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Study of Road Maintenance Fund Needs Approach with Link Based and Network Based

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ABSTRACT
Dynamical systems approach can describe the process of roads pavement damage and road maintenance funding allocation scenarios. One of the important thing to predict road maintenance fund needs in the future is how to estimate the traffic that is going through in each link on the road network. Currently there are two ways to forecast future traffic flow, first approaches by link based and the other is network-based. Network-based approach requires data free flow speed of each link as an input. In dynamic, free flow speed is affected by the value of IRI (International Roughness Index). This paper aims to look at the differences total requirement of road maintenance funds need for each year in which the estimated future traffic flows by link-based and network-based. There are four scenarios allocation of maintenance funds in each year of analysis, ie 20%, 40%. 60% and 80% of the total requirement. From the analysis, it is known that the total funding need for road maintenance at the end of the estimated future traffic flows by way a network-based smaller when compared with the link based. In addition, it is known that the road maintenance fund allocation by 80% of the needs, it turns out the total funding need maintenance at the end of the analysis is the smallest.

Keywords: *Link Based, Network Based, Free Flow Speed*

1. INTRODUCTION

Road maintenance needs can be measured quantitatively by considering rate of service standards to be achieved, but the allocation of road maintenance costs often do not have measurable criteria. Dynamic system is very useful to understand the relationship between qualitative and quantitative aspects of road asset management. Dynamical systems approach can also describe the process of roads damage and scenarios of road maintenance funding allocation [1]. Saeidah Fallah doing research whose goal is to see road maintenance funds needs are dynamically, but the her research did not look the relationship between implementation of road maintenance delay to the amount of traffic.

One of the important thing to predict maintenance fund needs in the future is how to estimate the traffic in each link in the road network. Ministry of Public Works Directorate of Highways Indonesia generally use tools HDM (Highway Development and Managemen), this tool is very helpful in predicting deterioration model and estimated road maintenance fund needs and treatment scenarios. Both of these tools are introduced by Asian Development Bank dan World Bank in early 2000. Traffic estimation method used in both this tool is Linkbased approaches. In **Figure 1**, the movement of traffic on a road network is generally as described follows.

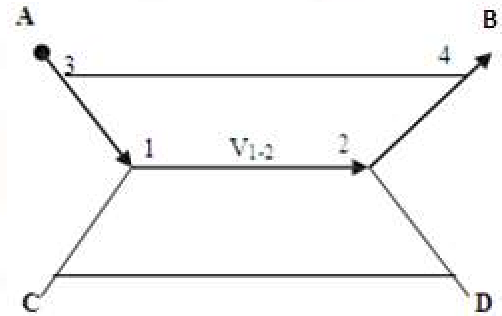

Figure1. Schematic movement from C to B through link1 - 2

Under normal conditions, traffic flow from C to B uses link 1-2, the total flow in sections 1-2 is V1-2. However, if in sections 1-2 decreased in performance due to road deterioration and the road can not be repaired immediately because of limited funds, so the speed in sections 1-2 become slower and then the travel time will increase. So flow in link 1-2 will reduce. Traffic flow that comes from C will choose a new route that can provide faster travel time, for example, using link 3-4 towards B. Consequently, the total traffic flow in link 3-4 will increase while in link 1-2 will reduce. Link-based method can not describe this problem. It takes survey traffic counting to validation traffic flow that has been forecasted in previous years. Consider this problem, to forecast future traffic flow becomes inaccurate if multiplying the present traffic with growth factors in link.

What if the traffic estimation method in link changed by using network-based approaches, where road users are assumed will be looking fastest travel time. This method requires information such as an Origin Destination Matrix (OD Matrix), zoning, road network map, the length of each road and width of the road. Needed OD matrix for each year of analysis, and the future of OD matrix resulted from base year OD matrix multiplied by Growth Factor, it is useful as a means for validation.

Both of these methods when used to estimate the road maintenance fund needs in the future will certainly be different, whether the link based method will give a total cost of road maintenance less than Network-Based approaches?.

1.1. Research Purposes

The purpose of this paper area:

a) Calculate traffic prediction in the link with link-based approaches, calculate the estimated cost of road maintenance every year and find out the value of IRI at the end of the analysis.
b) Calculate traffic in link that is dynamically change due to influenced by IRI with Network-based approaches, calculate the estimated cost of maintenance of roads each year and find out value of IRI at the end of the analysis
c) Shows the difference in total cost of road maintenance needs, with the allocation of maintenance funds scripted 20%, 40%, 60% and 80% of the total annual cost of road maintenance. This scenario is applied to approaches Linkbased and Networkbased.

1.2. Scope of study

This study has several limitations that are used when analyzing, are:

a. Pavement type is a flexible pavement, and assumed the last maintenance done 2 years ago.
b. Growth Factor method of link-based and Network- based method is 3%.
c. The IRI being used in the link is the average IRI
d. During the evaluation there is no addition of roads and increase capacity by adding lanes.
e. Drainse on the road network is considered in good condition
f. Traffic flow in the first year (2015) is the output of transport modeling with tools EMME-4.

1.3. Research Methodology

In general, the research methodology is shown in **Figure2**.

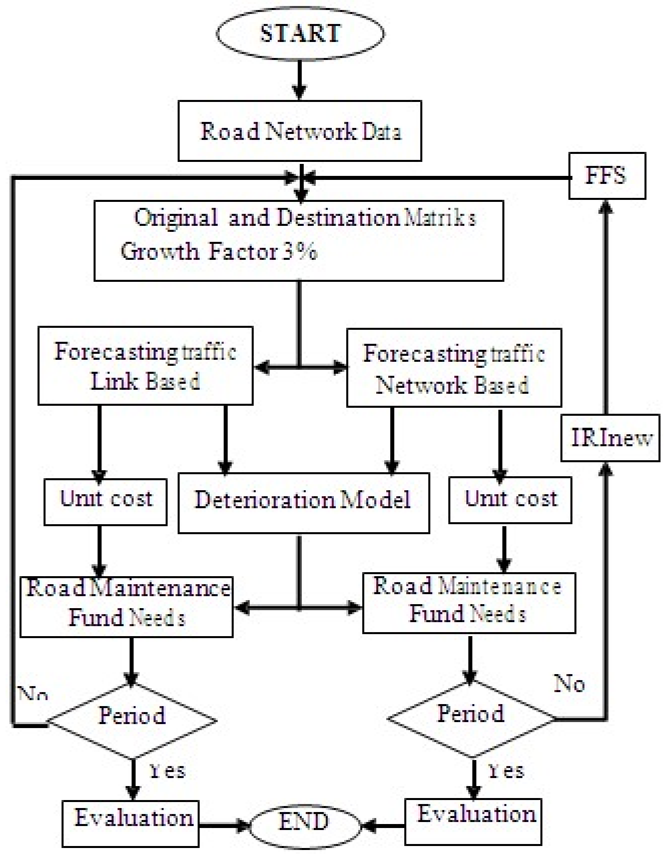

Figure2. Research methodology

2.1. Road network data

The road network data used in this study are the road network map in shp format and data link characteristics (length, width and the value of IRI).

