EUROPEAN ACADEMIC RESEARCH
Vol. IV, Issue 11/ February 2017

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Road Network Performance Evaluation: *Empirical Evidence from Assosa Town*

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Abstract:

Road network growth may be understood as a process of addition such that the road networks are progressively added within a functional area joined together in a system. The general objective of this study is to evaluate the road network performance of Assosa town using the pre defined indicators. The affectivity will be expressed by five indicators as road density, serviceability, performance, traffic density and connectivity.

Required data was collected from primary and secondary sources. The primary data were obtained from field measurements. Field survey was carried out at the study area, using the Street Map (2016) as guide. The work in this study also covers a literature study, collection of data and related regulation, indicator development, and evaluation of road network performance for the study area. The result of the study revealed that the road density is 2.87/km, road performance is 0.264, traffic load is 0.0329, road serviceability is 0.0015 and road connectivity is 0.415. The study concluded that the performance of the road network in the regional capital is not satisfactory except the road density. The study suggests that total length of paved and good condition roads must be increase to attain an optimum road network.

Key words: Urban Road, Road Network, Road Performance, Urban Ethiopia

1. INTRODUCTION

1.1 Study Background

The success and progress of human society depends on physical infrastructure for distributing resources and essential services to the public. The quality and efficiency of this infrastructure affects quality of life, the health of the social system, and the continuity of economic and business activity. A nation's economic strength is reflected in its infrastructure asset. The history of economic and social system walks parallel with infrastructure development. Demands on infrastructure and related services increase as people expect a higher quality of life and public services. But, more importantly, good infrastructure facilitates a higher quality of life (Gwilliam, K., 2003). Infrastructure development is, however, a long-term issue, which has an important attribute the long gestation period of infrastructure project. As a result, decisions on investment in infrastructure require a long-term perspective. Furthermore, there is no clear-cut method of allocating public funds among the various infrastructure sectors (Akatsuka, Y. et.al. 1999). This has led public authorities and national planners to believe that it is needed a kind of method to allocate the limited resources to achieve the national objectives, especially transportation aspect. The objective of road transport services is to form a traffic and road transport in safe, secure, fast, fluent, order and regular, comfort and efficient, integrated with others mode, reachable by all land region, and support fair distribution, development and stability to drive, to motor, and to support national development with reachable cost by community. According to that objective, it is needed a performance evaluation which considering accessibility

distribution, safety, efficiency, effectively, reachable cost, and integrity with others transport system.

The evaluation has a goal to value the level of service of existing road network. The evaluation result will be used to estimate and build the strategy of road network rehabilitation and development. The evaluation has a role in developing sustainable transportation system, which has a meaning as a sustainable system for individual/community, economy, and environment. Road network development program starts with giving an input, in a kind of investment (money and human resources), then resulting an output, in a kind of physical road infrastructure. The using of this infrastructure makes an outcome, in a kind of traffic interaction in that road network.

Network growth may be understood as a process of addition such that the road networks are progressively added within a functional area joined together in a system. Many descriptive and analytical methods have been used to describe network growth. The general objective of this study is to evaluate the road network performance of Assosa town using the pre defined indicators. The affectivity will be expressed by five indicators as road density, serviceability, Performance, traffic density and connectivity. The work in this study covers a literature study, collection of data and related regulation, indicator development, and evaluation of road network performance for the study area.

1.2 Description of the Study Area

The study area is Assosa town. It is the capital city of Benishangul Gumz Region State, established in 1894 E.C. It is located 662km West of Addis Ababa and 96km far away from the Ethio-Sudan border. The geographical location of Assosa town is between 10°00' to 10°04' North latitude and 34°35' to 34°39' East longitudes (Municipality of Assosa, 2014). Total extent of the municipal area is approximately 24 sq. km. the town has an annual population growth rate of 2.5%

(Municipality of Assosa, 2014). The estimated population of the town is about 46,200 (CSA, 2015). Assosa has an aggregate population density of 1925 persons per square kilometre.

Figure 1: Partial View of the Road Network of the Study Area

The above figure shows the partial view of the central part of the study area. The Municipal area is divided into four (4) administration units (*kebeles*) namely Assosa 01, Assosa 02, Assosa 03 and Assosa 04. Assosa is a highly growing town in terms of population and infrastructures the region as well as in the country. The total road network constructed in the town from 1995 to 2016 E.C is about 68.1km, including asphalt, cobble stone and local earth roads.

