Performance Analysis of Urban Public Transport Service Enterprise in Addis Ababa: Data Envelopment Analysis

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Abstract
Measuring the public transit service enterprise's performance is a powerful tool for decision-making and managerial control to assess the utilization level of various inputs to obtain the desired outputs. Thus, this study aims to measure the performance of public bus transport enterprises of Addis Ababa using the Data Envelopment Analysis method during the year 2016/17 to 2017/18. There is an absence of studies in the country examining public transport sector efficiency using the DEA approach, which makes this research a chance. The study employed an input-oriented DEA model to measure bus transit efficiency. Thus, fleet size and a total number of employees are used as inputs, while covered vehicle km and total passengers transported per year are used as an output to measure performance. Then, the enterprises' technical efficiency and operational effectiveness are analyzed based on secondary data collected from each enterprise. The overall results show Anbessa and Sheger city buses are technically efficient and operationally effective in utilizing their inputs to deliver the desired output compared to others in the city. However, outcomes for Alliance city bus and Public Service Employees Transport Service Enterprise indicate that they utilize their inputs inefficiently and consumed their services ineffectively. Hence, these inefficient enterprises need significant improvements in using their resources to enhance their performance and deliver services incompetent with other operators in the city. Besides, the Government should encourage privately owned public transport operators in the city and provide subsidies and other incentives to all based on their existing performance.
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1. Introduction

The transport sector plays a substantial role in the country's overall development (Agarwal, 2016). The movement of people and goods mainly depends on transport, and it is also an expressive factor for a country to maintain a robust economy(Iles, 2005). Due to its low running and initial cost, route flexibility, and permeability into town and city centers, a conventional bus is the dominant public transport mode in most cities of developing countries (Iles, 2005; Verma & Ramanayya, 2014). Besides, buses are the most common choice for most commuters as it is the cheapest mode of travel (Armstrong-Wright and Thiriez, 1987). Hence, the provision of adequate and proper public bus transit services is one of the most vital components for the well-being of growing and expanding urban areas (Murray et al., 1998).

However, cities in developing countries, including Addis Ababa, face a simultaneous increase in urban population, income, and private vehicle ownership, which joined with resource limitations and creates a puzzling environment for their urban transportation system(Henning et al.,2011; Norouzian-Maleki et al., 2020). Moreover, recently, a rapid increase in private vehicles set pressure on most cities of the developing world's urban transportation system. As Greene and Wegener (1997) mentioned, the growth of using personal cars aggravated the problem of congestion, traffic noise, and air pollution. Also, it harms public transport operations in the city and hurts the efficiency of transit service agencies.

Hence, in such a situation, Government should encourage people to use public transportation by designing various policies (Hafezi et al., 2013; Hwe et al., 2006). Thus, multiple governments worldwide have used various approaches to encourage changing private car users by public transit, such as buses or subways. Promoting public transport is a significant option to minimize the problems associated with urban transport in most cities in developing countries. Besides, it significantly contributes to reducing traffic congestion, air pollution, providing an alternative means of travel, and contributing highly to the worth of urban life (Estrada et al., 2020; Vuchic, 2005). Therefore, policymakers in such cities should quickly plan and implement performance-enhancing actions for their urban transport systems proportionate with the challenges they face. It requires the ability to conduct performance assessments, learn from good practice elsewhere, and recognize the areas and scale of prospective improvement (Henning et al., 2011).

The public transport system of Addis Ababa city is composed of mainly Light Rail Transit and Bus operations. The Government owns public bus operators, such as Anbessa city bus, Sheger city bus, and Public Service Employees' Transport Service Enterprise (PSETSE). The only privately owned city bus is the Alliance

city bus. Also, the state-owned transit operators have been subsidized by Addis Ababa City Administration. For instance, in 2017/18, 52.2% of the revenue for Anbessa city bus obtained from AACA through subsidy and 41.2% was from traffic revenue, and the remaining were from other sources. Similarly, for Sheger city bus on the same year subsidy cover, 49% of the income and 43.4% is obtained from traffic revenue (AATA, 2017/18). So, almost half of the revenue for these enterprises had covered by the city administration.

Though the Government invests a massive amount of capital in the city's public transit systems, transport is still a considerable challenge for all stakeholders. Therefore, giving significant attention to measuring and improving a transit system's performance is critical due to the severe operating environment and financial difficulties in which the sector provides service in the city. Because measuring a transit system's performance is an effective tool for ensuring the continuous improvement of service quality and allocating resources and other incentives among competing transit operators in the city.