2.2. Estimates Traffic with Link-based approaches

In the first year, traffic is the output transport modeling with tools EMME 4. Forecasting traffic for next year, traffic on previous year multiplied by 3% as growth factor. The formula to estimate traffic in link-base approach is [3]:

□□□□□□□□□$_{□}$ = □□□□□□□□□$_0$ ∗ (1 + □□)$^{□}$ 1

Where:
□□□□□□□□□$_{□}$ = number of vehicles per day on link i in year n
□□□□□□□□□$_0$ = number of vehicles per day on link i in the first year
x = growth factor
n = years

2.3. Estimates traffic with link-based approaches

Forecasting traffic flow with network-based approaches using transport modeling tools EMME-4. It takes a information matrix Origin Destination (OD Matrix), growth factors OD Matrix, maps road network, road width, and the free flow speed on each road. Growth factors OD Matrix is 3%.

Tamin said that the transport infrastructure network systems affect the movement of the system and vice versa[2]. Which differentiates it from link-based method compared to network-based is that the free flow speed is a function of IRI. While travel time is a function of free flow speed and travel time of the main things for road users to choose the sections that will be used. Roughness is unevenness of roads pavement surface, presented in a scale that describes unevenness of road surface. The International standard pavement roughness measurement is called IRI, the unit is m / km. The worse the road conditions would lead to reduced travel speeds on roads.

Sayers.et, al[3]. recommended value of the speed of some IRI values. Dwilaksono Toto doing research to see correlation between free flow speed and IRI in Java[4]. The correlation equation addressed in equation 2:

□ = 0,0747□^{2} − 3,4179 □ + 62,673 2

Where:
Y = free flow speed (km/jam)
X = average IRI in Link (m/km)

2.4. Road Deterioration Model

There are two types of models that can be used to predict Road deterioration (RD) and Work Effects (WE)[5]:
 Model Absoulut
 Model Incremental

Absolute models predict pavement conditions at a particular point in time as a function of the independent variable, while the incremental models give the changing conditions of the initial conditions as a function of the independent variables. Both types of these models include the emperical models. Which means, these models are usually generated from the statistical analysis of the observations in the study of the trend of deterioration.

There are two types of deformation models distress, ie rutting and roughness. Rutting is defined as the accumulation of permanent deformation or not of overcoming traffic problem on the pavement, in the form of a tire tread groove within a certain time period[6]. There are four components of rutting, namely; initial densification, structural deformation, plastic deformation and wear form studded tires.

Roughness is defined as the deviation of the surface is completely flat with characteristics that affect the dynamic size vehicle, driving quality, load dynamics and surface drainage. Roughness model consists of several components, namely cracking, disintegration, deformation and maintenance.

In this study, the incremental roughness is calculated as a result of structural damage[7], the formula is:

Δ□□□□□$_{□}$ = □□$_{□}$ ∗ □$^{(□∗K□□□∗□□□□□□3)}$ ∗ (1 + □N□□□$_{□}$)$^{-5}$ ∗ □□4 3
□NP□$_{□}$ = Max[(□NP$_{□}$ − □□N□□□) ; 1,5] 4

Where:
SNPK$_b$ = Adjustment Structural Numbers due to cracking at the end of year analysis
SNP$_a$ = Adjustment Structural Numbers due to cracking in the early years analysis
dSNPK = reduction in adjusted structural number of pavement due to cracking its value is 3.6
ΔIRI$_s$ = incremental change in roughness due to structural deterioration during the analysis year (m/km, IRI)

YE4 = annual number of equivalent standard axles (millions/lane)
Kgm = calibration factor for environmental coefficient its value is 7
AGE3 = pavement age since last overlay (rehabilitation), reconstruction or new construction (tahun)
a0 = roughness coefficient structural components 134
m = environmental coefficient 0,025

$$IRI_t = IRI_0 + \Delta IRI_t \quad ....5$$

where:
IRIt = IRI at the end of year of analysis (m/km, IRI)
IRI0 = IRI at early year of analysis (m/km, IRI)

2.5. Equivalent standard axle loads (ESAL)

This study has not validate the average weight of each class of vehicles passing through the road network of the study area. Therefore, using the Flexible Pavement Design Guidelines issued by the Ministry of Public Works Directorate General of Highways[8], where there are 8 classes of vehicles as shown Table 1.

Tabel 1: Vehicle Damage Faktor (VDF) for each class group

No.	Type of Class	VDF Value
1	Passenger vehicles (Class 2)	0.0001
2	Utility vehicles (Class 3 & 4)	0.0030
3	Small bus (Class 5A)	0.3000
4	Big Bus (Class 5B)	1.0000
5	small truck (Class 6A)	0.8000
6	big truck (Class 6B)	1.6000
7	Truck Trailers (Class 7A, 7B dan 7C)	7.6000

2.6. Annual axle loading

Total weight of the axle for a year (ESAL) is calculated by multiplying the value of VDF with the number of vehicles passing each group on link.

$$ESAL_{ij} = \sum 365 * AADT_{ij} * VDF_j * 10^{-6} \quad ....6$$

Where:
ESALij = is the axle load during the i year in million
ESAL for vehicle class j
VDFj = Vehicle damage factor for vehicle class j
AADTij = Annual average daily traffic class j during the i year

2.7. Treatment program

Type of treatment is determined how much the damage, assessment parameter is the value of IRI. **Appendix 1** showed parameters of road maintenance treatment based on the value of IRI.

2.8. Unit Cost

Appendix 2 shown the unit price of each maintenance activity per line width. Unit price is obtained from the Directorate General of Highways for the price of 2015.

