The Connectivity Quality As Part Of Network Quality For A Sparse Road Network

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ABSTRACT : As a developing country, in terms of road network, Indonesia is dominated by sparse road network : the regency, the provincial and the national road network. Therefore, the network quality of the road network is capital to be formulated. This paper is designated to present the research result on formulating the connectivity quality as part of network quality. The network quality is formulated based on network performance to execute its function. The main functions are to connect different points of the region, to flow the traffic and to cover the area on a certain density. The connectivity quality must measure how well the nodes are connected each other. The quality must be measured against a desired condition. This principal is derived afterward into three measures, i.e. : the percentage of number of connected nodes, the percentage of the total road length and the ratio of total shortest path distance. Connectivity quality is calculated for each vehicle category. A special matrix method for transportation network analyses must be used to execute the whole calculation.

Keywords: *network quality, connectivity quality, sparse road network.*

1. INTRODUCTION

Indonesia, as a developing country, is dominated by sparse road network. The sparse road network mainly are the regency road networks, the provincial road networks and the national road networks (Hitapriya, 2014, 2015). At present, common road network evaluation are based on physical segmental quality and traffic engineering quality. The segmental physical quality deal with the road segment pavement and geometric quality. While traffic engineering quality normally is evaluated based only on traffic flow fluidity measure (Hitapriya, 2014, 2015, Tamin, 2008). For a sparse road network, it can be thought easily that those two qualities mentioned above are not enough, therefore network quality needs to be formulated (Hitapriya, 2008,2010, 2014, 2015). As an example, it can be mentioned that the development of the Suramadu Bridge in Surabaya, the Jakarta By-Pass Road in Jakarta, the Pasopati Bridge in Bandung, the Normandy Bridge in France, the Honshu-Shikoku Bridge in Japan are all for improving the Connectivity Quality of the existing road network. Thus, those all are for improving network quality (Hitapriya, 2010, 2014, 2015, Anonim, 1992, Yoshinaga, Kishimoto & Ohe, 2001).

In general, network quality of a road network is not yet considered and formulated, while it is very important, especially for a sparse road network. The network quality must be formulated based on the road network performance in executing its functions. While the road network main functions are to connect different points in the region, to flow the traffic and to cover the regions in certain coverage and density. Network quality in terms of traffic

flow quality has been formulated, in terms of traffic flow itinerary quality (Hitapriya, 2014, 2015).

This paper present the research result on developing the network quality of a road network, in terms of connectivity quality, together with its calculaltion method.

2. LITERATURE REVIEW

Basic Network Quality of a Road Network. Network quality had ever been formulated in several cases (Ridwan, 2008, Tamin, 2008, Taaffe, Gauthier & O'Kelly, 1996, John Black 1981). Unfortunately, those formulations are either partial for certain cases only, unintegrated or can be considered imperfect in certain points. In a new research, Road Network Quality has been formulated as the network performance to execute its function. The three main functions are : to connect different points in the region, to flow the traffic circulating in the region and to cover the region in certain coverage and density. This formulation of road network functions and road network quality is presented in Table 1 below (Hitapriya, 2014, 2015).

Table 1. Basic Network Quality of a Road Network

Function	Quality	Explanation
To connect different points	Connectivity	How well important points are connected each other.
	Accessibility	How well important points can be accessed from other points.
To flow the traffic	Itinerary	How good traffic flow itinerary are.
	Fluidity	How fluid are the traffic flow
To cover the region	Coverage	How large the road network cover the area
	Density	How dense is the road network

Source : (Hitapriya, 2014, 2015)

Road Network Model. The road network model ever used in road transportation analysis are very various, e.g. : simple node-link network, transport demand network model, traffic light coordination network model, cell tranmission network model (Tamin, 2008, Binning & Crabtree, 2002, INRO Consultant, 1999, Daganzo, 1994, Ortuzar & Willumsen, 1994). For this analysis the simple node link network model is the most appropriate (Hitapriya, 2014, 2015). The model is presented in Figure 1 below.

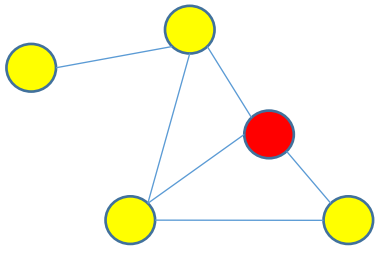

Figure 1. Simple Node Link Network Model

Special Matrix Method for Transportation Network Analysis. A special matrix calculation technic has been developed initially for executing road network calculation. The idea is triggered by the necessity to analyse transportation network and the existence of spreadsheet type software. Network data can be presented in a form of a list or a matrix. To be able to be calculated by using spreadsheet type software, the data must be presented in a matrix form. This method is based on a special n × n matrix, a special matrix operation and

algebra min-plus operation (Hitapriya, 2014, 2015, Suprayitno, Mochtar & Wicaksono, 2014). This special technic is necessary to be developed since the existing matrix technics is not adequate for this purpose (Munir, 2012, Arifin, 2001, Goldberg, 2000, Baccelli, Cohen, Olsder & Quadrat, 1992, Hamdy, 1992, Hillier & Lieberman, 1990, Bondy & Murty, 1982, Brand & Sherlock, 1970).

Three Form of Matrix are used in this method, i.e. : basic matrix, expanded matrix and indicative matrix (Hitapriya, 2014, 2015). These three types of matrix are presented in Tabel 2 below.

Tabel 2. Three Types of Matrix

Basic Matrix

BM	1	2	3	4
1				
2				
3				
4				

Expanded Matrix

EM	1	2	3	4	SR
1					
2					
3					
4					
SC					

Indicative Matrix

IM	1	2	3	4	SR	IR
1						
2						
3						
4						
SC						
IC						

Special Matrix Operation was developed around mathematical operation for constant, variabel, set and matrix (Hitapriya, 2014, 2015). Example of three special matrix operations needed for Connectivity Quality calculation are presented below.

- **Matrix Expansion :**

$$\begin{aligned} me.M &= \chi\, m.M \\ &= m.M + SR_i + SC_j + SM \\ SR_i &= \sum m_{I,j} \\ SC_j &= \sum m_{i,J} \\ SM &= \sum m_{i,j} \text{ or } \sum SR_i \text{ or } \sum SC_j \end{aligned}$$

- **Matrix Expansion Indicative :**

$$\begin{aligned} mi.M &= \iota\, me.M \\ &= me.M + IR_i + IC_j + SI \\ IR_i &= C_1 \text{ if } \textit{mathematical condition } IR_i, \text{ else } C_2 \\ IC_j &= C_1 \text{ if } \textit{mathematical condition } IC_j, \text{ else } C_2 \\ SI &= \sum IR_i \text{ or } \sum IC_j \end{aligned}$$

- **Min-Plus Algebra Matrix Multiplication**

$$\begin{aligned} m.M &= m.A \underline{\otimes} m.B \\ m.M_{ij} &= \underline{\oplus}_{p=1}^{p=n} (a_{iP} + b_{Pj}) \\ &= \min_{p=1}^{p=n} (a_{iP} + b_{Pj}) \end{aligned}$$

3. CONNECTIVITY QUALITY DEVELOPMENT

Quality Components Development. Network function – to connect different points – can be derived into two quality components : connectivity and accessibility. This paper discuss only the Connectivity Quality.

Network Quality should be measured in number with a maximum number as an ideal condition. For this purpose a desired condition is needed as a reference for an ideal condition, since ideal condition does not exist. The ideal condition should be represented by an Expected Network.

In principal, Connectivity Quality deals with wether all of the points of the region which should be connected are all well connected. This connectivity, therefore, should be expressed in several measures :

- precentage of number of connected points : a ratio between the number of the Existing Network connected nodes to that of the Expected Network.
- precentage of total road length : a ratio between the Existing Network total road length to that of the Expected Network.
- precentage of total shortest path distance : a ratio of the Existing Network total shortest path length to that of the Expected Network.

