Impacts of Public Transit on Economic Sustainability: A Case of Addis Ababa Light Rail Transit, Ethiopia

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Abstract

Sustainability of urban public transits is widely accepted but, there are diversified opinions and debates regarding modes of public transit. It is an unanswered whether road-based or rail-based public transport is more sustainable for rapidly growing cities like Addis Ababa. This study is done to empirically evaluate the economic sustainability impacts by Addis Ababa light rail transit (AA-LRT) using performance indicators like travel time, travel cost and employment generation. Likely, it investigates whether AA-LRT is more economically sustainable or not, compared to other road-based public transits such as City-buses and Midi-buses and compared to the situation before the start of AA- LRT operation. Samples for onboard surveys were selected from transit users and experts through proportional quota sampling. Empirical quasi experiment, multi-criteria analysis and comparative impact analysis approaches were used together with Paired-samples t-test, One way ANOVA, Ordinal and Logistic Regression. Findings indicate AA-LRT is really producing economic benefits such as travel time savings and affordable travel costs since 2015. Benefits are found to be more economically sustainable in AA-LRT than other road-based public transits. Furthermore, travel time and travel cost benefits in the post-AA-LRT period are better than situations before the start of AA-LRT in 2015. Thus, AA-LRT makes a more significant contribution to economic sustainability. However, it has little weaknesses like inadequate crossing facilities, overcrowded and delayed trips, troubled transfer, fare, and ticket system. To enhance the economic sustainability and address shortcomings, new designs like overhead crossings; expansion of rail network coverage; increasing number of trains and speed; integration among transits; implementation of flat fare and improving ticket system are recommended.

Keywords: Comparative approach; Economic sustainability; Light Rail Transit; Travel-cost analysis; Travel-time analysis

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Background and Introduction

According to Barrella (2012) and Knowle and Ferbrache (2016) many types of research are done on urban transport mainly on improving the ability of transport investment to progress economic growth. Economic sustainability assessment is essential because it provides an enabling environment for investment to meet its purposes and maintains the system (Phil et al. 2003, Litman, 2005a & 2015). The number of studies that evaluate the sustainability of urban transit projects using indicators are growing and gaining greater support in recent decades. Particularly economic sustainability assessment models often include various dimensions and indicators (Dhingra, 2011 & World Bank [WB], 2012).

Although opinions regarding light rail transit (LRT) are diversified with arguments in favor and against this mode, several countries of the world have initiated or expanded light rail transit services in the last 15 years. Compared with road-based transits, urban rail-based transits mainly LRT systems provide a variety of economic and transportation benefits (Bhatta, & Drennan, 2003; Gleave, 2005; Mahmud, Hoque & Bashir, 2000). International Association of Public Transport, UITP (2006) and Kenworthy (2006) indicated that in many cities, where a car is the dominant mode of transport, the major transport problems are higher journey duration and cost. Due to the growing population and transport demand in various cities of developing regions like the city of Addis Ababa, the primary focus of urban and transport planning is towards road-based transport. The dominant transits are City-buses, Midi-buses, and Mini-buses (Federal Democratic Republic of Ethiopia [FDRE], 2011; Mohapatra, 2015).

In the city, there is a high dependency on walking and private vehicles for daily

trips, but the overall supply of transport services is still lagging the actual demand. This situation resulted in severe transport and related economic problems such as traffic congestion, longer travel time and higher travel cost. As a response, a new urban light rail transit project which is named Addis Ababa light rail transit (AA-LRT) has started its operation of passenger service in the densely populated corridors since 2015 (Henok, 2018). AA-LRT service is planned and expected to produce transport and economic sustainability benefits and to be a more attractive transit option (Mohapatra, 2015 & United Nations Economic Commission for Africa [ECA], 2017).

As this project is new and unique mainly in Sub-Saharan Africa little is studied and known about its operation and performance. It is, therefore, desirable to study the impacts of AA-LRT and its contribution and progress towards economic sustainability. To what extent this AA-LRT is economically sustainable vis-à-vis the situation in pre-AA-LRT period as well as other on-road public transits is not clear. Thus, it was these questions and research gaps that motivated the author to undertake this study. The author's motivation has also come from a question in the city about how much of the economic benefits were more attributable to AA-LRT. The impact of AA-LRT is examined only from the perspective of economic sustainability using defined performance indicators or parameters such as travel time, travel cost, employment, and business enhancement. The author believed that the current knowledge gap about the economic sustainability of urban public transits needs to be bridged using advanced analysis tools such as multi-criteria analysis, comparative approaches, empirical experiments and using information from service user's perspective.

