Analysis on calculation of Vehicle Operating Cost (VOC) at Gejayan intersection before and after fly over ring road operation in Yogyakarta

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Abstract. Gejayan intersection is located in Sleman Regency of Yogyakarta. Fly Over will be constructed at the intersection in the ring road of Yogyakarta. The nearest intersection to the east is Gejayan Intersection with a distance of 1573.11 meters. Gejayan intersection performance in 2018 has reached saturation by having Level of Service E. The more severe conditions will occur in the next 10-20 years. If it is planned using Fly Over on the ring road in Yogyakarta connecting Gejayan intersection, the vehicles flow must have other alternative by road widening. The most important step is to predict the Vehicle Operating Costs (VOC). After the Fly Over operation, VOC can be calculated to determine the cost saving. The scenario to predict VOC was 80% of vehicle volume would pass the Fly Over, and the 20% would still use the existing road. The results showed that the cost saving of Vehicle Operating Costs (VOC) of the existing road compared to the fly over use in 2019 was IDR 37,941,324,952. In 2039 the saving would be IDR 240,232,694,488. If the road was only widened, the cost saving of VOC in 2019 would be IDR 9,084,204923 and in 2039 would be IDR 72,107,188,198.

Keywords: Vehicle Operating Cost, Cost Saving, Fly Over, Intersection Performance.

1. Introduction
Gejayan intersection is located in the series of northern ring road intersection in Sleman Regency of Yogyakarta. The most west are Jombor Intersection, Monjali Intersection, Kentungan Intersection, Gejayan/Condong Catur Intersection, and UPN Intersection. Gejayan intersection is located in commercial area and has 4 causeways, namely north (U), south (S), east (T), and west (B). The north – south causeway is Kaliurang Street and east – west causeway is north ring road. Here are 5 intersection networks in the north ring road.
In 2018, Fly Over will be constructed at intersection in Yogyakarta ring road. In the area, there are 4 intersections. The middle one is Kentungan Intersection and the closest intersection to the east of Kentungan Intersection is Gejayan Intersection with a distance of 1573.11 meters. From signalized intersection performance of Gejayan Intersection in 2018, the signalized intersection of Gejayan Intersection saturation Yogyakarta already has value 1.33 in 2018 or in other word has LOS E (between 0.8 until 0.1). The prediction of signalized intersection performance in 2028 showed that DS value reached 2.76. It means that the intersection capacity is not capable to serve the number of vehicles passing through the intersection. Condition and situation in the intersection at peak hours will be more jammed, the speed will increase, and the travel time will be longer.

The delay at the intersection for every vehicle in 2018 has a value of 223.3 second/smp. It indicates that every vehicle passing the unsignalized intersection will stop at the intersection for 223 seconds to allow vehicles from other direction to cross the intersection.

If an intersection has LOS E value, then the drivers will already feel uncomfortable when passing the intersection. Similar to the delay at Gejayan signalized intersection Yogyakarta, every vehicle has 50% chance or more to queue at the unsignalized intersection. The more severe conditions will occur in the next 10-20 years.

If it is planned using Fly Over or Underpass at the ring road in Yogyakarta connecting 4 intersections including Gejayan intersection, indeed we need to think the concept maturely to serve the vehicles flow from west to south and vice versa as well as east to south and vice versa. The vehicles flow must have other alternatives, namely by performing road widening according to the flow that will pass the road segments mentioned above. The most important step is to predict the Vehicle Operating Costs (VOC) and the profit after the Fly Over operation. After performing the Fly Over operation, the calculation of cost saving of VOC could be determined.
VOC was obtained from the calculation of every vehicle passing Gejayan intersection and predicted according to vehicle growth in Yogyakarta. From the result, it could be multiplied to all aspects of costs ranging from materials and mechanic wage. Finally, the load cost in certain speed in the desired year could be determined.

The scenario performed in predicting VOC was 80% of vehicle volume that would pass the Fly Over, and 20% of vehicle volume still used the existing road.

2. Literature review
The basic objective of planning is to estimate the amount and need for transportation in the future or in the year of the plan to be used for various types of investment. To better understand and find the best solution, a transportation system approach is needed. The transportation system in general (macro) can be broken into several smaller (micro) systems that each interact and influence. (Tamin, 1997).