On top of that, studies have conducted on the performance of public transport system of the city; such as Abreha, 2007; Berhan et al., 2013; Gebeyehu & Takano, 2007a; Gebeyehu & Takano, 2007b; Berhan, 2013 and Mihretie, 2013; however, all of them were concentrated on measuring the performance of public transport of the city emphasizing only the Anbessa bus service in the city. Also, there is a deficiency of studies in the city scrutinizing transit operators' efficiency using the DEA approach, which generates an opportunity for this research. But, some studies are conducted in the country using DEA in other sectors. To begin, Boru (2014) conducted a study on the Ethiopian banking system's efficiency using the DEA approach. The finding indicates that the bank industry's efficiency level was at a modest level. Similarly, (Dagnaw & Wang, 2018; Garamu, 2016; Zenebe, 2017) are conducted to study the efficiency of bank sectors in Ethiopia using the DEA approach. On the other hand, (Seid, 2006) using DEA to measure the efficiency of selected hospitals in the city, and (Mutyasira, 2017) applied the DEA approach to Ethiopia's farming system.

Hence, this study would expect to fill the gap observed in the empirical literature. It also contributes to applying the DEA approach to the country's public transit system and other related sectors to measure the efficiency of organizations and identify the inefficient sectors for improvement using slack variables analysis. Therefore, this study aims to measure the enterprise's technical efficiency and operational effectiveness using the Data Envelopment Analysis model for the year 2016/17 to 2017/18.

2. Literature Review

2.1. Transit Performance Measurement

The term performance refers to any appraisal or comparison measure, and it can be considered a quantitative or qualitative characterization of performance (Eboli & Mazzulla, 2012). Performance measurement is well-defined as assessing an organization's output as a product of the management of its internal resources (money, people, vehicles, facilities) and the environment in which it operates (Transportation Research Board, 2002). Further, it is described as the technique to evaluate how good or bad is the performance of transit service is under the prevailing operating condition (Raoniar et al., 2015).

Moreover, measuring public transit performance is an essential tool for the transport service enterprise. It generally lets them validate whether the service is delivered efficiently and effectively, to recognize areas where performance enhancement may be needed, to confirm that community and customers are satisfied; and to support decision making bodies; such as transport authorities and funding institutions, to decide where, when and how service should be provided (Henning et al.,2011). Performance measures also serve as a navigation tool that helps an organization decide where it wants to go and how to get there. It has numerous practical applications, such as trend analysis, comparisons, goal setting, system upgrading, and incentives for managers and employees. It also helps to identify potential problems and optimal solutions (Dhingra, 2011).

As Eboli & Mazzulla (2012) measurement of transport performance embodies a very vibrant tool for confirming the continuous rise of the quality of the provided transit services, and for allotting resources among competing transport agencies. Besides, performance evaluations are an objective means of appraising performance. They are commonly thought of as one of two basic types:

    i.   Efficiency measures designate the association between work accomplished and the resources required to perform it.

    ii.   Effectiveness measures are mostly thought of as displaying how effective a transport system is concerning accomplishing its aims. Usually, this is considered with passengers carried and is measured by such factors as passengers per vehicle hour or a mile or percentage of costs recovered from operating revenues (Carotenuto et al., 2017; Carter and Lomax,1992; Dajani & Gilbert,1978; Fielding et al.,1985; Cook and Lawrie, 2004).

Public transit performance assessments can reveal various viewpoints. Many regularly- used transit performance indicators, like load factor and cost per vehicle per km, measure operational efficiency. Other indicators; like, rider comfort, trip speed, reliability, affordability, integration, and pleasure, reveal the user experience. User-oriented indicators are significant for developing public transit systems that account for user

demands and invite even choice riders. It is an extent that needs thoughtful thought in most developing cities currently (Dhingra, 2011).

