SIMULATING NETWORK IMPACTS FOR INTRODUCING TWO-WAY TRAFFIC SYSTEM AND PEDESTRIAN AREA AT THE CITY CENTRE: A Case of Yogyakarta City, Indonesia

Danang Parikesit[1]

ABSTRAK

Dua strategi pembangunan perkotaan penting yang diadopsi Kota Yogyakarta adalah (1) revitalisasi pusat kota melalui penataan manajemen lalulintas dan prioritas bagi pejalan kaki, dan (2) dekonsentrasi pembangunan kota dan pengembangan pusat kota baru. Selain mendorong investasi swasta, strategi ini akan memperbaiki kualitas udara di pusat kota dan pemanfaatan kapasitas jaringan jalan. Jumlah pejalan kaki, kendaraan tidak bermotor dan angkutan umum akan mengurangi emisi dan konsumsi energi.

Penelitian dilakukan pada proses evaluasi rencana perubahan jalur satu arah menjadi dua arah dan uji coba pedestrianisasi dengan piranti lunak EMME/2. Pengenalan lalulintas dua arah di jalan Abubakar Ali – Pasar Kembang serta segmen pejalan kaki di pusat kota akan mengurangi lalulintas menerus dan memindah lalulintas ke sistem loop yang dikenalkan sekitar pusat kota. Skenario tersebut mengurangi 20% kendaraan-km dan 13% kendaraan-jam. Meskipun kecepatan kendaraan berkurang dari 25,5 km/jam menjadi 23,5 km/jam, skema ini tetap menunjukkan penghematan BBM tahunan sebesar 251.892 liter atau setara Rp 453.266.302,00 dengan tingkat harga BBM saat ini. Skema ini akan mengurangi polusi udara di wilayah penelitian sebesar 13,04% - 15,69% serta peningkatan kondisi transportasi tidak bermotor.

Penelitian lebih lanjut akan diarahkan untuk menerka dampak dari jaringan transportasi yang lebih luas serta mengembangkan kerangka kerja untuk penghambat pengemudi motor serta manajemen parker yang sesuai.

Kata kunci*: manajemen lalulintas, pedestrianisasi, EMME/2, Yogyakarta*

INTRODUCTION

The rapid urbanization experienced by many cities in Indonesia has seriously posing a challenge in meeting their demand for mobility. Cities are becoming megapolitan, land use can not be controlled with ease, and wide income distribution creates disaggregated needs for transport infrastructure and services. Growing Asian cities as reported by Newman and Kenworthy (1999), has been associated with high density areas in the city's perimeter and urban relocation dynamics, especially with regard to housing location. Indonesian cities are no exception. Recent data compiled by Kasto, et.al (reported in Parikesit, et.al, 2004) demonstrated that urban population has steadily increased from 22.3% in 1980 to 30.9% in 1990, and then reaching 42.4% in 2000. It means that not only the percentage is higher, but the rate of change (that is the percentage increase) is also becoming bigger, from average 0.72% per year between 1980 – 1990, to average 0.96% per year between 1990 and 2000.

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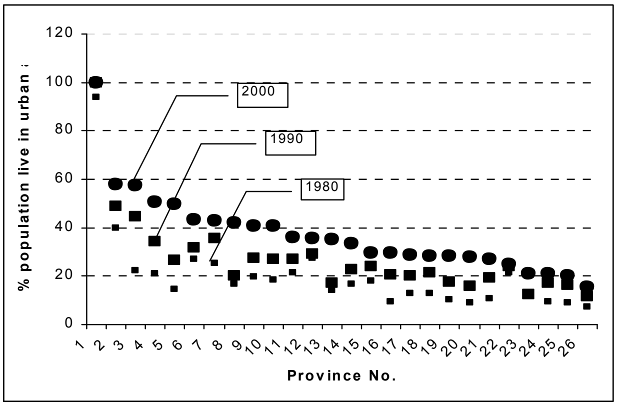

Figure 1. Percentage of urban population living in a province
(source: Parikesit, 2004, pp. 7)

The City of Yogyakarta on the other hand, has an opposite trend. When other cities are growing in the exponential rate, the urban area of Yogyakarta has an increasing trend of urbanization but at a decreasing rate, that is the rate of increase tends to be lower overtime. Figure 2 below demonstrates that the business as usual scenario of urban population will stabilize its density around 60% - 70% of its province population, or around 2 – 2.30 million people.