Therefore, the results of this study could help to fill the research gap and contribute to the existing body of knowledge about the economic sustainability of public transits mainly AA-LRT. As this AA-LRT project services are continuing and findings of this study stem from the latest analysis completed in late 2020, it will raise understanding and encourage dialogue on approaches of evaluating economic sustainability of urban transits.

Material and Methods

Study Area

To complete this study, it was important to identify the site where the research work could be undertaken. This study manipulated the research setting to obtain knowledge about the operation of AA- LRT and other transits from 2015 to 2019 in their naturally occurring states. By considering data availability, AA-LRT phase-I which started operation since Sept. 2015 in Addis Ababa city, capital of Ethiopia, seemed to be an ideal site for this research. Particular sites or traffic analysis zones (TAZ) include the rail stations along the East to West line mainly from 'Ayat' station up to 'Torhayloch' station as well as adjoining roads and urban settlements where survey and quasi-experiments are done.

Mixed Research and Impact Evaluation Approaches

A mixed research method was an ideal technique to conduct this research and provide empirical and more conclusive evidence using various approaches than a single research approach could. Considering the research questions which require both quantitative and qualitative evidence, a sequential strategy of a mixed method was specifically suitable to obtain different but complementary data on the topic and best understand the impacts on travel time and cost.

First, the author conducted a transport survey and quasi-experiments to empirically test travel time and travel cost of the four transit modes to collect quantitative evidence. As the second phase, detailed discussion and interviews were made with the selected transit users and experts for qualitative evidence.

Comparative and Impact Evaluation Approaches

Economic impacts can be evaluated through quantification, assignment of values to outcome variables, and comparative approaches. The economic sustainability impacts of AA-LRT project were compared with a scenario that would have existed had this project not been undertaken i.e. before 2015. To this end, temporal comparison techniques were applied using pre and post-AA-LRT scenarios (i.e. before and after 2015) and Multi-criteria Evaluation (MCE) such as travel time saving, travel cost affordability. Besides, a spatial and inter-modal comparison were done on the contemporary performance of four public transit modes (as independent groups) such as AA-LRT, City-buses, Midi-buses, and Mini-buses on the above outcome variables.

The methodology of this study properly considers a large amount of uncertainty and subjective judgments which are commonly included in such evaluation approach through expert consultation. Moreover, this study was done based on key elements of theory of change (ToC) that could be used as basis for impact evaluation such as progress, achievement or failure and efficacy to promote social change. Much of the evidence came from case studies and econometric models such as Diff-in-diff to analyze the impacts of the four transit modes and Pre/post impact evaluation. Generally, this comparative approach could help to adequately determine and compare relative economic sustainability performance and differential impact analysis of each transit.

Sampling, Data Types and Sources

For primary data onboard survey was done on 290 samples that were selected through proportional quota and accidental sampling from service users or passengers of public transits only from one LRT line i.e., "Ayat" to" Torhayloch" using a formula with a 95% confidence level. Expert sampling technique was also used to select experts in the area. The study also used secondary data collected through careful document review. Finally, analyses were done using 271 respondents or 93 percent of response rate.

Multi-modal Travel Time Variability Quasi-Experiment

A corridor-level day-to-day repeated measurement approach on total travel time performance of four public transit modes mainly AA-LRT, City-buses, Midi-buses, and Mini-buses were done to characterize and compare these four transit modes in terms of their relative length of total travel time. This empirical analysis could help to determine which transit mode is contributing most for the shortest and longest total travel time of the passengers.

A quasi experiment of travel time and collection of primary data was conducted on sites or TAZ in the AA-LRT corridor from 'Ayat' to 'Torhayloch' station and adjoining road highway mainly 'Ayat', 'Megenagna', 'Mexico' and 'Torhayloch' stations. Accordingly, the author could measure a total of 48 travel time in minutes from each mode and record data by making actual travel by these four modes. These total travel time measurements include three components such as walking time, waiting time and in-vehicle journey time in minutes on both peak hours (7:00 AM-9:00 AM and 5:00 PM-7:00 PM) and off-peak hours (11:00 AM-3:00 PM). Evaluation and comparison of these public transit modes in terms of their total travel time was made by considering the same conditions/factors for all such as the same route, direction, distance, and time period of the day and using average global

travel time range, which averages around 70 minutes per person per day (Hitge & Vanderschuren, 2015; Metz, 2008).

The significance of the mean difference between each transit mode in terms of their total travel time was analyzed and compared using a One-Way ANOVA test. Additionally, comparison to some stated objectives, design, and capacity for anticipated performance of AA-LRT was also employed such as the speed of 70km/hr, waiting time or service frequency of 6 minutes for AA-LRT. This comparison approach was used to evaluate and compare the targeted AA-LRT service benefits with the delivered service benefits. In general, four levels of service or LOS (see Appendix-A) have been employed in order to measure performance benchmark of these transits i.e., Los 1, Los 2, Los 3 and Los 4 in which Los 1 is the highest Los and Los 4 is the lowest one (Dhingra, 2011).