The Connectivity Quality Measures are summarized in Tabel 3 as follows.

Tabel 3. Connectivity Quality Measures

Quality	Measure
Connectivity	Number of points connected, existing compared to expected network.
	Total road length, existing compared to expected network.
	Shortest path distance, existing compare to expected network.
Accessibility	Not treated.

The three Connectivity Quality Measures, as defined above, are illustrated through a simple virtual case below.

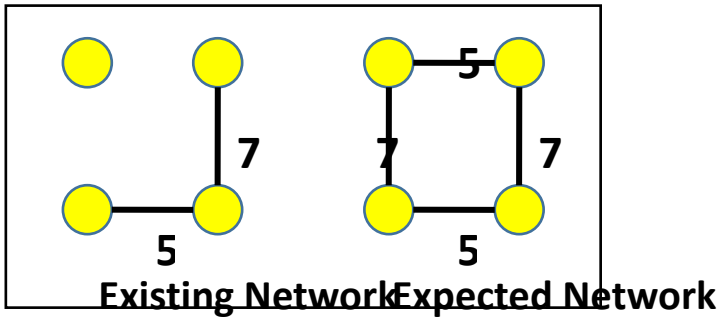

Figure 2. Connectivity Quality Illustration

The Connectivity Quality of the sample above can be calculated manually easily. Calculation result indicated that : there is one unconnected node, the existing total road length is 50% of that of the expected one, while the existing total shortest path distance is still unacceptable. The calculation result is presented in Table 4.

Tabel 4. Connectivity Quality Calculation

	Number of Connected Node	Total Road Length	Total Shortest Path
Existing Network	3	12	∞
Expected Network	4	24	110
Difference	-1	-12	∞
Pourcentage	75%	50%	∞%

3.1. Calculation Method Development.

The connectivity calculation of the simple sample above can be done manually very easily. But the case network are always large and complicated, therefore a Special Calculation Method need to be developed. The method must be based on Special Matrix Method for Transportation Network Analysis in order to able to be done by using a spreadsheet software.

Based on that Special Matrix Operation Method, certain 3 Calculation Steps are needed to execute Connectivity Quality calculation. These are presented as follow.

Precentage of Number of Connected Nodes for a Vehicle Class
- Number of Connected Nodes - Expected Network for a Vehicle Class
  - Indicative Matrix of Connected Nodes - Expected Network for a Vehicle Class
    - Matrix of Link Length – Expected Network for a Vehicle Class for a Vehicle Class
- Number of Connected Nodes - Existing Network for a Vehicle Class
  - Indicative Matrix of Connected Nodes - Existing Network for a Vehicle Class
    - Matrix of Link Length – Existing Network for a Vehicle Class for a Vehicle Class

Precentage of Total Road Length for a Vehicle Class
- Total Road Length - Expected Network for a Vehicle Class for a Vehicle Class
  - Expanded Matrix of Link Length – Expected Network for a Vehicle Class for a Vehicle Class
    - Matrix of Link Length – Expected Network for a Vehicle Class for a Vehicle Class
- Total Road Length - Existing Network for a Vehicle Class for a Vehicle Class
  - Expanded Matrix of Link Length – Existing Network for a Vehicle Class for a Vehicle Class
    - Matrix of Link Length – Existing Network for a Vehicle Class for a Vehicle Class

Ratio of Total Shortest Path Length for a Vehicle Class
- Total Shortest Path Length - Expected Network for a Vehicle Class
  - Expanded Matrix of Shortest Path Length - Expected Network for a Vehicle Class
    - Matrix of Shortest Path Length - Expected Network for a Vehicle Class
      - Matrix of Link Length – Expected Network for a Vehicle Class
- Total Shortest Path Length - Existing Network for a Vehicle Class
  - Expanded Matrix of Shortest Path Length - Existing Network for a Vehicle Class
    - Matrix of Shortest Path Length - Existing Network for a Vehicle Class
      - Matrix of Link Length – Existing Network for a Vehicle Class

3.2. CALCULATION TRIAL

Bangkalan Regency Road Network and the Model. Bangkalan Regency Road Network was taken as a Test Case for a real calculation trial. It is choosen since the road network is still a sparse network and not yet well developed. Therefore, this case is appropriate to test the Connectivity Quality developed above.

The road network model consists of 61 nodes and 79 links. The links represent 4 classes of roads: the Suramadu bridge and its access road, the national road, the provincial road and the regency road. The node represent the region's important points, the intersection and the dummy points. The regions important points are 'kecamatan' center, transportation

terminals and other activity centers. Calculation Trial has been done for 6 vehicle classes: Truck 1, Truck 2, Truck 3, Pick-up & MPV, Car and Motorcycle.

The Bangkalan Regency Road Network, The Road Network Model together with The Road Classifiaction related to the Class of Vehicle are presented in Figure 3.

Expected Network. First, to analyze the Connectivity Quality we need an Expected Network, as a reference of an 'ideal condition' to which the Existing Network is compared. Afterward calculation can be made. The existing MPV Class Network and the Expected MPV Class Network are presented in Figure 4.

Basic Network Data. Basic network data to calculate the Connectivity Quality for the MPV Vehicle Class are Link Length Matrix of Existing Network and Link Length Matrix of Desired Network; both are for MPV Vehicle Class. These two are presented in Tabel 5 and Tabel 6.

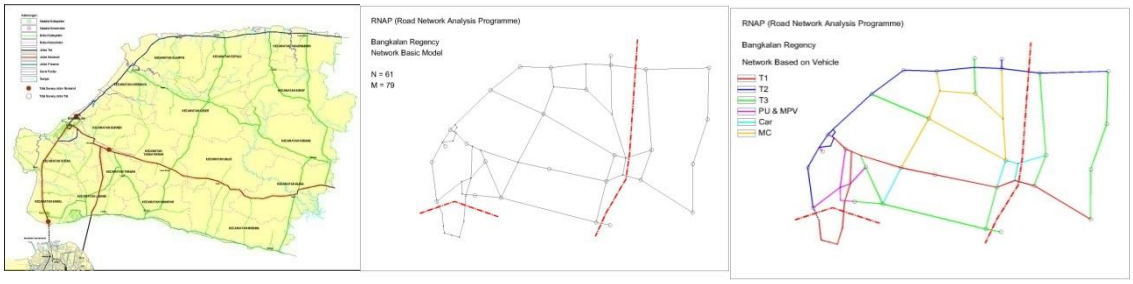

Figure 3. Bangkalan Road Network, Model and Road ClassificationDue to the number of pages limitation for this paper, as an example, only Connectivity Quality calculation for MPV Vehicle Class is presented in this paper.