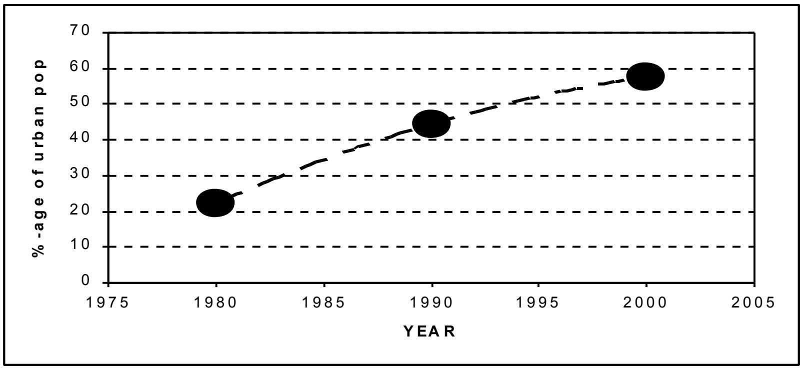

Figure 2. Trend in percentage of urban population for Yogyakarta Province
(source: Data collection)

The situation is obviously a result of exogenous and indigenous factors. Besides the economic and geographical carrying capacity of the region, the local governments of Yogyakarta, both at provincial and city level have determined basic strategies in regard with urban development. Two of the important strategies in urban development currently adopted by the city of Yogyakarta, Indonesia are (1) the revitalization of the city center through improved traffic management and pedestrianization and (2) deconcentration of city development and promoting new growth centers. Parikesit and Zudianto (2002) revealed by creating a two-tiered approach, the city will gain several objectives, namely creating new employment and economic centers, creating more efficient urban space and ensuring the city center to be environmentally friendly – thus remain attractive for local visitors as well as for tourists.

The City Government of Yogyakarta is currently considering a pilot pedestrianization scheme in Malioboro Street, its main busy street. With approximately 30,234 cars and 179,813 motorcycles (PUSTRAL, 2004), the street's capacity cannot cope with its demand. The motorized modes have also created a severe and prolonged congestion problem. As a result, the air quality has worsened overtime. The recent survey conducted by Environmental Impacts Control Office of the Yogyakarta City Government in 2003, shows that the ambient level at Malioboro area especially HC (Hydrocarbon) is above the national emission standard. Although other parameters are still below the emission standards, in two years they have increased by almost 30% (i.e. CO).

The pedestrianization scheme basically aims at creating a zero emission zone in the city centre and discouraging through traffic. By achieving its objectives, it is expected that such scheme will contribute significantly to the two strategies mentioned above. This research is attempted to investigate the transport and emission reduction impacts of such road closure.