Multi-modal Travel Cost Variability Quasi-Experiment

Another experiment of travel cost and collection of primary data was conducted on sites which are indicated the above experiment such as the AA-LRT corridor from 'Ayat' to 'Torhayloch' station and adjoining road highway. Accordingly, the author could measure a total of 48 travel cost tests from each mode and record data by making an actual journey by those four modes during both peak hours and off- peak hours.

Just like travel time experiment the evaluation and comparison of these public transit modes in terms of total travel cost or expenditure in Ethiopian Birr (ETB) was made by considering the same conditions or factors for all like the same corridor, route, direction, distance and time period of the day for more valid and reliable measurement. Finally, the significance of mean fare difference and affordability between transit modes were analyzed using One Way ANOVA test.

Operationalization and Measurement of Variables and Indicators

As shown in Table below, variables or parameters which are applicable for developing region (Dhingra, 2011) were used to measure economic sustainability, performance, and impact of public transits.

Data Analysis Methods and Tools

A paired sample t-test was used to test hypotheses and analyze the significance of travel time and travel cost mean differences between pre- and post-AA-LRT scenarios. The hypothesis regarding the significance of mean differences among the four public transits for variables such as travel time and travel cost saving were also analyzed using One way ANOVA. Ordinal regression and multinomial logistic regression models were jointly utilized to analyze and look at how much variance predictor variables (trips by four transit modes) explain in the outcome variable (Benefit level) using nominal and ordinal data. So, the researcher wanted to see how much variance is explained in the "benefit level" by those transit modes.

In addition, interviews and discussions were transcribed and thematic analysis was performed including coding of qualitative data before identifying and reviewing key themes. Each theme was analyzed to find an understanding of participants' opinions and insights regarding the contributions of the AA-LRT on the travel time, cost, and employment enhancements.

Results

The findings regarding economic sustainability effects produced by AA-LRT operation are presented as follows:

Table 1: Operationalization Frameworks for Variables, Indicators, and Measurements

S/N	Parameters	Issues to be addressed	Indicators
1	Total travel time saving	How long the transit takes from origin to destination? Travel time in comparison to other modes; How well does the transit follow planned schedules? How affordable is it using a public transit mode?	How many minutes spent on the same trip distance in pre and post LRT periods? How long is walking, waiting and in-vehicle time? Commuting time of 1 to 1.2 hours per day is used as a standard or threshold.
2	Affordability of travel cost	How easy is it to access tickets and pay to use the mode?	The proportion of travel fares as shares of monthly income. Travel expenditure below 15% is used as a standard or threshold. Fares in comparison to other modes; and number & location of ticket shops.

Source: Adapted from developing sustainability transportation performance measures for TXDOT's Strategic Plan: Technical Report (Ramani et al., 2009)

How AA-LRT Service has Produced Economic Effects

According to the ordinal and multinomial logistic regression output indicated in Table 3, how much variance independent variables explained in that dependent variable was the major focus area. This could help to determine which transit mode is the independent variable with the highest impact on "high-level trip benefit" in the Post-AA-LRT period as the outcome variable. The statistical results of Parameter Estimates indicate there are statistically significant differences among the four transit modes as explanatory variables in their influence on

Table 2: Transit Modal Choices and Shares: using Friedman ANOVA and Cochran Q test

Which one is frequently used?	Value 0 (No)	Value 1 (Yes)	Test Statistics		Mean Rank
AA-LRT	40	231	N	271	3.32
City-bus	174	97	Cochran's Q or Chi-Square	225.98ᵃ	2.33
Midi-bus	186	85	df	3	2.25
Minibus	206	65	Asymp. Sig.	.000	2.10
Total	606	478			

N.B: here, Total is beyond the sample size because of multiple responses by each respondent

Source: Computed using survey data, (2020).

A Cochran Q and Friedman ANOVA test on

Table 2 indicated that the null hypothesis is rejected and the median of differences among these four modal shares is statistically significant, Chi-Square =225.98a, p<.001, two-tailed. Thus, the majority or 231 (85 percent) of respondents ranked AA-LRT as the first or most frequently used mode of all. On the other hand, City-bus, Midi-bus, and Mini-bus are the 2nd, 3rd, and 4th frequently used modes respectively.

outcome variable (i.e., high level of trip benefit), p<.001. The amount of variance score (or Estimate) for AA-LRT, City-bus, Midi-bus, and Mini-bus is -1.32, 1.08, 1.29 and 2.22 respectively.