1.3 Study Objectives and Scopes

The general objectives of this study are as follows:

- To evaluate the performance of road network in Assosa town using some selected indicators
- To compare the results with some standards
- To make some valuable recommendations for the road network performance improvements based on the outcome of the study.

2. RELATED LITERATURES REVIEW

The road network effectively is defined as an ability of the road infrastructure to fulfil its basic objective, which does not just

measure in benefit and cost only, but it is measured in the ability to fulfil several objectives. In general, the road networks are effective when all stakeholders in road development receive the benefit from it. To measure the effectiveness of road infrastructure, it is needed a series of indicator, which will give a measurement about how the elements of the system interact agree with the objectives. The characteristic of the indicators are: forecast ability (that compares future alternative projects or strategies), clarity (should be understood by stakeholders), usefulness (that gives clear information to all stakeholders), ability to diagnose problems (there should be a connection between the measure and the actions that affect it), temporal effects (the measure is comparable across time) and relevance (that is relevant to planning and budgeting processes).

As indicated in Mannering Fred L. et.al. (2004) Road networks are observed in terms of its components of accessibility, connectivity, and traffic density, level of service, compactness, and density of particular roads. Level of service is a measure by which the quality of service on transportation devices or infrastructure is determined, and it is a holistic approach considering several factors regarded as measures of traffic density and congestion rather than overall speed of the journey. Access to major roads provides relative advantages consequent upon which commercial users locate to enjoy the advantages. Modern businesses, industries, trades and general activities depend on transport and transport infrastructure, with movement of goods and services from place to place becoming vital and inseparable aspects of global and urban economic survival. Developments of various transportation modes have become pivotal to physical and economic developments. Such modes include human porter age, railways, ropeways and cableways, pipelines, inland waterways, sea, air, and roads.

According to Litman,T. (2007) there are no standardized indicator sets for comprehensive transport planning. Each

institution develops their own set of indicators based on the need and institutions abilities. In selecting a set of performance measures, it is important to recognize the distinction between input, output and outcome measures. Input measures reflect the resources that are dedicated to a program, output measures reflect the products of a program, and outcome measures look at the impact of the products on the goals of the agency. The dominant objective was to deliver services to the public at minimum cost. However, public administrations are now expected to meet service level targets at reduced costs and to develop mechanisms for customer feedback. The saying in Pickrell, S et.al (2001) explained that publicly-funded agencies have come under increasing pressure to be accountable to the public, the owners and customers of the agencies and the transportation systems they deliver**.**

Road network performance measures have been called the "backbone" of asset management systems and are considered to be a critical tool to report successes and opportunities. In the modern era of sustainability, performance measurement is also seen as key to measuring progress on that front. Transportation systems are recognized for the benefits they provide to the economy in terms of access and mobility but are also recognized for putting pressure on our environment. According to Pickrell, S et.al (2001) it is noted that the use of performance measurement to benchmark performance of one agency against another can be problematic. Benchmarking may help an agency to initially define a reasonable or desirable level of performance but it may not be useful as an ongoing comparison**.**

3. RESEARCH METHODOLOGY

3.1 Types and Sources of Data

Required data was collected from primary and secondary sources. The primary data were obtained from field

measurements. Field survey was carried out at the study area, using the Street Map (2016) as guide. The satellite imagery of the study area was also obtained from Google Earth 2016 in order to update the existing road networks. This study covered the entire roads network of Assosa town. Secondary data were obtained from the documents of the Municipality of the town. Finally, the results are presented in tables, charts and maps.

3.2 Performance Evaluation Index

There is tension between convenience and comprehensiveness when selecting indicators. A smaller index using easily available data is more convenient to use, but may overlook important impacts and therefore distort planning decisions. A larger set can be more comprehensive but have unreasonable data collection costs and be difficult to interpret (Litman, T. 2007). To measure the performance of urban road network, it is needed a series of indicator, which will give a measurement about how the elements of the system interact and agree with the objectives. The characteristic of the indicators are: forecast ability (that compares future alternative projects or strategies), clarity (should be understood by stakeholders), usefulness (that gives clear information to all stakeholders), ability to diagnose problems (there should be a connection between the measure and the actions that affect it), temporal effects (the measure is comparable across time) and relevance (that is relevant to planning and budgeting processes). Therefore, based on these major characteristic, we develop the following five performance evaluating indexes for the study area:

Table 1: Summary of the five performance evaluation indexes

S/No	Performance Evaluation Index	Descriptions
1	Road availability/Road density	It is the ratio between total road lengths with area width. Road availability has a unit km/km^2. The road density explains how dense the road network is in the area
2	Road Performance	A ratio between lengths of road in stable condition

		with total road length of the area. Road performance has no unit or km/km.
3	Traffic Volume Load	It is the ratio between total lengths of road with number of vehicles. This indicator has a unit km/no of vehicle. This indicator shows percentage usage of constructed roads by vehicles in the city.
4	Road Serviceability	It is the ratio between total lengths of road with number of people in the town. The unit of this index is km/people. This indicator shows the easily availability of roads for peoples in the city.
5	Road Connectivity (permeability)	Refers to the directness of links and the density of connections in path or road network. A well-connected road or path network has many short links, numerous intersections, and minimal dead-ends.

In general, this research uses analytical research approach which means it uses facts or information already available in the office and analyzes these to make a critical evaluation using some evaluation tools. The evaluation has a goal to value the level of service of existing road network of Assosa town. The evaluation result will be used to estimate and build the strategy of road network rehabilitation and development at the study area.

4. RESULTS AND DISCUSSION

The road performance of the study area is analyzed using five pre-defined indicators, namely road performance, road availability, traffic load, road connectivity and road services. Those indicators were calculated using aggregate data from the municipality of Assosa that covers from 1995 to 2016.

4.1 Determination of Existing Road Density (RD) of the Study Area: Road density is the ratio of the length of the total road network to the land area of the town. In this case the road network includes all roads in the town: arterial, sub arterial collectors and local roads. The total land area of Assosa is nearly 24 km^2 and the total road length constructed from 1995

to 2016 including asphalt, local earth road and cobble stone is about 68.9km. Therefore, the road density:

$$\boldsymbol{RD} = \textit{Total road length in km / Total Area}$$
$$= 68.9km / 24km^2 = 2.87/km$$

The road density is compared with the standard road density specified in (Odaga, A. et.al. 1995) which states that road density is high when it is more than 120m per square kilometres, medium when it is more than 30m and less than 120m and low when it is less than 30m per square km. The total length of the roads was converted to kilometres (km) from meters (m). This analysis showed that the road density was high comparing it with the standard as highlighted in (Odaga, A. et.al, 1995).

4.2 Determination of Existing Road Performance (*RP*): Total asphalt road with maintenance is 7.2km and local earth road is 42.7km. In this case we have to use the road length in stable condition and this is determined by deducting total earth road length and total asphalt road with maintenance from the total road length because this type of roads are not comfortable to ride.

$$\boldsymbol{RP} = \textit{(Total road length-Total gravel road and asphalt roads under maintenance)/total length of road in km}$$
$$\boldsymbol{= (18.2)/68.9 = 0.264}$$

Most of the existing road networks in Assosa are local earth roads, with poor condition. Such roads are unwalkable during the rainy seasons by forming muddy surfaces. In general, as we observe from the above result, the road performance is low in the considered year gap from 1995 to 2016. So based on the evaluation indicator of road performance, increasing the total

length of paved roads will increase road performance then the road network performance will be good.

4.3 Determination of Traffic Load (*TL*) of the Study Area: Traffic load (traffic density) is a ratio between total lengths of road with number of vehicle. This indicator has a unit km/no of vehicle. Which tells us how the number of vehicles affects the total road network and we can calculate using the above data as

$$\boldsymbol{TL=}\ \textit{Total length/Total number of vehicles}$$
$$= 68.9/2097 = 0.0329$$

The road network of Assosa town suffered from regular maintenance, planned expansion and from a lack of long-term maintenance plans. It is therefore even more critical to provide mobility options other than just encouraging the use of the private car. This illustrates moreover the limited availability of road infrastructures and especially of quality paved roads. It is therefore necessary to seek adapted transport solutions which optimize the use of road infrastructures currently available.

