TRIP ASSIGNMENT MODEL WITH CONSIDERATION OF VEHICLE EMISSION: CASE FOR CIMAHI CITY

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ABSTRACT

Many cities in Indonesia are facing problems related to traffic and transportation such as Cimahi city which is located in the west part of West Java, Bandung. Traffic growth in Cimahi is caused by industrialisation and urbanisation which represent the main factor of increasing population and travel demand in Cimahi. The Local Government of Cimahi has started to avoid congestion by improving infrastructure facilities or other traffic management. Traffic assignment in four-step modelling is carried out as a basic to simulate the traffic management system. Traffic congestion generally happens especially in peak periods caused by the increasing number of private cars. Based on the reasons, the study only considers private car as a mode of transportation that will be assigned in peak hour periods. The technique of assignment used is user equilibrium and traffic assignment is run by using generalized cost. Generalized cost is calculated by actual cost and perceived cost (emission cost). CUBE software has been employed for this research to analyze traffic performance. CUBE software applies existing condition (base) and four scenarios. After modeling scenarios, those are acquired that scenario 4 as the best alternative for congested reduction in Cimahi. Indeed, Scenario 4 is recommended because significant result of v/c ratio value reduction and reducing number of congestion links by considering emission cost.

Keywords: traffic assignment, private car, peak hour, emission.

INTRODUCTION

Transportation in developing countries has important roles due to its contribution to national and regional economic, industrial, social, and cultural development (Sheffi, 1985; Meyer and Miller, 2001). However, the developing countries are facing problems related to transportation. Managing different aspects of transportation is a difficult task especially in a densely populated country such as Indonesia. Transportation problems are caused by the increasing number of private cars and motorcycles and inadequate transportation facilities.

Nowadays, one of the developing cities in Indonesia that starts to face the congestion problem is Cimahi city which is located in the west of Bandung city, Indonesia. It consists of three districts (middle, center and south) and 15 sub-districts are covered by those three districts. Figure 1 shows the Cimahi-Bandung city location.

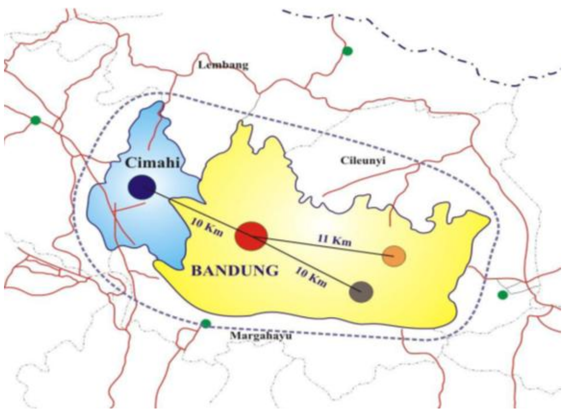


Figure 1. Location of Cimahi – Bandung City

As a matter of fact, Bandung city is one of the metropolitan cities that is very famous as an industrial city. Cimahi city, which is located nearby Bandung city, presents a continuous building up area between them. It means that Cimahi has important roles for supporting industries in the development of Bandung. It will improve the economic growth in Cimahi in which the gross regional domestic product from the industrial sector is an indication of the economic macro development of Cimahi. In 2007, industry sector (69%) contributes to the biggest portion of the gross regional domestic product (GRDP) portion of Cimahi.

Consequently, population will be increasing because many employees who work in Bandung live in Cimahi. Density is also multiplied by the presence of military personnel and people who seek jobs in Cimahi.

The existence of Baros toll-road, railway in Bandung, and Padalarang road, can be accessed by travelers from one city to another city through Cimahi city. It will increase the traffic volume in Cimahi road network. According to the Statistical department, the existence of Baros toll-road and railway increases the number of traffic flow around 21.2% per year and 25.2% per year. Indeed, the negative impact of their existence is traffic growth which can influence the road condition because of over loading. According to the Ministry of Public Works, 52.36% Cimahi road is in poor condition, which impact on degradation of road service and eventually will increase traffic congestion.

Before this problem becomes a big problem, the Cimahi government should be more concerned about the traffic growth. Traffic management strategies are needed as the solution of the problem, which should be implemented to improve the quality of life, economic efficiency, and the environment (Zito, 2005; Yin, 2006).

The traffic congestion problem has become severe in road network and will be worsened in the near future. To minimize the problems, the study is going to simulate traffic management strategies to analyze urban transportation and its environmental impacts. Traffic assignment, which is a step in four steps modeling, is used to model the travel demand (Ortuzar and Willumsen, 1994; Thomas, 1991; Mcshane and Roess, 1990). Indeed, traffic assignment models have been used to provide estimate of traffic flows on strategic highway systems. These scenarios include an integration of socio-economic, environmental and demonstration of simulation tools to improve the scenario design, assessment and policy level decision support such as CUBE (Citilabs, 2005).

RESEARCH METHODOLOGY

The methodology of this research is carried out by four tasks including the preparation, data collection, process and analyses data, and final phase. Figure 2 shows the entire phases of the research.

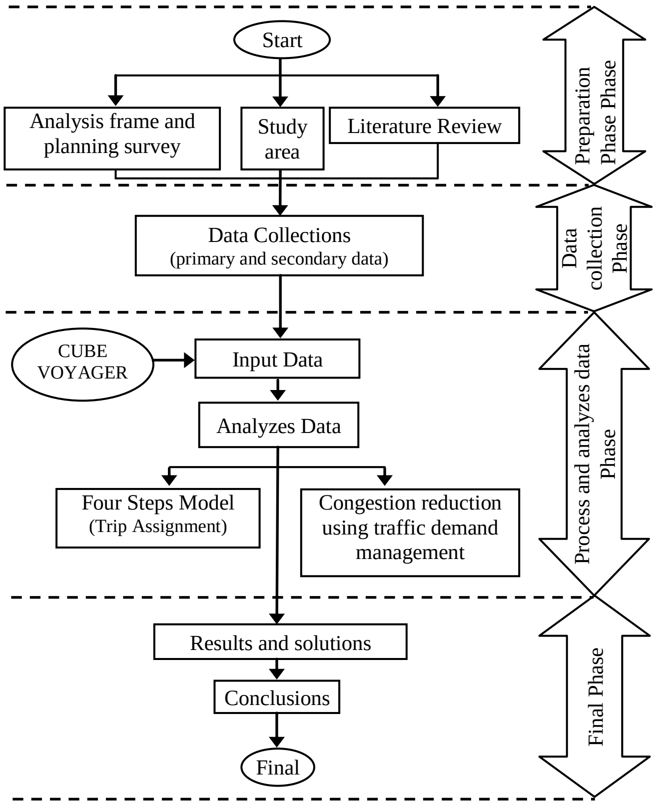


Figure 2. Research methodology

The data collection is obtained from primary data and secondary data. Primary data related to performance of road network was directly collected in the area by using the survey methods, as following:

a. Home interview survey is carried out to obtain the origin and destination data. The data observed are about travel pattern of the resident of household such as the origin and destination zone, the trip purposes, travel modes and so on. The total samples collected in Cimahi zones are 450 samples.