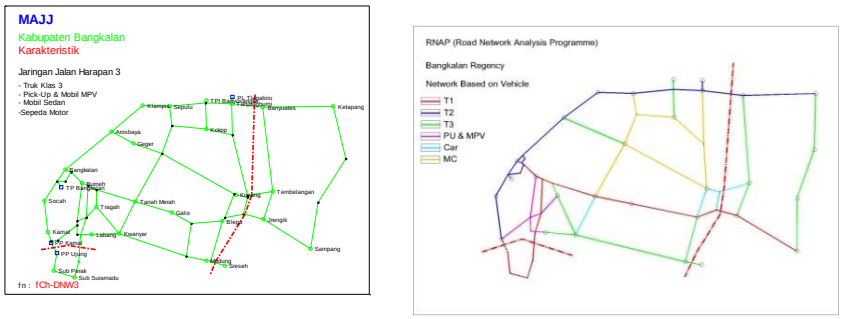

Figure 4. Existing and Expected MPV Network

Tabel 5. Matrix of Link Length - Existing Network for MPV Vehicle Class

mSD22e_T3

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	41.4	35.3	62.8	52.4	64.0	40.8	32.4	27.4	7.0	15.5	19.9	28.8	34.3	57.5	57.4	43.6	37.8	0.0	13.7	2.6	59.0	733.5	1
Labeng	2	41.4	0.0	6.1	57.4	47.0	58.6	35.3	26.9	14.0	34.4	26.4	21.5	39.6	45.2	68.4	68.3	54.5	48.7	0.0	30.8	44.0	69.9	838.3	1
Kwanyar	3	35.3	6.1	0.0	51.3	40.9	52.5	29.2	20.8	7.9	28.3	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	0.0	24.7	37.9	63.8	722.4	1
Modung	4	62.8	57.4	51.3	0.0	10.4	22.0	22.0	30.4	43.3	55.9	47.8	42.9	61.1	66.7	89.8	89.2	76.0	70.1	0.0	52.3	65.4	90.8	1,107.5	1
Blega	5	52.4	47.0	40.9	10.4	0.0	11.6	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	0.0	41.9	55.0	80.4	910.0	1
Konang	6	64.0	58.6	52.5	22.0	11.6	0.0	23.3	31.7	44.6	57.1	49.1	44.1	62.3	67.9	91.0	80.1	77.2	71.3	0.0	53.5	66.7	81.7	1,110.2	1
Galis	7	40.8	35.3	29.2	22.0	11.6	23.3	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	0.0	30.2	43.4	69.3	736.5	1
Tanah Merah	8	32.4	26.9	20.8	30.4	20.0	31.7	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	0.0	21.8	35.0	60.8	627.1	1
Tragah	9	27.4	14.0	7.9	43.3	32.9	44.6	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	0.0	16.8	30.0	55.8	587.8	1
Socah	10	7.0	34.4	28.3	55.9	45.5	57.1	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	0.0	6.8	9.6	52.0	615.2	1
Bangkalan	11	15.5	26.4	20.3	47.8	37.4	49.1	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	0.0	5.0	18.1	43.5	498.5	1
Burneh	12	19.9	21.5	15.4	42.9	32.5	44.1	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.2	0.0	9.4	22.5	48.4	511.1	1
Arosbaya	13	28.8	39.6	33.5	61.1	50.7	62.3	39.0	30.6	25.8	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	0.0	18.2	31.4	30.2	591.2	1
Geger	14	34.3	45.2	39.1	66.7	56.3	67.9	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	0.0	23.8	37.0	35.8	697.2	1
Kokop	15	57.5	68.4	62.3	89.8	79.4	91.0	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	0.0	46.9	60.1	13.2	997.6	1
Tanjungbumi	16	57.4	68.3	62.2	89.2	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	0.0	46.9	60.0	1.6	972.5	1
Sepulu	17	43.6	54.5	48.4	76.0	65.6	77.2	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	0.0	33.1	46.3	15.3	766.6	1
Klampis	18	37.8	48.7	42.6	70.1	59.7	71.3	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	0.0	27.3	40.4	21.2	690.6	1
TPI Banyusangka	19	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
TP Bangkalan	20	13.7	30.8	24.7	52.3	41.9	53.5	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	0.0	0.0	16.4	48.4	567.9	1
FP Kamal	21	2.6	44.0	37.9	65.4	55.0	66.7	43.4	35.0	30.0	9.6	18.1	22.5	31.4	37.0	60.1	60.0	46.3	40.4	0.0	16.4	0.0	61.6	783.3	1
PL Tlagabiru	22	59.0	69.9	63.8	90.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	0.0	48.4	61.6	0.0	1,002.5	1
		733.5	838.3	722.4	1,107.5	910.0	1,110.2	736.5	627.1	587.8	615.2	498.5	511.1	591.2	697.2	997.6	972.5	766.6	690.6	0.0	567.9	783.3	1,002.5	16,067.4	21

3.3. Connectivity Quality Calculation.

Connectivity Quality is measured in terms of ratio value between the property value of the existing network to the property value of the desired network. Three property values are compared, i.e. : number of connected nodes, total road length and total shortest path distance. All these property value are calculated by using Special Matrix Method for Network Analysis mentioned above. Those three calculation are presented below.

Tabel 6. Matrix of Link Length – Expected Network for MPV Vehicle Class

mSD22e_T3

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	41.4	35.3	62.8	52.4	64.0	40.8	32.4	27.4	7.0	15.5	19.9	28.8	34.3	57.5	57.4	43.6	37.8	0.0	13.7	2.6	59.0	733.5	1
Labeng	2	41.4	0.0	6.1	57.4	47.0	58.6	35.3	26.9	14.0	34.4	26.4	21.5	39.6	45.2	68.4	68.3	54.5	48.7	0.0	30.8	44.0	69.9	838.3	1
Kwanyar	3	35.3	6.1	0.0	51.3	40.9	52.5	29.2	20.8	7.9	28.3	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	0.0	24.7	37.9	63.8	722.4	1
Modung	4	62.8	57.4	51.3	0.0	10.4	22.0	22.0	30.4	43.3	55.9	47.8	42.9	61.1	66.7	89.8	89.2	76.0	70.1	0.0	52.3	65.4	90.8	1,107.5	1
Blega	5	52.4	47.0	40.9	10.4	0.0	11.6	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	0.0	41.9	55.0	80.4	910.0	1
Konang	6	64.0	58.6	52.5	22.0	11.6	0.0	23.3	31.7	44.6	57.1	49.1	44.1	62.3	67.9	91.0	80.1	77.2	71.3	0.0	53.5	66.7	81.7	1,110.2	1
Galis	7	40.8	35.3	29.2	22.0	11.6	23.3	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	0.0	30.2	43.4	69.3	736.5	1
Tanah Merah	8	32.4	26.9	20.8	30.4	20.0	31.7	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	0.0	21.8	35.0	60.8	627.1	1
Tragah	9	27.4	14.0	7.9	43.3	32.9	44.6	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	0.0	16.8	30.0	55.8	587.8	1
Socah	10	7.0	34.4	28.3	55.9	45.5	57.1	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	0.0	6.8	9.6	52.0	615.2	1
Bangkalan	11	15.5	26.4	20.3	47.8	37.4	49.1	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	0.0	5.0	18.1	43.5	498.5	1
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Arosbaya	13	28.8	39.6	33.5	61.1	50.7	62.3	39.0	30.6	25.8	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	0.0	18.2	31.4	30.2	591.2	1
Geger	14	34.3	45.2	39.1	66.7	56.3	67.9	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	0.0	23.8	37.0	35.8	697.2	1
Kokop	15	57.5	68.4	62.3	89.8	79.4	91.0	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	0.0	46.9	60.1	13.2	997.6	1
Tanjungbumi	16	57.4	68.3	62.2	89.2	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	0.0	46.9	60.0	1.6	972.5	1
Sepulu	17	43.6	54.5	48.4	76.0	65.6	77.2	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	0.0	33.1	46.3	15.3	766.6	1
Klampis	18	37.8	48.7	42.6	70.1	59.7	71.3	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	0.0	27.3	40.4	21.2	690.6	1
TPI Banyusangka	19	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
TP Bangkalan	20	13.7	30.8	24.7	52.3	41.9	53.5	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	0.0	0.0	16.4	48.4	567.9	1
FP Kamal	21	2.6	44.0	37.9	65.4	55.0	66.7	43.4	35.0	30.0	9.6	18.1	22.5	31.4	37.0	60.1	60.0	46.3	40.4	0.0	16.4	0.0	61.6	783.3	1
PL Tlagabiru	22	59.0	69.9	63.8	90.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	0.0	48.4	61.6	0.0	1,002.5	1
		733.5	838.3	722.4	1,107.5	910.0	1,110.2	736.5	627.1	587.8	615.2	498.5	511.1	591.2	697.2	997.6	972.5	766.6	690.6	0.0	567.9	783.3	1,002.5	16,067.4	21

3.4. Precentage of Nodes Connected.

The number of connected nodes, either for the Existing Network and the Desired Network is calcualted based on Matrix Indicative of Connected Nodes Existing Network and Desired Network, for MPV Vehicle Class. The Indicative Matrice are developed based on the Expanded Matrices, which are built based on the Link Length Matrices. The two Indicative Matrices are presented in Tabel 7 and Tabel 8 below.