DESCRIPTION OF THE PILOT PEDESTRIANIZATION SCHEME

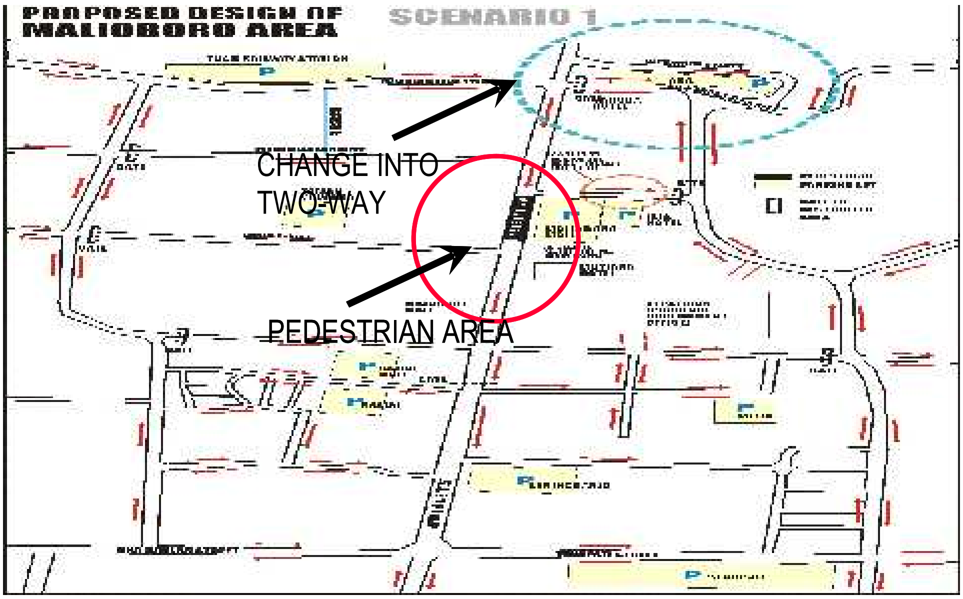

Figure 3. Proposed Pilot Two-way system and Pedestrian Area
Source: LCI, ITDP, 2004

The pilot pedestrianization scheme focuses on a permanent road closure in the middle part of Malioboro Street. After several workshops and technical meetings, the city government decided to initiate develop pedestrian area in the front of Malioboro Mall. The main consideration of the scheme is to exploit the highest potentials of pedestrian activities, improving the shopping comfort and thus gaining public support.

Figure 3. shows the location of road closure and the likely traffic rerouting scheme.

By closing a road segment in the front of Malioboro Mall, traffic flow needs to be adjusted accordingly. Except non-motorized traffic, vehicles traveling along Malioboro Street should be rerouted along Sosrowijayan and Dagen streets. The road closure is a compliment to the change from one-way street of Pasar Kembang (eastbound direction) and Abubakar Ali (westbound direction) into two-way streets. The purpose of the change into two-way street and pedestrian area is to reduce the burden of through traffic traveling along Malioboro – Ahmad Yani Streets. The traffic flow will then be redirected to use surrounding road network.

USING EMME/2 TO SIMULATE NETWORK IMPACTS OF THE PROPOSED SCHEME

Theoretical foundation

The network simulation model was developed to solve the complex equation. It attempts to reveal the rational choice of road user when they are conflicted with network information and situation.

The road network is represented by links and nodes and acts as a channel to facilitate the movement of traffic. The ultimate condition sought after by the user and the system is the equilibrium. Sheffi (1985) categorized the state of equilibrium into user-equilibrium (UE) and stochastic-user-equilibrium (SUE). The UE is characterized by a condition when no traveler can improve his/her travel time by unilaterally changing routes, and SUE identifies a stable state when no traveler believes that his/her travel time can be improved by unilaterally changing routes. The other approach is by adopting a system optimum where traffic organizes itself to yield minimum total transport costs – hence maximizing its utility. The later principle, known as Wardrop second principle (Ortuzar and Willumsen, 1994) reveals a system approach looking at the dynamic of traffic system in rearranging its travel decision.

Most models assume that system approach based on generalized costs will be most appropriate. However, it was also agreed that formulating and providing a numerical analysis of generalized costs is itself a complex research subject.

Mathematical representation of the proposed approach is as follows:
Min

$$f(v) = \sum_{a \in A} \int_0^{v_a} s_a(v + x_a)dv + \sum_{i \in I}^{-} \sum_{a_1 \in A_i}^{-} \sum_{a_2 \in A_i}^{+} \int_0^{Va1a2} P_{a1a2}\left(v + x_{a1a2}\right)dv \quad \text{..........(1)}$$

Subject to :

$$v_a = \sum_{k \in K} \delta_{ak} h_k \qquad a \in A$$

$$v_{a1a2} = \sum_{k \in K} \delta_{a1k} \delta_{a2k} h_k \qquad a_1 \in A_i ; a_2 \in A_i ; i \in \bar{I}$$

$$\sum_{k \in K_{pq}} h_k = \left(\frac{g_{pq}}{\eta_{pq}}\right) + \gamma_{pq} \qquad p \in P ; q \in Q$$

$$h_k \geq 0 \qquad k \in K_{pq} ; p \in P ; q \in Q$$

with :

