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Analysis of the Relationship between Transportation Costs and Performance of Arterial Roads in Order to Achieve Optimal Traffic Management in Kendari City

Nasrul[1], Usman Rianse[2], Hasbullah Syaf[2], Laode Magribi[1]

[1]*Faculty of Engineering, Halu Oleo University-Kendari, Indonesia.*

[2]*Faculty of Agriculture, Halu Oleo University-Kendari, Indonesia.*

Abstract

The performance of a road is determined by the level of road service. The service level variable consists of two variables, namely the vehicle speed (s) and the volume capacity ratio (VCR).The road service level is the sum of the volume of vehicles divided by the capacity. One of the determinants of service level is transportation cost. The cost of personal transportation incurred by people in Indonesia is very high compared to developed countries. So that transportation planning is needed in calculating transportation costs. The purpose of this study is to determine the relationship between road service levels and transportation costs and to implement a mathematical model in the form of traffic management. The research method uses actual research analysis and analysis of transportation costs (BT) on the level of services (LOS). In this study, it was found that road performance is good if the vehicle speed tends to increase and the VCR tends to be small. Obtained the equation $s=117.68e^{-1.62VCR}$ and BT= -4604.5Ln (VCR) +3942 equation on the low classification VCR(≤0.3), the $BT = 2244e^{0.49(VCR)}$ equation was obtained on the medium classification VCR (0.3-0.7), and the BT = 4753.9Ln (VCR)+4857.2 equation was obtained on the low classification VCR (≥0.7). The costs incurred for the road section of Lippo Plaza Kendari with VCR = 0.55 is Rp. 2983 and the road section of Kendari Central Market with VCR= 0.58 is Rp. 2982.

Keyword: Cost, transportation, level, service

INTRODUCTION

The road service level is a combined condition shown by the relationship between vehicle volume divided by capacity and speed (Sukirman, 1994) where traffic behavior is represented by Level of Service (Direktorat Jenderal Bina Marga,1997). Methods in determining the level of road service need to take into account several factors such as transportation costs incurred by road users.

The average expenditure of each family in Indonesia for private transportation is already above 25% of the income they receive each month, while in developed countries the cost of transportation is already below 10%.

Even transportation costs in Indonesia are three times that of Singapore and Malaysia. Transportation planning in terms of taking into account the transportation costs incurred by road users is very important and is one of the criteria by which alternative planning or designs should be evaluated. Therefore, the basic understanding or study of the concept or model of road performance analysis in the form of road service levels, especially urban and suburban arterial roads, by developing variables related to transportation costs is very important.

LITERATURE REVIEW

a. Level of Service (LOS)

The level of service is a measure of the limiting effect caused by an increase in traffic volume. The indicators of road service level are volume, speed, capacity and cost of transportation. Service levels for arterial roads are mostly developed by linking speed and the ratio of volume to road capacity.

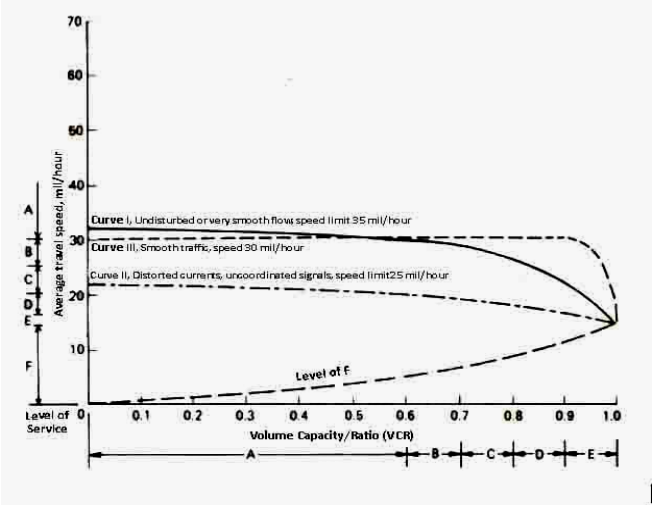

Figure 1. Relationship between speed, service level and volume to capacity ratio for urban and suburban arterial roads (Morlock, 2013)

To evaluate the level of road service, an indicator of the volume capacity ratio (VCR) under review can be used (Chetan,2012). The speed of the vehicle surveyed on the road cannot be used as an indicator of the level of road service. the service level indicator is the VCR. This is

because road users who drive the vehicle even though the value of the condition volume to capacity ratio is small, it can slow down the speed of the vehicle (Prasanta Kumar, 2011).

