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インドネシアMakassar市の自動車騒音低減のためのTDM-TMSの提案

Road Traffic Noise Reduction Using TDM-TMS Strategies in Makassar City, Indonesia

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The objective of this paper is to propose travel demand management (TDM) and traffic management system (TMS) strategies in order to mitigate the road traffic noise (RTN) in Makassar City, Indonesia. The TDM-TMS strategies involve three in one car, two in one motorcycle, prohibition of horn sound, and Bus Rapid Transit. The ASJ RTN-Model 2008 is used to predict the RTN and GIS is applied to evaluate the effectiveness of various TDM-TMS scenarios as well as the present condition. The results show the TDM-TMS strategies as a noise measure provide noise reduction of about 6dB, and it is significant and sufficient effectiveness in reducing the RTN in Makassar. The authors wish that the results of this study give a suggestion for transportation policy to reduce the RTN reduction in the future in Makassar City.

Keywords: Road traffic noise, Travel demand management, Traffic management system, Makassar City
キーワード：自動車騒音の低減, 交通需要管理(TDM),交通管理システム(TMS),マカッサル市

1. Introduction

1.1 Background

Nowadays, the increase of vehicle number in developing countries including Indonesia leads to the rise of the road traffic noise (RTN), and the RTN becomes a serious problem in living environment. Therefore, a guideline to reduce the RTN is needed. However, in many cities in developing countries such as Indonesia, any guidelines for the RTN mitigation have not been established yet, unlike developed countries. For example, in Japan, an integrated noise-GIS (Geographic Information System) which provides general functions for urban traffic noise modeling, noise prediction, environmental assessment, and noise abatement design, has been established [1],[2],[3]. Regarding the condition, the authors conduct a research to develop a method to find an optimal solution for the RTN problem in Makassar City, Indonesia, based on the reference scheme conducted in Japan.

In the first research [4], the authors have shown that the level of the RTN at 35 roadside of main roads in Makassar City are 74dB (L_{Aeq}) averagely. It indicates that more than 90% areas exceed the highest value of Indonesian's noise standard (70dB) [5].

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In addition, motorcycles dominate the traffic (67%) fleet in the city, contrary to the heavy vehicle (2%). Under these situations, the average speed of the vehicles is less than 40 km/h; a low speed category. Nevertheless, the traffic flow is still in steady state condition [6]. Due to the above condition, the drivers generate the horn many times to keep their safety; the time of horns widely changes from 13times/10minutes to 149times/10minutes. By taking such conditions into consideration when predicting the RTN by applying the ASJ RTN-Model 2008 [7], we could make the predicted level of the RTN close to the measured value. The above results show the noise level by road traffic in Makassar City must be reduced. Therefore, it is necessary to evaluate the RTN of existing sound source and to find the method to reduce in new plans.

Then, the authors tried to construct the RTN-GIS of Makassar City in order to perform the spatial evaluation of the RTN along roads in Makassar City by using POEM [8]. The noise maps obtained in the RTN-GIS enable us to evaluate the number of buildings that exceed the noise level of the Environmental Quality Standard (EQS) for Noise in Indonesia [5]. The result of the evaluation of EQS for 35 roads has presented the achievement rate is only 23.2% in the current condition.

By making use of this RTN-GIS in Makassar City, the authors attempted to apply two types of noise reduction measures; simple noise barrier and drainage pavement, to reduce the RTN problem in Makassar City [9]. Considering the real road side condition, the authors tried various scenarios for each road and got a result that the achievement rate of EQS in 35 roads after noise reduction measures implementation is 43.4% (20.2 points up). However, these methods not only require a high cost but also are restricted to roads having a sufficient space beside the roads. Therefore, another noise measures are needed.

The authors think that methods to decrease the number of vehicles are useful for the RTN reduction when considering the present traffic condition in Makassar City, and travel demand management (TDM) and traffic management system (TMS) are examined.

1.2 Objective

Regarding the above background, the objective of this paper is to propose TDM-TMS strategies in order to mitigate the RTN in Makassar City, Indonesia.

2. TDM-TMS in Reducing RTN

Some experiences from developed countries show the effectiveness of the TDM-TMS measures in reducing the RTN problem. Both categories of the measures may reduce noise through reductions in traffic volume, changes in composition and daily distribution of the traffic, speed reductions, and changes in driving patterns [10].

Table 1 shows general TDM-TMS measures in reducing the RTN. These strategies involve short term (3-5 years), middle term (5-10 years), and long term (10-15 years). Considering the availability to collect necessary data of each measure, this study focuses on four implementation TDM-TMS strategies such as 'three in one for car,' 'two in one for motorcycle,' 'prohibition of horn sound,' in short term and 'Bus Rapid Transit' in middle term, which are marked by '#' in Table 1. The detail of each measure is as follows:

1) Three in one

Three in one (hereafter abbreviated as 3IN1) measure is a ridesharing or car-pooling policy to reduce the number of light vehicles especially for private passenger car. This program means that one private passenger car must take three people or more including a driver in a car. This strategy could restrict the people to use private car and encourage for using public transport.

2) Two in one

As the number of private car is not large in Makassar City and the noise reduction by 3IN1 is small as well, 3IN1 measures should be combined with other strategy for effective noise reduction. Therefore, the authors propose, as the second strategy, two in one (hereafter abbreviated as 2IN1) measure, which is a ridesharing or car-pooling policy for motorcycles. As the authors' previous research [4] has shown that motorcycle is dominant traffic in Makassar City, 2IN1 measure might reduce the number of motorcycles and reduce the noise.