b. Roadside interview is done by directly interviewing the driver of the vehicle at selected location.
c. Traffic counting is a survey to count the traffic at certain point. The counting is needed for calibrating and validating the model.

Secondary data related to institutional survey such as socioeconomic data in which the data are used to divide the zone and to select the roads as representation of the network.

ANALYSIS

A. Data Collection

The network created from the collected data consists of arterial road, collector road and toll road. Figure 3 presents this network in Cimahi area by using Mapinfo software. Map info outputs are coordinate of the link and node, length of link, and number of links and nodes. CUBE program uses base location and distance of the links is based on coordinate which represented by the Mapinfo.

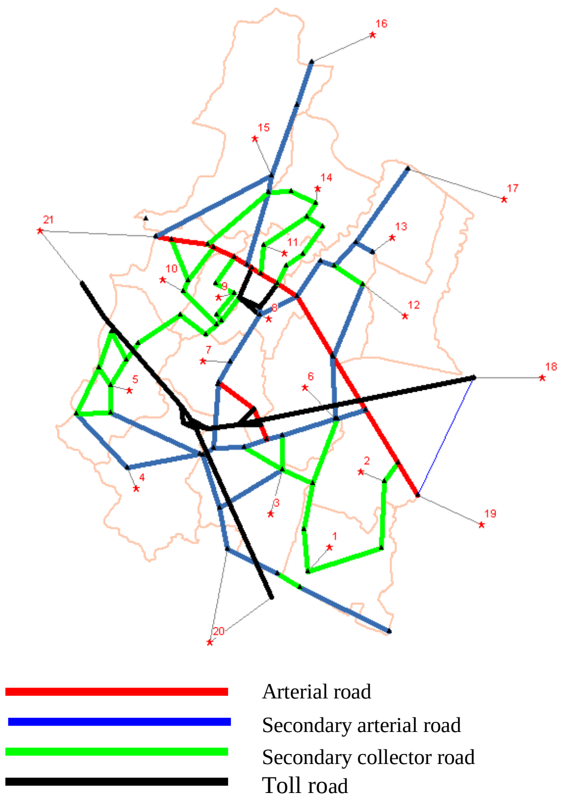


Figure 3. Road network of Cimahi

There are 21 zones consist of fifteen internal zones and another is external zones. External zones are areas outside the study area that influence travel pattern in Cimahi. The external and internal zones are presented at Table 1.

The result of home interview survey is shown in Table 2. RSI (roadside interview) illustrates in Table 3 and the result of traffic counting can be seen in Table 4.

Table 1. External and internal zones

No	Zones	Internal/External
1	Padasuka	Internal
2	Leuwigajah	Internal
3	Melong	Internal
4	Cibabat	Internal
5	Cigugur Tengah	Internal
6	Pasir Kaliki	Internal
7	Citeureup	Internal
8	Cipageran	Internal
9	Karang Mekar	Internal
10	Cimahi	Internal
11	Setiamanah	Internal
12	Cibeber	Internal
13	Baros	Internal
14	Utama	Internal
15	Cibereum	Internal
16	North Bandung (Lembang,Subang)	External
17	North Bandung (Geger kalong, Dago)	External
18	Middle Bandung (Merdeka, Braga)	External
19	South Bandung (Buah Batu, Ling Selatan)	External
20	South Bandung (Soreeang, Banjaran)	External
21	West Bandung (Padalarang, Purwakarta)	External

Table 2. Home interview survey matrix

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	6	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	1
2	0	8	1	1	0	0	0	0	1	0	1	2	1	2	3	0	0	0	0	0	0
3	0	4	0	2	1	0	1	0	0	0	2	1	2	0	2	0	1	0	0	0	1
4	1	1	0	14	2	1	3	4	1	3	0	2	0	0	1	0	6	8	0	0	2
5	0	0	0	2	0	5	1	0	0	0	0	0	4	0	1	0	2	0	0	0	1
6	0	0	0	1	6	52	0	0	0	0	0	0	0	0	0	0	1	3	0	0	4
7	0	0	7	3	1	0	28	0	3	1	2	0	1	0	0	0	1	1	6	0	0
8	0	0	0	2	0	0	0	2	12	0	2	0	5	0	0	0	1	3	0	1	0
9	0	1	0	1	0	0	1	11	0	4	0	0	0	0	2	0	2	5	3	0	0
10	0	0	0	3	0	0	1	0	4	16	0	1	0	0	0	0	1	0	0	0	0
11	0	1	0	0	0	0	2	2	0	0	0	0	4	0	1	0	0	0	0	0	0
12	0	2	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
13	0	3	0	0	3	0	1	6	0	1	8	0	0	1	2	0	1	0	0	0	0
14	0	1	0	0	0	0	0	0	0	1	0	0	3	0	0	0	1	0	1	0	0
15	0	2	2	1	1	0	0	0	2	0	1	0	2	0	2	0	1	3	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	5	2	2	1	1	2	1	1	0	1	1	1	0	0	0	0	0	0
18	1	0	0	9	0	3	1	3	5	0	0	0	0	0	3	0	0	0	0	0	0
19	0	0	0	0	0	0	1	0	3	0	0	0	0	2	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	2	1	4	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0