Tabel 7. Indicative Matrix of Number of Connected Nodes – Existing Network for MPV Class

mSD22e_CU

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	14.6	20.7	40.8	48.5	55.5	36.8	28.4	15.5	7.0	15.5	18.7	28.8	34.3	57.5	57.4	43.6	37.8	52.3	13.7	2.6	59.0	689.1	1
Labang	2	14.6	0.0	6.1	26.2	34.2	41.3	22.5	14.1	11.7	21.6	19.8	14.8	33.0	38.6	61.7	61.6	47.9	42.0	56.5	24.2	12.7	63.2	668.5	1
Kwanyar	3	20.7	6.1	0.0	20.1	28.1	35.2	16.4	8.0	7.9	27.7	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	57.1	24.7	18.8	63.8	658.4	1
Modung	4	40.8	26.2	20.1	0.0	10.4	17.5	17.0	25.4	28.0	47.8	40.4	35.5	53.6	59.2	82.4	82.3	68.5	62.7	77.1	44.8	38.9	83.8	962.4	1
Blega	5	48.5	34.2	28.1	10.4	0.0	7.1	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	74.2	41.9	46.6	80.4	941.6	1
Konang	6	55.5	41.3	35.2	17.5	7.1	0.0	18.7	27.1	40.0	52.5	44.5	39.6	57.8	63.3	86.5	80.1	72.6	66.8	81.3	49.0	53.6	81.7	1,071.7	1
Galis	7	36.8	22.5	16.4	17.0	11.6	18.7	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	62.6	30.2	34.9	69.3	751.5	1
Tanah Merah	8	28.4	14.1	8.0	25.4	20.0	27.1	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	54.1	21.8	26.5	60.8	633.7	1
Tragah	9	15.5	11.7	7.9	28.0	32.9	40.0	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	49.1	16.8	13.6	55.8	586.5	1
Socah	10	7.0	21.6	27.7	47.8	45.5	52.5	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	45.3	6.8	9.6	52.0	634.5	1
Bangkalan	11	15.5	19.8	20.3	40.4	37.4	44.5	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	36.8	5.0	18.1	43.5	516.6	1
Burneh	12	18.7	14.8	15.4	35.5	32.5	39.6	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.2	41.7	9.4	16.8	48.4	527.2	1
Arosbaya	13	28.8	33.0	33.5	53.6	50.7	57.8	39.0	30.6	25.6	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	23.5	18.2	31.4	30.2	596.1	1
Geger	14	34.3	38.6	39.1	59.2	56.3	63.3	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	29.1	23.8	37.0	35.8	707.7	1
Kokop	15	57.5	61.7	62.3	82.4	79.4	86.5	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	6.5	46.9	60.1	13.2	985.5	1
Tanjungbumi	16	57.4	61.6	62.2	82.3	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	6.4	46.9	60.0	1.6	965.4	1
Sepulu	17	43.6	47.9	48.4	68.5	65.6	72.6	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	8.6	33.1	46.3	15.3	756.6	1
Klampis	18	37.8	42.0	42.6	62.7	59.7	66.8	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	14.5	27.3	40.4	21.2	686.5	1
TPI Banyusangka	19	52.3	56.5	57.1	77.1	74.2	81.3	62.6	54.1	49.1	45.3	36.8	41.7	23.5	29.1	6.5	6.4	8.6	14.5	0.0	41.7	54.9	8.0	881.2	1
TP Bangkalan	20	13.7	24.2	24.7	44.8	41.9	49.0	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	41.7	0.0	16.4	48.4	591.1	1
PP Kamal	21	2.6	12.7	18.8	38.9	46.6	53.6	34.9	26.5	13.6	9.6	18.1	16.8	31.4	37.0	60.1	60.0	46.3	40.4	54.9	16.4	0.0	61.6	700.9	1
PL Tlagabiru	22	59.0	63.2	63.8	83.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	8.0	48.4	61.6	0.0	997.0	1
		689.1	668.5	658.4	962.4	941.6	1,071.7	751.5	633.7	586.5	634.5	516.6	527.2	596.1	707.7	985.5	965.4	756.6	686.5	881.2	591.1	700.9	997.0	16,509.6	22

Tabel 8 Indicative Matrix of Number of Connected Nodes – Expected Network for MPV Class

mSD22e_T3

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	41.4	35.3	62.8	52.4	64.0	40.8	32.4	27.4	7.0	15.5	19.9	28.8	34.3	57.5	57.4	43.6	37.8	0.0	13.7	2.6	59.0	733.5	1
Labang	2	41.4	0.0	6.1	57.4	47.0	58.6	35.3	26.9	14.0	34.4	26.4	21.5	39.6	45.2	68.4	68.3	54.5	48.7	0.0	30.8	44.0	69.9	838.3	1
Kwanyar	3	35.3	6.1	0.0	51.3	40.9	52.5	29.2	20.8	7.9	28.3	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	0.0	24.7	37.9	63.8	722.4	1
Modung	4	62.8	57.4	51.3	0.0	10.4	22.0	22.0	30.4	43.3	55.9	47.8	42.9	61.1	66.7	89.8	89.2	76.0	70.1	0.0	52.3	65.4	90.8	1,107.5	1
Blega	5	52.4	47.0	40.9	10.4	0.0	11.6	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	0.0	41.9	55.0	80.4	910.0	1
Konang	6	64.0	58.6	52.5	22.0	11.6	0.0	23.3	31.7	44.6	57.1	49.1	44.1	62.3	67.9	91.0	90.1	77.2	71.3	0.0	53.5	66.7	81.7	1,110.2	1
Galis	7	40.8	35.3	29.2	22.0	11.6	23.3	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	0.0	30.2	43.4	69.3	736.5	1
Tanah Merah	8	32.4	26.9	20.8	30.4	20.0	31.7	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	0.0	21.8	35.0	60.8	627.1	1
Tragah	9	27.4	14.0	7.9	43.3	32.9	44.6	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	0.0	16.8	30.0	55.8	587.8	1
Socah	10	7.0	34.4	28.3	55.9	45.5	57.1	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	0.0	6.8	9.6	52.0	619.2	1
Bangkalan	11	15.5	26.4	20.3	47.8	37.4	49.1	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	0.0	5.0	18.1	43.5	498.5	1
Burneh	12	19.9	21.5	15.4	42.9	32.5	44.1	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.2	0.0	9.4	22.5	48.4	511.1	1
Arosbaya	13	28.8	39.6	33.5	61.1	50.7	62.3	39.0	30.6	25.6	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	0.0	18.2	31.4	30.2	591.2	1
Geger	14	34.3	45.2	39.1	66.7	56.3	67.9	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	0.0	23.8	37.0	35.8	697.2	1
Kokop	15	57.5	68.4	62.3	89.8	79.4	91.0	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	0.0	46.9	60.1	13.2	997.6	1
Tanjungbumi	16	57.4	68.3	62.2	89.2	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	0.0	46.9	60.0	1.6	972.5	1
Sepulu	17	43.6	54.5	48.4	76.0	65.6	77.2	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	0.0	33.1	46.3	15.3	766.6	1
Klampis	18	37.8	48.7	42.6	70.1	59.7	71.3	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	0.0	27.3	40.4	21.2	690.6	1
TPI Banyusangka	19	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
TP Bangkalan	20	13.7	30.8	24.7	52.3	41.9	53.5	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	0.0	0.0	16.4	48.4	567.9	1
PP Kamal	21	2.6	44.0	37.9	65.4	55.0	66.7	43.4	35.0	30.0	9.6	18.1	22.5	31.4	37.0	60.1	60.0	46.3	40.4	0.0	16.4	0.0	61.6	783.3	1
PL Tlagabiru	22	59.0	69.9	63.8	90.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	0.0	48.4	61.6	0.0	1,002.5	1
		733.5	838.3	722.4	1,107.5	910.0	1,110.2	736.5	627.1	587.8	615.2	498.5	511.1	691.2	897.2	997.6	972.5	766.6	690.6	0.0	567.9	783.3	1,002.5	16,067.6	21

Precentage of Total Shortest Path Length. The total shortest path distance, either for the existing network and the desired network are gotten from the Expanded Shortest Path Matrix, existing and desired network, for MPV. The shortest path matrices are calculated based on Link Length Matrices by using Min-Plus Algebra matrix power operation. The two expanded matrices are presented in Tabel 11 and Tabel 12 below.