3) Prohibition to generate vehicle horn

The authors' previous research [4] also shows drivers generate the horn sound many times to keep their safety in a heavy traffic in Makassar City. Thus, extraneous noisy sounds are added to the RTN and the RTN becomes high. Therefore prohibition to generate vehicle horn is an important policy for reducing the RTN. As the perfect achievement of this strategy is very difficult, the effectiveness for various achieved percentage is examined while combining 3IN1 and 2IN1 measures to get the better noise reduction in short term.

4) Bus Rapid Transit (BRT)

For the middle term, the authors propose the exchange of the public transport mode in the city from the current system, Para-transit system (micro bus) to bus rapid transit (BRT) system, which is a TDM measure and might reduce the

Table 1 Integrated TDM-TMS for the RTN Mitigation

Term Plan (Year)	Reduction Measures	
	Travel Demand Management (TDM)	**Traffic Management System(TMS)**
Short-term (3 – 5)	• Ridesharing or carpooling policy: # Three in one for private car (3IN1) # Two in one for motorcycle (2IN1)	• Central blocks, traffic islands, parking bays, cycle tracks • The installation of physical separations between the ways • Traffic signal & Roundabout • Motorcycle restriction and exclusive lane # Prohibition to generate vehicle horn
Middle-term (5 – 10)	# Change of public transport mode from Para-transit to Bus Rapid Transit (BRT) • Scheduling Activities • Congestion Pricing • Parking Management	• Change of a bidirectional street to one-way • Actuated Traffic Control System (ATCS)
Long-term (10 – 15)	• Development of Light Rapid Transit (LRT) or Mass Rapid Transit (MRT) system • Land use and zoning	• Road Pricing (Expressway)

traffic volume. The current Para-transit system has small passenger capacity, and it does not have a bus stop or shelter for passengers. On the other hand, the BRT system has a larger passenger capacity, and it is expected to transit not only for the captive demand but also for the private car demand because the BRT system has similar convenience to the private cars and reliability in travel time aspect.

In examining the effectiveness of the above four TDM-TMS measures in reducing the RTN in Makassar City, three steps of examinations are conducted in this paper. Firstly, the RTN reduction for 3IN1 program, a joint program of 3IN1 and 2IN1, and the horn prohibition program are calculated. Then, the RTN reduction for the BRT system under the selected condition of the first step is predicted. Lastly, the results of the RTN reduction in the first and second steps are evaluated from the viewpoint of the achievement of the EQS in Indonesia.

3. Effectiveness of the TDM-TMS in Reducing the RTN

3.1 3IN1, 2IN1, Prohibition of Horn

In the first step, the effectiveness of 3IN1, 2IN1 and prohibition of horn programs is examined. As 3IN1 and 2IN1 programs lead to the reduction of the traffic volume, the traffic volume after the implementation of them must be estimated when predicting the RTN reduction by these measures. Table 2 shows the RTN survey result of 35 roads in Makassar City [4], here d_m and d_l mean a median of road and the distance between the end of roadside and measurement point, respectively. And, 'noise level' presents the predicted $L_{Aeq,day}$ by using the ASJ RTN Model-2008 [7] while assuming traffic volumes, speed, and number of horns shown in Table 2 in order to examine their own effectiveness of 3IN1 and 2IN1 programs. For predicting the RTN after implementing 3IN1 and 2IN1 programs, the numbers of light vehicle (LV) and motorcycle (MC) are assumed under the condition of keeping the total number of passengers.

(1) 3IN1 and 2IN1

At first, the effectiveness of single 3IN1 program is examined. The number of LV in Table 2 is changed while keeping the total number of passengers and $L_{Aeq,day}$ under new traffic volume is predicted by using the ASJ RTN-Model 2008 when the rates of achievements of 3IN1 is