To sum up, as most literature on performance measurement indicates a model of transit performance forwarded by Fielding et al., (1985) used commonly to measure the performance of public transport system by defining technical efficiency as the ratio of service output (production) to inputs and operational effectiveness as the ratio of consumption to inputs as shown in the next figure 1. It shows the relationship between the three performance measures and lists the indicators related to inputs and outputs variables in the public transit system.
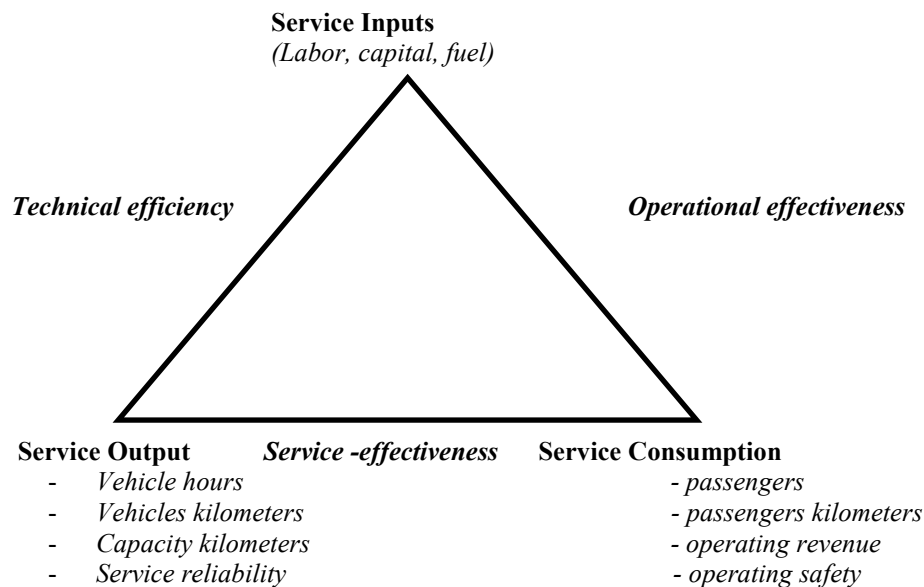

Figure 1. Structure for a transit performance notion model
(Source: adapted from Fielding et al., 1985; Chiou et al., 2010)

i.   Technical efficiency

It denotes the process through which service inputs (resources) are converted into outputs. It means that a transport service provider devotes capital for vehicles, fuel, workforces, and other resources and produces a specific yield for the public, such as vehicle km, seat –km, and service hours. Therefore, an operator is considered efficient if it can decrease inputs to produce a fixed amount of outputs or maximize output while using the same or fewer inputs.

ii.   Operational effectiveness

It shows the connection between service inputs (resources) and consumed service. Thus, a transit operator spends capital to deliver its service; several passengers consume its service per day/month/year. Hence, an Operator will achieve higher operational or cost-effectiveness, if it enhances the number of passengers without increasing the total cost of generating the service.

iii.   Service effectiveness

It measures the relationship between produced output and consumed service or shows how well the community consumes the delivered services by operators. This is because all of the delivered services (i.e. vehicle –km, seat-km, etc.) are not used by a community. Hence, if it attracts more users without enhancing services or minimizes service but still serves the same number of passengers, it will be more effective.

Therefore, this study's main emphasis is also to evaluate the performance of public bus transit operators in Addis Ababa city based on the Transit Performance Concepts Model forwarded by Fielding et al.,(1985).

2.2. Previous Studies

DEA is one of the powerful techniques used for measuring the performance of various DMUs that consume multiple inputs to generate various outputs. And, it has been widely used to measure the performance of public transport systems. For instance; Kral and Rohacova, 2013; Han and Hayasn, 2008 are employed the DEA model to measure the mass transit system's efficiency and identify the efficient and inefficient DMUs in their studies. Besides, Barnum et al., (2007) also applied DEA in measuring the park's efficiency and ride a lot in public transport systems using DEA. Some studies that used DEA are summarized as follows with input and output variables used for their research.

Table 1. Studies Applying DEA in the public transit system

Author(s)	DMUs	Inputs	Outputs	DEA Model
Kral, P. and Rohacova, V. (2013)	20 Transport companies	the average number of employees, total km driven, the total number of vehicles, tangible fixed asset, and operation cost	total number of passengers, total sales	VRS-DEA
Ayadi (2013)	12 urban transit system in Tunisia	total number of bus park, number of staff, fuel consumed	traveled km	DEA Regression model
Lao, et.al (2009)	24 fixed routes in Monterey country, USA	operation time, round trip distance, number of bus stops, persons with disabilities, and commuter 65 and above	total number of passenger	DEA
Han and Hayasn(2008)	652 Urban transport system	number of employees, number of vehicles, energy consumption	number of passengers	DEA
Barnvma, et. al. (2007)	16 park and ride lot	number of parking spaces, operating cost	number of the parked car, revenue	DEA and SFA

3. Materials and Method

3.1. Materials

For the study, annual reports were collected from Anbessa city bus, Sheger city bus, Alliance city bus, and PSETSE bus for the year 2016/17 and 2017/18.