Table 3: Ordinal Regression and Multinomial Logistic Model

Parameter Estimates

	Estimate	Std. Error	Wald	df	Sig.
[AALRT=0]	-1.32	.34	14.91	1	.000
[AALRT=1]	0ᵃ	.	.	0	.
[CityBus=0]	1.08	.27	15.71	1	.000
[CityBus=1]	0ᵃ	.	.	0	.
[MidiBus=0]	1.29	.27	22.27	1	.000
[MidiBus=1]	0ᵃ	.	.	0	.
[MiniBus=0]	2.22	.31	51.23	1	.000
[MiniBus=1]	0ᵃ	.	.	0	.

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

Source: Computed using survey data, (2020).

Additionally, as indicated in the Appendix-B, 52.9 percent of the change seen on the dependent variable is explained by the major independent variable.

Are Economic Effects More Sustainable in AA-LRT than Other Transit Modes and the Situation before AA-LRT Period?

To appraise the level of economic sustainability of AA-LRT vis-a-vis other public transit options and with the situation before the start of AA-LRT in 2015, a comparative analysis was used.

Travel Time Analysis Using Scenario of Pre Vs. Post-AA-LRT Period

Travel Time Analysis Using Scenario of Pre Vs. Post-AA-LRT Period

Table 4: Travel Time in Pre vs. Post-AA-LRT Period: Using Paired Samples T-Test (in minutes)

Paired Samples	Mean	Paired Differences Mean	Interval of the Difference Lower	Interval of the Difference Upper	t	df	Sig.
Pre-LRT travel time	64.87	35.15	34.06	36.24	63.57	270	.000
Post-LRT travel time	29.72						

Source: Computed using survey data, (2020).

In Table 4, Paired Samples T-Test indicated the mean difference between the length of travel time before AA-LRT and after AA-LRT period has statistical significance. On average, participants showed that the length of total travel time before AA-LRT period (m=64.87 minutes) was higher than the length of travel time after the start of AA-LRT (m=29.72 minutes), t=63.57, p<.001, two-tailed.

Travel Time Analysis Using Multi-modal Travel Time Variability Experiment

Regarding the contemporary vehicle-to-vehicle total travel time variability experiment, Table 5 showed trip travel time of all four components (walking, waiting, in-vehicle and total time) for the four public transit modes within the same trip time, trip period, trip distance and direction. The total travel time for AA-LRT, City-bus, Midi-bus and Mini-bus is 69, 138, 132 and 126 minutes respectively. Waiting time for AA-LRT, City-bus, Midi-bus, and Mini-bus is also 20, 37, 42 and 50 minutes respectively. The shortest total travel time is attributed to AA-LRT. But, both the longest total travel time and higher travel time ratio (relative to AA-LRT) is attributed to City-bus followed by Midi-bus and Mini-bus within the same trip.

With regard to the magnitude of travel time variation among transit modes, the Coefficient of variation (CV) of travel time (i.e. a ratio of the Standard Deviation to the mean) is calculated to be 26 percent.

Table 5: Multi-Modal Total Travel Time Variability Experiment

Transit Mode	Origin – destination stations (17.3km)	Trip travel time (in a minute)			
		Walking	Waiting	In-vehicle	Total
AA-LRT	Ayat-Torhayloch	-	20	49	69
City-bus	Ayat-Megenagna-Mexico-Torhayloch	10	37	91	138
Midibus	Ayat-Mexico-Torhayloch	10	42	80	132
Minibus	Ayat-Megenagna-Mexico-Torhayloch	15	50	61	126

Source: Computed Using Survey Data, (2020).

In addition, one -way ANOVA test results in Table 6 showed that the null hypothesis is rejected which means the mean difference between the four public transit groups in their total travel time is statistically significant, F=2548.91, p<.001, two-tailed. When the mean difference (I-J) of all transits compared to each other, the mean total travel time of AA-LRT is smaller than City-buses, Midi-buses, and Mini-buses by 68.9, 62.8 and 57.0 minutes respectively.

Although, there are significant differences among these four modes, the mean travel time by AA-LRT has the greatest difference with the rest three modes. Mean travel time by AA-LRT is far shorter than City-bus, Midi-bus and Mini-bus by 68.8, 62.8 and 57 minutes respectively. This analysis shows that the shortest and longest total travel time is attributable to AA-LRT and City-buses respectively.