Table 2 Result of Road Traffic Noise Survey

Road No.	Road Characteristics					$L_{Aeq,day}$	Traffic Volume (vehicle/10min)			Speed (km/hour)			Horn (times/10min)		
	Length (km)	Lane	Width (m)	dm (m)	dl (m)	(dB)	HV	LV	MC	HV	LV	MC	HV	LV	MC
1	1.287	2	5.00	0.00	1.50	76.3	2	199	431	22.5	25.4	27.5	0	64	85
2	1.425	2	7.00	0.00	1.20	72.5	4	123	248	24.5	24.7	30.6	0	27	93
3	0.502	2	7.00	0.00	2.80	74.2	10	128	438	28.7	26.1	31.2	0	29	88
4	0.303	2	7.00	0.00	3.50	72.3	8	59	222	39.0	25.0	25.9	0	13	41
5	1.212	2	7.00	0.00	3.00	75.4	4	181	227	23.1	22.2	26.2	0	60	68
6	0.858	2	7.00	0.00	3.00	72.6	3	245	401	20.0	25.0	29.5	0	17	40
7	1.500	2	4.00	0.00	2.50	76.1	20	93	314	22.7	26.0	29.2	1	14	9
8	1.300	2	5.00	0.00	1.10	76.1	8	102	375	21.8	23.1	22.1	5	21	36
9	3.727	2	6.00	0.00	1.00	73.3	3	84	245	25.8	23.5	25.9	3	35	64
10	5.806	2	7.00	0.00	3.50	74.9	8	119	413	18.0	23.4	28.4	0	24	89
11	1.565	2	5.00	0.00	2.20	75.4	11	105	336	24.1	25.4	28.2	0	43	62
12	1.170	2	7.00	0.00	3.50	72.4	2	173	273	24.0	28.8	30.6	0	28	49
13	0.445	2	7.00	0.00	3.50	74.1	23	88	215	21.5	23.3	29.3	4	41	29
14	1.414	2	4.00	0.00	2.20	75.1	2	64	447	24.0	23.8	27.7	2	18	28
15	3.826	4	14.00	0.00	3.50	76.9	36	392	957	27.2	26.1	26.3	0	48	90
16	0.956	4	12.00	2.90	2.50	71.8	17	139	377	29.5	27.9	33.0	6	58	73
17	0.690	4	12.00	0.00	3.60	72.8	8	380	512	19.0	23.8	27.9	1	67	54
18	2.067	4	13.00	0.00	2.75	73.9	2	265	404	24.0	28.7	28.3	0	54	44
19	0.835	4	13.00	0.00	1.00	72.5	5	80	224	25.7	27.5	33.5	1	13	22
20	1.239	4	14.00	0.00	2.50	72.7	11	310	514	23.6	27.2	31.3	3	78	24
21	0.891	4	14.00	1.40	2.50	72.4	13	94	259	23.1	28.6	33.6	8	22	31
22	0.622	4	14.00	0.00	1.75	69.6	1	85	110	29.0	31.4	33.5	0	8	5
23	1.339	4	14.00	0.00	3.21	72.9	1	269	351	16.0	28.9	30.4	0	36	15
24	0.321	4	14.00	0.00	4.00	73.5	2	219	337	24.0	24.4	25.4	0	37	52
25	1.707	4	12.00	0.25	1.30	74.6	12	196	260	30.0	33.3	34.6	0	30	24
26	0.231	4	14.00	3.20	4.65	72.0	3	278	349	22.5	21.9	24.9	0	35	36
27	1.072	4	14.00	0.00	1.35	72.7	6	311	442	20.0	24.4	32.0	0	44	41
28	2.641	4	14.00	2.00	1.50	74.3	19	203	530	28.0	31.7	35.1	0	48	49
29	1.878	4	14.00	2.80	3.00	73.2	12	224	597	26.3	30.1	35.8	0	54	34
30	4.506	4	14.00	2.50	6.00	75.1	11	455	979	25.3	28.2	36.6	1	65	26
31	4.506	4	14.00	2.50	6.00	73.8	14	469	857	27.7	31.2	31.7	0	55	36
32	1.670	6	18.00	2.00	1.00	72.5	13	268	493	36.8	35.1	40.3	0	57	40
33	4.373	6	21.00	2.20	6.00	74.9	47	729	1339	24.6	25.6	32.1	24	67	31
34	11.970	6	21.00	3.00	3.50	76.3	28	541	1319	23.9	26.6	33.0	3	58	33
35	11.970	6	21.00	2.50	3.50	75.7	27	337	1002	32.0	35.9	41.9	1	29	56

varied from 0% to 100%. The result is shown in Fig.1. It can be found that the relation between noise reduction and the achievement rate of 3IN1 is linear and the maximum value, which occurs when the achievement rate is 100%, is 0.45dB.

Then the effectiveness of a joint program of 3IN1 and 2IN1 is examined. The numbers of LV and MC in Table 2 are changed while keeping the total number of passengers and $L_{Aeq,day}$ under new traffic composition is predicted by using the ASJ RTN-Model 2008 when the rates of achievements are varied from 0% to 100%. Table 3 shows an example of the result for 20% achievement of 3IN1 and 20% achievement of 2IN1 program jointly; here 'Diff' means the difference between $L_{Aeq,day}$ after 2IN1 and 3IN1 program and current $L_{Aeq,day}$ shown in Table 2. It is found that the noise reductions for 35 roads vary from 0.4dB to 0.5dB and the RMS (root mean square) value is 0.45dB. Fig.2 shows the contour value of noise reduction in decibel (dB) for all combinations of this scenario. This indicates the noise reduction is 2.8dB if this joint program of 3IN1 and 2IN1 is perfectly achieved. However, this value is still not enough to solve the RTN problem in Makassar City.