Tabel 9. Expanded Matrix of Link Length – Existing Network for MPV Class

mSD22e_T3

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	41.4	35.3	62.8	52.4	64.0	40.8	32.4	27.4	7.0	15.5	19.9	28.8	34.3	57.5	57.4	43.6	37.8	0.0	13.7	2.6	59.0	733.5	1
Labang	2	41.4	0.0	6.1	57.4	47.0	58.6	35.3	26.9	14.0	34.4	26.4	21.5	39.6	45.2	68.4	68.3	54.5	48.7	0.0	30.8	44.0	69.9	838.3	1
Kwanyar	3	35.3	6.1	0.0	51.3	40.9	52.5	29.2	20.8	7.9	28.3	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	0.0	24.7	37.9	63.8	722.4	1
Modung	4	62.8	57.4	51.3	0.0	10.4	22.0	22.0	30.4	43.3	55.9	47.8	42.9	61.1	66.7	89.8	89.2	76.0	70.1	0.0	52.3	65.4	90.8	1,107.5	1
Blega	5	52.4	47.0	40.9	10.4	0.0	11.6	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	0.0	41.9	55.0	80.4	910.0	1
Konang	6	64.0	58.6	52.5	22.0	11.6	0.0	23.3	31.7	44.6	57.1	49.1	44.1	62.3	67.9	91.0	90.1	77.2	71.3	0.0	53.5	66.7	81.7	1,110.2	1
Galis	7	40.8	35.3	29.2	22.0	11.6	23.3	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	0.0	30.2	43.4	69.3	736.5	1
Tanah Merah	8	32.4	26.9	20.8	30.4	20.0	31.7	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	0.0	21.8	35.0	60.8	627.1	1
Tragah	9	27.4	14.0	7.9	43.3	32.9	44.6	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	0.0	16.8	30.0	55.8	587.8	1
Socah	10	7.0	34.4	28.3	55.9	45.5	57.1	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	0.0	6.8	9.6	52.0	615.2	1
Bangkalan	11	15.5	26.4	20.3	47.8	37.4	49.1	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	0.0	5.0	18.1	43.5	498.5	1
Burneh	12	19.9	21.5	15.4	42.9	32.5	44.1	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.2	0.0	9.4	22.5	48.4	511.1	1
Arosbaya	13	28.8	39.6	33.5	61.1	50.7	62.3	39.0	30.6	25.6	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	0.0	18.2	31.4	30.2	591.2	1
Geger	14	34.3	45.2	39.1	66.7	56.3	67.9	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	0.0	23.8	37.0	35.8	697.2	1
Kokop	15	57.5	68.4	62.3	89.8	79.4	91.0	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	0.0	46.9	60.1	13.2	997.6	1
Tanjungbumi	16	57.4	68.3	62.2	89.2	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	0.0	46.9	60.0	1.6	972.5	1
Sepulu	17	43.6	54.5	48.4	76.0	65.6	77.2	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	0.0	33.1	46.3	15.3	766.6	1
Klampis	18	37.8	48.7	42.6	70.1	59.7	71.3	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	0.0	27.3	40.4	21.2	690.6	1
TPI Banyusangka	19	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
TP Bangkalan	20	13.7	30.8	24.7	52.3	41.9	53.5	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	0.0	0.0	16.4	48.4	567.9	1
FP Kamal	21	2.6	44.0	37.9	65.4	55.0	66.7	43.4	35.0	30.0	9.6	18.1	22.5	31.4	37.0	60.1	60.0	46.3	40.4	0.0	16.4	0.0	61.6	783.3	1
PL Tlagabiru	22	59.0	69.9	63.8	90.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	0.0	48.4	61.6	0.0	1,002.5	1
		733.5	838.3	722.4	1,107.5	910.0	1,110.2	736.5	627.1	587.8	615.2	498.5	511.1	591.2	697.2	997.6	972.5	766.6	690.6	0.0	567.9	783.3	1,002.5	16,067.6	21

Tabel 10. Expanded Matrix of Link Length – Expected Network for MPV Class

mSD22e_T3

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	41.4	35.3	62.8	52.4	64.0	40.8	32.4	27.4	7.0	15.5	19.9	28.8	34.3	57.5	57.4	43.6	37.8	0.0	13.7	2.6	59.0	733.5	1
Labang	2	41.4	0.0	6.1	57.4	47.0	58.6	35.3	26.9	14.0	34.4	26.4	21.5	39.6	45.2	68.4	68.3	54.5	48.7	0.0	30.8	44.0	69.9	838.3	1
Kwanyar	3	35.3	6.1	0.0	51.3	40.9	52.5	29.2	20.8	7.9	28.3	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	0.0	24.7	37.9	63.8	722.4	1
Modung	4	62.8	57.4	51.3	0.0	10.4	22.0	22.0	30.4	43.3	55.9	47.8	42.9	61.1	66.7	89.8	89.2	76.0	70.1	0.0	52.3	65.4	90.8	1,107.5	1
Blega	5	52.4	47.0	40.9	10.4	0.0	11.6	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	0.0	41.9	55.0	80.4	910.0	1
Konang	6	64.0	58.6	52.5	22.0	11.6	0.0	23.3	31.7	44.6	57.1	49.1	44.1	62.3	67.9	91.0	90.1	77.2	71.3	0.0	53.5	66.7	81.7	1,110.2	1
Galis	7	40.8	35.3	29.2	22.0	11.6	23.3	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	0.0	30.2	43.4	69.3	736.5	1
Tanah Merah	8	32.4	26.9	20.8	30.4	20.0	31.7	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	0.0	21.8	35.0	60.8	627.1	1
Tragah	9	27.4	14.0	7.9	43.3	32.9	44.6	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	0.0	16.8	30.0	55.8	587.8	1
Socah	10	7.0	34.4	28.3	55.9	45.5	57.1	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	0.0	6.8	9.6	52.0	615.2	1
Bangkalan	11	15.5	26.4	20.3	47.8	37.4	49.1	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	0.0	5.0	18.1	43.5	498.5	1
Burneh	12	19.9	21.5	15.4	42.9	32.5	44.1	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.2	0.0	9.4	22.5	48.4	511.1	1
Arosbaya	13	28.8	39.6	33.5	61.1	50.7	62.3	39.0	30.6	25.6	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	0.0	18.2	31.4	30.2	591.2	1
Geger	14	34.3	45.2	39.1	66.7	56.3	67.9	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	0.0	23.8	37.0	35.8	697.2	1
Kokop	15	57.5	68.4	62.3	89.8	79.4	91.0	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	0.0	46.9	60.1	13.2	997.6	1
Tanjungbumi	16	57.4	68.3	62.2	89.2	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	0.0	46.9	60.0	1.6	972.5	1
Sepulu	17	43.6	54.5	48.4	76.0	65.6	77.2	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	0.0	33.1	46.3	15.3	766.6	1
Klampis	18	37.8	48.7	42.6	70.1	59.7	71.3	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	0.0	27.3	40.4	21.2	690.6	1
TPI Banyusangka	19	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
TP Bangkalan	20	13.7	30.8	24.7	52.3	41.9	53.5	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	0.0	0.0	16.4	48.4	567.9	1
FP Kamal	21	2.6	44.0	37.9	65.4	55.0	66.7	43.4	35.0	30.0	9.6	18.1	22.5	31.4	37.0	60.1	60.0	46.3	40.4	0.0	16.4	0.0	61.6	783.3	1
PL Tlagabiru	22	59.0	69.9	63.8	90.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	0.0	48.4	61.6	0.0	1,002.5	1
		733.5	838.3	722.4	1,107.5	910.0	1,110.2	736.5	627.1	587.8	615.2	498.5	511.1	591.2	697.2	997.6	972.5	766.6	690.6	0.0	567.9	783.3	1,002.5	16,067.6	21

3.5. Precentage of Total Shortest Path Length.

The total shortest path distance, either for the existing network and the desired network are gotten from the Expanded Shortest Path Matrix, existing and desired network, for MPV. The shortest path matrices are calculated based on Link Length Matrices by using Min-Plus Algebra matrix power operation. The two expanded matrices are presented in Tabel 11 and Tabel 12 below.

