A mathematical model for optimisation of traffic operations performance

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Abstract

This paper describes a model which is used to optimise the traffic operating conditions to obtain the desirable situation of traffic operations performance in term of total passenger productive capacity and analyse traffic-related environmental impacts. The results of the model application for three scenarios are discussed in aspects of level of service, maximum vehicle service capacity, environmental impacts and total productive capacity. The results revealed that the mathematical model is a useful tool in traffic operations performance evaluation and traffic-generated environmental pollution analysis.

1 Introduction

Traffic-generated environmental pollution requires serious attention in the metropolitan areas of most countries. This is due to many factors. Firstly, in many urban areas, rapidly increasing traffic volumes, lower vehicle operating speeds, the type of fuel used and/or the elder age of vehicles, have resulted in excessive gas emissions and the generation of traffic noise pollution. Secondly, traffic problems such as congestion, and their resulting effects on the quality of the urban environment, are becoming major items in the key agenda of issues, and environmental considerations will play a dominant role in urban traffic systems in the future. Thirdly, there are significant relationships between the characteristics of an urban traffic system and the quality of the urban environment. Thus, it is necessary to analyse motor vehicle emissions, vehicle-
generated noise and introduce some technological changes or
policies/regulations to control and reduce them (Ma[2]).

This paper highlights a mathematical model which optimises traffic
operations performance in term of total passenger productive capacity of a road,
i.e. the maximum amount of travel which can be accommodated on the facility
during a given time period, which is a combination of the person capacity and
the speed, subject to reduce traffic congestion and minimise environmental
pollution produced by motor vehicles.

2 Conceptual framework

In this research, the basic hypothesis is that an optimal set of operating
conditions and strategies for achieving them exist and can be obtained in a given
area. To investigate this hypothesis, the main goals of this paper are to:
(a) determine the optimal values of operating conditions in an urban
traffic artery;
(b) compare the existing conditions with the optimal values and thus
the operating problems in the artery;
(c) determine the appropriate strategies for the artery.

Traffic operation performance is considered to be optimal when the passenger
productive capacity of each traffic route is maximised with the following
conditions being satisfied:
• existing vehicular characteristics, e.g. types of vehicles (car, bus,
truck and motorcycle), physical characteristics of each type of
performance (acceleration/deceleration, maximum speed), number
of vehicles and location of transportation facilities;
• available right-of-way;
• desirable environmental quality in terms of air and noise pollution
control.

An attempt is made to investigate the influence of some strategies on the air
and noise qualities-based service flow rates. In particular, according to the
existing situation, the impacts of adding a lane for a high occupancy vehicle,
controlling traffic volumes, and promoting low emission vehicles will be taken
into account.

3 The mathematical model description

In the model, different transport modes, traffic movements, traffic lanes, vehicle
characteristics, uniform segments and disturbed segment-intersections with
traffic control and intersections without traffic control have been considered.

The objective function is to maximise the total passenger productive capacity
of a road, subject to: 1. Traffic demand is less than maximum vehicle service
capacity: \( Q/C < 1.0 \); 2. Concentration of emission is lower than the current
emission standard: \( C_e (\text{concentration of a pollutant}) < S_e (\text{emission standard}) \); 3.
Traffic noise is lower than the current noise standard: \( L_{eq} (\text{noise level}) < S_n \)
The main part of this model consists of: "initialise", "calculate" and "print". In the sub-procedure of calculation, q/c rate, Ce and Leq are computed by applying inputs. If these three conditions are satisfied simultaneously, the optimal result of total passenger productive capacity will be achieved; Otherwise, in the part of optimisation which belongs to the sub-procedure of calculation, different strategies are considered. The basic control variable is traffic flow Q from which other variables are derived. From this point, this study takes insight into three alternatives which are related to traffic flow adjustment. They are: 1. add an HOV lane; 2. control an access rate of large vehicles (trucks) to the arterial road; 3. promote low emission vehicles together with controlling an access rate of large vehicles (trucks) to the arterial. The program runs forward until an alternative is found which can meet the three conditions mentioned above. The model approach methodology is shown as figure 1.