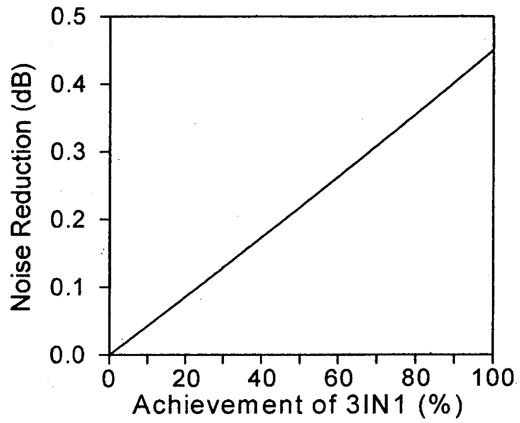


Fig.1 Noise Reduction by 3IN1 Measure

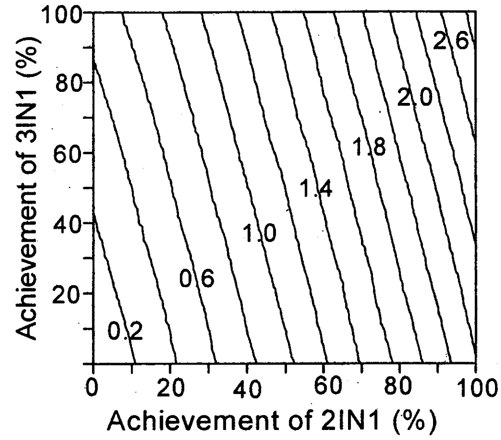


Fig.2 Noise Reduction by 3IN1 and 2IN1 Measure

Table 3 Noise Reduction by Joint Measure of 3IN1 and 2IN1

Road No.	Number of Vehicles (vehicle/day)			$L_{Aeq,day}$ (dB)		
	HV	LV 20% 3IN1	MC 20% 2IN1	Present	After Measure	Diff
1	22	1837	3875	74.8	74.3	0.5
2	36	1123	2231	72.0	71.5	0.5
3	95	1106	3940	72.6	72.1	0.5
4	83	535	1994	69.1	68.7	0.4
5	41	1642	2040	70.4	69.9	0.5
6	29	2156	3608	72.5	72.0	0.5
7	195	850	2826	72.7	72.3	0.4
8	76	927	3372	74.5	74.0	0.5
9	33	765	2209	72.4	71.9	0.5
10	75	1074	3716	71.7	71.3	0.4
11	109	964	3028	72.8	72.3	0.5
12	20	1567	2459	70.5	70.0	0.5
13	233	802	1938	69.6	69.2	0.4
14	19	555	4022	73.9	73.5	0.4
15	356	3578	8610	74.2	73.8	0.4
16	173	1255	3394	70.8	70.4	0.4
17	80	3400	4605	72.2	71.8	0.4
18	22	2456	3634	71.3	70.9	0.4
19	52	720	2018	69.6	69.1	0.5
20	106	2832	4626	72.3	71.8	0.5
21	132	851	2330	68.9	68.5	0.4
22	12	733	992	66.3	65.8	0.5
23	14	2493	3155	70.4	70.0	0.4
24	23	1977	3031	69.6	69.2	0.4
25	118	1747	2343	71.0	70.5	0.5
26	31	2406	3143	69.5	69.0	0.5
27	63	2816	3976	72.5	72.1	0.4
28	187	1840	4774	72.6	72.2	0.4
29	120	2026	5374	72.0	71.6	0.4
30	111	4123	8807	72.9	72.5	0.4
31	136	4247	7715	72.5	72.1	0.4
32	127	2319	4440	72.0	71.5	0.5
33	470	6607	1205	73.7	73.3	0.4
34	279	4902	1187	74.2	73.8	0.4
35	272	3051	9015	72.9	72.5	0.4

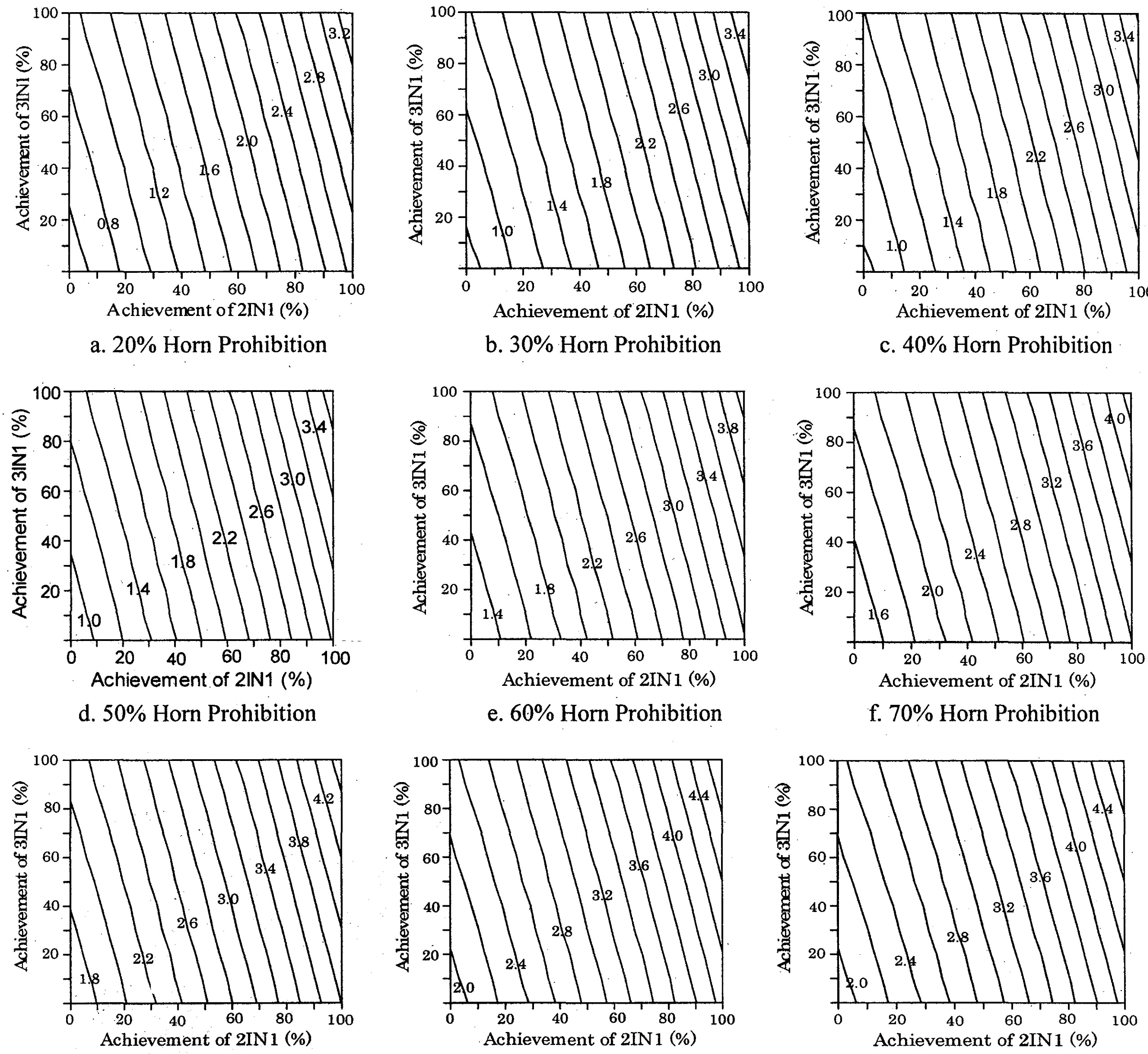
(2) Prohibition of Horn

As mentioned in **1.1**, the drivers generate the horn many times (13 times/10 minutes to 149 times/10 minutes) in Makassar City, and consequently the horn sounds increase the RTN. Therefore horn prohibition might be useful for the reduction of the RTN. On this aspect, the effectiveness of horn prohibition program is examined. The same procedure as the authors previous one [4] is used for predicting the effect of horn on the RTN. Table 4 shows an example of the predicted $L_{Aeq,day}$ when 20% of the number of horn sound are prohibited. It is found that the noise reduction is significant at only 5 roads and the RMS of noise reduction at 35 roads is 0.47dB. This implies the increase of percentage of horn prohibition is needed for effective reduction of the RTN.