3.2. Method

Data envelopment analysis (DEA) is a technique for evaluating the relative efficiency of Decision-Making Units (DMUs) that produce similar products (Charnes, Cooper, and Rhodes 1978; Azadeh, Salehi, & Kianpour, 2018; Norouzian-Maleki et al., 2020). It is also a relatively new "data-oriented "method for assessing the performance of a set of peer entities or DMUs, which change multiple inputs into multiple outputs(Cooper, Seiford, and Zhu,2011).

The DEA frontier is non-parametric; no functional formulation wants to be stated, and each input/output variable can be measured in its usual measurement units; such as the hectare, meters, or numbers (Almawsheki & Shah, 2015).

DEA has been practiced in many sectors, such as Banks, hospitals, education, health care, finance, utilities, and Agricultural sectors. Also, DEA has been applied in Transport sectors like ports, railways, airlines, urban transit, airports, etc. So, DEA determines each transit enterprise's efficiency within a group relative to other operators in the group.

The most basic DEA model is the CCR model that Charnes, Cooper, and Rhodes proposed in 1978. It was developed to assess the relative efficiency of homogeneous DMUs with multiple inputs and multiple outputs. Also, the DEA-CCR model is used because it states the overall technical efficiency of each DMU (Almawsheki & Shah, 2015).

The CCR model is considered the most popular DEA technique, which assumes that there are n DMUs that each use m inputs to produce s output(s) (Banker, Charnes, and Cooper 1984). The CCR model measures the DMU's relative efficiency by comparison to a group of other DMUs that use the same input(s) and output(s). The CCR model is expressed as follows:

$$h_0 = \frac{\sum_{j=1}^{s} W_j Y_{jo}}{\sum_{i=1}^{r} V_i X_{io}} \tag{1}$$

Maximise:

Subject to: $\dfrac{\sum_{j=1}^{s} W_j Y_{jm}}{\sum_{i=1}^{r} V_j X_{im}} \leq 1 \quad m = 1,2,\ldots,n \tag{2}$

$W_j \geq 0; \quad j = 1,2,\ldots,s \tag{3}$

$V_i \geq 0; \quad i = 1,2,\ldots,r$

Where:

Y_{jo} = Output j of the DMU 0;

X_{io} = Input i of the DMU 0;

W_j = Weight for the output j:

V_i = Weight for the input j;

n = Nº of DMU;

s = Nº of inputs;

r = Nº of outputs

If $h_o = 1$, it means that DMU $_o$ is efficient relative to other similar DMUs. If $h_o < 1$, then the DMU $_o$ is inefficient.

Therefore, for this study the DEA-CCR input orientation model is employed and the step-wise procedure used is described as follows;

Selection of DMU → Selection of Variables (Input &output) → DEA-CCR Model & Input-Orientation → DEAP 2.1 Software → Efficiency score & Slack variable analysis → Conclusion &recommendations
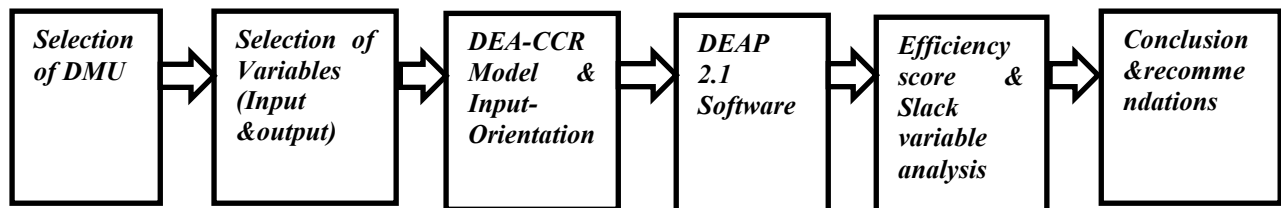
Figure 2. Research Procedure of the study

Thus, as shown above, DMUs were first selected (i.e. Anbessa, Sheger, PSETSE, and Alliance city bus enterprise) were included for the study. Regarding the number of DMUs, the study was supported by a rule of thumb; i.e. Dyson, et. al. (2001) suggest that if there are M inputs and N outputs, there need to be at least 2M*N DMUs in the set to be compared. So, there are two inputs and one output, and four DMUs ($n \geq 2*2*1$) for this study.