- Indicators and Sets
  $p \in P$ origin zones
  $q \in Q$ Destination zones

$i \in I$	nodes of auto network
$a \in A$	links of auto network
$a \in A_i^-$	links "ending" at node i
$a \in A_i^+$	links "starting" at node i
$k \in K_{pq}$	origin zones

- Constants

δ_{ak}	1 if a link belong to path k
g_{pq}	auto demand from p to q (person)
η_{pq}	car occupancy for OD pair p,q (person/car)
γpq	additional demand (vehicles)
x_a	additional volumes on link a (vehicles), volad
x_{a1a2}	additional volumes on turn a (a_1a_2), pvolad

- Functions

Sa(va)	Volume delay or cost function on link a, fdxx
P_{a1a2} (v_{a1a2})	penalty function on turn (a1a2), fpxx

- Variable

v_a	auto volume on link a, volau
v_{a1a2}	auto volume on turn (a1, a2), pvolau
hk	flow on path k

The OD (origin-destination) matrix is developed using existing traffic flow entering and leaving the closed network – thus producing a synthetic matrix. This approach is employed since no dedicated OD survey was carried out during data collection and the network is too small to recognize the actual origin and destination of the travel. A bi-proportional approach originally developed by Furness (Ortuzar and Willumsen, 1994) was proposed to obtain synthetic OD matrix. With α and β reflect the polarities for p (origin) and q (destination) zones respectively, the principle is as follows:

$$g_{pq} = \alpha_p . \beta_q \text{ for every OD pair (p,q)......(2)}$$

subject to:

$$\sum_q g_{pq} = O_p \quad \text{for every origin p}$$

$$\sum_p g_{pq} = D_q \quad \text{for every destination q}$$

$$g_{pq} \geq 0 \quad \text{for every OD pair (p,q)}$$

$$\sum_p O_p = \sum_q D_q$$

Characteristics of the simulation software

EMME/2 software was developed in the early 80's by The Center of Research on Transportation (CRT), University of Montreal. Since 1986, further development and technical support of EMME/2 has been provided by INRO Consultant (INRO, 1998). Abbreviated from Equilibre Multimodal, Multimodal Equilibrium, the software is an advanced transport modeling software combining numerical with graphical solution of transport simulation problems. The software used in the research is EMME/2 Release 9. Like any other transport simulation models, it requires a series of basic inputs, namely:

a. Road network characteristics and link costs
b. OD matrix
c. Traffic flow characteristics

After several steps of simulation it produces various outputs:

a. Auto Time dan Volume on network
b. Auto Time and Volume on intersection
c. Shortest path analysis
d. Transit Volume and times
e. Transit Time table

Modeling assumptions and risks

Assumptions and risks are like the two sides of a coin. When assumptions can not be maintained then the risks associated with models' predictability will rise. Modeling travel behavior in a closed network bear several risks as follows:

a. Its predictability depends on the quality of traffic and network data. Most western model assumes standard PCU values and travel characteristics. However, as pointed out by other researches, the vehicular travel behavior in a mixed traffic often jeopardizes the concept of standard PCU. The "disruption level" as a basis for measuring equivalent standard car unit might not appropriate in such situation. The issue of capacity might also a big issue related with the effective road width. Indonesian highway capacity manual (MKJI, 1997) identified that the existing road width should be adjusted with side friction factors to obtain effective width and thus capacity. The road capacity in a congested urban center is indeed very sensitive with the marginal change in the side friction. As the congestion build up in an exponential scale over time, little disruption of side street activities will trigger the rapid decline of urban street capacity.

b. Public transport service. Irregular public transport service poses a modeling problem since the software can not accept probabilistic stop-and-go model of public transport operation. In the exercise, public transport is treated like other vehicular traffic allowing a steady flow of movement with lower travel speed. This assumption bears some risks for underestimating the role of public transport in promoting pedestrian area.

c. Modeling pedestrian crossings. The software has yet to integrate pedestrian crossing into the model. Pedestrian crossing modeling is a crucial in ensuring the success of a city center. The analysis is at the moment focusing on traffic assignmnt impacts of pedestrian scheme.