3.6. Calculation Result.

Calculation indicates the following value of Connectivity Quality. In terms of Number of Connected Node, the network performance is 100%. In terms of Total Road Length, the network performance is 74%, a road betterment of 84.55 km is needed to achieve the expected network. In terms of Shortest Path Distance, the existing total shortest path distance is 121% of the expected network one, means there is a difference of 2,871.70 km. Calculation Result is presented in Tabel 13

Tabel 11. Expanded Matrix of Shortest Path Length – Existing Network for MPV Class

mSD22e_CU

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
Kamal	1	0.0	14.6	20.7	40.8	48.5	55.5	36.8	28.4	15.5	7.0	15.5	18.7	28.8	34.3	57.5	57.4	43.6	37.8	52.3	13.7	2.6	59.0	689.1	1
Labang	2	14.6	0.0	6.1	26.2	34.2	41.3	22.5	14.1	11.7	21.6	19.8	14.8	33.0	38.6	61.7	61.6	47.9	42.0	56.5	24.2	12.7	63.2	668.5	1
Kwanyar	3	20.7	6.1	0.0	20.1	28.1	35.2	16.4	8.0	7.9	27.7	20.3	15.4	33.5	39.1	62.3	62.2	48.4	42.6	57.1	24.7	18.8	63.8	658.4	1
Modung	4	40.8	26.2	20.1	0.0	10.4	17.5	17.0	25.4	28.0	47.8	40.4	35.5	53.6	59.2	82.4	82.3	68.5	62.7	77.1	44.8	38.9	83.8	962.4	1
Blega	5	48.5	34.2	28.1	10.4	0.0	7.1	11.6	20.0	32.9	45.5	37.4	32.5	50.7	56.3	79.4	78.8	65.6	59.7	74.2	41.9	46.6	80.4	941.6	1
Konang	6	55.5	41.3	35.2	17.5	7.1	0.0	18.7	27.1	40.0	52.5	44.5	39.6	57.8	63.3	86.5	80.1	72.6	66.8	81.3	49.0	53.6	81.7	1,071.7	1
Galis	7	36.8	22.5	16.4	17.0	11.6	18.7	0.0	8.4	21.3	33.8	25.8	20.9	39.0	44.6	67.8	67.7	53.9	48.1	62.6	30.2	34.9	69.3	751.5	1
Tanah Merah	8	28.4	14.1	8.0	25.4	20.0	27.1	8.4	0.0	12.9	25.4	17.4	12.5	30.6	36.2	59.4	59.3	45.5	39.7	54.1	21.8	26.5	60.8	633.7	1
Tragah	9	15.5	11.7	7.9	28.0	32.9	40.0	21.3	12.9	0.0	20.4	12.4	7.4	25.6	31.2	54.3	54.3	40.5	34.7	49.1	16.8	13.6	56.8	586.5	1
Socah	10	7.0	21.6	27.7	47.8	45.5	52.5	33.8	25.4	20.4	0.0	8.6	12.9	21.8	27.4	50.5	50.4	36.7	30.8	45.3	6.8	9.6	52.0	634.5	1
Bangkalan	11	15.5	19.8	20.3	40.4	37.4	44.5	25.8	17.4	12.4	8.6	0.0	4.9	13.2	18.8	42.0	41.9	28.1	22.3	36.8	5.0	18.1	43.5	516.6	1
Burneh	12	18.7	14.8	15.4	35.5	32.5	39.6	20.9	12.5	7.4	12.9	4.9	0.0	18.2	23.7	46.9	46.8	33.1	27.1	41.7	9.4	16.8	48.4	527.2	1
Arosbaya	13	28.8	33.0	33.5	53.6	50.7	57.8	39.0	30.6	25.6	21.8	13.2	18.2	0.0	5.6	28.7	28.6	14.9	9.0	23.5	18.2	31.4	30.2	596.1	1
Geger	14	34.3	38.6	39.1	59.2	56.3	63.3	44.6	36.2	31.2	27.4	18.8	23.7	5.6	0.0	34.3	34.2	20.5	14.6	29.1	23.8	37.0	35.8	707.7	1
Kokop	15	57.5	61.7	62.3	82.4	79.4	86.5	67.8	59.4	54.3	50.5	42.0	46.9	28.7	34.3	0.0	11.6	13.8	19.7	6.5	46.9	60.1	13.2	985.5	1
Tanjungbumi	16	57.4	61.6	62.2	82.3	78.8	80.1	67.7	59.3	54.3	50.4	41.9	46.8	28.6	34.2	11.6	0.0	13.7	19.6	6.4	46.9	60.0	16.3	965.4	1
Sepulu	17	43.6	47.9	48.4	68.5	65.6	72.6	53.9	45.5	40.5	36.7	28.1	33.1	14.9	20.5	13.8	13.7	0.0	5.8	8.6	33.1	46.3	15.3	756.6	1
Klampis	18	37.8	42.0	42.6	62.7	59.7	66.8	48.1	39.7	34.7	30.8	22.3	27.2	9.0	14.6	19.7	19.6	5.8	0.0	14.5	27.3	40.4	21.2	686.5	1
TPI Banyusangka	19	52.3	56.5	57.1	77.1	74.2	81.3	62.6	54.1	49.1	45.3	36.8	41.7	23.5	29.1	6.5	6.4	8.6	14.5	0.0	41.7	54.9	8.0	881.2	1
TP Bangkalan	20	13.7	24.2	24.7	44.8	41.9	49.0	30.2	21.8	16.8	6.8	5.0	9.4	18.2	23.8	46.9	46.9	33.1	27.3	41.7	0.0	16.4	48.4	591.1	1
PP Kamal	21	2.6	12.7	18.8	38.9	46.6	53.6	34.9	26.5	13.6	9.6	18.1	16.8	31.4	37.0	60.1	60.0	46.3	40.4	54.9	16.4	0.0	61.6	700.9	1
PL Tlagabiru	22	59.0	63.2	63.8	83.8	80.4	81.7	69.3	60.8	55.8	52.0	43.5	48.4	30.2	35.8	13.2	1.6	15.3	21.2	8.0	48.4	61.6	0.0	997.0	1
		689.1	668.5	658.4	962.4	941.6	1,071.7	751.5	633.7	586.5	634.5	516.6	527.2	596.1	707.7	985.5	965.4	756.6	686.5	881.2	591.1	700.9	997.0	16,509.6	22