The selection of input and output variables is a significant part of evaluating the efficiency of the enterprise. So, based on the objective and mission of the transit agencies, literature review on input and output factors used in other studies, and availability of data the following variables are used as inputs and output in this study: Input variables (number of employees and number operated buses), output variable (total covered km) to measure technical efficiency; also to measure operational effectiveness total number of passengers transported in a year is used as an output variable.

Then, the study employed a CCR-DEA input-orientation model by cross-sectional data to evaluate the enterprise's efficiency. It is because input orientation is assumed that the inputs in an organization are controllable compared to outputs. Enterprise can control its resources used in providing transit services (number of buses, number of employees, etc.); but cannot manage the number of passengers transported on their services.

Last, DEAP 2.1 software was used to compute all operators' efficiency scores based on the CCR input-oriented model. The following figure shows the flow technique of DEA-CCR efficiency analysis and slack variables investigation for the study.
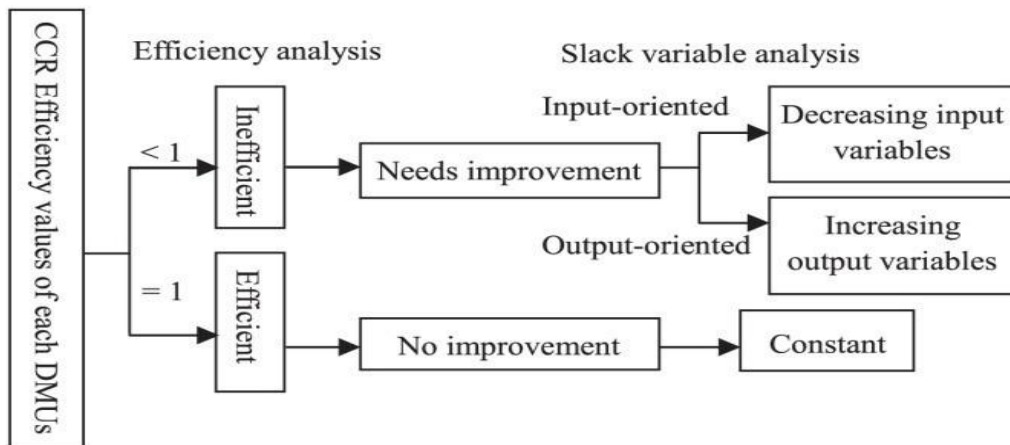
Figure 3. The flow of DEA-CCR model and Slack Variables Investigation

Hence, as can be seen in the above figure, concerning the efficiency value analysis of DMUs, when the efficiency score of the enterprise is less than one, it indicates the enterprise is technically inefficient, besides the inference is that the operating input to yield the output being used is not appropriate. Therefore, it should be an obligatory to decline input or enhance output reliant on the nature of the orientation model used. Thus, slack variable investigation can be used for inefficient DMU to display and advance the significant causes of inefficiency. The analysis will also categorize the use rate of variables (input and output), by evaluating how to increase the operational efficiency of inefficient DMUs by showing how much output to increase and/or how much input to decline, then building the inefficient DMU efficient (Almawsheki & Shah, 2015).

4. Results and Discussion
This section of the study presents the outcomes of technical efficiency and operational effectiveness of public bus transport enterprise in the city. Cross-sectional data for 2016/17 and 2017/18 were used and applying DEA-CCR with an input-orientation model.

4.1. Analysis of Technical Efficiency
Figure 4, illustrates the result for technical efficiency of public bus transit providers in the city during 2016/17 and 2017/18. Thus, it can be observed, the technical efficiency score for Anbessa and Sheger city buses was equal to one in 2016/17. This displays that they were technically efficient in utilizing their inputs (i.e. vehicles and staff) to offer the defined output (covered km) as related to their peer operators. The score for Alliance (0.751) and PSETSE (0.344) indicates that they were technically inefficient in providing service in the city. The mean result for 2016/17 indicates 0.774; it implies that the aggregate public bus transport service during the year was technically inefficient in the city.