Vehicle Operating Costs (VOC) is a value that states the amount of costs incurred for a vehicle operation. VOC consists of several components, namely:

2.1. Running cost
Fuel Cost
Oil / Lubricant Cost
Tire Usage Cost
Maintenance Cost (repair and maintenance, General Overhaul)
Over Head costs (Incidental expenses)

2.2. Fixed cost
Insurance
Capital Interest
Depreciation (Vehicle Depreciation)
Time Value

2.3 VOC calculation by using PCI model
Vehicle operating costs are costs used for vehicles from one place to another (transportation activities). The method used to calculate vehicle operating costs used today is the Pacific Consultants International Inc. method. Tokyo, Japan (PCI).

In this case the vehicle operating costs are the sum of the movement costs (operating costs) and fixed costs. The formulas used in calculating Vehicle Operational Costs based on the PCI Method are as follows:

- Equation for Fuel Consumption:
  Sedan (PC) : \( Y=0.03719S*S-4.19966S +175.9911 \)
  Mini/Medium Bus : \( Y=0.06846S*S-8.02987S +340.6040 \)
  Large Bus : \( Y=0.12922S*S-13.68742S+541.0279 \)
  Mini Truck : \( Y=0.06427S*S-7.06130S+318.3326 \)
  Large Truck : \( Y=0.11462S*S-12.85594S+503.7179 \)
  Where:
    \( Y \) = Fuel consumption (liter/1000 km)
    \( S \) = Running Speed (Km/Hour)

- Equations for Engine Oil Consumption:
  Sedan (PC) : \( Y=0.00025S*S-0.02664S+ 1.441710 \)
  Mini/Medium Bus : \( Y=0.00057S*S-0.06130S+ 3.317530 \)
  Large Bus : \( Y=0.00030S*S-0.12968S+ 7.062390 \)
  Mini Truck : \( Y=0.00048S*S-0.05608S+ 3.073830 \)
Large Truck: \[ Y = 0.00100S^2 - 0.11715S + 6.409620 \]

- Equations for Tire Usage:
  - Comparison of tire usage on toll road and ring road

  \[
  \begin{align*}
  \text{Toll road} & \quad \text{Ring road} \\
  \text{Passenger vehicle} & : 1.94 & : 1.00 \\
  \text{Bus} & : 1.10 & : 1.10 \\
  \text{Truck} & : 1.10 & : 1.10 \\
  \end{align*}
  \]

  Equations for Tire Usage:
  - Sedan (PC): \[ Y = (0.0008848S - 0.0045333) \]
  - Mini/Medium Bus: \[ Y = (0.0012356S - 0.0064667) \]
  - Large Bus: \[ Y = (0.0012356S - 0.0064667) \]
  - Mini Truck: \[ Y = (0.0011553S - 0.0005933) \]
  - Large Truck: \[ Y = (0.0011553S - 0.0005933) \]

  \[ Y' = Y \times \frac{\text{tire}_\text{price}}{1000\text{km}} \]

- Equation for Maintenance Cost:
  - Maintenance cost for spare parts
  - Comparison of spare part usage on toll road and ring road:

  \[
  \begin{align*}
  \text{Toll road} & \quad \text{Ring road} \\
  \text{Passenger vehicle} & : 1.73 & : 1.27 \\
  \text{Bus} & : 1.26 & : 1.26 \\
  \text{Truck} & : 1.26 & : 1.26 \\
  \end{align*}
  \]

  Maintenance costs for spare parts of vehicles passing toll roads:
  - Sedan (PC): \[ Y = 0.0000064S + 0.0005567 \]
  - Mini/Medium Bus: \[ Y = 0.0000320S + 0.0020891 \]
  - Large Bus: \[ Y = 0.0000320S + 0.0020891 \]
  - Mini Truck: \[ Y = 0.0000191S + 0.0015400 \]
  - Large Truck: \[ Y = 0.0000191S + 0.0015400 \]

  Where:
  \[ Y' = Y \times \frac{\text{vehicle\_value}}{1000\text{km}} \]
  \[ S = \text{Running Speed (Km/\text{Hour})} \]

- Maintenance hours for workers

  \[
  \begin{align*}
  \text{Sedan (PC)} & : Y = 0.00362S + 0.36267 \\
  \text{Mini/Medium Bus} & : Y = 0.02311S + 1.97733 \\
  \text{Large Bus} & : Y = 0.02311S + 1.97733 \\
  \text{Mini Truck} & : Y = 0.01511S + 1.21200 \\
  \text{Large Truck} & : Y = 0.01511S + 1.21200 \\
  \end{align*}
  \]

  \[ Y' = Y \times \frac{\text{hourly\_mechanic\_fee}}{1000\text{km}} \]