Figure 1. The model approach diagram.
The objective and subjective formulas used in the model are given by:

**Objective formula**

**Total passenger productive capacity:**

\[
TPRODCAP = \sum_{i=1}^{k} \sum_{l=1}^{m} \sum_{i=1}^{i} TS(m,l,k) \cdot MAXCAP(m,l,k) \cdot \sum_{i=1}^{m} \sum_{l=1}^{i} PF(m,l) \cdot Occ.(m,l)
\]  

(1)

**Subjective formulas**

**Maximum vehicle service capacity:**

- signalised intersections

\[
MaxCap. = IMaxCap \cdot NL \cdot f_w \cdot f_r \cdot \frac{TG}{TC} > Q_k
\]    

(2)

- uniform segments

\[
MaxCap. = IMaxCap \cdot NL \cdot f_w \cdot f_r > Q_k
\]    

(3)

**Concentration of a pollutant**

downwind:

\[
C_c(j,k,p) = \frac{0.7 \cdot TE(j,k)}{(u+0.5) \cdot (2 + \sqrt{X_c^2 + Y_c^2 + Z_c^2})} < S_c(j)
\]    

(4)

upwind:

\[
C_c(j,k,p) = \frac{7 \cdot TE(j,k) \cdot (H_b - Z_c)}{W_r \cdot (u+0.5) \cdot H_b} < S_c(j)
\]    

(5)

**Noise level**

\[
Leq = 10 \log \left( \frac{1}{N} \sum_{i=1}^{N} \sum_{m=1}^{M} Q \cdot 10^{ \frac{L_{eq,0}}{10} } \right) < S_n
\]

(6)

where

- TPRODCAP: total productive capacity of a road from road section 1 to section k in passenger-kilometres per hour,
- TS (m, l, k): average travel speed of vehicle mode m at lane i on section k,
- MAXCAP (m, l, k): maximum vehicle service capacity of vehicle mode m at lane l on section k,
PF (m, l): proportion of vehicle mode m at lane l,
Occ.(m, l): occupancy of vehicle mode m at lane l,
MaxCap.: maximum vehicle service capacity,
IMaxCap.: ideal maximum vehicle service capacity of a segment, here using 1800 pcphpl,
NL: number of lanes on section k,
f_w: adjustment factor for lane width,
f_v: heavy vehicle factor,
TG: green time at a signalised intersection in second,
TC: cycle time length at a signalised intersection in second,
Q_k: traffic flow on road section k in vph,
C_j (j, k, p): concentration of pollutant j at a location p for downwind side and upwind side of road section k respectively in g/m³,
Q_{k+1}: traffic flow on road section k+1 in vph,
TE (j, k): total quantity of pollutant j emitted by all vehicles on section k in g/time period,
u: average wind speed in m/s,
X_g, Y_g: effective distance in metre parallel and perpendicular to the wind direction from midpoint of the section k to the location of the receiver respectively,
Z_g: effective height of receiver above the ground in metre,
H_b: average height of roadside building in metre,
W_r: right-of-way of the section k in metre,
L_{eq}: noise level in dB,
N: number of interval time i,
L_{im}^D: average noise level during interval time i generated by vehicle mode m at the distance D from traffic noise source.

4 Model application

To validate the model, an urban traffic artery E Do Hori Route in Osaka city (Japan) has been studied as a case. There are 7 signalised intersections, numbered as A, B, C, D, E, F and G, on the artery of 1.89 km, which is one of the most busy routes in Osaka city due to its commercial location. This paper chose the artery because all necessary data to apply this model are available and worse situation of traffic environmental pollution exists on this artery. Also there are several intersections within a short distance on this artery, forcing vehicles to stop and start within a short interval time, resulting in excessive emission produced.

Traffic on this artery is composed of several types of motorised vehicles including private cars, small trucks, big trucks and motorcycles which consist of light style motorcycles since they share lanes with higher speed vehicles, e.g. passenger cars. A 12-effective daytime traffic volume census data were available for the study artery. Based on it, the traffic flow rate on the artery is computed out and given in table 1.
**Table 1. Input data (traffic flow)**

<table>
<thead>
<tr>
<th>section</th>
<th>cars</th>
<th>buses</th>
<th>s. trucks</th>
<th>big trucks</th>
<th>motorcycles</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>770</td>
<td>12</td>
<td>400</td>
<td>176</td>
<td>75</td>
<td>1433</td>
</tr>
<tr>
<td>BC</td>
<td>807</td>
<td>21</td>
<td>354</td>
<td>132</td>
<td>48</td>
<td>1362</td>
</tr>
<tr>
<td>CD</td>
<td>810</td>
<td>22</td>
<td>346</td>
<td>139</td>
<td>56</td>
<td>1373</td>
</tr>
<tr>
<td>DE</td>
<td>727</td>
<td>21</td>
<td>289</td>
<td>83</td>
<td>42</td>
<td>1162</td>
</tr>
<tr>
<td>EF</td>
<td>2367</td>
<td>38</td>
<td>901</td>
<td>192</td>
<td>216</td>
<td>3714</td>
</tr>
<tr>
<td>FG</td>
<td>2053</td>
<td>27</td>
<td>827</td>
<td>151</td>
<td>183</td>
<td>3241</td>
</tr>
</tbody>
</table>

*unit: vph per section. There are 3 lanes on sections AB, BC, CD and DE, and 6 lanes on sections EF and FG. Source: Miyauchi planning research office, 1993.