Moreover, the result for 2017/18 shows, only the Sheger city bus was technically efficient, and the result for others is less than one it shows that they were technically inefficient. Besides, the result shows, except for the Sheger city bus, the result of efficiency for all operators in the city was declined and the mean result was reached 0.612 and reduced by 79% during this year in the city.
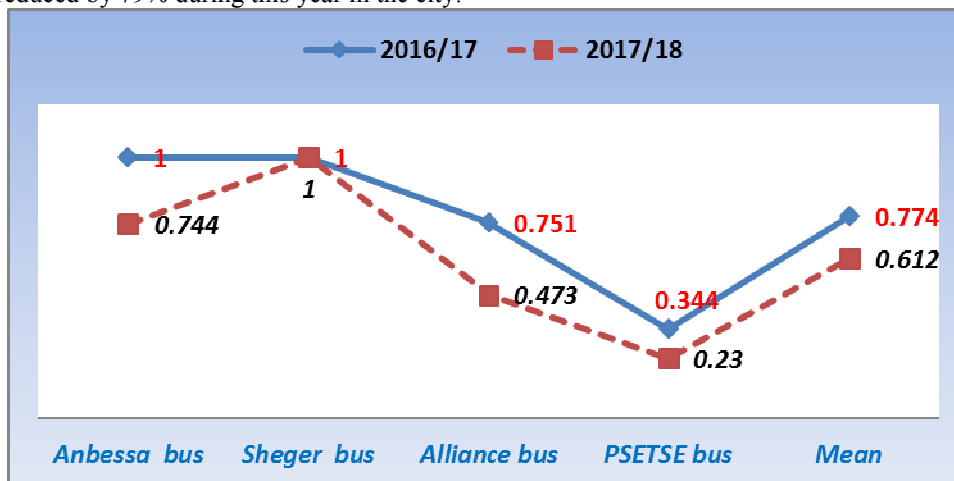

Figure 4. Technical efficiency of public transport enterprise

On top of that, slack variable analysis suggests that inefficient DMUs should improve their input variables to enhance their technical efficiency and become efficient. This is possible by either increasing or decreasing the input levels. Thus, based on 2016/17, slack variable analysis suggests that Alliance city bus needs to improve its technical efficiency by 24.9% and PSETSE by 65.6% to become technically efficient. So, Figure 5 shows the percentage changes in each transit operator's improvement to become efficient in the years.
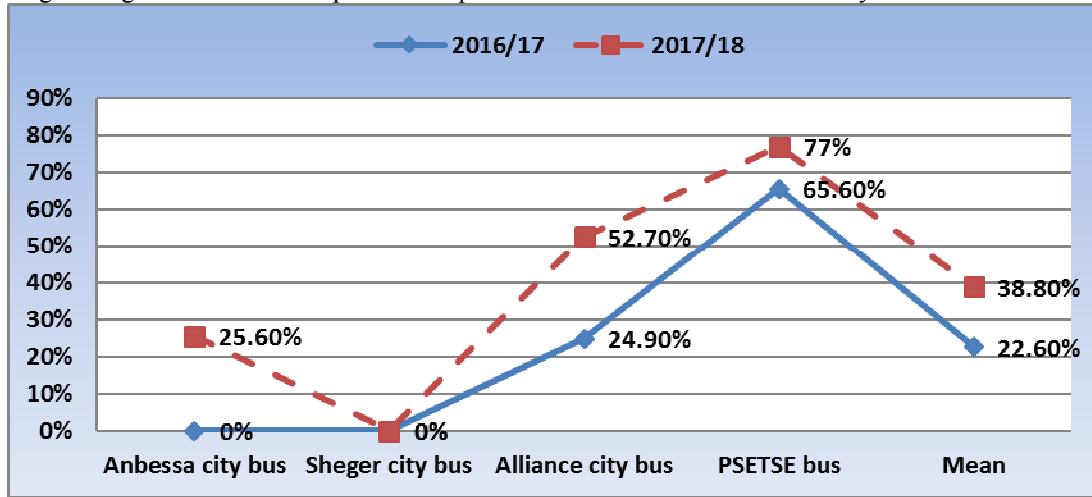

Figure 5. Percentage Change for Improvement of each inefficient enterprise

4.2. Analysis of Operational Effectiveness

Similarly, figure 6 illustrates the operational effectiveness results for each transit operator using the same input but with different outputs (i.e. the number of passengers per year). Thus, the effectiveness score only for the Anbessa city bus is equal to 1 during the two different years; and it implies that Anbessa is operationally effective in the city. The Sheger city bus was also scored one in 2017/18, and it was an operationally effective operator in the city. However, Alliance city bus and PSETSE were operationally ineffective for both years compared to other operators in the city in utilizing their inputs to produce desired outputs. Moreover, the mean result shows the city's public transport sector was operationally ineffective in the city for both years.