Table 3. The matrix of roadside interview survey

Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	1	0	1
2	0	1	0	3	1	1	1	1	0	5	0	0	2	1	0	3	2	0	2	30	1
3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	3	3	3	1	1
4	0	2	0	1	15	0	0	0	0	1	0	0	1	0	10	1	27	16	17	23	4
5	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	4	2	9	4	5
6	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	2	0	0	0	0	1	0	0	0	0	1	1	6	8	2	4	0
8	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	0	6	4	2	1	0
9	0	0	0	0	5	0	0	0	0	0	0	0	0	0	1	0	1	2	2	11	0
10	0	1	0	1	2	0	0	1	0	0	0	0	0	0	5	2	21	21	9	132	1
11	0	0	0	1	1	0	0	0	0	2	0	0	0	0	2	0	5	1	2	6	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	0
13	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	3	1	2	25	1
14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	3	0	0
15	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
16	0	1	1	3	0	0	0	1	1	5	0	0	0	0	4	0	1	1	1	0	0
17	0	1	3	9	0	0	4	4	1	25	2	0	1	0	4	1	9	7	14	148	10
18	0	1	1	20	0	2	2	2	0	32	0	0	0	0	1	1	1	0	2	1	10
19	1	3	1	6	0	1	1	5	1	18	0	0	0	0	0	1	4	2	0	12	10
20	4	26	0	21	0	2	4	6	7	71	0	6	22	16	20	21	83	19	14	74	42
21	0	3	0	3	0	0	2	2	3	6	1	0	1	1	12	1	26	22	10	43	7

Table 4. Traffic counting data

Location	Time	Motorcycle	Passenger Car	Truck	Un-motorized	Total
Leuwigajah-Simpang Leuwigajah	06.00 – 18.00	11,498	3,183	1,385	291	16,357
Leuwigajah-Simpang Najung	06.00 – 18.00	10,730	3,273	1,523	301	15,827
Jl Dustira-Cimahi	06.00 – 18.00	6,680	5,067	405	102	12,254
Cimahi-Jl Dustira	06.00 – 18.00	16,901	11,440	1,295	147	29,783
Ciwaruga-Cirabat	06.00 – 18.00	5,367	1,843	191	42	7,443
Cirabat-Ciwaruga	06.00 – 18.00	5,744	1,812	194	26	7,776
Jl Sriwijaya-Jl Gandawijaya	06.00 – 18.00	14,867	7,900	608	325	23,700
Jl Gandawijaya-Jl Sriwijaya	06.00 – 18.00	4,823	5,516	94	243	10,676
Jl Gandawijaya-Jl Ry Cimahi	06.00 – 18.00	20,154	6,613	1,480	288	28,535
Jl Kol Maturi-Lembang	06.00 – 18.00	10,151	2,808	297	126	13,382
Jl Kol Maturi-Jl Ry Barat	06.00 – 18.00	10,820	3,608	240	137	14,265
Cimindi- Leuwigajah	06.00 – 18.00	12,231	2,258	262	461	15,212
Leuwigajah-Cimindi	06.00 – 18.00	21,168	5,353	254	530	27,235
Soreang-Nanjung	06.00 – 18.00	8,197	2,358	643	168	11,366
Nanjung- Soreang	06.00 – 18.00	6,786	2,072	1,008	261	10,127
Jl Ry Cimahi-Jl Ry Barat	06.00 – 18.00	27,383	8,328	1,022	410	37,143
Jl Ry Cimahi-Cibeureum	06.00 – 18.00	22,432	8,495	1,141	435	32,503
Cimindi-Bandung	06.00 – 18.00	67,760	9,496	1,473	488	79,217
Bandung-Cimindi	06.00 – 18.00	45,243	9,045	935	344	55,567
Jl Ry barat-Padalarang	06.00 – 18.00	16,596	5,850	2,332	61	24,839
Padalarang-Jl Ry barat	06.00 – 18.00	17,289	6,285	2,046	47	25,667

Table 5. OD matrix

Origin Zone	Destination Zone																					Oi
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1	0	219	73	329	1	219	183	256	73	329	73	1	146	1	621	1	475	475	475	1	438	4,385
2	230	0	575	1,725	2,146	383	728	268	422	1,878	958	1,763	2,018	1,571	1,763	690	1,495	1,035	1,610	8,623	460	30,429
3	332	1,803	0	1,660	949	1	332	806	949	1,471	1,139	569	509	569	2230	1	569	759	332	1,423	237	16,701
4	360	1,240	320	0	1,360	920	2,041	1,520	680	1,480	400	640	360	80	3,641	1	4,161	3,521	1,080	1,080	1,040	25,929
5	1	1,104	85	1,528	0	1,995	457	170	170	170	1	1	3,396	170	1,231	1	849	255	1,783	425	849	14,650
6	99	1	1	347	893	0	1	1	1	33	33	1	1	33	1	1	182	612	33	1	446	2,721
7	1	66	232	894	298	1	0	2,451	3,280	431	431	99	298	99	166	1	2,021	1,557	1,060	166	1	13,553
8	218	73	436	945	73	145	1	0	2,982	1,091	727	73	1,055	73	109	1	545	1,309	982	727	73	11,638
9	26	145	290	251	53	1	567	1,042	0	501	396	79	26	40	369	1	554	422	290	132	1	5,168
10	24	144	96	347	72	24	108	192	335	0	24	275	24	156	335	120	958	659	156	994	240	5,281
11	44	588	174	392	1	87	262	392	850	87	0	131	1,220	479	349	218	174	174	44	44	65	5,776
12	1	67	1	32	1	1	11	9	8	25	8	0	21	5	13	1	1	11	3	1	4	224
13	86	1,272	1	194	1,681	1	151	1,207	1	151	1,681	216	0	453	711	86	409	172	345	323	1	9,142
14	1	996	310	44	133	44	133	1	266	111	531	89	1,041	0	465	1	266	22	199	111	44	4,807
15	171	1,450	1,791	2,004	1,327	1	426	171	1,279	4,690	469	426	1,109	1,535	0	426	1,706	1,279	426	426	1,066	22,089
16	1	459	459	1	918	1	1	1	1	918	1	1	184	1	505	0	918	92	92	1,148	1	5,702
17	17	135	17	332	56	90	52	28	180	590	214	1	141	67	287	225	0	67	180	630	281	3,600
18	153	192	383	1,591	614	518	134	479	614	11,600	345	58	115	134	575	1	1	0	38	1	959	18,506
19	108	269	1	106	808	1	269	1,078	916	1,778	1	1	323	539	216	1	269	108	0	1,617	1,617	10,028
20	17	116	232	156	183	1	66	33	100	1,769	166	33	398	33	498	199	797	372	106	0	700	5,976
21	163	408	815	421	204	299	136	231	136	4,348	177	41	136	27	910	621	951	707	95	639	0	11,456
Dj	2,053	10,746	6,293	13,302	11,680	4,734	6,078	10,337	13,241	33,452	7,774	4,498	12,671	6,066	14,995	2588	17,301	13,607	9,329	18,510	8,524	

B. Data Analysis

1. Origin-Destination Matrix

An origin-destination (OD) matrix, which contained the number of trips from any zone i to zone j, was obtained by home interview survey and road side interview summarized in Table 5. It can be seen that Leuwigajah sub-district (zone 2) provides the highest total production due to the high number of population and number of vehicle. On the other hand, the highest total attraction in zone 20 is in south Bandung regency (Soreang and Banjaran).