The analysis shows that passenger cars occupy about 60.6% of the total traffic using this artery. Buses as motorised public modes of transport constitute about 1.4%. Trucks consisting of small trucks and big trucks were found to comprise 26.1% and 7.0% respectively. Finally, motorcycles, popular modes used for personal short-distance travel, comprise 4.9%. Regarding traffic control characteristics on this artery, fixed-time control system exists with time cycle length of 160 seconds at one intersection and 150 seconds at other six intersections. Particularly, there is external green time for right-turn traffic while at the phase of red time for left-turn and going straight movements. So the right-turn is protected (in Japan, the driving is on left-hand). The detail traffic signal control at every intersection is listed in table 2.

**Table 2 Input data (traffic control characteristics at intersections)**

<table>
<thead>
<tr>
<th>Approach*</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>60</td>
<td>56</td>
<td>49</td>
<td>90</td>
<td>42</td>
<td>-</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>87</td>
<td>56</td>
<td>64</td>
<td>46</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>56</td>
<td>49</td>
<td>90</td>
<td>42</td>
<td>-</td>
<td>42</td>
</tr>
<tr>
<td>8</td>
<td>87</td>
<td>56</td>
<td>64</td>
<td>-</td>
<td>85</td>
<td>103</td>
<td>85</td>
</tr>
</tbody>
</table>

*approaching direction to a 4-leg intersection. Source: Miyauchi planning research office, 1993.

5 Results analysis

5.1 General analysis

A change in scenario did not have a significant influence on vehicle running speed, time delay and average vehicle travel speed. The performances of these different strategies in conventional terms (running speed, time delay, average travel speed and LOS) varied depending on locations. Here each scenario is analyzed.
For scenario 1, the time delay had some reduction, compared with the scenario 0 (base-case), leading to improvements of the average travel speed, MaxCap and degree of saturation (q/c), within particular ProdCap considerably increasing. However, there is little influence on the concentration of a pollutant and noise level, which are still above their accepted standards.

Scenario 2 represents controlling the access rate of trucks approaching to the study-artery. This is a short-term strategy and easy to implement. In this scenario, running speed and average travel speed increased and ProdCap is improved. Just as in scenario 1, there is no influence on environmental quality in terms of air pollution and noise which are still above standard levels.

Scenario 3 is a quite long-term engineering solution. As expected, in this scenario, not only the traditional terms (TS, q/c) can be improved, but also the concentration of a pollutant and noise can be significantly reduced, leading to a large increasing of ProdCap, compared with scenarios 0. Therefore this scenario meets the purpose of this study.

5.1.1 Level Of Service (LOS) analysis
Table 3 tells that traffic performance at intersections A, B, and C is operated at level of service D, while at level of service C for intersections D, E, G and level of service B at the intersection F. Since all three scenarios can reduce the traffic delay and upgrade the degree of saturation (q/c) with a small value at the intersection, the LOS did not change much.

Table 3. A comparison of level of service at intersections

<table>
<thead>
<tr>
<th>scenario</th>
<th>criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>delay</td>
<td>35.8</td>
<td>33.4</td>
<td>36.6</td>
<td>14.1</td>
<td>20.9</td>
<td>10.3</td>
<td>19.0</td>
</tr>
<tr>
<td></td>
<td>q/c</td>
<td>0.80</td>
<td>0.79</td>
<td>0.78</td>
<td>0.57</td>
<td>0.82</td>
<td>0.65</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Los</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>delay</td>
<td>31.5</td>
<td>29.5</td>
<td>32.9</td>
<td>12.3</td>
<td>18.1</td>
<td>9.2</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>q/c</td>
<td>0.64</td>
<td>0.62</td>
<td>0.62</td>
<td>0.43</td>
<td>0.70</td>
<td>0.56</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Los</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>delay</td>
<td>31.2</td>
<td>29.5</td>
<td>32.9</td>
<td>12.3</td>
<td>18.1</td>
<td>9.2</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>q/c</td>
<td>0.64</td>
<td>0.62</td>
<td>0.62</td>
<td>0.43</td>
<td>0.70</td>
<td>0.56</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Los</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>delay</td>
<td>34.4</td>
<td>30.4</td>
<td>33.9</td>
<td>13.1</td>
<td>19.2</td>
<td>9.8</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>q/c</td>
<td>0.75</td>
<td>0.67</td>
<td>0.67</td>
<td>0.50</td>
<td>0.76</td>
<td>0.61</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>Los</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