According to Direktorat Jenderal Bina Marga (1997), traffic volume is the number of vehicles passing through a time union point at a certain location. The road capacity (C) is obtained by the formula:

C = CO x FCW x FCSP x FCSF x FCCS (pcu/hour) **(1)**

Where:

C is the capacity (pcu/hour)

CO is the basic capacity (pcu//hour)

FCW is the capacity correction factor for road width

FCSP is the capacity correction factor due to direction sharing (does not apply to one-way roads)

FCSF is a capacity correction factor due to side drag

FCCS is a capacity correction factor due to city size (total population)

b. Transportation costs

Transportation costs consist of two components, namely costs incurred by road users and costs incurred by regulations or the government (Kunail Jain, 2013). Transportation costs are the accumulation of vehicle operating costs and the value of travel time. Vehicle operating costs consist of fixed costs (depreciation and insurance) and unfixed costs (fuel, vehicle oil, sparepart and vehicle tires). Pavement construction also affects vehicle operating costs (Fiona Tan, 2012).

BOK = BT + BTT **(2)**

Where:

BOK = Vehicle Operating Costs

BT = Fixed Costs

BTT = Unfixed Costs

The travel time value can be determined by mode choice, route choice, speed choice and dwelling cgoice (Booz-Allen and Hamilton, 2000). Travel time value can be calculated by several calculation methods, like income approach, housing price approach, mode choice approach, running speed choice approach, transfer price approach and diversion ratio approach (Sugianto G, 2012). One of the methods used to calculate the value of travel time is the income approach (Iqbal Caesariawan, 2015). This calculation only uses two factors, namely the gross regional domestic product (GRDP) of each person and the annual working hours of each person.

$$\lambda = \frac{\frac{GRDP}{Total\ Population}}{Annual\ Working\ Time} \quad \textbf{(3)}$$

METHODOLOGY

The research was conducted at two points on MT. Haryono street, namely in front of Lippo Plaza Kendari) and in front of Kendari Central Market. The design of this research was carried out by conducting a literature study, modeling the relationship between speed (s) and Volume Capacity Ratio (VCR) with s = {f (VCR)}, modeling the relationship between transportation costs (BT) and the speed function (s) with BT = f (s), modeling the relationship between transportation costs (BT) and VCR with BT = f {f (VCR)}, and conducting field trials with a model that has been developed between transportation costs and the value of the VCR. The sample of this research is all the amount of traffic at two points MT. Haryono street on each segment during peak hours, in the morning, afternoon and evening for one week. The variables of this research are traffic volume and road capacity. Data analysis in this research using actual capacity analysis and level of service (LOS) analysis.

RESULT AND DISCUSSION

In this study, it was found that the development of a new model of the relationship between velocity and Volume Capacity Ratio (VCR) is described on a curve.

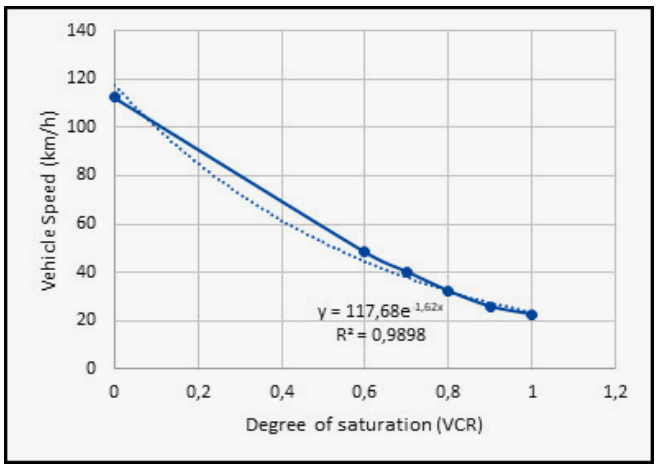

Figure 2. Relationship between vehicle speed to value of VCR

In developing a new model of the velocity relationship with the VCR, an equation is obtained, namely:

$$s = 117.68e^{-1.62VCR} \quad \textbf{(4)}$$

Where:

s = Speed

VCR = Volume Capacity Ratio

Transportation costs are the accumulation of vehicle operating costs and the value of travel time. Vehicle operating costs consist of fixed costs (depreciation and insurance) and unfixed costs (fuel, vehicle oil, sparepart and vehicle tires).