RESULTS OF THE SIMULATION

a. Issue in developing an OD matrix
The development of OD matrix for such a closed and limited network from externally defined zones has its risks. While it is essential to maintain the integrity of the results, the trips originating from the internal zone, i.e. Malioboro area can not be captured. Figure 4 below indicates that the trip going from and ending to a certain zone ignores the fact that Malioboro is also a zone of trips origin and destination. Using bi-proportional approach and traffic flow at the end of the network, the estimation of origin and destination matrix yield a satisfactory result with a convergence value below 10%.

The inability of measuring trips going to and coming out from Malioboro area (the trips coming out from Malioboro are mostly those living in the area), has a drawback. It will be impossible to estimate the actual demand for Malioboro as a destination zone, and thus posing a difficulty to use simulation result to plan and design transport infrastructure facility for the area, i.e. parking.

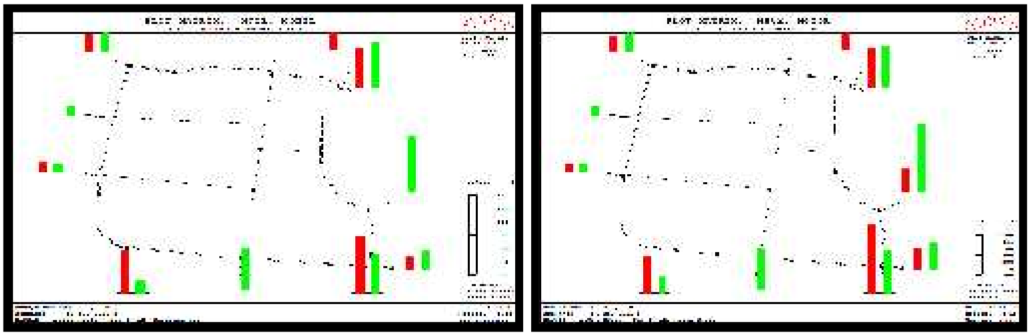

Figure 4. Simulated OD for four-wheeled vehicle (left) and motorcycle (right)
Source: LCI, ITDP, 2004

b. Simulation summary
Traffic assignment simulation has demonstrated a significant reduction in the traffic flow in the intended road segments, notably along Malioboro and Ahmad Yani streets. Traffic along Malioboro and Ahmad Yani Street, is redirected to artificial ring road, creating higher traffic flow along those roads. Figure 5 below shows the differences between base scenario and proposed scenario. The proposed scenario is benefited substantially from the change from one-way street into two-way system along Abubakar Ali – Pasar Kembang streets, allowing westbound-eastbound traffic to avoid the obligation passing through Malioboro – Ahmad Yani Streets.

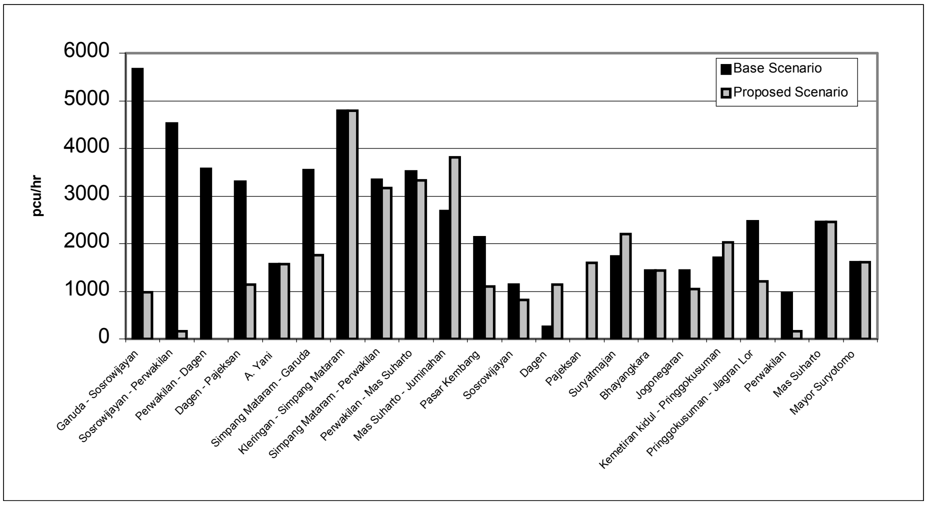

Figure 5. Traffic volume in a base and proposed scenario (peak volume)
Source: LCI, ITDP, 2004