4.4 Existing Road Serviceability (*RS*) of the Study Area: The estimated population for 2015 of Assosa town is about 46,200 (CSA, 2015) and the total length of road in the town is 68.9km. Road serviceability is a ratio between total lengths of road with number of population in that area. Using the above data we can calculate this as

$$\textbf{RS} = \text{Total road length/population}$$
$$= 68.9/46{,}200 = 0.0015$$

As it is observed from the result, road serviceability in the city is at poor state from 1995 to 2016 and the rate in change is very low which means the construction of new cobble stone roads is not much reachable by the peoples and to increase the

accessibility/serviceability of roads in the city, we have to work hard in developing good road network in which it increases peoples benefit and development of the regional capital city.

4.5 Existing Road Connectivity (RC) of the Study Area: Connectivity reflects both the number and modality of joints along a route. The connectivity in the road network of the study area was tested using gamma index. From the point of view of road network connectivity to tourists' attractions and accommodations, a high value of the gamma index indicates that there is high connectivity level to those attraction sites. The Gamma index is defined as the ratio of the actual number of links to the maximum number of nodes on a graph. Given the number of nodes, the maximum number of links is 3(v – 2). Hence, the gamma index is defined as follows:

$$\gamma = \frac{e}{3(\upsilon-2)}, \quad 0.1 \leq \upsilon \leq 1$$

Where:

- γ = Connectivity index
- e = Number of edges,
- v = Number of vertices

In this case, the value of e = 51, and that of v = 43. Hence, **γ = *0.415* = *41.5%.*** This is always expressed in percentages and the connectivity level that is less than 49% is an indication of low level of road network connectivity. When it is 50%, it is averagely connected and when it is 60% and above, it means there is high level of road network connectivity. In other words, as indicated by (Kofi, 2010], a connectivity index of 1.4 to 1.8 represents an acceptable street network in the area by using Beta Index. The optimal connectivity index for a perfect grid network is 2.5 and from the above results the connectivity index of the city is not perfect grid and also is not in the acceptable range as well.

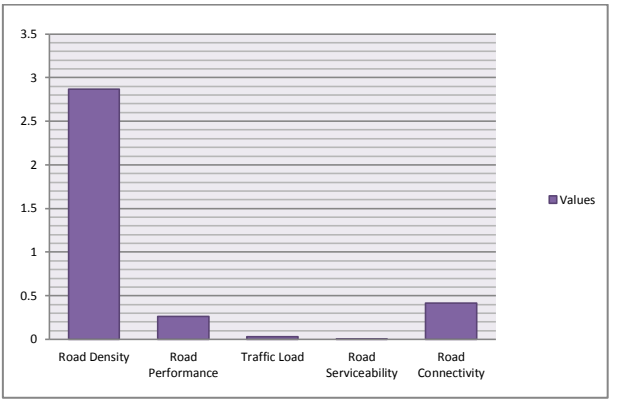

Figure 2: Summary of performance indictor indexes

The overall values of the five road network performance indicators are shown in figure 2. As we refer from the figure, the calculated value of road density is 2.87, road performance is 0.264, traffic load is 0.0329, road connectivity is 0.415 and road serviceability is 0.0015. According to the numerical vales (actually expresses the real situation), the road density is good but the serviceability of the road is highly poor that needs due consideration by the concerned bodies.

5. CONCLUSION AND RECOMMENDATIONS

By following the empirical and theoretical analysis carried out in this study, the road performance of Assosa town was evaluated using five indicators, namely road performance, road availability, traffic load, road serviceability and connectivity. Those indicators are calculated using aggregate data from 1995 to 2016. By using statistical analysis, it can be drawn a conclusion that the performance of the existing road network is not satisfactory that needs due consideration. Based on the findings of the research, the followings are recommended for Ethiopia

- The road network has to be modified frequently because the population, the way of living and socio economic activity of the town is changing dynamically.

- The city administration must always evaluate the performance of the road network to take timely corrective measures regarding the road network.
- The total length of paved and good condition roads in the city must be increase to attain a optimum road network
- The construction of cobble stone paved road should consider the outreach areas of the town
- To attain increasing road serviceability, there should be the construction new roads conceding with increasing number of population of the regional city

ACKNOWLEDGEMENTS

This research is partially supported by the grant from Assosa University of Research Directorate Office. The author would like to thank the anonymous reviewers for their insightful review and constructive suggestions, which resulted in a significant improvement of the manuscript.

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