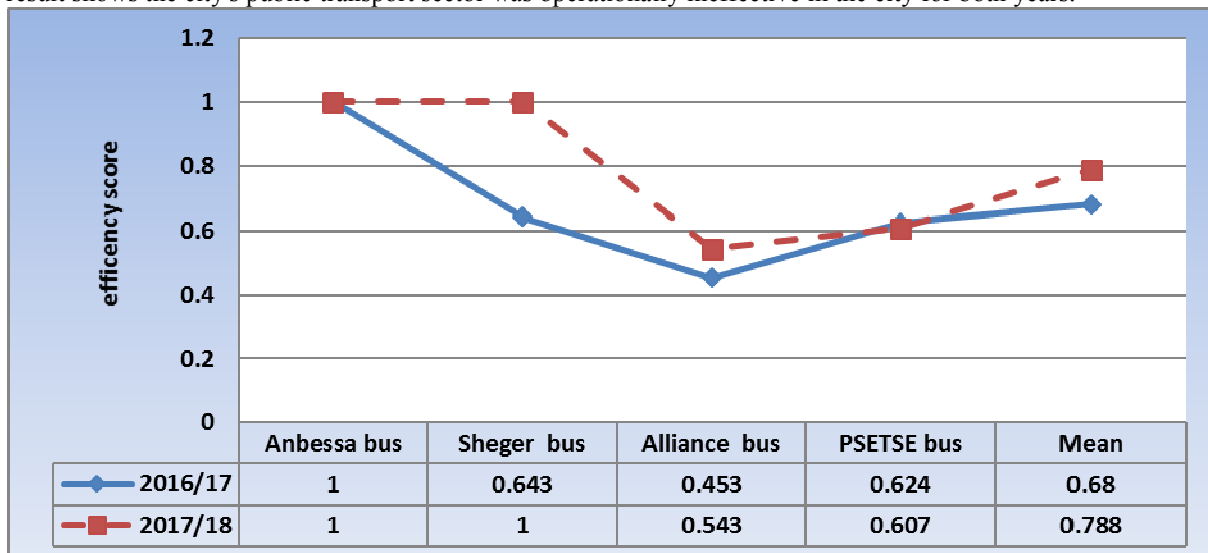|	Anbessa bus	Sheger bus	Alliance bus	PSETSE bus	Mean
2016/17	1	0.643	0.453	0.624	0.68
2017/18	1	1	0.543	0.607	0.788

Figure 6. The operational effectiveness of public transport enterprise

Lastly, based on the above results, this study suggests the inefficient and ineffective transit enterprise should improve their performance. Thus, slack variable analysis has been annexed for them to become efficient transit agencies in the city.

5. Conclusion

This study evaluates the public bus transport sector's technical efficiency and operational effectiveness using the DEA approach for the first time in the city. Findings of the study indicate that Anbessa city bus and Shegr city bus were technically efficient in 2016/17, while Alliance city bus and PSETSE were inefficient in public transport operation in Addis Ababa city. Besides, in 2017/18, Sheger city bus was the only technically efficient

transit service operator. The others Anbessa bus, PSETSE, and Alliance city bus were inefficient. Moreover, the mean result for both years shows public transport systems of the city was technically inefficient with the outcome of 0.774 and 0.612 in 2016/17 and 2017/18, respectively.

On the other hand, operational effectiveness shows only the Anbessa city bus was effective for both years in the city. Also, the effectiveness result for Sheger city bus has improved and became effective in 2017/18. The result for other transit service operators shows that they were ineffective, and they need to improve their efficiency level based on the outcome for slack analysis.

To sum up, Anbessa and Sheger city bus performs better than Alliance city bus and PSETSE bus. It indicates that Alliance and PSETSE are utilized their resources inefficiently to produce the desired output and are consumed ineffectively by the users. Hence, they need significant improvements in using their resources to produce the desired outcome, enhance their performance, and deliver services incompetent with other city operators.

Hence, the Government should encourage privately owned public bus transit operators in the city and provide subsidies and other incentives to all bus transit operators based on their current performance to promote the enterprise and enhance its operational efficiency.

