few commuters that uses the electronic card payment system (e-Purse), a significant number have had challenges using the system. Challenges such as non-availability of the electronic payment device in most BRT buses and lack of access to where the e-Purse card can be recharged easily. Regardless of these challenges, commuters prefer the e-Purse card payment system to the paper ticketing system if the e-Purse card payment system is adequately improved upon. Interestingly, most commuters seem to be satisfied with the Lagos BRT services. In addition, the usage of Smartcards by commuters has a significant positive relationship with BRT service satisfaction. Contrarily, e-Purse capacity to effectively manage electronic fare collections is doubtful due to its limited capacity. Also, the superiority of e-Purse local monitoring station as well as the security of fare payment devices in off- board locations and bus stops cannot be clearly proven indicating a need for increase in their absorptive capacity. More so, the issue of innovation and integration of other services and products (such as; the storage of commuter's data and analysis of passenger flows) into the contactless smart card still remains a myth. Also, there is absence of competition in the electronic payment system service provision and this may be the reason for the absence of innovation and other value-added services within the electronic payment system.

Based on the findings of this study, the study recommends the following:

- The BRT policies should be redesigned to include features/ services that will increase commuters' patronage particularly the older population.
- Fare structure policies that will accommodate more low income earners should be adopted as well.
- Also, operators should ensure transparency in fare charges and also make the electronic payment cards more accessible thereby improving commuters' confidence with respect to charges and card availability. Transparency in fare charges via text messages that can

alert commuters of the charge deductions after paying for a ride.
- Also, proper handling of bus transfers with regards to charging fares and the inclusion of user information on smart cards are also important.
- BRT operators should ensure the availability of tap to pay machines in all BRT buses and commuters should be adequately educated on the usability and accessibility of the electronic payment card (e-Purse card).
- Transport regulatory Authorities should show interest in standards for a broad range of solutions deployed within its purview. This is because such solutions influence the success of transport projects as well. Solutions often times not developed for particular climes may prove costly to maintain and improve. The inability to guarantee compliance to operational and technical requirements with regards to user's technical private partners shouldn't be tolerated by regulatory authorities.

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