2.9. Scenario allocated road maintenance fund

Road maintenance fund allocation scenarios for analysis with Link-Based and Network-Based approach are 20%, 40%, 60% and 80% of total road maintenance funds per each year. Due to limited funding, the roads that need to be addressed in the coming year chosen by considering the parameter value IRI, Cost, and AADT. Each segment is scored against all three parameters. Priority is determined based on the total scores of all three parameters.

Calculation of road Deterioration, selection of treatment and priority, and funding requirement of road maintenance against budgeting allocation scenario is using microsoft office-excel as a tool

3. Data and analysis

Research area located in the province of Bali, this province was chosen because of its territory in the form of an island, therefore the traffic flow continuously from outside the region can be eliminated.

Implementation of regional autonomy to the district/city level, then published the Law of the Republic of Indonesia No. 38 of 2004, which is on the Way. There are settings that road authority; nationals roads, province's roads, county's road and city's road. Until now the technical information about the damage roads under authority of province, county's and city's is not as complete national's road, which is the authority of central government. Therefore, this research is still limited to the national road.

3.1. National road network map and matrix origin destination Bali's

This study uses a national road network map based on the Decree of the Minister of Public Works no. 248 / KPTS / M / 2015. The national road network map on Bali island in shp format is shown in Figure 3.

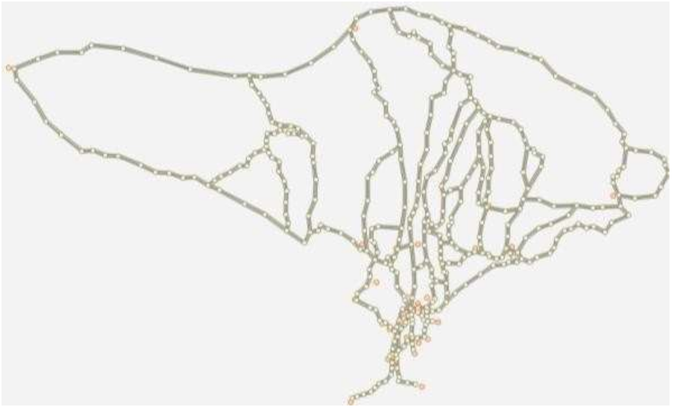

Figure3. National road network map in Bali Island

The number of zones in the study area is divided into 33 zones. Zoning divided by district and sub-district administration. In downtown Denpasar and Bangli is divided into several zones based on the subdistrict.

Origin and destination distribution in the base year (2011) is shown in appendix 3.

3.2. Road characteristics and AADT at early year (2015)

Characteristics of data used is length of road, average width of the road, average IRI, and AADT. This data is obtained from Agency that handles national roads on Bali island. Every 6 months the agency traffic measurement and national road conditions conducted. Traffic information on national roads is used to validate the movement model from 2011 to 2015. This paper does not discuss in more detail how to validate models and forecasting models with the EMME4 transport modeling program. Appendix 4 shown characteristic of national road on Bali island.

4. Analysis

Analysis of road maintenance cost requirement with link based and network based approach for all national road network in Bali island. The analysis phase were traffic forecasting and then with various funding allocation scenarios calculated road maintenance fund need for each year.

4.1. Traffic forecasting with link-based approaches

Traffic forecast with Link-based approaches the way is multiply the growth factor to the existing traffic flow (see eq. 1). So for the next 10 years, the traffic forecasting are shown in Appendix 5. The traffic growth in each link is predicted 3% per year upto 2025.

4.2. Total road maintenance cost needs with link-based

From the results of Appendix 5, following the pattern of the calculation described in Figure 2 are used to determine the needs of road maintenance funds from 2015 to 2025 (detail see appendix 6).

Table 2: Total road maintenance cost needs with link-based and benefit

Type of Analysis	Total Cost (2015-2025)	Benefit
Linkbased_20	1.063.857,7	0
Linkbased_40	528.738,2	535.119,5
Linkbased_60	373.709,0	690.148,7
Linkbased_80	330.619,5	733.238,2

Linkbased_20 and so on, meaning was analyzed by means of linkbased approach and allocation of cost maintenance every year is 20% of total cost maintenance needs of road network every year analysis. Simulation with multiple scenarios allocation of funds, it is known that the total cost of road maintenance needs until 2025 with an allocation of 20% of the total cost of road maintenance needs per year is Rp. 1.063.858.000.000. The condition of the road at the end of 2025 was deteriorating of the initial analysis (see Fig. 6). While if allocated funds amounting to 80% of the total requirement in each year, the total needs of the maintenance fund in 2015 until 2025 was Rp. 330.620.000.000,-. This number was not too significant losses than if allocated 60% of the requirement. This also applies to IRI, where allocations of 60% or 80% is not too large impact on improving the value of IRI

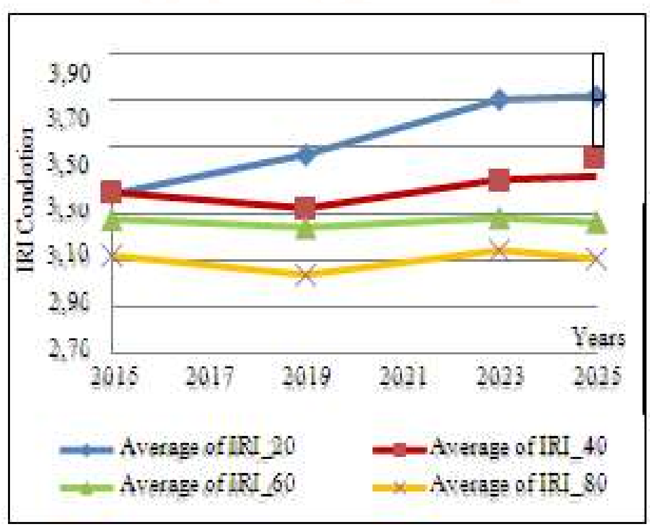

Figure4. IRI Condition per year by different allocation budget scenario with link-based analysis

Allocation road maintenance fund 20% of the total cost needs of each year, then at the end of 2025 the total cost of road maintenance bigger, other impact is the average value of IRI in the road network is greater than if the allocation of road maintenance funds increased to 40% of the total cost needs of each year. **Figure 4** showed that there is a difference of each analysis at the end of 2025. This difference can be termed as an benefit for road managers. For road users, the advantage is travel speed undisrupted due to road damage, in the end there are savings in fuel consumption. The difference in total cost of road maintenance until 2025 in each year on the type of analysis is shown in Tabel 2. The differences can be a benefit for manager if allocation budget for maintenance bigger than it should be. Benefit from the allocation of40% is the difference between the total cost of the allocation of 20% to the total cost of the allocation of 40%, thus permanently for all scenarios allocation.