5.1. Implications of the study

This study has significant implications both for practitioners and academics. From the management perspective, this study's results may provide managers and decision-makers to know the performance level of the enterprise in the city. It supports them to identify the inefficient DMUs and source of the enterprise's inefficiency; based on the result of slack variable analysis, they can change the inefficient organization to efficient. Moreover, they can measure the efficiency level of depots, routes, branches using the DEA approach to identify the efficient and inefficient DMUs and improve based on the result of DEA.

From the research perspective, this study addresses a research gap by using DEA in the city's public transport sector. DEA can be used in research on various sectors of the country (e.g. hospitals, banks, schools, etc.) by applying similar procedures to know their performance level in the provision of service for the community and identify the inefficient DMUs for policy insight development to improve the services, especially in developing countries.

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Annex 1. Descriptive Statistics of the Variables 2016/17 and 2017/18

	Input variables				Output variables			
	# of Operated buses		# of Employees		# of passengers (for effectiveness measure)		Vehicle-km (for efficiency measure)	
	2016/17	*2017/18*	2016/17	*2017/18*	2016/17	*2017/18*	2016/17	*2017/18*
Max	447	*438*	3398	*3559*	133,770,900	*105,758,047*	18,759,848	*16,220,017*
Min	70	*80*	333	*339*	8,064,000	*6,763,518*	644,965	*653,622*
Average	217.333333	*230*	1449.33333	*1455.5*	51,942,436	*42,322,041*	7,520,084	*7,771,630*
SD	170.008578	*155.3984*	1450.3235	*1496.682*	61125633.32	*46659006.3*	8367299.89	*7769753.6*

Annex – 2 Slack Variable Analysis: Suggestion for improvement of inefficient enterprises
i. Technical efficiency result
Year: 2016/17

DMU		*Original value*		*Projected value*
Alliance city bus (Te: 0.751)	*Output 1*	*1910880*	Output 1	1910880
	Input 1	*70*	Input 1	52
	Input 2	*452*	Input 2	339
PSETSE (Te: 0.344)	*Output 1*	*644965*	Output 1	644965
	Input 1	*149*	Input 1	17
	Input 2	*333*	Input 2	114

Note: Anbessa and Sheger bus are efficient

Year: 2017/18

DMU		Original value		Projected value
Anbessa city bus **(Te:0.744)**	*Output 1*	*16220017*	Output 1	16220017
	Input 1	*438*	Input 1	325
	Input 2	*3559*	Input 2	1936
Alliance city bus **(Te: 0.473)**	*Output 1*	*1712880*	Output 1	1712880
	Input 1	*80*	Input 1	34
	Input 2	*432*	Input 2	204
PSETSE **(Te:0.230)**	*Output 1*	*653622*	Output 1	653622
	Input 1	*151*	Input 1	13
	Input 2	*339*	Input 2	78

Note: Sheger bus is efficient

ii. Operational effectiveness result

Year: 2016/17

DMU		Original value		Projected value
Sheger city bus *(e: 0.643)*	Output 1	19800000	*Output 1*	*19800000*
	Input 1	121	*Input 1*	*66*
	Input 2	782	*Input 2*	*502*
Alliance city bus *(e: 0.453)*	Output 1	8064000	*Output 1*	*8064000*
	Input 1	70	*Input 1*	*26*
	Input 2	452	*Input 2*	*204*
PSETSE *(e: 0.624)*	Output 1	8184814	*Output 1*	*8184814*
	Input 1	149	*Input 1*	*27*
	Input 2	333	*Input 2*	*207*

Note: Anbessa is efficient

Year: 2017/18

DMU		Original value		Projected value
Alliance city bus *(e:0.543)*	Output 1	7718400	*Output 1*	*7718400*
	Input 1	80	*Input 1*	*39*
	Input 2	432	*Input 2*	*234*
PSETSE *(e: 0.607)*	Output 1	6763518	*Output 1*	*6763518*
	Input 1	151	*Input 1*	*34*
	Input 2	339	*Input 2*	*205*

Note : Anbessa and Shger are efficient

Note i. *Input 1: # of buses*
        Input 2: # of employees
        For analysis of operational effectiveness output 1 is the number of people transported per year.
        For analysis of technical efficiency output 1 is the total vehicle–covered km per year.
        Projected value is a value for improvement to enhance their efficiency score

Note ii. *Government Fiscal Year (FY) in Ethiopia: July 8- July 7*
  Ethiopian Fiscal year (EFY)   Gregorian (European Year Equivalent)
      2009 E.C……………………………………….… 2016/2017
      2010 E.C……………………………....………… 2017/2018