The noise reductions for combination with 3IN1, 2IN1, and prohibition of horn when varying the achievement rate of each program from 10% to 100% are calculated. The results are shown in Fig.3. In this figure, noise reductions vary from 0.6 to 4.6dB.

Table 4 Noise Reduction by Horn Prohibition

Road No.	Number of Vehicle (vehicle/10min)			Number of Horn (times/10min) After 20% Prohibition			$L_{Aeq,day}$ (dB)		
	LV	HV	MC	LV	HV	MC	Present	After Measure	Diff
1	191	0	439	51	0	68	76.7	76.7	0.0
2	107	6	230	22	0	74	74.6	74.6	0.0
3	139	8	451	23	0	70	74.0	74.0	0.0
4	60	4	223	10	0	33	71.2	71.2	0.0
5	199	5	222	48	0	54	72.4	72.3	0.1
6	285	1	434	14	0	32	74.0	74.0	0.0
7	116	24	318	11	1	7	73.6	72.9	0.7
8	106	8	354	17	4	29	76.9	76.9	0.0
9	68	6	209	28	2	51	75.3	75.3	0.0
10	138	4	375	19	0	71	72.7	72.7	0.0
11	108	10	332	34	0	50	74.7	74.7	0.0
12	165	2	262	22	0	39	71.9	71.9	0.0
13	79	27	196	33	3	23	71.3	71.3	0.0
14	88	3	421	14	2	22	75.7	75.7	0.0
15	370	25	1097	38	0	72	75.4	75.4	0.0
16	148	20	342	46	5	58	73.2	73.2	0.0
17	421	5	423	54	1	43	73.4	73.4	0.0
18	275	0	323	43	0	35	73.0	73.0	0.0
19	54	3	182	10	1	18	69.5	69.5	0.0
20	339	11	497	62	2	19	74.1	74.1	0.0
21	101	22	229	18	6	25	72.0	70.1	1.9
22	57	1	70	6	0	4	64.5	64.5	0.0
23	289	4	330	29	0	12	72.4	71.2	1.2
24	176	5	292	30	0	42	71.2	71.2	0.0
25	190	6	192	24	0	19	71.7	71.7	0.0
26	273	3	286	28	0	29	70.7	70.7	0.0
27	305	10	518	35	0	33	75.3	73.8	1.5
28	208	13	551	38	0	39	75.0	75.0	0.0
29	243	8	497	43	0	27	73.1	73.1	0.0
30	471	13	815	52	1	21	73.0	73.0	0.0
31	474	21	749	44	0	29	72.8	72.8	0.0
32	313	31	456	46	0	32	73.4	73.4	0.0
33	816	36	1348	54	19	25	74.4	74.4	0.0
34	631	25	1190	46	2	26	75.0	75.0	0.0
35	303	33	896	23	1	45	73.8	73.8	0.0



a. 20% Horn Prohibition
b. 30% Horn Prohibition
c. 40% Horn Prohibition
d. 50% Horn Prohibition
e. 60% Horn Prohibition
f. 70% Horn Prohibition
g. 80% Horn Prohibition
h. 90% Horn Prohibition
i. 100% Horn Prohibition

Fig. 3 Noise Reductions by Joint Measure of 3IN1, 2IN1, and Horn Prohibition

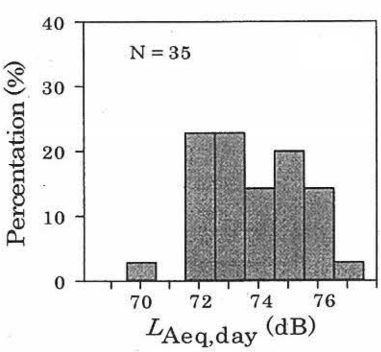
(3) Combination Program for Target $L_{Aeq,day}$

As each noise abatement cannot reduce the noise to the desired noise level as shown in **(1)** and **(2)**, combination program of 3IN1, 2IN1 and horn prohibition is finally examined in the first step of examination of noise reduction.

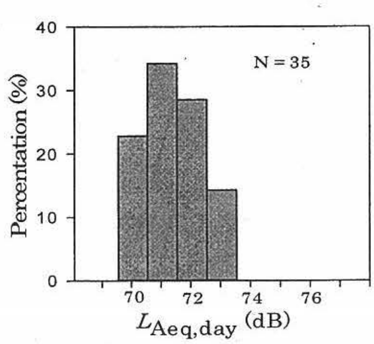
Figure 4(a) shows the distribution of the present $L_{Aeq,day}$ in 35 roads in Makassar City. Here the authors determine the goal as Figure 4(b) on basis of a concept that large noise must be reduced preferentially and the average value should be also reduced.

Furthermore, by using simulation, a good combination is searched among the results in order to achieve the 35 $L_{Aeq,day}$ shown in Fig.4(b). An example of the good combination is shown in Table 5. This is selected among scenarios as the authors' pleasures. Here C-40-70-80 in the column scenario, for example, means 40% achievement of 3IN1, 70% achievement of 2IN1, and 80% achievement of horn prohibition, and $L_{Aeq,day}{}^{*}$ shows the predicted $L_{Aeq,day}$ after this scenario is achieved. It can be found in Table 5 that the maximum and average reduction of the RTN are 3.9 and 2.4dB, respectively, and the maximum and the average of $L_{Aeq,day}{}^{*}$ are 73.1 and 71.7dB, respectively.