It is evident that the potential benefit of pedestrian scheme can only be exploited if the scheme is complimented by the introduction of two-way street system along Abubakar Ali – Pasar Kembang Street. Without such measure, the pedestrian scheme will create a tremendous bottle neck along Malioboro Street, jeopardizing the initial intention for project. The city government should thus treat the scheme as a bundled project instead of separate and independent project. The bundling ensures benefits can be exploited fully.

Table. 1. Summary results

No	Variables (in peak hour)	Types of vehicles	Base scenario	Proposed scenario
1	Vehicle kilometer	Four-wheeled	2,492.1	2,003.3
		Motorcycle	10,199.2	8,268.4
2	Vehicle hours	Four-wheeled	93.6	82.1
		Motorcycle	418.1	361.1
3	Travel speeds (kph)	Four-wheeled	27	24
		Motorcycle	24	23

Source: Simulation results

While it is important to note that overall travel speed is decreased from 27 kph to 24 kph for car and from 24 kph to 23 kph for motorcycle, the main benefit for the scheme is attributable to the substantial reduction in the travel demand, both in total travel distance and travel time. The reduction of travel speed will increase full consumption. The optimum fuel consumption (known as "fuel economy") for both diesel and gasoline fueled car is estimated to be around 60 – 80 kph (Parikesit, 1996). The increase in the fuel consumption is offset by the decrease in the travel distance and time. In total, the simulation yield less fuel consumption and thus produce travel costs savings.

Table 1 above shows the summary of vehicle travel characteristics.

c. Impacts of pedestrian scheme

The simulation exercise demonstrates that the introduction of two-way street along Abubakar Ali - Pasar Kembang and pedestrian scheme in the city center has forced vehicular traffic to reassign its routes to the allowable road segment. While the majority of vehicles will be using Abubakar Ali – Pasar Kembang and Gandekan – Suryotomo for eastbound-westbound traffic in a relatively even proportion, the southbound and northbound direction require more attention. Figure 6 below demonstrates the graphical results of the simulation.

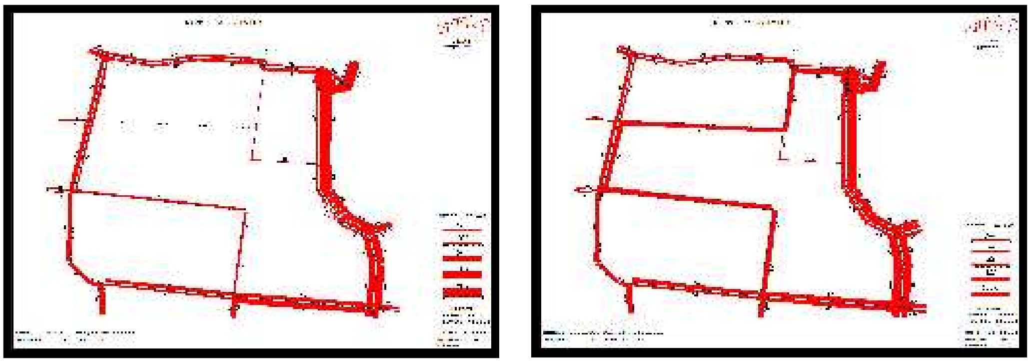

Figure 6. Simulation results for four-wheeled traffic (left) and motorcycle traffic (right)

Source: LCI, ITDP, 2004

The proposed scenario gives a tremendous burden to Mataram Street. Figure above shows that the bulk of north and south-bound direction of traffic using Mataram Street. With the existing V/C Ratio of 0.78 the scheme will produce the ratio of 0.82. Not only the road segment suffers from the increase in traffic volume and reduced V/C ratio, the Suryotomo junction also receiving a great burden from reassigned traffic. It is thus important that during implementation, the intersection's capacity is improved by redesigning its geometry, i.e. introduce canalization for right turn vehicles and narrowing the intersections' arms – thus reducing the loss time for crossing it. The results of the simulation on Suryotomo junction is shown in Annex 2.