4.3. Traffic forecast with network based

In this approaches, the traffic flow forecasted does not based on growth traffic in link, but Origin Destination Matrix growth every year. Then, Matrix Origin Destination (OD Matrix) is charged on road network. Modeling of traffic flow on the road network using EMME-4, production by INRO Canada.

One of the outputs of the EMME-4 used are traffic flow in every link in each year. The next step is to calculate the number of vehicles by vehicle class and then calculated the total ESAL (see Table 1 and equation 6).

Damage incremental in each link as a result of total ESAL, incremental damage in each segment as a result of total ESAL, calculated using equation 2, then at the end of n year predicted value of IRI (see eq. 5) and the total funding of road maintenance needs in year n. Due to allocation of funds scripted always less than needed, then there is a process of evaluation of priority roads will be maintained, Once selected, a new IRI value used to calculate the free flow speed at the beginning of year n + 1 using **equation 2**. This free flow speed information becomes the input current road network modeling with EMME-4 in the year n + 1, and so on.

As a result, there are differences in total traffic flow in link, that is calculated by link-based approaches andNetwork-based. Appendix 7 shown the differences. The differences around 5%, traffic forecasting with link- based higher than network-based.

4.4. Total road maintenance cost needs with network- based

Following calculation pattern described in Figure 2, the road maintenance cost needs from 2015 to 2025 showed at Appendix 8.

Networkbased_20 and so on, meaning was analyzed by means of network based approach and allocation of cost maintenance every year is 20% of total cost maintenance needs of road network every year analysis. Simulation with multiple scenarios allocation of funds, it is known that the total cost of road maintenance needs until 2025 with an allocation of 20% of the total cost of road maintenance needs per year is Rp. 781.422.000.000.

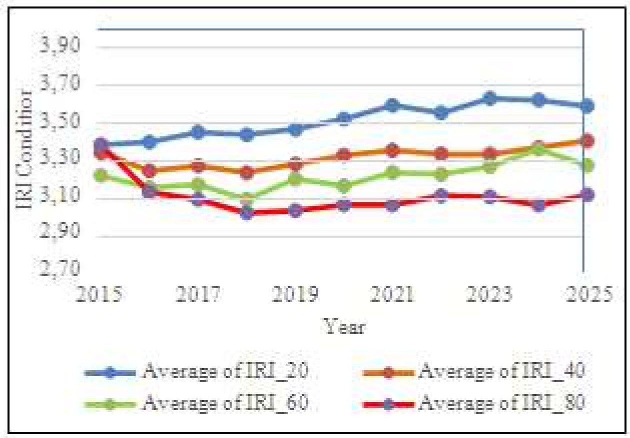

Figure5. IRI Condition per year by different allocation budget scenario with network-based analysis

Similar to the results of analysis with Linkbased approaches, Using Network-based approaches and the planned allocation of road maintenance fund 20% of the total requirement per year, the total cost of maintenance of the road at the end of 2025 is the biggest than if the funds allocated is greater than 20%. It also gives the average value of IRI in the road network was getting worse. **In Figure 5** is shown that the difference IRI condition in difference allocation scenarios maintenance of roads. Average of IRI_20 and so on, meaning average IRI per year for allocation budget 20% from maintenance needs. The difference in total cost of road maintenance until 2025 in each year on the type of analysis is shown in **Table 3.**.

Table 3: Total road maintenance cost needs with network-based and benefit

Analysis Types	Total Cost (Rp.1.000.000,-)	Benefit (Rp.)
Networkbased_20	781,422	0
Networkbased_40	521,417	260,005
Networkbased_60	432,214	349,208
Networkbased_80	324,832	456,590

5. Discussion

Link-based analysis method approaches and network-based basically aimed is to try estimate of road maintenance cost needs in the future. Link-based would be very precisely and easy to implement by road asset managers to estimate the need for road maintenance funds in the short term at least for planning policy for funding up to 2 year. Data traffic in each segment needs to be updated annually in order to illustrate the impact of a road maintenance delays, implementation of these survey, it will add to the cost for road asset manager. These funds would be much better to increase road maintenance fund.

While network-based method that is modified to consider the influence of the IRI, it takes more effort, because managers need additional knowledge that is road transport modeling. But is more indicative the actual condition road user behavior.

Appendix 7 and appendix 8 indicated differences in estimation road maintenance costs needs in the future, which is analyzed with link-based and network-based approaches. With link-based approaches, road maintenance fund allocation plan by 20% of the total requirement road maintenance fund in 2015, the total requirement for 10 year analysis (2015-2025) was Rp. 1.063.857.700.000, this figure is very much compared to when traffic is expected in the future using a network- based approaches, as well as considering the IRI against the free flow speed in the next year, then total needs of road maintenance fund is Rp. 781.422.000.000.

Table 4: The diferences Total Cost Maintenance Linkbased and Networkbased

Alloc. Plan.	Total Maintenance Cost (Fiscal Need) at The End 2025 (Rp. 1.000.000,-)		Difference
	Analysis Types		
	Link-based	Network- based	
20%	1,063,857.71	781,422	282,436.03
40%	528,738.24	521,417	7,321.48
60%	373,709.04	432,214	(58,505.07)
80%	330,619.55	324,832	5,788.04

Allocations plan 60% of the total road maintenance cost needs with link-based less than network-based. There are different sections that need to be maintained, due to differences traffic flow forecast. Consequently, there is differences roads maintenance programme. Example, randomly drawn average daily daily traffic (AADT) estimates using linkbased and network-based methods on 4 road segments in 2018, 2022 and 2025. Table 5 is shown that AADT link-based increases constantly according to the growth assumption on the segment, while network-based can sometimes be higher than linked AADT estimates but in the coming year may be lower.