Table 1. Total fixed costs on MT. Haryono street

No.	Vehicle Speed (km/hour)	Depreciation		Insurance		Total Fixed Costs (Rp)
		Per 1000km	Cost (Rp)	Per 1000 km	Cost (Rp)	
1.	10	0.00000667	1,400.00	0.00000760	1,596.00	2,996.00
2.	20	0.00000571	1,200.00	0.00000380	798.00	1,998.00
3.	30	0.00000500	1,050.00	0.00000253	532.00	1,582.00
4.	40	0.00000444	933.33	0.00000190	399.00	1,332.33
5.	50	0.00000400	840.00	0.00000152	319.20	1,159.20
6.	60	0.00000364	763.64	0.00000127	266.00	1,029.64
7.	70	0.00000333	700.00	0.00000109	228.00	928.00
8.	80	0.00000308	646.15	0.00000095	199.50	845.65
9.	90	0.00000286	600.00	0.00000084	177.33	777.33
10.	100	0.00000267	560.00	0.00000076	159.60	719.00
11.	110	0.00000250	525.00	0.00000069	145.09	670.09
12.	120	0.00000235	494.12	0.00000063	133.00	627.12

Source: Analysis Result, 2020

Table 2. Total unfixed costs on MT. Haryono street

No.	Vehicle Speed (km/ hour)	Fuel		Uses of Oil		Sparepart		Vehicle Tires		Total Unfixed Costs (Rp)
		Per 1000 km	Cost (Rp)	Per 1000 km	Cost (Rp)	Per 1000 km	Cost (Rp)	Per 1000 km	Cost (Rp)	
1.	10	0.21061937	1,611.24	0.00183405	495.19	0.000000621	130.35	0.0000134	26.76	2,263.54
2.	20	0.16343907	1,250.31	0.00153805	415.27	0.000000685	143.79	0.0000222	44.46	1,853.83
3.	30	0.12764477	976.48	0.00131605	355.33	0.000000749	157.23	0.0000311	62.15	1,551.20
4.	40	0.10323647	789.76	0.00116805	315.37	0.000000813	170.67	0.0000399	79.85	1,355.65
5.	50	0.09021417	690.14	0.00109405	295.39	0.000000877	184.11	0.0000488	97.55	1,267.19
6.	60	0.08857787	677.62	0.00109405	295.39	0.000000941	197.55	0.0000576	115.24	1,285.80
7.	70	0.09832757	752.21	0.00116805	315.37	0.000001005	210.99	0.0000665	132.94	1,411.51
8.	80	0.11946327	913.89	0.00131605	355.33	0.000001069	224.43	0.0000753	150.63	1,644.29
9.	90	0.15198497	1,162.69	0.00153805	415.27	0.000001133	237.87	0.0000842	168.33	1,984.16
10.	100	0.19589267	1,498.58	0.00183405	495.19	0.000001197	251.31	0.0000930	186.03	2,431.11
11.	110	0.25118637	1,921.58	0.00220405	595.09	0.000001261	264.75	0.0001019	203.72	2,985.14
12.	120	0.31786607	2,431.68	0.00264805	714.97	0.000001325	278.19	0.0001107	221.42	3,646.25

Source: Analysis Result, 2020

Table 3. Transportation Costs on MT. Haryono street

No.	Vehicle Speed (km/hour)	Vehicle Operating (Rp)		Value of Travel Time (Rp)	Transportation Costs (Rp)
		Total Fixed Costs (Rp)	Total Unfixed Costs (Rp)		
1.	10	2,996.00	2,263.54	2210.43	7469.97
2.	20	1,998.00	1,853.83	1105.21	4957.04
3.	30	1,582.00	1,551.20	736.81	3870.01
4.	40	1,332.33	1,355.65	552.61	3240.59
5.	50	1,159.20	1,267.19	442.09	2868.47
6.	60	1,029.64	1,285.80	368.40	2683.85
7.	70	928.00	1,411.51	315.78	2655.28
8.	80	845.65	1,644.29	276.30	2766.25
9.	90	777.33	1,984.16	245.60	3007.09
10.	100	719.60	2,431.11	221.04	3371.75
11.	110	670.09	2,985.14	200.95	3856.18
12.	120	627.12	3,646.25	184.20	4457.57

Source: Analysis Result, 2020

From the results of transportation costs obtained, the development of a model formulation of vehicle speed towards transportation costs is obtained.

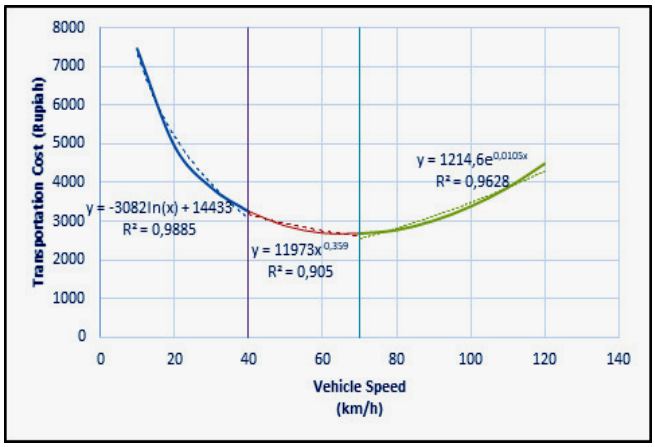

Figure 3. Development of a formulation model of vehicle speed against transportation costs

At a relatively lower speed, which is below 40 km/hour, there is a significant tendency for greater transportation costs incurred. At medium speeds between 40-70 km /hour the tendency of transportation costs incurred is getting smaller. at higher speeds above 70 km/hour, the transportation costs incurred will be even greater.