5.1.2 Maximum Vehicle Service Capacity And Maximum Incapacity
Maximum vehicle service capacity (MAXCAP) and maximum vehicle incapacity MAXINCAP) is enlarged with the application of every scenario. MAXINCAP is defined as the maximum traffic flow rate which can enter a road uniform segment. In particular, significant result was obtained after applying the scenario 2 which taken into consideration the effect of adding one lane on the
main approach bound to an intersection, exactly adding one lane at the westbound for intersections A, B, C and D; and at southbound for intersections E, F and G. The same results for MAXCAP were obtained by applying scenario 2 and 3 since neither changed the geometric layout of an intersection, but they had the desirable influence on increasing an intersection’s MAXCAP and a segment’s MAXINCAP. The detailed results are shown in table 4 and table 5 respectively.

Table 4. Maximum vehicle service capacity

<table>
<thead>
<tr>
<th>scenario</th>
<th>inter</th>
<th>section</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>1,823</td>
<td>1,811</td>
<td>1,575</td>
<td>2,328</td>
<td>4,678</td>
<td>5,682</td>
<td>4,593</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>2,299</td>
<td>2,291</td>
<td>1,984</td>
<td>3,114</td>
<td>5,446</td>
<td>6,615</td>
<td>5,370</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>1,915</td>
<td>1,909</td>
<td>1,648</td>
<td>2,436</td>
<td>4,807</td>
<td>5,820</td>
<td>4,715</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>1,915</td>
<td>1,909</td>
<td>1,648</td>
<td>2,436</td>
<td>4,807</td>
<td>5,820</td>
<td>4,715</td>
</tr>
</tbody>
</table>

*unit: vehicles per hour.

Table 5. Maximum vehicle entry capacity

<table>
<thead>
<tr>
<th>scenario</th>
<th>segment</th>
<th>AB</th>
<th>BC</th>
<th>CD</th>
<th>DE</th>
<th>EF</th>
<th>FG</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>2,715</td>
<td>2,465</td>
<td>2,460</td>
<td>2,033</td>
<td>4,316</td>
<td>4,691</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>3,213</td>
<td>2,951</td>
<td>2,884</td>
<td>2,779</td>
<td>5,476</td>
<td>5,847</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>2,884</td>
<td>2,572</td>
<td>2,582</td>
<td>2,102</td>
<td>4,435</td>
<td>5,139</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2,884</td>
<td>2,572</td>
<td>2,582</td>
<td>2,102</td>
<td>4,435</td>
<td>5,139</td>
</tr>
</tbody>
</table>

*unit: vehicles per hour.

5.1.3 Traffic environmental pollution analysis

According to air pollution history in Osaka, NO\(_{2}\) (nitrogen dioxide) and SPM (suspended particulate matters) emissions from motor vehicles are now major cause of air pollution. In this paper, only emission of NO\(_{2}\) is discussed due to the time limited and lack of information on describing SPM’s emission characteristics, e.g. emission parameters. The present Japanese environmental standard for NO\(_{2}\) is 0.06 ppm, according to reference [6].

Table 6 shows that the concentration of NO\(_{2}\) is above the present standard at every intersection. The situation is worse at intersections B and C because the value is noticeably higher. Traffic noise generated by vehicles at intersections A, B and C is above the noise standard level. After applying scenario 1 and 2, we can see that there is a little reduction in the concentration of NO\(_{2}\) and in the noise level. Results obtained by applying scenario 3 - promoting low emission vehicles - is quite desirable. Exactly, it not only solved the traffic-related air pollution problem, but it also significantly reduced the pollutant NO\(_{2}\) emitted by motor vehicles.
In addition, with respect to noise reduction in scenario 3, as stated before, presently there is no detailed information describing this point. According to reference [3] and [6], some experiments related to noise produced by low emission vehicles had been done by some Japanese automobile companies and motor vehicles research institutions. It was figured out that, in general, the noise can be reduced several dB, compared with the normal vehicle under the same traveling conditions.