Table 5: AADT using network-based and link-based

Years	Links	AADT by Network based	AADT by Link based
2018	Sp.Cokroaminoto - Sp.Tohpati	18.479	17.607
	Jln. A. Yani - Jln. S. Parman (Seririt)	340	329
	Bts. Kota Gianyar - Sidan	2.672	2.549
	Sp. Lap. Terbang (Dps) - Tugu Ngurah Ra	35.976	34.273
	Jln. Astina Timur (Gianyar)	2.672	2.549
2022	Sp.Cokroaminoto - Sp.Tohpati (Jln. G. Su	21.194	21.023
	Jln. A. Yani - Jln. S. Parman (Seririt)	404	392
	Bts. Kota Gianyar - Sidan	2.929	3.044
	Sp. Lap. Terbang (Dps) - Tugu Ngurah Ra	39.301	40.924
	Jln. Astina Timur (Gianyar)	2.790	3.044

6. Conclusion

From the analysis, and network-based approach to link-based, it can be concluded some of the following:

1. Traffic Flow forecasting approaches link-based will always be increased even though the road is not repaired, it becomes different if carried out with a network-based approach.
2. Allocating 20% of the total road maintenance needs in every year, at the end of 2025 will have the highest total cost compared to if the allocation of funds 40%, 60% and 80%.
3. At the end of 2025, the total cost of maintenance smaller when analyzed with a network-based approach, difference could reach 28% of the link-based analysis.

7. Acknowledgements

The researchers would like to thank to rector of Mulawarman University and scholar for his support.

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Appendix 1: Road maintenance programme consider IRI[10]

Name of program	Name of Sub-Programme	Range of IRI	IRI (n+1)	Treatment Details
routine maintenance	Routine Maintenance (Pr)	0 – 3.0	IRI min + 0.5	maintenance of drainage systems
	Conditions Routine Maintenance (Prk)	3.0 – 4	IRI min - 0.5	maintenance of road shoulders; vegetation clearance
				Compaction, leveling, and reformation of shoulder.
	Prevent if maintenance (Pp)	4.0 – 6.0	IRI min - 0.5	Patching, sealing for surface crack, road maintenance equipment
	Minor rehabilitation (RMn)	6.0 – 8.0	to 3.0	Non-structural overlay
Improvement	Major rehabilitation (Rmy)	8.0 – 12.0	to 3.0	Structural overlay and repair drainage system

Appendix 2: Unit cost for each treatment

No	Description	Unit	Cost / km
I	**Routine maintenance and Conditions (IRI 0 - 4)**		
	a. Pav. width upto 4.5 m and shoulder 2x1 m	Km	36,785
	b. Pav. width upto 5 m and shoulder 2x1 m	Km	37,488
	c. Pav. width upto 6 m and shoulder 2x1.5 m	Km	40,866
	d. Pav. width upto 7 m and shoulder 2x2 m	Km	44,244
	e. Pav. width upto s/d 14 m and shoulder 2x2 m	Km	54,987
II	**Prevent if maintenance (IRI 4 - 6)**		
	a. Pav. width upto 4.5 m and shoulder 2x1 m	Km	468.413
	b. Pav. width upto 5 m and shoulder 2x1 m	Km	510.385
	c. Pav. width upto 6 m and shoulder 2x1.5 m	Km	607,365
	d. Pav. width upto 7 m and shoulder 2x2 m	Km	694,582
	e. Pav. width upto 14 m and shoulder 2x2 m	Km	1,364,499
III	**Minor Rehabilitation (IRI 6.0 - 8.0)**		
	a. Pav. width upto 4.5 m and shoulder 2x1 m	Km	780,689
	b. Pav. width upto 5 m and shoulder 2x1 m	Km	850,641
	c. Pav. width upto 6 m and shoulder 2x1.5 m	Km	1,012,275
	d. Pav. width upto 7 m and shoulder 2x2 m	Km	1,157,637
	e. Pav. width upto 14 m and shoulder 2x2 m	Km	2,274,165
IV	**Improvement**		
	Major Rehabilitation (IRI 8.0 - 12.0)		
	a. Pav. width upto 4.5 m and shoulder 2x1 m	Km	2,431,018
	b. Pav. width upto 5 m and shoulder 2x1 m	Km	2,675,174
	c. Pav. width upto 6 m and shoulder 2x1.5 m	Km	3,220,695
	d. Pav. width upto 7 m and shoulder 2x2 m	Km	3,757,813
	e. Pav. width upto 14 m and shoulder 2x2 m	Km	7,310,172
	Reconstruction (IRI > 12)		
	a. Pav. width upto 4.5 m and shoulder 2x1 m	Km	3,006,939
	b. Pav. width upto 5 m and shoulder 2x1 m	Km	3,314,358
	c. Pav. width upto 6 m and shoulder 2x1.5 m	Km	4,279,337
	d. Pav. width upto 7 m and shoulder 2x2 m	Km	4,993,006
	e. Pav. width upto 14 m and shoulder 2x2 m	Km	9,774,596

Appendix 3: Original and destination matrix on base year 2011[9]

No.	Zona	Zona																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	Pecatu	0	50	110	20	50	10	0	0	0	10	0	70	0	40	10	30	30	30	30	10	0	0	40	10	60	50	290	30	40	0	0	0	30
2	Tanjung Benoa	30	0	100	40	130	10	0	0	20	10	0	180	30	60	0	110	130	80	150	10	10	0	90	10	50	180	250	0	50	10	0	0	50
3	Jimbaran	130	300	0	40	270	10	0	10	10	50	0	260	20	70	10	60	100	170	260	40	30	0	50	30	150	280	200	30	70	10	30	0	10
4	Tuban	30	150	70	0	70	0	0	0	0	0	0	130	0	90	20	80	170	50	110	20	10	0	20	0	40	160	110	20	0	0	0	0	0
5	Kuta	300	580	390	30	0	10	0	0	0	0	0	370	0	30	0	40	80	10	170	70	20	0	10	30	170	150	130	10	70	10	0	0	40
6	Kerobokan	30	50	80	10	50	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Kerobokan Kelod	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Can	3	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0