2. Modeling Transportation

Trip generation

The factor effecting of production-attraction is named independent variable (X). There are 17 identified of independent variables of production-attraction. The results of analysis regression are demonstrated in Figure 4 and Figure 5, while the equation of trip production and attraction are shown in Equation (1) and (2).

$$Y = -2047.05+1.5X_3-5.672X_{14}+3.209X_{17} \qquad (1)$$

where Y is the trip production (trips/day),
X_3 is zonal households,
X_{14} is number of private cars per zone,
X_{17} is number of motorcycles per zone.

$$Y = -109.209+612.82\ X_7+62.16\ X_9-2.04\ X_{15} \qquad (2)$$

where Y is the trip attraction (trip/day), X_7 is number of schools per zone, X_9 is number of small industries per zone, X_{15} is total dwelling unit per zone.

Trip Distribution

In this study, the production and attractions for each zone are predicted by trip generation model in order to predict the flow of trips Oi and Dj from each production zone i to each attraction zones j. Thus, productions-attractions model are provided to distribute the zonal trip end.

Entropy maximum is one of the distribution models which is used for balancing matrix. The iteration stops when the correction are small enough or the constraints are met within reasonable tolerances such as FO, FD, and Fd value is equal 1 or within in interval $0.95 \leq$ FO, FD, Fd ≤ 1.05. This research can reach a balanced condition by having 21 iterations. Table 6 and Table 7 illustrate when the iteration have arisen the constraint or reasonable tolerances.

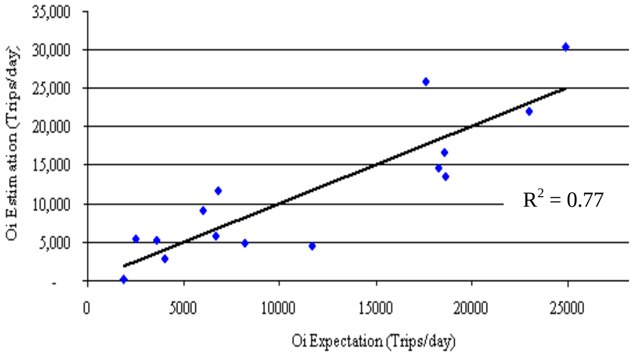


Figure 4. Trip production regressions

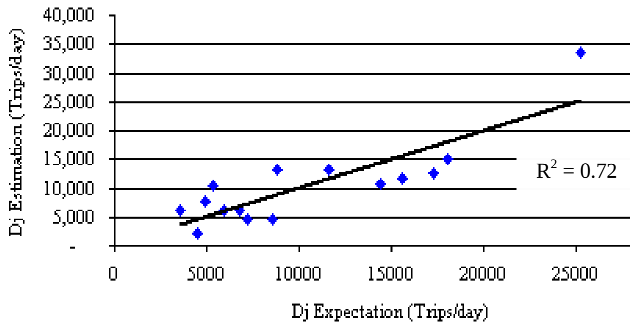


Figure 5. Trip attraction regressions

Table 6. The last iteration (FO=1 and FD =1)

Origin	Destination Zones																					Oi	Oi'	FOi
Zones	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21			
1		910	219	645	3	786	287	107	94	297	77	3	284	2	1,218	5	857	2,429	2,331	1	1,065	11,727	11,730	1.00
2	428	-	581	1,142	2,024	464	386	142	371	573	342	3,090	2,813	1,561	377	1,371	1,074	1,786	2,665	2,359	384	24,928	24,931	1.00
3	862	3,522	-	997	2,048	1	160	479	940	505	929	1,122	8,854	636	1,958	2	460	1,826	767	353	223	18,624	18,645	1.00
4	737	1,911	231	-	5	987	774	713	531	401	127	489	209	70	2,522	2	2,651	3,282	966	262	770	17,630	17,641	1.00
5	2	1,435	135	1,266	-	3,806	315	142	236	166	1	1	3,511	266	1,516	3	961	422	2,835	90	1,117	18,299	18,296	1.00
6	211	2	1	212	1,581	-	0	0	1	19	22	2	1	62	1	2	245	1,207	63	-	344	373	33,976	1.00
7	3	144	236	595	575	1	-	1,616	2,904	333	390	217	496	251	328	2	3,684	4,153	2,714	56	1	18,690	18,701	1.00
8	181	92	322	457	102	104	0	-	1,546	399	311	93	496	107	127	1	582	1,005	723	71	90	6,001	5,808	1.00
9	24	205	238	136	82	1	197	361	-	204	188	113	29	65	477	2	658	360	238	14	1	3,588	3,590	1.00
10	14	65	25	59	72	15	30	43	125	-	7	254	17	165	280	255	362	364	83	70	172	2,478	2,478	1.00
11	54	553	51	140	2	116	153	184	664	48	-	252	1,446	860	492	970	281	202	48	6	122	6,648	6,646	1.00
12	15	398	3	137	12	16	74	65	93	27	76	-	302	70	137	22	19	147	35	2	44	1,901	1,876	1.00
13	77	453	-	49	1,243	1	63	4	1	73	771	239	-	717	896	134	379	289	555	34	1	6,000	5,971	1.00
14	2	1,528	277	26	225	5	127	6	420	123	559	279	2,495	-	1,071	7	563	35	306	23	135	6,204	8,211	1.00
15	233	2	1,263	925	1,655	2	321	128	1,599	4,134	390	1,061	2,100	266	-	2,448	1,739	1,617	517	69	2,570	23,026	23,037	1.00
16	2	687	400	1	1,793	1	1	1	1	1,180	2	4	249	4	1,662	-	1,157	169	162	271	2	7,743	7,748	1.00
17	30	180	13	168	83	170	51	23	247	2	242	3	236	104	349	590	-	111	2,283	132	366	3,379	33,380	1.00
18	961	904	1,305	1,741	1,946	2,107	239	419	893	11,907	414	167	516	380	1,280	6	2	-	214	1	2,280	27,673	27,681	1.00
19	571	1,074	3	100	2,169	3	406	797	1,128	1,544	1	2	1,228	1,290	406	5	467	529	-	1,258	3,252	16,229	16,234	1.00
20	37	239	224	122	204	1	42	100	51	639	70	34	309	33	390	397	574	942	258	-	586	5,161	5,164	1.00
21	242	455	625	211	296	274	55	188	184	3,357	198	54	280	85	2,231	1,874	1,053	970	125	112	-	1,285	12,868	1
Dj	4,530	14,373	5,952	8,846	15,587	8,564	3,557	5,334	11,630	25,247	4,947	7,228	17,275	6,764	18,088	7,828	17,176	21,119	15,362	5,011	13,095			
Dj'	4,635	14,809	6,153	9,149	16,122	8,862	3,679	5,518	12,028	26,112	5,116	7,479	17,871	6,995	10,709	8,098	17,766	21,844	15,888	5,185	13,544			
FDj	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97			