Table 6: Comparisons Between Transits in Their Total Travel Time Using Bonferroni Post Hoc Tests

Transit type (I)	Transit type (J)	Mean Difference (I-J)	Sig.	ANOVA df	ANOVA F
AA-LRT	City-bus	-68.93*	.000	3	2548.91
	Midi-bus	-62.87*	.000		
	Mini-bus	-57.04*	.000		
City-bus	AA-LRT	68.93*	.000		
	Midi-bus	6.06*	.000		
	Mini-bus	11.89*	.000		
Midi-bus	AA-LRT	62.87*	.000		
	City-bus	-6.06*	.000		
	Mini-bus	5.83*	.000		
Mini-bus	AA-LRT	57.04*	.000		
	City-bus	-11.89*	.000		
	Midi-bus	-5.83*	.000		

*. The mean difference is significant at the 0.05 level.
Source: Computed using survey data, (2020).

Affordability of Travel Cost in the Pre and Post AA-LRT Period: Paired Samples T-Test

In Table 7, Paired Samples T-Test indicates that the null hypothesis is rejected and the mean difference between the percentage of monthly travel cost per income in Pre AA-LRT and Post AA-LRT period has statistical significance. On average, participants showed that proportion of monthly travel cost per income in Pre-AALRT period (m=22.17 percent) is higher than Post AA-LRT period (m=12.94 percent), t=27.89, p<.001, two-tailed.

Table 7: The proportion of Monthly Travel Cost per Income in Pre AA-LRT vs Post-AA-LRT Period Using Paired Samples T-Test

Paired Samples	Mean	Paired Differences Mean	Interval of the Difference Lower	Interval of the Difference Upper	t	df	Sig.
% of monthly travel cost per income in Pre AA-LRT	22.17	9.22	8.57	9.88	27.89	270	.000
% of monthly travel cost per income in Post AA-LRT	12.94						

Source: Computed Using Survey Data, (2020).

Although, there are significant mean travel cost differences for the same trips by these four modes, the mean travel cost by AA-LRT has the greatest difference with the rest three modes (Table-8). Mean travel cost by AA-LRT is by far smaller than City-bus, Midi-bus and Mini-bus by 3, 4.50 and 9.70 ETB respectively. Findings also show that the mean travel cost of Mini-bus is larger than AA-LRT, City-bus, and Midi-bus by 9.7, 6.7 and 5.2 ETB respectively. The mean total travel cost by AA-LRT, City-buses, Midi-buses, and Mini-buses is 6, 9, 10.5 and 15.7 ETB respectively with increasing rate. Thus, findings show the smallest and largest travel cost for the same trip in the corridor is attributable to AA-LRT and Mini-buses, respectively.

Shortcomings of AA-LRT Operation

Regarding shortcomings, results indicate that AA-LRT operation has produced certain weaknesses such as excessive and inconvenient ground-level crossings; disintegration among transits for transfer

Table 8: Multiple Comparisons between Transits in their Travel Fare using Bonferroni Post Hoc Tests

Transit type (I)	Transit type (J)	Mean Difference (I-J)	Sig.	ANOVA df	ANOVA F
AA-LRT	City-bus	-3.00*	.000	3	268.44
	Midi-bus	-4.50*	.000		
	Mini-bus	-9.70*	.000		
City-bus	AA-LRT	3.00*	.000		
	Midi-bus	-1.50*	.000		
	Mini-bus	-6.70*	.000		
Midi-bus	AA-LRT	4.50*	.000		
	City-bus	1.50*	.000		
	Mini-bus	-5.20*	.000		
Mini-bus	AA-LRT	9.70*	.000		
	City-bus	6.70*	.000		
	Midi-bus	5.20*	.000		

*. The mean difference is significant at the 0.05 level.
Source: Computed using survey data, (2020).

options; distance-based fare and troubled ticket procedures; and overloaded trips mainly in peak hours.

Discussions

The results regarding the direct and indirect economic sustainability effects produced by the operation of AA-LRT are discussed as follows.

The Typical Transit Modal Choice, Usage and Share of Passengers

Bhatta and Drennan (2003) and Gleave (2005) indicated that nowadays all over the world urban planners and policymakers are seeking out more sustainable modes of transport because of an interest in high-density urban development as well as continuing concerns like traffic congestion, travel time, travel cost, and accident. In general, shift from road-based transport into more sustainable transport has resulted in an emphasis on the economic opportunities offered through mass transit, principally light rail (Kenworthy, 2006; Litman & Felix, 2002; Steg & Gifford, 2005).

Likely from the findings of this study, it is possible to understand that AA-LRT is a dominant transit mode which is giving passenger service to the people. People selected AA-LRT passenger service with the highest modal share and as their most frequently used transit mode for the daily trip.