Tabel 12. Expanded Matrix of Shortest Path Length – Expected Network for MPV

mASD31e_MC

		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
Kamal	1	0	14.6	20.7	40.8	48.5	55.5	36.8	28.4	15.5	6.96	15.5	18.7	28.8	34.3	54.9	57.4	43.6	37.8	52.3	13.7	2.62	59	14	9.29	5.28	64.3	63.5	58.3	45	79.8	70.5
Labang	2	14.6	0	6.1	26.2	34.2	41.3	22.5	14.1	11.7	21.6	19.8	14.8	33	33.2	40.6	51.3	37.5	42	46.2	24.2	12.7	52.9	22.4	19.4	15.4	58.2	49.2	44	30.3	73.7	56.3
Kwanyar	3	20.7	6.1	0	20.1	28.1	35.2	16.4	8.04	7.92	27.7	20.3	15.4	32.6	27.1	34.5	45.2	31.4	37.3	40.1	24.7	18.8	46.8	24.9	25.5	21.5	52.1	43.1	37.9	24.2	67.6	50.2
Modung	4	40.8	26.2	20.1	0	10.4	17.5	17	25.4	28	47.8	40.4	35.5	47.5	42	39.9	40.9	46.3	52.2	46.4	44.8	38.9	42.5	45	45.6	41.6	44.6	25.4	20.2	4.16	60.1	32.5
Blega	5	48.5	34.2	28.1	10.4	0	7.08	11.6	20	32.9	45.5	37.4	32.5	37.1	31.6	29.5	30.5	35.9	41.8	36	41.9	46.6	32.1	49.9	53.2	49.2	34.2	15	9.81	12.5	49.7	22.1
Konang	6	55.5	41.3	35.2	17.5	7.08	0	18.7	27.1	40	52.5	44.2	39.6	30.9	25.4	23.1	24.1	29.7	35.6	29.6	49	53.6	25.7	57	60.3	56.3	27.8	8.68	11.2	19.6	43.3	23.4
Galis	7	36.8	22.5	16.4	17	11.6	18.7	0	8.41	21.3	33.8	25.8	20.9	33	27.4	34.9	42.1	31.8	37.6	40.4	30.2	34.9	43.7	38.3	41.6	37.6	45.8	26.7	21.4	21.2	61.3	33.7
Tanah Merah	8	28.4	14.1	8.04	25.4	20	27.1	8.41	0	12.9	25.4	17.4	12.5	24.6	19	26.4	37.1	23.4	29.2	32	21.8	26.5	38.7	29.9	33.2	29.2	44	35.1	19.9	29.6	59.5	42.1
Tragah	9	15.5	11.7	7.92	28	32.9	40	21.3	12.9	0	20.4	12.4	7.45	25.6	31.2	39.3	50	36.3	34.7	44.9	16.8	13.6	51.6	17	20.3	16.3	56.9	48	42.8	32.2	72.4	55
Socah	10	6.96	21.6	27.7	47.8	45.5	52.5	33.8	25.4	20.4	0	8.55	12.9	21.8	27.4	48.1	50.4	36.7	30.8	45.3	6.78	9.58	52	20.9	16.3	12.2	57.3	60.5	55.3	51.9	72.8	67.5
Bangkalan	11	15.5	19.8	20.3	40.4	37.4	44.2	25.8	17.4	12.4	8.55	0	4.92	13.2	18.8	39.5	41.9	28.1	22.3	36.8	4.97	18.1	43.5	27.3	24.8	20.8	48.8	52.5	47.2	44.5	64.3	59.5
Burneh	12	18.7	14.8	15.4	35.5	32.5	39.6	20.9	12.5	7.45	12.9	4.92	0	18.2	23.7	38.9	46.8	33.1	27.2	41.7	9.37	16.8	48.4	22.4	23.5	19.5	53.7	47.5	42.3	39.6	69.2	54.6
Arosbaya	13	28.8	33	32.6	47.5	37.1	30.9	33	24.6	25.6	21.8	13.2	18.2	0	5.58	26.3	28.6	14.9	9.04	23.5	18.2	31.4	30.2	40.6	38.1	34	35.5	39.6	42.1	49.7	51	54.4
Geger	14	34.3	33.2	27.1	42	31.6	25.4	27.4	19	31.2	27.4	18.8	23.7	5.58	0	20.7	31.4	17.7	14.6	26.3	23.8	37	33	46.2	43.6	39.6	38.3	34	36.5	44.1	53.8	48.8
Kokop	15	54.9	40.6	34.5	39.9	29.5	23.1	34.9	26.4	39.3	48.1	39.5	38.9	26.3	20.7	0	11.6	11.9	17.8	6.49	44.5	53	13.2	56.3	59.6	55.6	18.5	25.8	29	42	34	41.3
Tanjungbumi	16	57.4	51.3	45.2	40.9	30.5	24.1	42.1	37.1	50	50.4	41.9	46.8	28.6	31.4	11.6	0	13.7	19.6	6.4	46.9	60	1.58	67	66.7	62.7	6.9	26	30	43	22.4	42.3
Sepulu	17	43.6	37.5	31.4	46.3	35.9	29.7	31.8	23.4	36.3	36.7	28.1	33.1	14.9	17.7	11.9	13.7	0	5.85	8.63	33.1	46.3	15.3	53.3	52.9	48.9	20.6	37.7	40.9	48.5	36.2	53.2
Klampis	18	37.8	42	37.3	52.2	41.8	35.6	37.6	29.2	34.7	30.8	22.3	27.2	9.04	14.6	17.8	19.6	5.85	0	14.5	27.3	40.4	21.2	49.6	47.1	43.1	26.5	43.5	46.7	54.3	42	59
TPI Banyusangka	19	52.3	46.2	40.1	46.4	36	29.6	40.4	32	44.9	45.3	36.8	41.7	23.5	26.3	6.49	6.4	8.63	14.5	0	41.7	54.9	7.98	61.9	61.6	57.6	13.3	32.3	35.5	48.5	28.8	47.8
TP Bangkalan	20	13.7	24.2	24.7	44.8	41.9	49	30.2	21.8	16.8	6.78	4.97	9.37	18.2	23.8	44.5	46.9	33.1	27.3	41.7	0	16.4	48.4	27.7	23	19	53.8	56.9	51.7	49	69.3	64
PP Kamal	21	2.62	12.7	18.8	38.9	46.6	53.6	34.9	26.5	13.6	9.58	18.1	16.8	31.4	37	53	60	46.3	40.4	54.9	16.4	0	61.6	11.4	6.88	2.66	66.9	61.6	56.4	43.1	82.4	68.6
PL Tlagabiru	22	59	52.9	46.8	42.5	32.1	25.7	43.7	38.7	51.6	52	43.5	48.4	30.2	33	13.2	1.58	15.3	21.2	7.98	48.4	61.6	0	68.6	68.3	64.3	8.48	27.6	31.6	44.6	24	43.9
Sub Suramadu	23	14	22.4	24.9	45	49.9	57	38.3	29.9	17	20.9	27.3	22.4	40.6	46.2	56.3	67	53.3	49.6	61.9	27.7	11.4	68.6	0	4.69	8.71	73.9	65	59.7	49.2	89.4	72
Sub Perak	24	9.29	19.4	25.5	45.6	53.2	60.3	41.6	33.2	20.3	16.3	24.8	23.5	38.1	43.6	59.6	66.7	52.9	47.1	61.6	23	6.68	68.3	4.69	0	4.01	73.6	68.3	63.1	49.8	89.1	75.3
PP Ujung	25	5.28	15.4	21.5	41.6	49.2	56.3	37.6	29.2	16.3	12.2	20.8	19.5	34	39.6	55.6	62.7	48.9	43.1	57.6	19	2.66	64.3	8.71	4.01	0	69.6	64.3	59	45.7	85.1	71.3
Banyuates	26	64.3	58.2	52.1	44.6	34.2	27.8	45.8	44	56.9	57.3	48.8	53.7	35.5	38.3	18.5	6.9	20.6	26.5	13.3	53.8	66.9	8.48	73.9	73.6	69.6	0	19.1	25.7	46.7	15.5	38
Tembelangan	27	63.5	49.2	43.1	25.4	15	8.68	26.7	35.1	48	60.5	52.5	47.5	39.6	34	25.8	26	37.7	43.5	32.3	56.9	61.6	27.6	65	68.3	64.3	19.1	0	6.58	27.6	34.6	18.8
Jrengik	28	58.3	44	37.9	20.2	9.81	11.2	21.4	29.9	42.8	55.3	47.2	42.3	42.1	36.5	29	30	40.9	46.7	35.5	51.7	56.4	31.6	59.7	63.1	59	25.7	6.58	0	22.4	41.2	12.3
Sreseh	29	45	30.3	24.2	4.16	12.5	19.6	21.2	29.6	32.2	51.9	44.5	39.6	49.7	44.1	42	43	48.5	54.3	48.5	49	43.1	44.6	49.2	49.8	45.7	46.7	27.6	22.4	0	62.2	34.6
Ketapang	30	79.8	73.7	67.6	60.1	49.7	43.3	61.3	59.5	72.4	72.8	64.3	69.2	51	53.8	34	22.4	36.2	42	28.8	69.3	82.4	24	89.4	89.1	85.1	15.5	34.6	41.2	62.2	0	34.3
Sampang	31	70.5	56.3	50.2	32.5	22.1	23.4	33.7	42.1	55	67.5	59.5	54.6	54.4	48.8	41.3	42.3	53.2	59	47.8	64	68.6	43.9	72	75.3	71.3	38	18.8	12.3	34.6	34.3	0

Tabel 13 Calculation Result.