Table 7. The last iteration (Fd = 1)

Interval	%	Fij	Fij'	Fd
0 - 3	16	39,487	38,199	1.03
3 - 6	40	98,102	94,797	1.03
6 - 9	35	86,379	83,526	1.03
>9	9	21,595	20,879	1.03

Trip Assignment

Network is a utility program for processing highway networks. Figure 6 shows the output of the network.

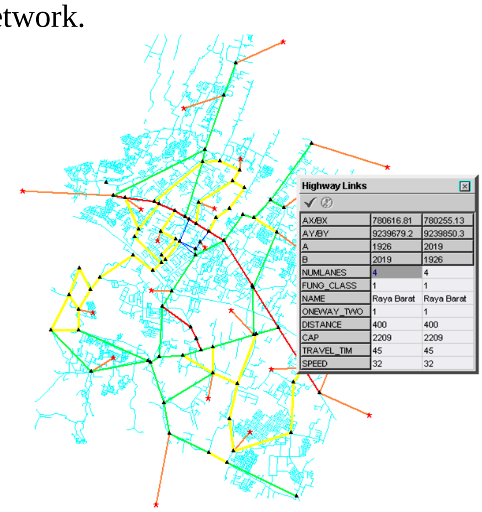


Figure 6. The network result

In this research, the script assignment for building paths using generalized cost relate to the control words that are available in the highway module. Those control worlds are as following:

a. Definition statements contain FILEI and FILEO. The FILEI has network and matrix and FILEO contain result of the assignment.
b. Computational Statements consists of:
   - Linkread Phase = LW.CAR_Path = COST. COST value represents generalized cost which include actual cost and emission cost.
   - The PHASE=ILOOP statement which contains Function and Pathload. FUNCTION set V=VOL (1). PATHLOAD PATH=COST with a specified volume is VOL (1) Mi.1.1.
   - ADJUST phase follows the ILOOP Phase. The goal of ADJUST Phase performs equilibrium assignment which is accumulation of trips on link volumes.

Meanwhile, Figure 7 illustrates that peak hour occurs at 7.00 a.m- 8.00 a.m. The percentage time of day depends on the type of road function. Based on the traffic counting data and location of traffic counting, AM percentage on arterial road (9%) and collector road (10.5%).

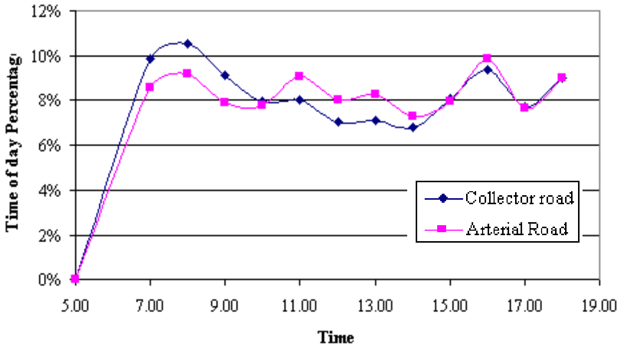


Figure 7. Percentage time of day

Figure 8 shows the output of the base condition after calibration and validation by CUBE program. The results identify congested links on arterial road and collector road. Some congested links on arterial road is caused by through traffic from Bandung City to Padalarang City. On the other hand, some congested links on collector road is caused by low capacity. Table 8 presents the congested links. Solution to congested links is by implementing a traffic management scheme such as improvement of facilities.