Similarly, this study showed that people are shifting their transit modal choice from motorized modes into light rail transit for daily trips. For example, the current use of AA-LRT service by 86.2% of the respondents is an indication that most of the people are shifting their modal choice. As it is expected or planned, AA-LRT is playing the greatest role in enhancing public transit use and helping the people to shift their daily modal choice by attracting people who were using motorized vehicles such as city buses, midi-buses, and mini-buses. This new LRT service is really becoming a response and better option to tackle the transport-related problems in the city.

How AA-LRT Produced Economic Sustainability Effects

From the findings of an ordinal regression model, it is clearly shown that the amount of variance score for AA-LRT is the lowest of all transit modes and the change on outcome variable going up one level from Mini-bus and others into AA-LRT. Therefore, it is possible to conclude that AA-LRT service is producing higher levels trip benefits than other modes of public transit including city-bus, midi-bus, and mini-bus. AA-LRT is also responsible for the higher level of influence (about 53 percent) and changes created on the dependent variable (high level trip benefit) than the three public transit modes. In general, AA-LRT is producing a higher level of economic sustainability benefits such as lower travel time & travel cost and higher employment opportunities than City-bus, Midi-bus, and Mini-bus in the city.

Are Economic Effects More Sustainable in AA-LRT than Other Transit Modes?

Travel Time in the Pre and Post AA-LRT Period

Several studies indicated that the time costs of travel using road-based motorized modes are excessive. It is also pointed out that mass transit such as light rail has the capacity to provide several advantages to travelers and community such as the difference in travel time decrease, lower street congestion and need for fewer automobiles (Dhingara, 2011; Hitge & Vanderschuren, 2015; Metz, 2008). Moreover, studies indicated that mass transit mainly urban LRT in a standard commuting situation is enhanced by the belief that it provides travel service with shorter average travel time than vehicles (Prashker & Avineri, 2005; Wang & Loo, 2018).

Similarly, the findings of this study show that there was more excessive travel time and cost for the daily trips of passengers in the Pre-AA-LRT period than the Post-AA-LRT period. For example, for a single trip from "Ayat" to "Mexico area" station, travelers consume more than an average of 65 minutes before the start of AA-LRT whereas after the start of AA-LRT they consume an average of only 29 minutes for the same trip. As length of travel time becomes shorter in Post AA-LRT period, AA-LRT is more sustainable than other modes because it could reduce the length of travel time from 65 minutes into 29 minutes by almost 100 percent for the same trip distance and time.

Multi-modal Travel Time Variability Experiment

Rodrigue, et al. (2017) indicated that total commuting times of 1 to 1.2 hours spent per day is a standard for normal commuting, which indicates the sustainability of public transits in terms of savings of time. Likely, findings of this study indicate that the total travel time by AA-LRT is shorter than other transits and fits the commonly accepted standard of commuting time. This means that commuting in the corridor has gradually shifted to faster transit mode and as a result, greater distances can be traveled using the same amount of time by AA-LRT.

The inter-modal travel time experiment and comparison show that total travel time by City-bus ranges up to 97% (almost double) higher than that of AA-LRT. Total travel time by Midi-bus and Mini-bus also ranges up to 93% and 87% higher than that of AA-LRT respectively due to poor road infrastructure and higher traffic congestion.

Besides, travel time ratio or proportions of travel time of each mode in relation to AA-LRT is beyond a widely accepted threshold level of 1.5 (Kieu, Bhaskar & Chung, 2013) which shows that there is a variation of total travel time among these modes. City-bus has the highest travel time ratio of all. Regarding the magnitude of travel time variation among transit modes, the calculated 26 percent of the coefficient of variation (CV) of travel time is found to be beyond a widely accepted maximum threshold level of 10% difference. This higher CV level indicated that the magnitude of total travel time differences mainly in-vehicle travel time and waiting time among the four modes is larger.

As per standards of levels of service (LOS) indicated in Appendix-A, the length of waiting time for these four modes is

calculated to be LoS4 which is far beyond the widely used average waiting time standards or threshold levels of 10-12 minutes. This means all the three motorized transits have a non-existent or poorly organized passenger service. However, the 20 minutes waiting time for AA-LRT is found to be in a situation that may require considerable improvements in terms of supply of vehicles, coaches, coverage, frequency of service and comfort. The total travel time by the three on-road transit modes is far beyond the global standard of 70 minutes per person per day. Whereas total travel time by AA-LRT (about 69 minutes) is slightly below this global threshold range by 1 minute which makes it a relatively better transit option than the other three public transits.