Table 4. Transportation cost formulation model

Classification of Speed	Total Cost Formulation Model	R^2
Low (<40 km/hour)	BT = -3082ln(*s*) + 14433	98.9%
Medium (40-70 km/hour)	BT = $11973(s)^{-0.359}$	90.5%
High (>70 km/hour)	BT = $1215e^{0.0105s}$	96.3%

Source: Analysis Result, 2020

The result of the equation between the degree of saturation and speed is entered into the function of vehicle speed against the corresponding transportation cost. Thus, the results of these calculations can produce a formulation of the relationship between VCR and transportation costs using the Original Least Square (OLS) method.

Table 5. The relationship between the value of vehicle speed and VCR to transportation costs

Level of Service	VCR	Speed	BT	Classification of Speed
E-F	1	22.53	4822.04	Low
D-E	0.9	25.74	4422.52	Low
C-D	0.8	32.18	3734.31	Low
B-C	0.7	40.23	3178.11	Medium
A-B	0.6	48.27	2976.89	Medium
A	0.5	52.35	2891.41	Medium
A	0.4	61.56	2728.04	Medium
A	0.3	72.38	2598.06	High
A	0.2	85.11	2969.58	High
A	0.1	100.08	3473.96	High
A	0	112.63	3964.42	High

Source: Analysis Result, 2020

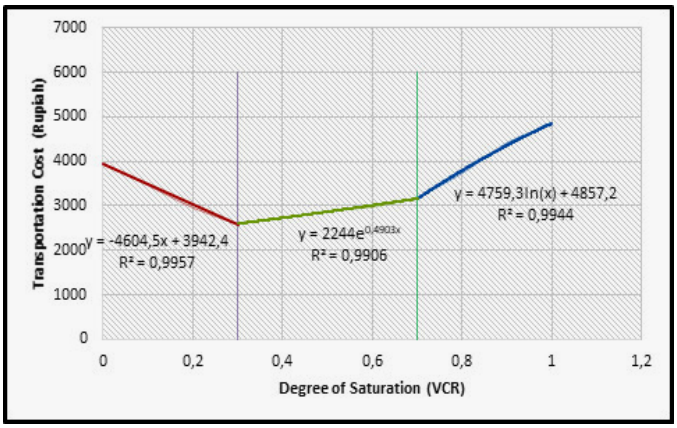

Figure 4. Development of a formulation model of VCR against transportation costs

There are three categories of VCR values. VCR values below 0.3 are categorized as low, VCR values 0.3-0.7 are categorized as moderate, and VCR values above 0.7 are categorized as high. Each VCR value category has a formula approach between the VCR value and the transportation costs incurred by the user.

Table 6. Transport cost formulation model against vcr

VCR	Transportation Cost Formulation Model	R^2
Low (<0.3)	BT = -4604.5Ln (VCR) + 3942.2	99.6%
Medium (0.3-0.7)	$BT = 2244e^{0.4903(VCR)}$	99.1%
High (>0.7)	BT = 4753.9Ln (VCR)+4857.2	99.4%

Source: Analysis Result, 2020

Validate the transportation cost equation against the VCR

a. At the point of observation in front Lippo Plaza Kendari with a VCR = 0.55, the transportation costs per one kilometer are obtained:

$s = 117.6\delta^{e-1.62(0,55)}$

= Rp. 2938

b. At the point of observation in front Kendari Central Market with a VCR = 0.58, the transportation costs per one kilometer are obtained:

$s = 117.68e^{-1.62(0,58)}$

= Rp. 2982

CONLUSIONS

Road performance will be better if the speed tends to increase and the VCR tends to be small. If the road capacity is good, the road performance will also get better. From the results of the development of the transportation cost formulation model for the VCR, 3 equations were obtained, namely BT = -4604.5Ln (VCR) +3942 on the low classification VCR (≤0.3), $BT = 2244e^{0.49(VCR)}$ on the medium classification VCR (0.3-0.7) and BT = 4753.9Ln (VCR)+4857.2 on the high classification VCR (≥0.7).

By implementing a mathematical model of transportation costs on road performance, the transportation cost per kilometer with VCR = 0.55 at the observation point in front of Lippo Plaza Kendari is Rp. 2938 and transportation costs per kilometer with VCR = 0.58 at the observation point in front of Kendari Central Market is Rp. 2982.

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