Since the simulation has produced a fuel consumption savings, it is now possible to estimate the air pollution impact of the scheme. Using Walsh Emission Factors developed further by Syahril et.al (2002), the selected parameter of air pollution reduction can be estimated (shown in Table 2).

Table 2. Emissions and air pollution impacts

No	Components	Baseline (ton)	Proposed scenario (ton)	Reduction
1	THC	171.88	144.92	15.69%
2	CO	710.29	603.64	15.01%
3	NOx	31.26	26.62	14.84%
4	N2O	0.46	0.40	13.04%
5	CH4	5.62	4.74	15.66%
6	PM10	1.82	1.54	15.38%
7	SOx	3.13	2.70	13.74%
8	CO2	4,265	3,685	13.60%

Note: Calculation is based on the Study on Air Quality in Jakarta, Indonesia: Future Trends, Health Impacts, Economic Value and Policy Options, Shanty Syahril, Budi P. Resosudarmo, Haryo Satriyo Tomo, 2002 using Walsh Emission Factors (2002)

Non-motorized traffic or NMT, as depicted in ANNEX 1 has enjoyed the benefit of two-way traffic system and road closure. The simulation scheme allows NMT to freely passing through Malioboro-Ahmad Yani Street and substantially reduced travel distance due to shorter travel distance. Earlier work by Parikesit (2003) has identified that the existing one-way traffic in Malioboro Area is not only encouraging violation of traffic regulation, but more importantly discouraging the use of NMT. Because of the high demand for NMT, particularly along Gandekan-Suryotomo Street, it is suggested that the city government provide a dedicated infrastructure for NMT on that corridor.

CONCLUSIONS AND FUTURE RESEARCH

The introduction of a two-way traffic system along Abubakar Ali – Pasar Kembang and pedestrian area at the city centre reduces through traffic and divert the existing traffic to use a loop system introduced around the city centre. It reduces traffic congestion and energy consumption and this vehicle emission. The scenario reduces 20% of vehicle-km travel, 13% of vehicle-hours, and will reduce average travel speed from 25.5 kph to 23.5 kph. As a consequence, the scheme will yield annual fuel consumption savings of 251,892 liter of gasoline or equivalent to Rp. 453,266,302 with the current fuel price. The scheme will have a reduction in the air pollution emitted by vehicular traffic between 13.04% - 15.69%. It will also benefit the use of non-motorized traffic in the city center.

Future research is to estimate impacts of the scheme to larger road network as well as to develop a framework for area wide traffic restraint and parking management.

ACKNOWLEDGEMENTS

The author would like to thank the City Government of Yogyakarta - ITDP/USAID for the Livable Community Project research grants provided through the Centre for Transportation and Logistics Studies. The author is indebted to Mr. Wiratama, MT. - transport analyst and EMME/2 modeler, Mr. Iwan Juhri and Ms. Restu Vita Dj. - project officers during data collection and analysis.

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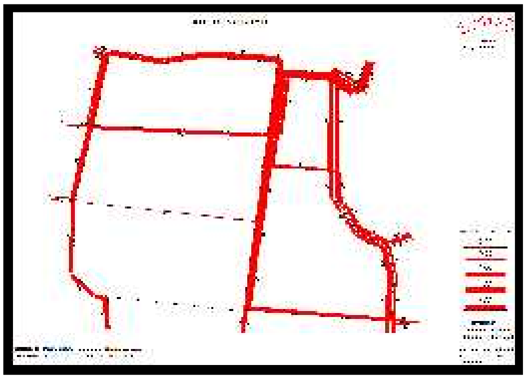
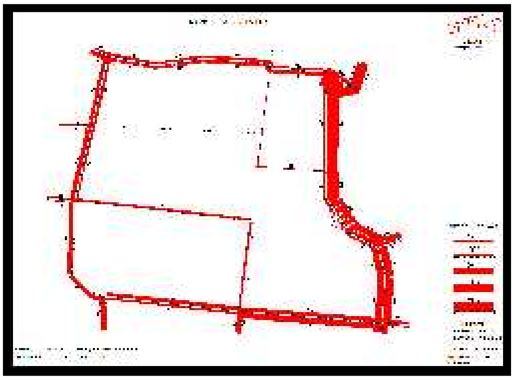
ANNEX 1: GRAPHICAL RESULTS OF SIMULATION