Hitge and Vanderschuren (2015) indicated that the superiority of the public transit system is due to their competitiveness and sustainability nature mainly through relatively shorter travel time. Likely, findings show that the key focus areas of mainly on-road public transit projects and AA-LRT to some extent should be on the reduction of travel time (mainly waiting and in-vehicle time), relative to AA-LRT and in real terms moving closer to the global average. These data clearly showed that the three on-road public transit modes are not competitive with AA-LRT on a variety of fronts. Firstly, their walking and waiting time are longer than that of AA-LRT. Secondly, the in-vehicle speed of the AA-LRT is higher than on-road public transits and trip by the AA-LRT is not subjected to traffic congestion.

The actual total travel and waiting time of AA-LRT was also evaluated and compared against its targeted or intended one (i.e., speed of 60km per hour and 6 minutes of waiting time or service frequency). Despite its relatively shortest traveling time, it is possible to understand that the existing total travel time of 69 minutes and waiting time of 20 minutes are far beyond the planned one. This actual trip frequency rate or waiting time of AA-LRT is three times greater than its initial plan or design of headway (i.e., 6 minutes). Unless urgent measures are taken, this problem has its own implication to the creation of serious problems on AA-LRT performance and full benefits of service users.

Even if AA-LRT is unanimously seen by most of the respondents as the better way to travel long distances quickly and cheaply than others, the crowd at rush hours and the disorganized waiting time discourages other passengers. It is too complicated, there are too many people in the morning and evening at stations and no one knows when it will arrive. Lack of trains and longer waiting times in rush hours negatively affect passengers and other public transit modes including minibus, which additionally take advantage of these busy times to increase their prices, to the point that some people opt to walk long distances in the end. Although the average travel time by AA-LRT is relatively the shortest, the length of its waiting time and slow speed of in-vehicle journey poses an area for significant improvement.

Most of the interviews also confirm that due to traffic jams and longer travel time by Midi-bus, Mini-bus and City-bus; private and public institution employees could not reach on time on workplaces. These longer trips are also more crowded, sophisticated, unsafe and with no seats mainly during peak hours. For example, according to data obtained from manager of Blen Private Mini-bus Taxi Association (2018) due to an increased number of road vehicles and road congestion, the length of travel time from 'Stadium area' up to 'Ayat station' reaches about 3hours by those motorized public transits mainly during peak hours. In addition, when larger numbers of people made a shift from those motorized transit modes to AA-LRT since 2015, an estimated large amount of money could be saved on vehicle operating costs and fuel importation every year. Consequently, with a smaller number of vehicles on the road, there could also be a smaller number of road traffic accidents and related further economic savings.

In general, by considering these huge savings of travel time it is simple to conclude that AA-LRT is more economically sustainable than other transit modes. Passengers' travel time savings could also bring additional economic benefits to AA-LRT users because time really is money.

Affordability of Travel Cost in the Pre and Post AA-LRT Period

Affordability implies the financial capacity to pay for the ability to reach destinations for everyday needs such as work and education without excessive economic hardships. The economic sustainability of any public transport project is determined by an increase in travel cost affordability or lower cost of travel which is expended by service users per month and distance (Cervero, 2011). Zhong et al, (2003) showed that unlike the middle and higher-income people the poor in Thailand and Indonesia avoid using Mini-buses and other types of Para-transit except in emergencies and non-routine situations when they have no other alternative because they cannot afford the fares.

Surveys undertaken in several African cities indicated that households spend between 8 percent and 15 percent of their total monthly expenditure to transport. On the contrary, certain extremely low-income community groups in many cities of developing countries spend more than 30 percent of their monthly income for similar travel by public transit (Paul & John, 2014).

Public transits in urban areas have different transport price rates and the affordability of travel cost is determined by considering the proportion of monthly household travel expenditure which is expected to be below 15 percent. Thus, a particular transit is said to be more affordable if the proportion is lower than 15 percent (Rodrigue, et al., 2017). Likely, as the findings indicate, the cost of transportation for the same daily trips in the corridor was higher before the start of AA-LRT than the Post-AA-LRT period (i.e. after 2015). Before the start of AA-LRT in 2015, people were spending an average of 22.17 percent of their monthly income which is beyond the commonly accepted standard of 15 percent. On the contrary, people nowadays in post-LRT period are spending 12.94 percent of their monthly income which fitted the global standard of 15 percent. As expected, AA-LRT brings about significant travel cost reductions (about 54%) in Post AA-LRT period.