	Connected Node	Total Road Length	Total Shortest Path
	node	*km*	*km*
Existing Network	22	242.67	16,509.58
Expected Network	22	326.82	13,637.87
Difference	0	-84.55	2,871.70
Pourcentage	100%	74%	121%

Furthermore, it can be imagined that this Network Quality Measurement can be used in Road Management Program. This method can be used easily to analyze a road network development program: to test the development impact of different scenarios, to measure the network performance, to measure the traffic flow performance, to measure the cost benefit analysis of different scenarios, to develop prioritization scheme, etc. Apart from

these analyses, this method can also be used to developed risk analysis of different possible risk scenarios.

Connectivity Quality must be measured against an Expected Condition. This has three quality measures, i.e. : the percentage of connected nodes, the percentage of the total road length and the ratio of total shortest path .

4. CONCLUSIONS.

It can be concluded that the research objective has been attained. The connectivity quality is already formulated and it is proven to be very important and useful.

The Connectivity Quality is defined as how well the nodes are connected each other. These all are comparison of certain properties values between those of the Existing Network compared to those of the Expected Network. A Special Matrix Method is needed to execute the whole calculation.

The Method to Analyze the Network Quality of a Sparse Road Network can be used to handle the road management program: calculating the improvement of network quality, to plan the needed program, to calculate the prioritization and the risk analysis.

References

Hitapriya Suprayitno. "Traffic Flow Quality as Part of Network Quality of A Sparse Road Network". *Procedia Engineering 125, page 564-570*. Elsevier. Amsterdam. 2015.

Hitapriya Suprayitno. "Development of A Special Matrix Technique for Road Network Analysis - Case of Identifying Unconnected and Miss-connected Nodes". *The 18th FSTPT International Simposium, Bandar Lampung 28 August 2015*. University of Lampung. 2015.

Hitapriya Suprayitno. Metoda Penilaian Kualitas Jaringan Jalan Utama – di Wilayah Kabupaten. *Disertasi RC 09-3399*. Civil Engineering Department. Faculty of Civil Engineering and Planning. Institute Technology Sepuluh November. Surabaya. 2014

H. Suprayitno, I.B. Mochtar & A. Wicaksono. "A Special Matrix Power Operation Development for Simultaneous Calculation of All Network's Shortest Path". *JATIT, 10 April 2014, Vol 62 no 1 2014.* Journal of Applied and Theoritical Information Technology. 2014.

H. Suprayitno, I.B. Mochtar & A. Wicaksono. "Assessment to A Max-Plus Algebra Power Operation on UnWeighted Transportation Network Model of Its Behavior, Connotation, and Utilization". *Prosiding Seminar Nasional X, Surabaya, 30 Januari 2014.* Jurusan Teknik Sipil. Institut Teknologi SepuluhNopember. 2014.

R. Munir. *Matematika Diskrit*. Edisi Kelima. Penerbit Informatika. Bandung. 2012.

Hitapriya Suprayitno. "Road Network Quality Components, Case of Rural Road Network with Low Traffics". *APTE 2010 - 7th Asia Pacific Conference on Transportation and the Environment - Semarang 12 June 2010*. Faculty of Engineering, Diponegoro University. Semarang. 2010.

H. Suprayitno. "Identifikasi Graf Pohon Berbasis Aljabar Maks-Plus – Pada Graf Tak Berarah Tak Berbobot"; *Seminar Nasional Teknik Sipil VI, 27 Januari 2010*; Jurusan Teknik Sipil, Intitut Teknologi Sepuluh Nopember (ITS); Surabaya. 2010.

A.S. Ridwan. "Petunjuk Survai Kinerja Transportasi di 33 Propinsi di Indonesia". *Studi Kinerja Sistem Transportasi di 33 Propinsi Indonesia*. Badan Penelitian dan Pengembangan, Departemen Perhubungan. Jakarta. 2008.

O. Z. Tamin. *Perencanaan, Pemodelan dan Rekayasa Transportasi : Teori, Contoh Soal dan Aplikasi*. Penerbit ITB. Bandung. 2008.

Hitapriya Suprayitno. "Penggunaan Konsep Konektivitas Teori Graf sebagai Pijakan bagi Upaya Penyusunan Metoda Penilaian Kualitas Jaringan Jalan Primer". *Seminar Nasional Teknologi Infrastruktur Perkotaan, Surabaya 12 Juli 2008*. Program Studi Diploma Teknik Sipil. Institut Teknologi Sepuluh Nopember (ITS). Surabaya. 2008.

J.C. Binning & M.R. Crabtree . *Transyt 11 User Guide*. TRL Software Bureau. Crowthorne. 2002.

A. Arifin. *Aljabar Linier*. Edisi Kedua. Penerbit ITB, Bandung. 2001

A.W. Goldberg,. "Basic Shortest Path Algorithms". *DIKU Summer School on Shortest Paths*. Microsoft Research. Silicon Valey. 2000.

INRO . *EMME/2 User's Manual – Software Release 9*. INRO Consultant Inc. Montreal. 1999.

J.E. Taaffe, H.L. Gauthier & M.E. O'Kelly . *Geography of Transportation*. Second Edition. Prentice Hall. New Jersey. 1996.

C. Daganzo. "The Cell Transmision Model : Network Traffic". *Working Papers*. Institute of Transportation Studies, University of California. Berkeley. 1994.

J.D. Ortuzar & L.G.Willumsen. *Modelling Transport*. Second Edition. John Wiley & Sons. New York. 1994.

F. Baccelli, G. Cohen, G.J. Olsder & J-P Quadrat. *Synchronization and Linearity – An Algebra for Discrete Event Systems*. John Wiley & Son. New York. 1992.

T.A. Hamdy. *Operation Research – An Introduction*. Fifth Edition. Maxwell Macmillan International. New York. 1992.

F.S. Hillier & G.J. Lieberman. *Introduction to Operation Research*. Fifth Edition, Holden-Day Inc.. San Francisco. 1990.

J.A. Bondy & U.S.R. Murty. *Graph Theory with Applications*. Fifth Printing. North-Holland. New York. 1982.

John Black. *Urban Transport Planning : Theory and Practice*. Cromm Helm. London. 1981.

T. Brand & A. Sherlock. *Matrices : Pure and Applied*. Contemporary Mathematics Series. Edward Arnold. London. 1970.

Anonim. La plus grande portee (856m) de travee centrale d'un pont a haubans. *Travaux no 672, janvier 1992*. Paris. 1992.

K. Yoshinaga, Y. Kishimoto & S. Ohe. Socio-economic impact of the Honshu-Shikoku bridges. *Proceeding of the 4th Symposium : Strait Crossing 2001, Bergen Norway, 2-5 September 2001*. A.A. Balkeman Publishers. Lisse. 2001.