	ggu	0	0	0		0														0								0						
9	Dalung	120	110	70	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Mengwi	120	180	90	80	40	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Abiansemal	20	20	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Danginpuri	180	550	670	390	880	0	10	0	0	0	0	0	10	10	0	20	40	20	160	10	0	10	0	0	0	10	10	10	10	0	10	10	0
13	Sumerta	0	20	30	10	30	0	0	10	0	0	0	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Kesiman	100	60	40	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	10	0	0	0	0	0	0	0	0
15	Penatih	40	30	30	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Pedungan	80	90	90	10	30	0	0	0	0	0	0	70	0	10	10	0	30	50	140	0	0	0	30	0	10	10	0	0	20	10	0	0	0
17	Sesetan	90	190	190	30	80	0	10	0	0	0	0	30	0	0	0	70	0	40	90	0	10	0	30	10	10	40	40	10	0	0	0	10	10
18	Sidakarya	90	130	210	100	70	0	0	0	0	0	10	0	0	0	0	50	70	0	80	20	0	0	10	0	20	10	40	0	0	20	0	0	0
19	Sanur	180	230	280	160	280	0	0	0	0	0	0	20	0	0	0	10	50	40	0	0	0	0	10	0	10	20	10	0	0	0	0	0	0
20	Pemongan	60	120	90	30	30	0	0	0	0	0	0	10	0	10	10	0	30	30	120	0	0	10	0	0	0	10	50	10	0	0	0	0	20
21	Ubung	40	70	70	10	60	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Peguyangan	10	60	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Tonja	40	60	110	0	40	0	0	0	0	0	0	0	0	0	0	10	20	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Padangsambian	100	40	90	40	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	10	10	20	0	0	0	0
25	Tegalharum	120	340	330	90	290	0	0	0	0	0	0	20	0	0	0	20	20	10	40	10	0	0	10	0	0	0	20	0	0	0	0	0	10
26	Dauhpuri	90	230	420	120	260	0	0	0	0	0	0	0	0	0	0	50	30	10	40	0	0	0	0	0	10	0	0	0	10	0	0	0	0
27	Gianyar	190	110	170	10	60	0	0	0	0	0	0	0	0	0	0	10	10	0	10	0	0	0	0	0	0	0	0	90	54	89	48	11	78
28	Klungkung	10	10	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80	0	29	33	19	4	22
29	Karangasem	20	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	48	29	0	33	42	8	29
30	Bangli	30	20	10	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	80	34	34	0	30	6	33
31	Buleleng	0	40	20	10	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	44	20	43	30	0	23	51
32	Jembrana	0	50	50	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	4	8	6	23	0	15
33	Tabanan	150	80	70	60	70	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	71	23	30	33	51	15	0

Appendix 4: Road characteristics and AADT at early year [10]

Seg. No.	Road segmen names	Length (Km)	Average Width (M)	SDI Average	IRI Average	Nilai AADT
001	Gilimanuk - Cekik	3,041	10,928	2,42	3,307	5141
002	Cekik - Bts. Kota Negara	27,224	7,139	13,28	3,354	22319
	Jln. A. Yani - Jln. Udayana (Negara)	1,923	12,181	0,75	3,325	11819
003	Bts. Kota Negara - Pekutatan	20,445	7,330	0,32	3,285	6880
	Jln. Sudirman, Gajahmada (Negara)	4,466	9,181	2,22	3,337	13001
004	Pekutatan - Antosari	29,964	7,198	6,81	3,491	15807
005	Antosari - Bts. Kota Tabanan	17,262	8,086	12,11	3,621	22689
	Simp. Kediri - Pesiapan (Tabanan)	4,020	17,776	2,56	3,628	32028

006	Bts. Kota Tabanan - Mengwitani	1,462	13,000	1,00	3,240	50795
	Jln. A. Yani (Tabanan)	2,025	11,900	0,71	3,785	43812
007	Mengwitani - Bts. Kota Denpasar	7,385	14,534	10,88	3,018	64924
	Jln. Cokroaminoto (Dps)	3,826	11,132	25,64	2,870	33975
	Jln. Cokroaminoto (Dps)	0,979	11,000	19,50	3,263	53609
	Jln. Sutomo (Dps)	0,936	12,500	0,00	2,500	28094
	Jln. Setiabudi (Dps)	0,770	10,000	0,00	4,113	20616
	Jln. Wahidin (Dps)	0,232	8,000	0,00	4,133	30654
	Jln. Thamrin (Dps)	0,376	9,000	11,25	3,875	21917
008	Sp.Cokroaminoto - Sp.Kerobokan	3,788	14,000	0,92	3,661	47775
009	Jln. Gunung Agung - Akses Kargo	4,424	13,435	2,33	3,319	21474
010	Jln. Western Ring Road (Sp.Gatot Subroto	4,460	14,000	1,00	3,000	21474
011	Kuta - Banjar Taman	5,467	14,000	8,00	3,379	21474
012	Denpasar - Tuban	10,781	8,677	0,90	3,272	23140
013	Simp. Kuta - Tugu Ngurah Rai	2,726	16,289	1,61	3,657	26367
014	Sp. Lap. Terbang (Dps) - Tugu Ngurah Ra	0,350	18,000	0,00	3,050	20037
015	Tugu Ngurah Rai - Nusa Dua	9,536	13,700	8,20	2,602	47469
016	Simpang Kuta - Simp. Pesanggaran	3,693	13,000	23,38	3,419	38948
017	Simp.Pesanggaran - Gerbang Benoa	0,604	19,000	2,14	4,067	7887
018	Simpang Pesanggaran - Simpang Sanur	8,390	13,824	4,61	3,434	23452
019	Simpang Sanur - Simpang Tohpati	4,390	13,023	8,86	2,805	24974
020	Sp.Cokroaminoto - Sp.Tohpati (Jln. G. Su	5,357	13,198	0,91	3,194	24712
021	Sp. Pantai Siut - Kosamba	11,806	7,000	0,74	3,011	55683
	Sp. Tohpati - Sp. Pantai Siut	15,899	16,000	2,34	2,892	55683
022	Sp. Tohpati - Sakah	12,965	11,452	0,85	3,740	55683
023	Sakah - Blahbatu	3,027	8,111	0,48	3,603	26302
024	Blahbatu - Semebaung	3,765	8,433	0,00	3,162	28347
025	Semebaung - Bts. Kota Gianyar	2,095	8,050	0,00	3,086	31158
	Jln. Ciung Wanara (Gianyar)	0,537	14,000	0,00	2,950	31158
	Jln. Astina Utara (Gianyar)	0,398	10,000	0,00	4,300	31158
026	Bts. Kota Gianyar - Sidan	1,253	12,000	0,00	3,131	31965
	Jln. Ngurah Rai (Gianyar)	0,667	7,000	2,14	3,257	31965
	Jln. Astina Timur (Gianyar)	0,984	8,228	0,00	4,056	31965
027	Sidan - Bts. Kota Klungkung	7,180	7,500	7,43	3,244	13311
	Jln. Untung Suropati, Flamboyan (Semarap	1,769	8,335	2,78	3,254	13311
028	Bts. Kota Klungkung - Kosamba (Bts. Kab.	10,101	11,300	1,62	3,476	31697
	Jln. Diponegoro (Semarapura)	0,815	7,251	0,00	3,247	31697
029	Kosamba (Bts. Kab. Karangasem) - Angente	4,376	8,949	5,80	3,701	11587
030	Angentelu - Padangbai	2,048	7,324	1,59	3,350	951
031	Cekik – Seririt	62,910	8,600	1,96	3,313	1578
	Jln. A. Yani - Jln. S. Parman (Seririt)	0,741	7,892	0,00	3,440	1160
032	Seririt - Bts. Kota Singaraja	18,656	16,224	7,85	3,453	15596
	Jln. Gajahmada - Dr. Sutomo - A. Yani (S	4,090	7,708	0,00	3,675	10857
033	Bts. Kota Singaraja - Kubutambahan	6,199	10,374	1,53	3,720	17764