Table 6 Concentration of pollutant NO₂ and noise at intersections

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO₂</td>
<td>0.103</td>
<td>0.238</td>
<td>0.301</td>
<td>0.190</td>
<td>0.162</td>
<td>0.075</td>
<td>0.167</td>
</tr>
<tr>
<td></td>
<td>noise</td>
<td>76.42</td>
<td>76.45</td>
<td>76.31</td>
<td>57.75</td>
<td>57.27</td>
<td>19.31</td>
<td>57.35</td>
</tr>
<tr>
<td>1</td>
<td>NO₂</td>
<td>0.093</td>
<td>0.222</td>
<td>0.264</td>
<td>0.143</td>
<td>0.152</td>
<td>0.075</td>
<td>0.155</td>
</tr>
<tr>
<td></td>
<td>noise</td>
<td>76.45</td>
<td>76.49</td>
<td>76.38</td>
<td>57.70</td>
<td>57.30</td>
<td>19.33</td>
<td>57.33</td>
</tr>
<tr>
<td>2</td>
<td>NO₂</td>
<td>0.091</td>
<td>0.225</td>
<td>0.297</td>
<td>0.188</td>
<td>0.159</td>
<td>0.074</td>
<td>0.166</td>
</tr>
<tr>
<td></td>
<td>noise</td>
<td>76.10</td>
<td>76.43</td>
<td>76.33</td>
<td>57.75</td>
<td>57.33</td>
<td>19.31</td>
<td>57.35</td>
</tr>
<tr>
<td>3</td>
<td>NO₂</td>
<td>0.005</td>
<td>0.016</td>
<td>0.017</td>
<td>0.012</td>
<td>0.009</td>
<td>0.003</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>noise</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* pollution standards are 0.06 ppm for NO₂. The noise standard for this artery is 60 dB due to its location characteristics. Source: reference [4].

5.1.4 Productive capacity analysis

Productive capacity is the traffic characteristic defined as the total number of passenger-kilometres transported in an hour. It can be used to assess the traffic performance of the artery. The results carried out in this study for each segment are shown in table 7.

Table 7. Total productive capacity for the artery

<table>
<thead>
<tr>
<th>Scenario</th>
<th>AB</th>
<th>BC</th>
<th>CD</th>
<th>DE</th>
<th>EF</th>
<th>FG</th>
<th>Tprod Cap.</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.80</td>
<td>3.09</td>
<td>6.28</td>
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<tr>
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<td>4.67</td>
<td>3.50</td>
<td>7.03</td>
<td>6.51</td>
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<td>6.24</td>
<td>36.7</td>
<td>11.2</td>
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<tr>
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<td>11.2</td>
</tr>
</tbody>
</table>

*unit: 1x 10^5 passenger-kilometres per hour.

The analysis revealed that for the existing situation, the total productive capacity of the artery is about 3.3 million passenger-kilometres per hour. For scenario 1, the total productive capacity of this artery is high, reaching 4.3 million passenger-kilometres per hour. It was thus improved by about 32%. For scenarios 2 and 3, the quantity of the total productive capacity increased, with the improvement of 11.2%, as compared with the scenario 0. So we know that increased productive capacity could be achieved either by scenario 1, scenario 2
or scenario 3, and particularly the scenario 1 having a great improvement on the productive capacity. However, as analysed in section 5.1.3, the former 2 scenarios can not overcome the environmental pollution but scenario 3 can reach this purpose.

Based on the above analysis, it is obvious that scenario 3 is the best alternative. It can not only improve the traffic operation performance in terms of average travel speed, time delay, q/c, but also reduce traffic-related pollution in terms of air pollution and noise, and achieve the optimal result of total productive capacity of the study artery.

6 Conclusion

This research involves programming a mathematical model which is used to minimise traffic-generated pollution and to optimise the traffic operating conditions to achieve the desirable situation in term of total passenger productive capacity, and assessment of traffic situation on an urban traffic artery in Osaka with applying three scenarios including geometric treatment, traffic management and low emission vehicle promotion. Based on results previously discussed, some conclusions are summarised as:

1. The mathematical model is a useful tool to analysis traffic-related pollution and noise; also to gain the optimal results of productive capacity which is used for evaluation of traffic operation performance;

2. The previous analysis also shows that the artery has a considerable potential to increase its total productive capacity by 11.2% after implementing scenario 3 which is evaluated as the best alternative. Finally the study recommends that noise reduction by using low-emission vehicles should be analyzed in detail when the relevant information is available.

References

5. Osaka motor vehicle pollution control committee, Osaka motor vehicle-generated pollution control, Osaka, 1997.