The result in the first step can be summarized that ridesharing/car-pooling and prohibition of horn could reduce the RTN in Makassar City. However the result is not satisfactory and Makassar City still need more noise reduction.



a. Present



b. After Measure

Fig.4 $L_{Aeq,day}$ Distribution

Table 5 $L_{Aeq,day}$ and Noise Reduction Selected among Combinations of 3IN1, 2IN1 and Horn Prohibition

Road No.	$L_{Aeq,day}$ (dB) Present	Measure Scenario	Noise Reduction (dB)	$L_{Aeq,day}$ (dB) After Measure
1	76.3	C-40-70-80	3.3	73.1
2	72.5	C-10-30-50	1.4	71.1
3	74.2	C-30-60-50	2.2	72.0
4	72.3	C-20-70-40	2.2	70.1
5	75.4	C-40-70-40	2.4	73.0
6	72.6	C-20-40-40	1.6	71.0
7	76.1	C-40-70-70	3.0	73.1
8	76.1	C-40-70-70	3.0	73.1
9	73.3	C-20-50-60	2.3	71.0
10	74.9	C-40-70-60	2.8	72.1
11	75.4	C20-70-50	2.3	73.1
12	72.4	C-50-70-30	2.4	70.0
13	74.1	C-30-60-30	2.1	72.1
14	75.1	C-30-80-60	3.0	72.1
15	76.9	C-60-80-90	3.9	73.0
16	71.8	C-20-50-30	1.8	70.0
17	72.8	C-40-40-50	1.8	71.0
18	73.9	C-30-50-40	1.9	72.1
19	72.5	C-10-30-50	1.4	71.1
20	72.7	C-30-40-40	1.6	71.1
21	72.4	C-20-70-50	2.3	70.1
22	69.6	C-00-00-00	0.0	70.1
23	72.9	C-30-50-40	1.9	71.1
24	73.5	C-20-30-50	1.5	72.0
25	74.6	C-30-60-60	2.5	72.1
26	72.0	C-30-50-50	2.0	70.1
27	72.7	C-30-40-40	1.6	71.1
28	74.3	C-40-60-50	2.2	72.1
29	73.2	C-30-60-50	2.2	71.1
30	75.1	C-50-70-70	3.1	72.0
31	73.8	C-40-40-50	1.8	72.1
32	72.5	C-10-50-20	1.5	71.1
33	74.9	C-50-70-60	2.9	72.1
34	76.3	C-40-70-80	3.3	73.1
35	75.7	C-30-80-50	2.7	73.1

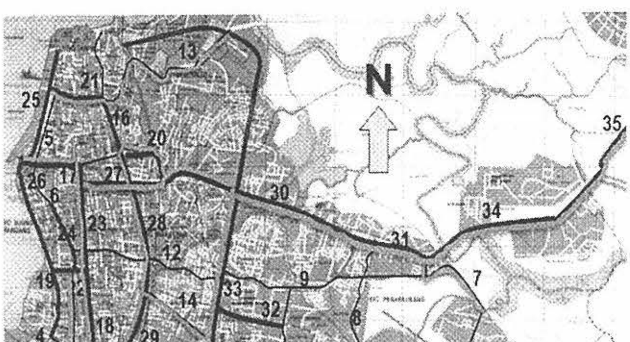
3.2 Bus Rapid Transit (BRT)

In the second step, the effectiveness of middle term plan (change of public transport mode from Para-transit to BRT) is examined.

Figure 5 shows a micro bus, called as Para-transit, which is now used as a public transport in Makassar City. This micro bus is categorized as a light vehicle and the passenger capacity is only 11. This system is now operating at 14 tracks in Makassar City, and the load factor (LF, ratio of the number of loaded passengers to the bus capacity)

Fig.5 Micro Bus in Makassar City

varies from 0.21 to 0.47 through whole tracks [11]. This Para-transit system has neither bus stop nor scheduled time and it causes traffic congestion in Makassar City. In order to solve the transportation congestion problem in the city, the local government of Makassar City has presented a plan to introduce BRT, whose capacity is 75 passengers including 25 standing passengers, in the place of Para-transit as a public transport in Makassar City [12]. Figure 6 shows 6 planning corridors overlapping with 35 target roads. As shown in this figure, the BRT system covers all arterial roads and some secondary roads in Makassar City. Among 35 target roads in this study, the BRT system is introduced at 21 roads as the BRT corridors and 14 roads as feeder lines (the roads that are not include BRT corridors). As according to the preliminary design, two middle lanes in a road (2-way) are used for BRT. And the planning headway is different among the six BRT corridors depending on the demand of each corridor. Actually, the headways vary from 1.7 to 5.0 minutes among the corridors; the number of BRTs in each corridor varies from 2 to 6 buses per 10 minutes. Table 6 shows the number of BRT for each corridor. Thus, the



Corridor 1 (BRT1) → 35, 34, 31, 30, 33
Corridor 2 (BRT2) → 23, 18, 10, 19
Corridor 3 (BRT3) → 15, 1, 2, 29, 28, 27, 17, 21
Corridor 4 (BRT4) → 13
Corridor 5 (BRT5) → 14, 20
Corridor 6 (BRT6) → 7

Fig. 6 Preliminary Design of the BRT Corridors

Table 6 Number of BRT and Headway

Corridor	Number of (vehicle/day)	Headway (minutes)
BRT-1	120	1.7
BRT-2	80	2.5
BRT-3	80	2.5
BRT-4	40	5.0
BRT-5	60	3.3
BRT-6	40	5.0

implementation of BRT might reduce the numbers of LV and MC by converting the passengers from small bus (Para-transit) to large bus (BRT), nevertheless it also might increase the number of HV (the percentage of HV in Makassar City is only 2% in the present time [4]).