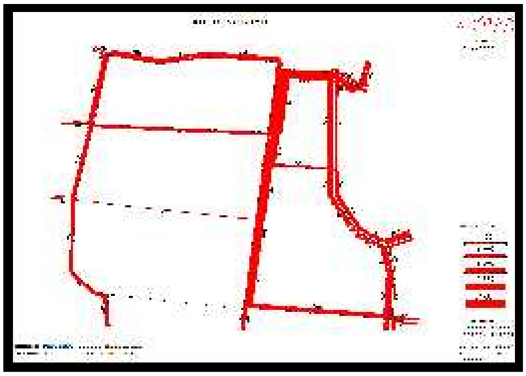
BASE CASE **PROPOSED SCENARIO**

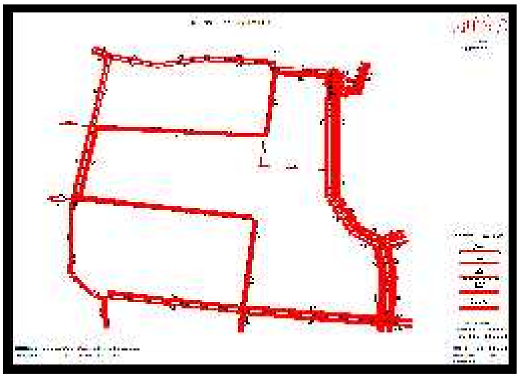
FOUR WHEELED TRAFFIC



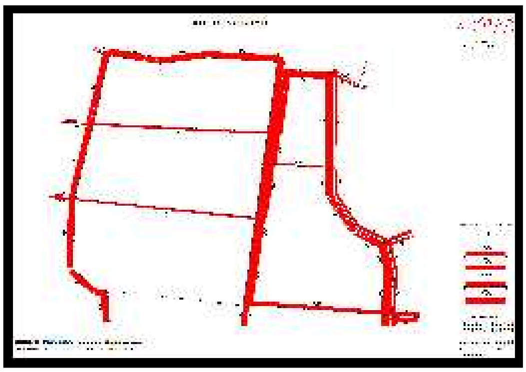


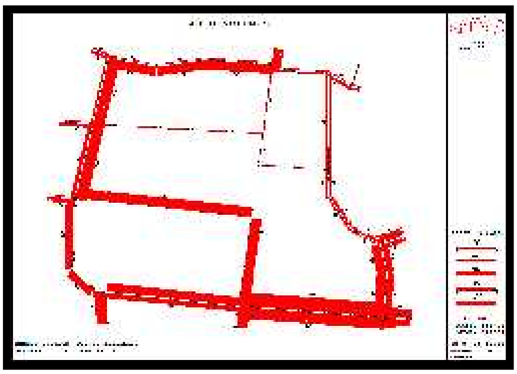
MOTORCYCLE TRAFFIC





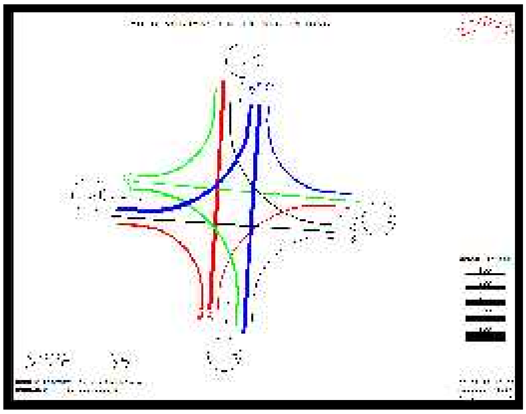
NON MOTORIZED TRAFFIC





ANNEX 2: RESULTS OF SIMULATION – SURYOTOMO INTERSECTION TURNING MOVEMENT

FOUR-WHEELED TRAFFIC



MOTORCYCLE TRAFFIC