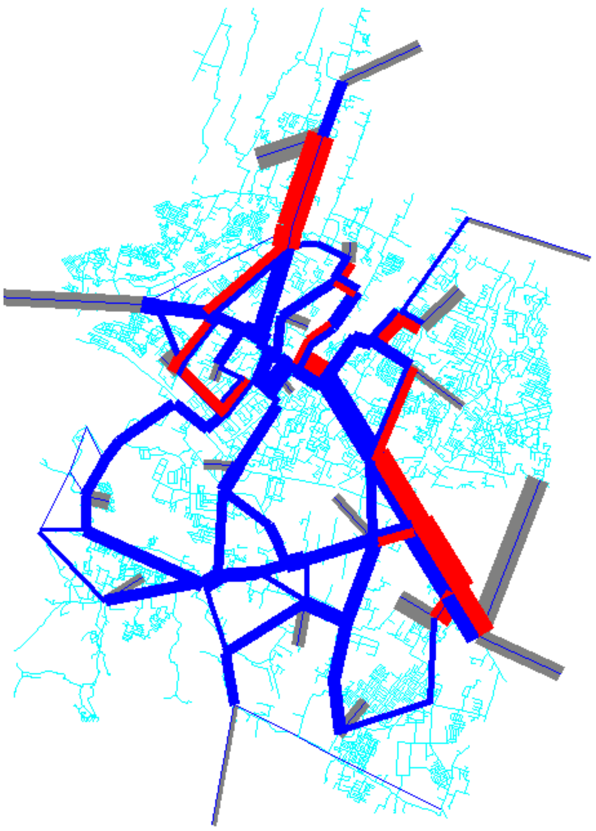


Figure 8. The result of existing condition

Table 8. Congested links on base condition

A	B	Link	Time (second)	VC ratio	Speed (km/hour)
1266	1660	Raya Cibereum	904.38	0.90	29.63
1269	1271	Kebun Kopi	822.42	2.15	8.21
1271	1266	Raya Cibereum	4,037.76	1.28	8.92
1271	1269	Kebun Kopi	109.45	0.95	27.25
1273	1271	Raya Cibeureum	667.21	0.97	24.99
1660	2065	Jati-Pesantren	414.80	0.89	31.55
1663	1266	Cimindi-Leuwigajah	155.66	0.85	27.21
1824	1921	Padasuka Indah	148.09	1.92	10.86
1828	1824	Sisingamangaraja	327.02	1.24	22.48
1847	2043	Raya Cimahi	424.83	0.98	24.61
1921	2012	Contong	761.10	1.74	13.54
2013	2012	Contong	133.17	1.59	16.24
2019	2013	Cisangka	286.63	1.16	22.03
2050	2272	Leuwidadap	82.17	0.93	26.55
2061	2064	Cihanjuang	272.64	1.16	24.46
2064	2067	Komplex (Babut Tengah)	450.24	1.71	9.30
2140	2017	Sangkuriang	498.77	1.19	26.47
2140	2208	Tegal Kawung	140.44	1.12	24.30
2152	2156	Babakan Citeureup	72.61	0.93	30.18
2152	2158	Leuwidadap	70.07	0.93	27.46
2158	2050	Leuwidadap	126.76	0.85	27.27
2208	2140	Tegal Kawung	370.21	1.71	14.10
2208	2248	Kolonel Masturi	1,077.57	1.45	15.53
2248	2208	Kolonel Masturi	4,288.59	2.22	5.98
2272	2043	Leuwidadap	76.75	0.92	26.61
		Sum	**16719.34**	**31.76**	**525.74**
		Average	**668.77**	**1.27**	**21.03**

DISCUSSION

The simulation builds scenarios by assignment with emission cost and assignment without emission cost.

A. Scenario 1

To solve the congestion problem in Cimahi city, scenario 1 tries to simulate road widening in congested links on collector road. The result of this scenario is divided into assignment with emission cost and assignment without emission cost. Table 9 and Table 10 show congested links after simulating scenario 1. Overall, this scenario 1 with emission cost can reduce v/c ratio (33%) and length congested links (56%). Moreover, the scenario 1 without emission cost produces the reduction v/c ratio (30%) and the reduction length of congested links (71%).

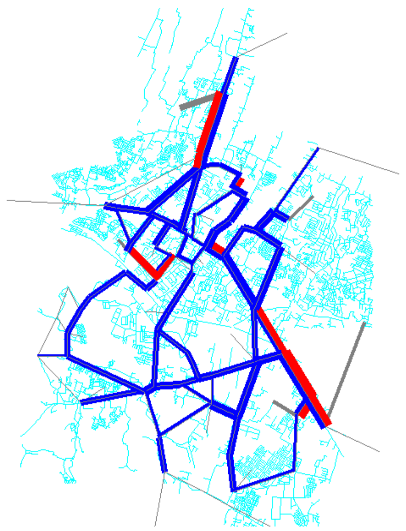
Table 9. Scenario 1 result with emission cost

A	B	Link	Distance (KM)	VC ratio		Percentage (%)
				Exsisting	SC 1	
1266	1660	Raya Cibereum	0.99	0.90	0.89	1%
1273	1271	Raya Cnbeurum	0.695	0.97	0.97	0%
1269	1271	Kebun Kopi	0.461	2.15	1.40	35%
1824	1921	Padasuka Indah	0.11	1.92	1.47	23%
1828	1824	Sisingamangaraja	0.606	1.24	1.21	2%
1921	2012	Contong	0.933	1.74	1.19	32%
2208	2140	Tegal Kawung	0.295	1.71	1.19	30%
2152	2156	Babakan Citeureup	0.31	0.93	0.88	5%
2248	2208	Kolonel Masturi	1.4467	2.22	1.19	46%
		Sum	**5.85**	**13.79**	**10.40**	25%
		Average	**0.65**	**1.53**	**1.16**	25%

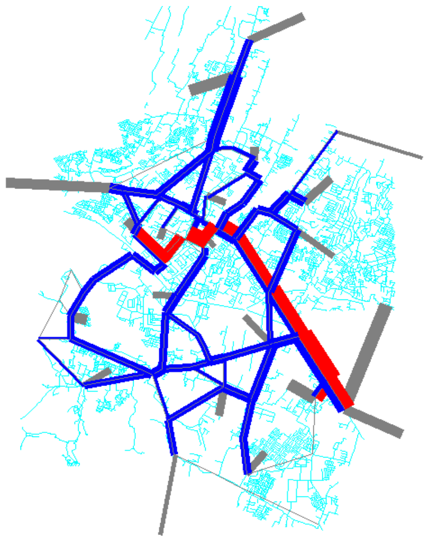
Table 10. Scenario 1 result without emission cost

A	B	Link	Distance (KM)	VC ratio		Percentage (%)
				Exsisting	SC 1	
1269	1271	Raya Cibeureum	0.695	0.97	1.05	-8%
1271	1266	Raya Cibereum	1.11	1.29	1.46	-13%
2208	2140	Raya Cimahi	0.43	0.98	1.22	-24%
2208	2140	Raya Cimahi	0.43	0.98	1.22	-24%
1847	2043	Padasuka Indah	0.11	1.92	1.99	-3%
1921	2012	Sisingamangaraja	0.606	1.21	1.98	-63%
2152	2156	Contong	0.933	1.70	1.85	-8%
		Sum	**4.73**	**10.77**	**11.33**	-63%
		Average	**0.59**	**1.35**	**1.42**	-8%

For further information, the result of scenario 1 with and without emission cost can be seen in Figure 9.