To calculate the RTN after the implementation of BRT, the vehicle composition of 35 roads is estimated. For the BRT road, at first, the numbers of BRT and Para-transit are estimated assuming the LF of BRT is 75%. Here MC of 1 rider takes precedence over MC of 2 riders when deciding the number of MC, and LV of 1 passenger takes precedence over LV of 2 or 3 passengers when deciding the number of LV. Then, the number of BRT to be needed at each BRT road can be estimated considering the headway of the BRT at the road. For the roads categorized as feeder line, the reduced numbers of MC and LV are estimated considering the average reduction of MC and LV caused by BRT. The number of HV is not changed at feeder roads.

On the basis of the above BRT design, the effectiveness of noise reduction of BRT is examined. Considering that the short-term plans examined in **3.1** are basic measure against the RTN, the effectiveness of BRT system is evaluated under the best condition of the first step shown in Table 5. The effectiveness is examined when the rates of reduction of MC and LV are varied from 0% to 100% and the good scenario when the largest noise reduction is obtained is searched.

After expecting the new traffic composition for all target roads, $L_{\mathrm{Aeq,day}}$ at each road under new traffic composition is calculated by using the ASJ RTN-Model 2008 in the same way as previous step. Table 7 shows an example of expected $L_{\mathrm{Aeq,day}}$ at each target road after 20% of vehicles are reduced in both MC and LV when assuming the LF of BRT is 75%. In this table, "Diff" means the difference between $L_{\mathrm{Aeq,day}}$ before and after BRT implementation. The "Diff" value varies from 0.0 to 5.4dB. The maximum (5.4dB) takes place at Road No.5 and the minimum (0.0dB) does at Road No.20, which presents noise reduction depends on how much LV and MC are reduced by the implementation of BRT. And the effectiveness of BRT is 2.7dB on average.

Figure 7 shows the noise reduction for all combinations of reduced percentages of MC and LV. Noise reductions vary from 2.0 to 6.0dB. Table 8 presents a selected combination scenario among them. Here, C-60-20 in the column scenario, for example, means 60% reduction of MC and 20% reduction of LV. It is found that the average and maximum of noise reduction are 4.7dB and 6.2dB, respectively. This implies BRT implementation could reduce the RTN in Makassar City to the desired noise level.

Table 7 $L_{\mathrm{Aeq,day}}$ After Implementation of BRT

Road No.	BRT Corridor	Number of Vehicle (vehicle/day)						$L_{\mathrm{Aeq,day}}$ (dB)		
		Present			After Measure			Present	After Measure	Diff
		LV	HV	MC	LV	HV+ BRT	MC			
1	BRT3	1681	22	2799	720	102	2665	73.1	71.9	1.1
2	BRT3	1174	36	2107	505	116	1900	71.1	69.3	1.7
3	Feeder	1021	95	3064	854	95	2918	72.0	70.3	1.7
4	Feeder	535	83	1441	447	83	1372	70.1	66.7	3.3
5	Feeder	1473	41	1473	1233	41	1403	73.0	67.7	5.4
6	Feeder	2156	29	3207	1805	29	3054	71.0	70.6	0.5
7	BRT6	767	195	2041	373	235	1953	73.1	70.3	2.8
8	Feeder	839	76	2435	702	76	2319	73.1	71.9	1.1
9	Feeder	764	33	1841	639	33	1753	71.0	70.4	0.7
10	BRT2	963	75	2684	382	155	2455	72.1	68.5	3.6
11	Feeder	964	109	2186	807	109	2082	73.1	70.3	2.7
12	Feeder	1324	20	1776	1108	20	1691	70.0	67.7	2.3
13	BRT4	766	233	1507	362	273	1421	72.1	67.4	4.7
14	BRT5	512	19	2682	287	79	2457	72.1	70.4	1.7
15	BRT3	2896	356	5740	1506	436	5713	73.0	71.9	1.1
16	Feeder	1254	173	2829	1049	173	2694	70.0	68.9	1.1
17	BRT3	2999	80	4093	2068	160	3951	71.0	70.5	0.5
18	BRT2	2358	22	3029	1115	102	2965	72.1	69.4	2.6
19	BRT2	758	52	1905	258	132	1641	71.1	66.4	4.6
20	BRT5	2698	106	4112	1601	166	4106	71.1	71.0	0.0
21	BRT3	851	132	1683	327	212	1439	70.1	64.9	5.2
22	Feeder	846	12	1102	708	12	1049	70.1	65.2	4.9
23	BRT2	2393	14	2630	1137	94	2570	71.1	68.4	2.6
24	Feeder	1976	23	2863	1654	23	2726	72.0	68.0	4.1
25	Feeder	1642	118	1822	1374	118	1735	72.1	68.6	3.4
26	Feeder	2221	31	2619	1859	31	2494	70.1	67.2	2.9
27	BRT3	2670	63	3535	1632	143	3420	71.1	70.8	0.2
28	BRT3	1650	187	3713	863	267	3535	72.1	70.3	1.8
29	BRT3	1922	120	4179	1089	200	4013	71.1	69.8	1.3
30	BRT1	3481	111	6361	1956	231	6181	72.0	70.5	1.5
31	BRT1	3807	136	6857	2249	256	6685	72.1	70.9	1.1
32	Feeder	2497	127	3700	2090	127	3524	71.1	70.0	1.0
33	BRT1	5585	470	8706	3396	590	8691	72.1	71.7	0.3
34	BRT1	4396	279	8576	2737	399	8529	73.1	72.2	0.8
35	BRT1	2893	272	6010	1691	392	5811	73.1	70.4	2.7