	Jln. Ng. Rai Selatan - Jln. Pramuka - Jl	6,007	7,004	1,56	3,102	13031
034	Kubutambahan - Km 124 Dps (Bon Dalem/Ds.	46,000	7,000	0,58	3,761	3750
035	Km 124 Dps (Bon Dalem/Ds. Tembok) - Bts.	30,637	9,027	0,90	3,327	8735
	Jln. Untung Surapati (Amlapura)	2,825	6,656	16,38	3,031	4068
036	Bts. Kota Amlapura - Angentelu	20,331	7,431	6,02	3,671	16208
	Jln. Sudirman - A. Yani (Amlapura)	2,584	9,871	1,11	3,271	16208
037	Bts. Kota Singaraja - Mengwitani	60,425	7,500	9,39	3,722	2564
	Jln. Jelantik Gingsir - Veteran (Singara	3,425	10,000	4,29	3,745	632
038	Sp. 3 Mengwi – Beringkit	0,413	9,108	0,00	4,050	632

Appendix 5: Traffic forecasting by link-based approach

No	NAMA RUAS	VOLUME										
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	Gilimanuk – Cekik	319	329	338	349	359	370	381	392	404	416	429
2	Cekik - Bts. Kota Negara	319	329	338	349	359	370	381	392	404	416	429
3	Jln. A. Yani -Jln. Udayana(Negara)	319	329	338	349	359	370	381	392	404	416	429
4	Bts. KotaNegara-PekutatanGajahmada	2134	2198	2264	2332	2402	2474	2548	2625	2703	2784	2868
5	Jln. Sudirman, (Negara)	2134	2198	2264	2332	2402	2474	2548	2625	2703	2784	2868
6	Pekutatan-Antosari	2134	2198	2264	2332	2402	2474	2548	2625	2703	2784	2868
7	Antosari - Bts. Kota Tabanan	2134	2198	2264	2332	2402	2474	2548	2625	2703	2784	2868
8	Simp. Kediri - Pesiapan (Tabanan)	2134	2198	2264	2332	2402	2474	2548	2625	2703	2784	2868
9	Bts. KotaTabanan-Mengwitani	11066	11398	11740	12092	12455	12829	13213	13610	14018	14439	14872
10	Jln. A. Yani (Tabanan)	11066	11398	11740	12092	12455	12829	13213	13610	14018	14439	14872
11	Mengwitani -Bts.Kota Denpasar	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
12	Jln. Cokroaminoto(Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
13	Jln. Cokroaminoto(Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
14	Jln.Sutomo(Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
15	Jln. Setiabudi (Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
16	Jln. Wahidin (Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
17	Jln. Thamrin (Dps)	20834	21459	22103	22766	23449	24152	24877	25623	26392	27184	27999
18	Sp.Cokroaminoto-Sp.Kerobokan	17963	18502	19057	19629	20218	20824	21449	22092	22755	23438	24141
19	Jln. GunungAgung-AksesKargo	25542	26308	27098	27910	28748	29610	30498	31413	32356	33327	34326
20	Jln. Western Ring Road (Sp. Gato Subro to	25487	26252	27039	27850	28686	29546	30433	31346	32286	33255	34252
21	Kuta –BanjarTaman	33572	34579	35617	36685	37786	38919	40087	41289	42528	43804	45118
22	Denpasar- Tuban	59895	61692	63543	65449	67412	69435	71518	73663	75873	78149	80494
23	Simp. Kuta – Tugu NgurahRai	73854	76070	78352	80702	83123	85617	88186	90831	93556	96363	99254
24	Sp. Lap. Terbang(Dps)-TuguNgurah Ra	33275	34273	35301	36360	37451	38575	39732	40924	42152	43416	44719
25	TuguNgurah Rai-Nusa Dua	55825	57500	59225	61001	62832	64716	66658	68658	70717	72839	75024
26	SimpangKuta-Simp. Pesanggaran	71137	73271	75469	77733	80065	82467	84941	87490	90114	92818	95602
27	Simp.Pesanggaran-GerbangBenoa	9581	9868	10164	10469	10783	11107	11440	11783	12137	12501	12876