Since the factors that determine travel cost rates and the government subsidies which are provided for both AA-LRT and City-buses are well considered in this study, the comparative transport prices shown by the travel cost experiment are reflective of the competitiveness of each transit option. The comparative travel cost experiment result shows that passengers spend the smallest amount of travel cost for trips by AA-LRT but the largest one for the same trips by Mini-buses in the corridor. It is AA-LRT service that shows statistically significant travel cost difference with the three transit options. Therefore, it is possible to infer that the affordability of travel fees is lower in all other on-road public transits than AA-LRT for the same trip distance, period and direction. AA-LRT is providing passenger service at more affordable price than other modes. This consequently helps families to save more amounts of their incomes and cover the costs of other needs such as education and health.

This investment in LRT has significant economic benefits for households, especially those with modest incomes. AA-LRT can play a key role in helping families manage the rising cost of petrol and other costs. As

these types of costs rise there is disproportionate impact on modest-income families, which have to expend ever-larger percentage of an already inadequate income of families on transport. Thus, for several households that cannot afford a vehicle, AA-LRT becomes almost the only affordable option for all time in the area.

Since the primary purpose of transportation is to fulfill a demand for mobility of people, this lower travel cost is significantly contributing by fulfilling this demand and by increasing the mobility of passengers in the area in comparison with other public transits and the situation before the start of AA-LRT. Thus, for many passengers, the availability of affordable light rail services can be the difference and better choice.

Shortcomings of AA-LRT Service

In spite of the various economic sustainability benefits, AA-LRT service has produced certain problems for passengers and residents. Accordingly, the existence of excessive ground-level crossings is not only inconvenient with the existing land use patterns but also major causes of traffic congestion, slower speed and reliability of AA-LRT trips. In addition, overcrowded LRT journeys particularly during peak hours, lack of transfer options due to disintegration among public transits, distance-based travel charge system and troubled ticket procedures are also major weaknesses. Besides, some of these shortcomings are also consequences of planning and design problems. Consequently, these shortcomings produce problems on passengers, pedestrians and other modes in the corridor.

Conclusions and Recommendation

The positive economic impacts produced by AA-LRT services are obvious and understandable. AA-LRT system has generated direct, indirect, short term and long-term economic benefits to the passengers, people, and the city. From an economic sustainability perspective, the significant benefits are savings of travel time and associated congestion reduction, reduced travel costs or increased affordability of transport fares. This means fewer motorized public transits like City-buses, Midi-buses, and Mini-buses are crowding and congesting the major downtown roads of the city. However, this new and unique AA-LRT project is giving the city a faster, cheaper and more convenient transit system that can fit the Addis Ababa's wishes to come. There is no question that AA-LRT is the best answer to the serious, long-term, and multi-dimensional transport problems facing the city of Addis Ababa.

AA-LRT system is also a viable alternative to other modes of transportation such as City-buses, Midi-buses, and Mini-buses because of relatively higher-level benefits and convenience associated with it. Currently, for a variety of economic sustainability reasons AA-LRT is almost unanimously accepted as a better option for the people. It becomes a more convenient means for the city to accommodate the growing transport demands. The sustainability benefits of AA-LRT far outweigh the benefits provided by other motorized public transits in nearly every criterion used in this study such as affordability of fares and saving of travel time. It is generally compared with Maxi-buses, Midi-buses, and Mini-buses and then the overall benefits provided by AA-LRT are found to be more economically sustainable and suitable for the city. AA-LRT is by far the best way to move people of all income, sex, and age groups to and from the workplace. The savings of travel time and travel costs by AA-LRT are still by far the best compared to alternatives and even the situation before the start of AA-LRT. Due to these higher-level benefits, AA-LRT tends to bypass road traffics and attract more ridership to make modal shift even among the car users and owners.

The advantages of AA-LRT operation outweigh the associated disadvantages and its shortcomings are also by far lower than the shortcomings of other transits. This is because; all of the economic benefits contribute to one of the core principles that guide the development of this light rail project i.e. economic sustainability. Accordingly, this study makes its own contribution to the existing body of knowledge and debates on modes of public transit in urban areas mainly between advocators of road-based versus rail-based public transit. It is important to note that, in many cases, the Author has concluded and agreed with those advocators of rail-based public transits mainly light rail. There is an agreement that light rail service has improved quality and choice of public transport and that system has been delivered much as planned.

Properly addressing the shortcomings of the AA-LRT are essential to maintain its sustainability benefits and address the transportation problems of the city at large. To this end, the Author has suggested solutions such as building alternative elevated crossings or overpasses by reducing the excessive ground-level crossings; expand the coverage of AA-LRT network and additional trains to cover more potential areas. Furthermore, plan modification and integration among transits for better transfer options and for improved travel and waiting time; and flat fare, modern ticket and control system are also suggested. Since this study did not include the project's cost-benefit analysis; it will be better for future research to focus on cost-benefit analysis for project profitability and cover environmental and social aspects.

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