- Equation for Vehicle Depreciation:

  \[
  \begin{align*}
  \text{Sedan (PC)} & : Y = \frac{1}{2.5 S + 125} \\
  \text{Bus} & : Y = \frac{1}{8.756 S + 350} \\
  \end{align*}
  \]
\[ Y = \frac{1}{6.129 S + 245} \]

Where:
\[ Y = \text{Vehicle depreciation per 1000 km was multiplied with the vehicle price} \]
\[ S = \text{Running Speed (Km/Hour)} \]

- **Equation for Interest Rate:**

  \[ Sedan \ (PC) : \quad Y = \frac{120}{500 S} \]
  \[ Bus : \quad Y = \frac{120}{2500 S} \]
  \[ Truk : \quad Y = \frac{120}{1750 S} \]

In which:
\[ Y = \text{Interest rate per 1000 km was multiplied with 0.5 from vehicle value. Interest rate } \]
\[ = 12\% / \text{year} \]
\[ S = \text{Running Speed (Km/Hour)} \]

### 3. Research Method

Surveys were conducted for primary data in the form of counting the total vehicles at Gejayan intersection, Yogyakarta. Surveys were conducted during peak hours, morning and evening. These surveys took note on types and amount of vehicle that went in and out at each Gejayan intersection. In addition, the secondary data was also used to support the calculation of traffic performance with data in the number of vehicle in 2013 until 2016 in Yogyakarta. The number of vehicle calculation of each intersection compared to the growth rate of vehicle produced degree of saturation that could determine the Level of Service at each intersection. The maximum saturation degree then was predicted up to 10 years and the researchers predicted the Vehicle Operating Costs (VOC) profit after the Fly Over operation. By calculating VOC, it could be seen how much the cost saving of VOC after Fly Over operation compared to before operation. VOC was obtained from calculation if every vehicle passed the Gejayan intersection and predicted according to vehicle growth in Yogyakarta. Then the result could be multiplied to all aspects of costs ranging from materials and mechanic wage. Finally, the load cost in certain speed in the desired year could be found.

### 4. Result and Discussion

Several scenarios assumption performed for the calculation of Vehicle Operating Costs to determine the level of cost saving efficiency are:

- **No Fly Over Construction**
  Without fly over construction at Gejayan intersection of Yogyakarta, its performance is getting worse from the existing year (2018). The saturation degree will be higher, the queue is getting longer, and the longer of vehicles will stop at Gejayan intersection of Yogyakarta. This will increase the vehicle operating costs if passing Gejayan intersection of Yogyakarta with the current condition.

- **Performing Road Widening**
  It is performed on the West and East side of the ring road. The road widening is 3 meters on the left shoulder. The function is to add lane and capacity for vehicles. So, the vehicles can use the existing road if the fly over would be constructed later.

- **Performing Fly Over Construction**
  Fly Over at Gejayan intersection of Yogyakarta with distance of 0.8 km is assumed can be
operated in 2018. For this assumption, calculation simulation will be conducted where the entire flow of vehicles passing through the ring road from west to east will pass the planned fly over consisting of 51,081 passenger cars and 4,958 heavy vehicles (truck and bus) in 2015. While in 2018 (with the assumption that Fly Over has operated), the number of vehicles passing through the fly over are 12,810 passenger cars and 1,742 heavy vehicles (truck and bus).

Scenario performed in predicting the VOC was 80% of vehicle volume would pass Fly Over, and 20% of vehicle volume still used the existing road.