28	SimpangPesanggaran-Simpang Sanur	29095	29968	30867	31793	32747	33729	34741	35783	36857	37962	39101
29	Simpang Sanur-Simpang Tohpati	15334	15794	16268	16756	17259	17776	18310	18859	19425	20007	20608
30	Sp.Cokroaminoto-Sp.Tohpati (Jln. G. Su	17094	17607	18135	18679	19239	19817	20411	21023	21654	22304	22973
31	Sp. PantaiSiut-Kosamba	7018	7229	7445	7669	7899	8136	8380	8631	8890	9157	9432
32	Sp.Tohpati-Sp.PantaiSiut	7018	7229	7445	7669	7899	8136	8380	8631	8890	9157	9432
33	Sp. Tohpati-Sakah	20482	21096	21729	22381	23053	23744	24457	25190	25946	26724	27526
34	Sakah-Blahbatu	19514	20099	20702	21323	21963	22622	23301	24000	24720	25461	26225
35	Blahbatu-Semebaung	19514	20099	20702	21323	21963	22622	23301	24000	24720	25461	26225
36	Semebaung - Bts. Kota Gianyar	19514	20099	20702	21323	21963	22622	23301	24000	24720	25461	26225
37	Jln.CiungWanara (Gianyar)	19514	20099	20702	21323	21963	22622	23301	24000	24720	25461	26225
38	Jln.AstinaUtara(Gianyar)	19514	20099	20702	21323	21963	22622	23301	24000	24720	25461	26225
39	Bts. Kota Gianyar-Sidan	2475	2549	2626	2704	2786	2869	2955	3044	3135	3229	3326
40	Jln. NgurahRai(Gianyar)	2475	2549	2626	2704	2786	2869	2955	3044	3135	3229	3326
41	Jln.AstinaTimur (Gianyar)	2475	2549	2626	2704	2786	2869	2955	3044	3135	3229	3326
42	Sidan -Bts. Kota Klungkung	2475	2549	2626	2704	2786	2869	2955	3044	3135	3229	3326
43	Jln.UntungSuropati, Flamboyan (Semarap	2475	2549	2626	2704	2786	2869	2955	3044	3135	3229	3326
44	Bts. Kota Klungkung-Kosamba (Bts.Kab.	3531	3637	3746	3858	3974	4093	4216	4343	4473	4607	4745
45	Jln. Diponegoro (Semarapura)	3531	3637	3746	3858	3974	4093	4216	4343	4473	4607	4745
46	Kosamba(Bts.Kab.Karan gasem) – Angente	5709	5880	6057	6238	6426	6618	6817	7021	7232	7449	7672
47	Angentelu- Padangbai	5709	5880	6057	6238	6426	6618	6817	7021	7232	7449	7672
48	Cekik–Seririt	319	329	338	349	359	370	381	392	404	416	429
49	Jln. A. Yani - Jln.S.Parman (Seririt)	319	329	338	349	359	370	381	392	404	416	429
50	Seririt-Bts.KotaSingaraja	319	329	338	349	359	370	381	392	404	416	429
51	Jln. Gajahmada-Dr.Sutomo – A.Yani(s	319	329	338	349	359	370	381	392	404	416	429
52	Bts. KotaSingaraja – Kubutambahan Pram	1001	1031	1062	1094	1127	1160	1195	1231	1268	1306	1345
53	Jln. Ng. Rai Selatan-Jln.uka-J1	1001	1031	1062	1094	1127	1160	1195	1231	1268	1306	1345
54	Kubutambahan - Km 124 Dps (Bon Dalem/Ds.	1001	1031	1062	1094	1127	1160	1195	1231	1268	1306	1345
55	Km124Dps (Bon Dalem/ Ds. Tembok)- Bts.	594	612	630	649	669	689	709	731	752	775	798
56	Jln. UntungSurapati (Amlapura)	594	612	630	649	669	689	709	731	752	775	798
57	Bts. KotaAmlapura–Angentelu	5709	5880	6057	6238	6426	6618	6817	7021	7232	7449	7672
58	Jln. Sudirman - A. Yani (Amlapura)	5709	5880	6057	6238	6426	6618	6817	7021	7232	7449	7672
59	Bts. KotaSingaraja–Mengwitani	2981	3070	3163	3257	3355	3456	3559	3666	3776	3890	4006
60	Jln. JelantikGingsir-Veteran (Singara	2981	3070	3163	3257	3355	3456	3559	3666	3776	3890	4006
61	Sp. 3 Mengwi-Beringkit	10472	10786	11110	11443	11786	12140	12504	12879	13266	13664	14073

Appendix 6: Total road maintenance cost needs every year with link-based

Analysis Types	Total maintenance cost needs every years(Rp.1.000.000,-)											Total cost
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Linkbased_20	33,226	32,656	32,656	57,263	74,033	85,120	72,285	106,090	119,570	225,754	225,204	1,063,858
Linkbased_40	33,226	32,656	31,368	43,487	46,139	46,139	47,421	47,421	53,673	68,179	79,030	528,738
Linkbased_60	33,226	31,648	31,648	32,656	32,656	32,656	33,938	32,650	32,650	37,486	42,496	373,709
Linkbased_80	33,226	28,772	28,772	28,772	28,772	28,772	28,772	28,772	28,772	33,608	33,608	330,620

Appendix 7: The differences in link traffic flow (link-based vs network-based)

No	Roads	Length(m)	IRI2015	IRI2020	LinkBased_20 approach		NetworkBased_20 approach	
					AADT 2015	AADT 2020	AADT 2015	AADT 2020
15	Jln. Setiabudi (Dps)	0.77	4.21	4.74	20,834	24,152	20,834	22,979
16	Jln. Wahidin (Dps)	0.23	4.23	4.76	20,834	24,152	20,834	22,979
17	Jln. Thamrin (Dps)	0.38	3.97	4.50	20,834	24,152	20,834	22,978

Appendix 8: The total road maintenance cost per year with network-based

Analysis Types	Total Maintenance Cost (Fiscal Need) per Years (Rp. 1.000.000,-)											Total cost(Rp.)
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Networkbased_20	33,226	32,656	32,656	57,263	59,915	66,167	66,167	90,267	93,909	131,420	117,777	781,422
Networkbased_40	33,226	32,656	31,368	38,527	41,178	41,178	41,178	59,438	59,438	69,109	74,119	521,417
Networkbased_60	33,226	31,648	30,359	37,736	30,577	37,736	30,577	48,837	48,837	48,837	53,847	432,214
Networkbased_80	33,226	32,656	28,772	28,772	28,772	28,772	28,772	28,772	28,772	28,772	28,772	324,832

Appendix 9: Differences maintenance program due to differences in forecasts traffic flow

Year	Networkbased_60						Linkbased_60					
	No.	Link	Lenght(Km)	Width (M)	Treatment	Cost (Rp.)	No.	Link	Lenght (Km)	Width (m)	Treat of	Cost (Rp)
2022	33	Sp. Tohpati - Sakah	12,97	11,5	Preventif	17.690.730	27	Simp. Pesanggaran Gerbang Benoa	0,60	19,0	Preventif	824.157
	13	Jln. Cokroam	0,98	11,0	Preventif	1.335.845	15	Jln. Setiabu	0,77	10,0	Preventif	1.050.664

		inoto (Dps)						di (Dps)				
	15	Jln. Setiabudi (Dps)	0,77	10,0	Preventif	1.050.664	16	Jln. Wahidin (Dps)	0,23	8,0	Preventif	316.564
	16	Jln. Wahidin (Dps)	0,23	8,0	Preventif	316.564	17	Jln. Thamrin (Dps)	0,38	9,0	Preventif	513.052
	17	Jln. Thamrin (Dps)	0,38	9,0	Preventif	513.052	13	Jln. Cokroamino to (Dps)	0,98	11,0	Preventif	1.335.845