(a) with emission cost



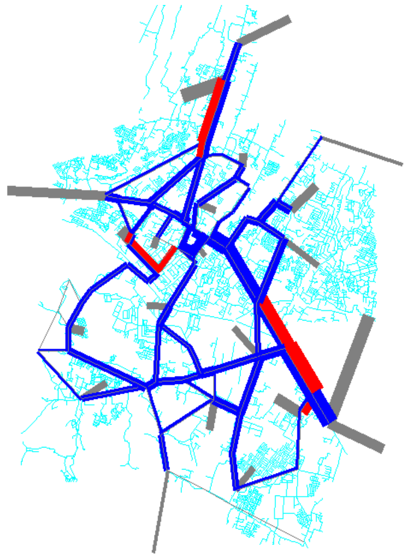
(b) without emission cost

Uncongested Link
Congested Link

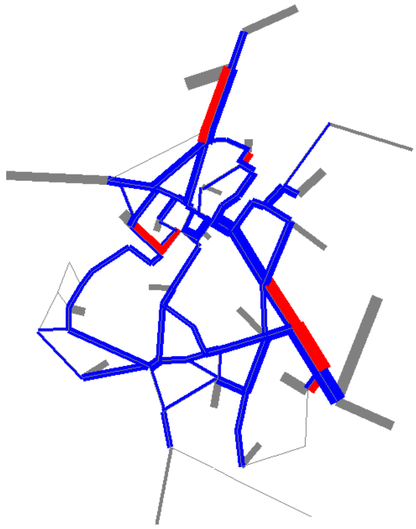
Figure 9. The result of scenario 1

B. Scenario 2

The scenario 2 tries to reduce high side friction on arterial road to achieve basic capacity. Due to the simulation of this scenario, there are reduction v/c ratio and reduction of congested links. Figure 10 illustrates the result of scenario 2 with and without emission cost. Furthermore, The result of scenario 2 by considering emission cost identifies 9 links in congestion which can be seen in Table 11. Additionally, the assignment result without emission cost identifies 8 links in congestion which can be seen in Table 12.



(a) with emission cost



(b) without emission cost

Uncongested Link
Congested Link

Figure 10. The result of scenario 2

Table 11. The scenario 2 result with emission cost

A	B	Link	Distance (KM)	VC ratio		Percentage (%)
				Exsisting	SC 2	
1266	1660	Raya Cibereum	0.43	0.90	0.85	5%
1271	1266	Raya Cibereum	0.933	1.28	1.01	21%
2208	2140	Tegal Kawung	1.478	1.71	0.96	44%
1269	1271	Kebun Kopi	0.461	2.15	1.40	35%
1824	1921	Padasuka Indah	1.532	1.92	1.20	37%
1828	1824	Sisingamangaraja	0.52	1.24	1.19	4%
1921	2012	Contong	0.606	1.74	1.19	32%
2013	2012	Contong	0.215	1.59	0.95	40%
2248	2208	Kolonel Masturi	1.4467	2.22	1.20	46%
		Sum	**7.62**	**14.76**	**9.96**	33%
		Average	**0.85**	**1.64**	**1.11**	33%

Table 12. The scenario 2 result without emission cost

A	B	Link	Distance (KM)	VC ratio		Percentag (%)
				Exsisting	SC 2	
1271	1266	Raya	1.11	1.29	1.02	21%
1266	1660	Kebun Kopi	0.461	2.16	1.40	35%
1847	2043	Padasuka	0.11	1.92	1.40	27%
1921	2012	Sisingamanga	0.606	1.21	1.22	-1%
2152	2156	Contong	0.933	1.70	1.19	30%
2140	2208	Tegal	0.295	1.71	1.20	30%
2061	2064	Babakan	0.31	0.96	0.96	0%
2152	2158	Kolonel	1.4467	2.22	1.20	46%
		Sum	**5.27**	**13.18**	**9.59**	**27%**
		Average	**0.66**	**1.65**	**1.20**	**27%**

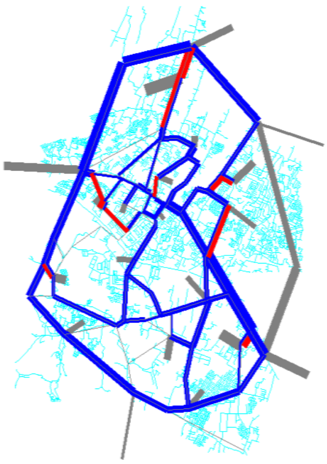
C. Scenario 3

Scenario 3 would connect discontinuous road from external to external road or from outside to town centre, which would improve travel within the community. Improved local connectivity would also make it easier to get to the external zone. This scenario improves local roads and would help reduce traffic congestion on arterial and collector road. Figure 11 illustrates the scenario 3 result.

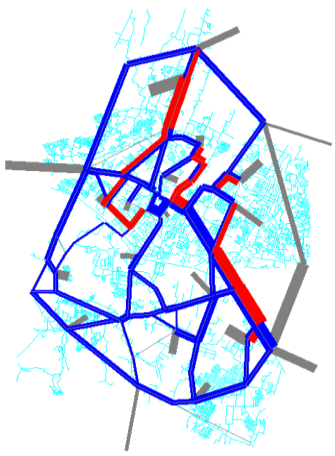
Table 13 shows the result of scenario 4 by considering emission cost. There are 6 congested links with the total length of 2.48 km. Otherwise, traffic assignment without emission cost has insignificant impact to reduce congestion in Cimahi city because road users can spend more time by using the ringroad. It can be seen in Table 14.