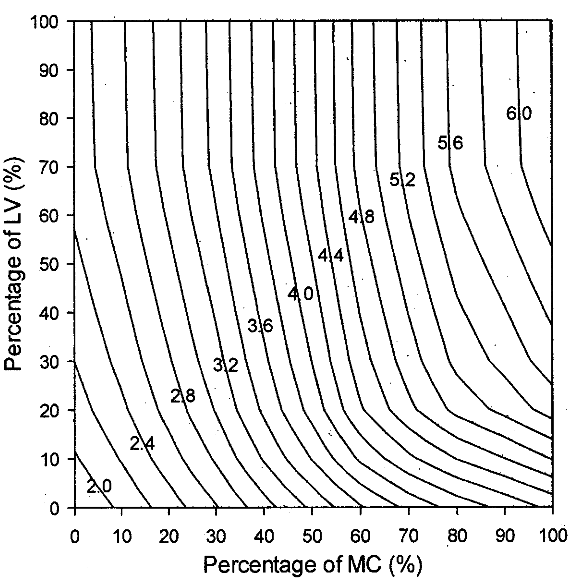


Fig. 7 Noise Reduction by the BRT System

3.3 Evaluation of Achievement Rate of the TDM-TMS Measures in Reducing the RTN

In the Environmental Quality Standards for Noise in Japan, the standard value is defined for each area type and time category, and achievement shall in principle be evaluated by obtaining numbers and rates of the houses at which noise levels exceed the environmental quality standards stipulated for the respective areas, which is commonly called 'spatial evaluation' [13]. In order to evaluate the effectiveness of TDM-TMS measures in reducing the RTN in Makassar City, the concept of spatial evaluation is applied with the proviso that the standard in Indonesia is used.

The noise map is drawn up on the basis of expected $L_{\mathrm{Aeq,day}}$ in Table 8 by using RTN-GIS in Makassar City which has been constructed in the previous study[8]. The noise level in front of each house is compared with noise standard and the number of houses satisfying the noise standard is counted. Figure 8 shows the achievement rate of the Environmental Quality Standards. The achievement rate of the EQS in the current time is only 23.2%, nevertheless expected achievement rate under the best condition might be improved to be 51.4%. This indicates that the implementation of the TDM-TMS measures in reducing the RTN in Makassar City provides 28.1% points up in the achievement rate of the EQS.

Table 8 Selected Noise Reductions

Road No.	Scenario	Noise Reduction (dB)	Road No.	Scenario	Noise Reduction (dB)
1	C-60-20	4.8	19	C-40-20	3.4
2	C-40-20	3.4	20	C-70-30	4.9
3	C-50-20	3.9	21	C-40-20	3.4
4	C-40-20	3.4	22	C-20-10	2.5
5	C-70-40	5.0	23	C-60-20	4.4
6	C-80-40	5.4	24	C-30-20	3.0
7	C-60-20	4.4	25	C-100-70	6.2
8	C-60-20	4.4	26	C-40-20	3.4
9	C-50-30	4.0	27	C-70-40	5.0
10	C-40-20	3.4	28	C-80-60	5.6
11	C-90-70	5.8	29	C-80-50	5.5
12	C-80-60	5.6	30	C-90-50	5.7
13	C-90-40	5.6	31	C-90-50	5.7
14	C-70-40	5.0	32	C-80-30	5.3
15	C-90-50	5.7	33	C-100-100	6.2
16	C-70-40	5.0	34	C-90-60	5.8
17	C-70-40	5.0	35	C-90-60	5.8
18	C-30-10	2.8			

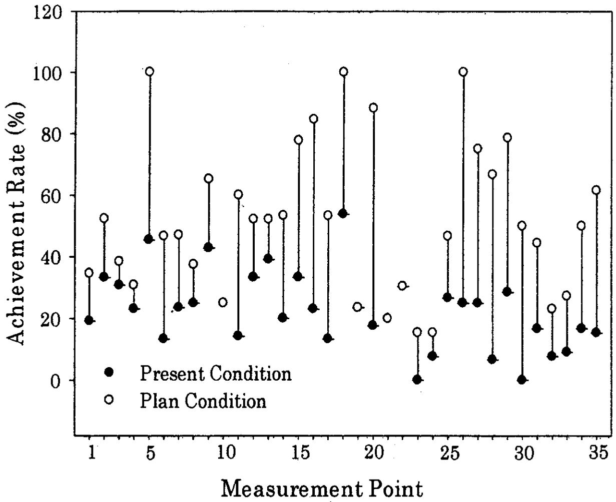


Fig.8 Achievement Rate by Measure

4. Conclusion

Travel demand management (TDM) and traffic management system (TMS) strategies are elaborated to mitigate the road traffic noise in Makassar City, Indonesia. At first, the effectiveness of three in one and two in one which are based on a ridesharing or car-pooling policy to reduce the number of light vehicles and motorcycle especially for private passenger car and prohibition to generate vehicle horn are examined as short-term measure. The expected noise reduction when these three measured are jointly carried is 2.4dB on average at whole 35 roads, however this is not satisfactory. Then, the introduction of BRT to 21 roads among 35 target roads in Makassar City is examined as middle-term measure. BRT system provides noise reduction of 4.7dB on average, and the implementation of the total TDM-TMS measures in reducing the RTN in Makassar City provides 28.1% points up in the achievement rate of the EQS.

The authors wish the results of this study are useful for a grand scenario to mitigate the road traffic noise in Makassar City in the future, and the sustainable environmental development can be achieved.

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