Table 13. Scenario 4 result with emission cost

A	B	Link	Distance (KM)	VC ratio		Percentage (%)
				Exsisting	SC 3	
1269	1271	Kebun Kopi	**0.461**	2.15	2.01	7%
1824	1921	Padasuka Indah	0.11	1.92	0.88	54%
1921	2012	Contong	**0.933**	1.74	1.11	37%
2061	2064	Cihanjuang	0.407	1.16	1.16	0%
2064	2067	Komplex (Babut Tengah)	0.567	1.71	1.71	0%
2248	2208	Kolonel Masturi	**1.4467**	2.22	0.91	59%
		Sum	**2.48**	**8.69**	**6.86**	21%
		Average	**0.50**	**1.74**	**1.37**	21%



(a) with emission cost



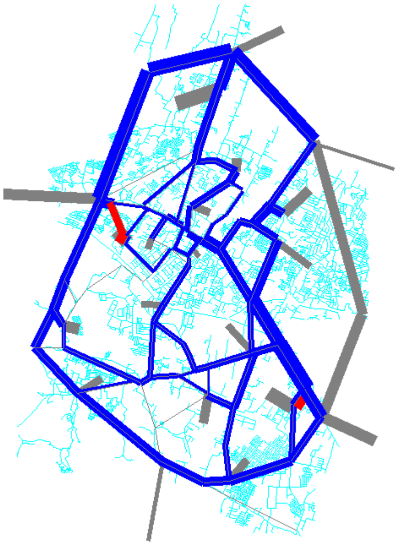
(b) without emission cost

Figure 11. The result of scenario 3

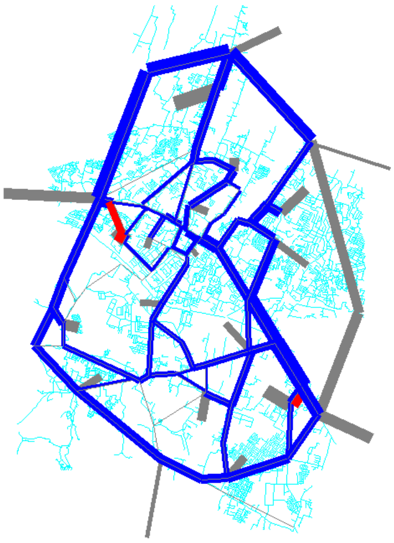
Table 14. Scenario 4 result without emission cost

A	B	Link	Distance (KM)	VC ratio		Percentage (%)
				Exsisting	SC 3	
1266	1660	Kebun Kopi	0.461	2.16	2.18	-1%
1271	1266	Raya Cibereum	1.11	1.29	1.10	14%
1824	1921	Jati-Pesantren	1.532	0.90	0.95	-7%
1847	2043	Padasuka Indah	0.11	1.92	1.57	18%
1921	2012	Sisingamangaraja	0.606	1.21	1.22	0%
2208	2140	Raya Cimahi	0.43	0.98	0.90	9%
2152	2156	Contong	0.933	1.70	1.69	1%
2248	2208	Contong	0.215	1.59	1.52	4%
1271	1269	Cisangka	0.857	1.16	0.97	16%
1660	2065	Cihanjuang	0.567	1.16	1.08	7%
1663	1266	Komplex (Babut	0.4152	1.71	1.71	0%
2013	2012	Sangkuriang	1.478	1.14	0.96	16%
2061	2064	Babakan	0.31	0.96	1.06	-11%
2064	2067	Leuwidadap	0.359	0.93	0.89	5%
2140	2017	Leuwidadap	0.645	0.85	0.81	5%
2140	2208	Tegal Kawung	0.295	1.71	0.95	44%
2050	2272	Kolonel Masturi	1.44667	1.45	0.99	32%
2152	2158	Kolonel Masturi	1.4467	2.22	1.23	44%
2158	2050	Leuwidadap	0.381	0.92	0.88	5%
2272	2043	Leuwidadap	0.407	0.82	1.05	-27%
		Sum	**14.00**	**26.79**	**23.71**	**12%**
		Average	**0.70**	**1.34**	**1.19**	**12%**

D. Scenario 4



(a) With emission cost



(b) Without emission cost

Figure 12. The result of scenario 4

This scenario improves the existing road network by increasing the number of lanes and widening roads. The aim of this scenario is to reduce congested link on collector road and arterial road. From the CUBE program, it is found that the scenario 4 result provides extremely v/c ratio reduction and number on congested link. Figure 12 illustrates the result of scenario 4. Table 15 illustrates the significant congestion reduction. Thus, the number of congestion link is merely identified 2 links which are Kebun Kopi and Contong. A reduction v/c ratio (54%) is an evidence that this scenario has significant impact on reducing congestion in Cimahi city. Table 16 shows the cmongested link

Table 15. Scenario 4 result with emission cost

A	B	Link	Distance (km)	VC Ratio		%
				Existing	Sc. 4	
1269	1271	Kebun Kopi	0.461	2.15	1.28	41
2013	2012	Contong	0.215	1.59	1.49	6
		Sum	0.676	3.74	2.77	26
		Average	0.338	1.87	1.38	26

Table 16. Scenario 4 result without emission cost

A	B	Link	Distance (km)	VC Ratio		%
				Existing	Sc. 4	
1266	1660	Kebun Kopi	0.461	2.16	1.30	40
1271	1266	Raya Cibereum	1.11	1.29	1.06	17
1847	2043	Padasuka Indah	0.11	1.92	1.10	43
1921	2012	Sisingam angaraja	0.606	1.21	1.10	9
2208	2140	Raya Cimahi	0.43	0.98	0.81	17
2152	2156	Contong	0.933	1.70	0.98	42
		Sum	3.65	9.27	6.35	32
		Average	0.61	1.55	1.06	32

CONCLUSIONS

The road widening is simulated by scenario 1, which the assignment with emission cost can increase v/c ratio (33%) and the assignment without emission cost (30%). To avoid congestion on arterial road, scenario 2 is built to remove road user of that road. The results can impact to decrease v/c ratio (42%) by considering emission cost and (34%) without emission cost. By building ringroad in scenario 3 it obtains the significant result for assignment with emission cost because it can reduce v/c ratio (37%). In contrast, scenario 3 result without emission cost provide reduce v/c ratio reduction only 14%. The last scenario represents combination of scenario 1 and scenario 2 which is providing the higher v/c ratio reduction which the reduction is 64% for considering emission cost and (50%) without considering emission cost.

The ‘congestion reduction’ scenario has the most important impact on reducing congestion. All of the scenarios have the positive effects in reducing congested link. Those scenarios focus on road network changes. The four scenarios by considering emission cost used to length of congestion links reduction are scenario 1 (56%), Scenario 2 (64%), scenario 3 (65%) and scenario 4 (96%). On the other hand, the assignment without emission cost can reduce length of congested link. It can be seen in all of scenario such as scenario 1(71%), scenario 2 (68%), scenario 3 (15%) and scenario 4 (78%).

After modeling four scenarios, those are acquired that scenario 4 as the best alternative for congested reduction in Cimahi. Indeed, scenario 4 is recommended because significant result of v/c ratio value reduction and reducing number of congestion links by considering emission cost

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