From the assumption results, the vehicle costs passing through Fly Over and those that still using the existing road can be determined. For more details, the table and graph of the total VOC/year, the cost saving of VOC/year due to the 3 meters road widening, and the cost saving of VOC/year if all vehicles passing the ring road use the planned fly over are presented. The following is presented in table 1.

| Year | Existing VOC | VOC of Widening | VOC of Fly Over | Savings of the Existing – Fly Over | Savings of the Existing – Widening |
|------|--------------|-----------------|----------------|----------------------------------|----------------------------------|
| 2018 | 74638656413  | 66062798235     | 38910424749    | 35728231664                       | 8575858177                       |
| 2019 | 78672095595  | 69587890672     | 40730770643    | 37941324952                       | 9084204922                       |
| 2020 | 85224899340  | 74957417722     | 42736380143    | 42488519197                       | 10267481618                      |
| 2021 | 89957361268  | 79072888340     | 44817236394    | 45140124874                       | 10884479298                      |
| 2022 | 97732325907  | 85389664304     | 47125155608    | 50607170298                       | 12342661603                      |
| 2023 | 103294923119 | 90201050069     | 49490825315    | 5380497804                        | 13093873050                     |
| 2024 | 112551199954 | 97646522332     | 52168575443    | 60385324511                       | 1490467622                       |
| 2025 | 119101883948 | 103279235147    | 54868442596    | 64233441351                       | 15822468800                     |
| 2026 | 130163769297 | 112073245080    | 58151644070    | 72012125226                       | 18090524126                     |
| 2027 | 137893657618 | 118676614364    | 61282615921    | 76611040796                       | 19217043245                     |
| 2028 | 151171210941 | 129086757604    | 64878655279    | 86292555662                       | 22084453336                     |
| 2029 | 160312758832 | 136839002262    | 68438840930    | 91873917901                       | 23473756569                     |
| 2030 | 176330945352 | 149192759858    | 72635169960    | 10369579757                       | 27138189674                     |
| 2031 | 187168689888 | 158307145900    | 7672042995     | 110448286893                      | 28861543987                     |
| 2032 | 206609625926 | 173007814946    | 81542242572    | 125067383353                      | 33601810980                     |
| 2033 | 219494530678 | 183740343088    | 86280394508    | 133214136169                      | 35754186797                     |
| 2034 | 243260435539 | 201288273429    | 91872606117    | 151387829421                      | 41972162109                     |
| 2035 | 258629579208 | 213947374535    | 97269256753    | 161360322635                      | 44682204673                     |
| 2036 | 287939797943 | 234968760059    | 10381790895    | 184121889887                      | 52971037883                     |
| 2037 | 306344007959 | 249927648135    | 110030554500   | 196313453458                      | 56416359823                     |
| 2038 | 342890154837 | 275214338232    | 11757255226    | 225317699661                      | 67675816604                     |
| 2039 | 365034171068 | 29229692870     | 124801476584   | 240232649483                      | 72107181987                     |
| 2040 | 411239332816 | 323492734124    | 133571282351   | 277668050464                      | 87746598691                     |
| 2041 | 438042444868 | 344514827565    | 141828031054    | 29621434319                      | 93527617303                     |
| 2042 | 497517096899 | 381676818293    | 152117860338    | 34539923651                      | 115840278605                     |
| 2043 | 530290910448 | 406693833615    | 161650117187    | 368558897296                      | 123551270868                     |
| 2044 | 608604178664 | 452194194141    | 173534315178    | 43506983485                      | 156409984523                     |
| 2045 | 648886232144 | 482059789615    | 184648586850    | 464237645293                      | 166826442528                     |
| 2046 | 752367066529 | 538252801649    | 198498138205    | 55386928324                      | 214114264880                     |
| 2047 | 805949792286 | 57402824216     | 211234572895    | 594715219391                      | 231906968070                     |
| 2048 | 953490298799 | 644194310488    | 227637197036    | 725853101762                      | 309295988310                     |

Volume of traffic using arterial roads. With the flyover, the level of network services will increase.
so that transportation costs decrease and demand will increase. If it is planned to use Simpang Tak Sebidang or flyover on the ringroad arterial road in Yogyakarta City that connects 4 Simpang including the Gejayan intersection. Another alternative is to widen the road according to the current that will pass through the roads mentioned above. BOK / th savings due to the widening of the 3 meter road in 2018-2048, and the BOK / th Savings which when all vehicles passing on the arterial road use / pass the Uneven Field which will be planned in 2018-2048. The following is presented in Figure 2.

5. Conclusion
- Total Vehicle Operating Costs (VOC) of the existing road in 2019 is IDR 78,672,095,595 and in 2039 is IDR 365,034,171,068
- Total Vehicle Operating Costs (VOC) of road widening in 2019 is IDR 66,062,798,236 and in 2039 is IDR 292,926,982,870
- Total Vehicle Operating Costs (VOC) of Fly Over in 2019 is IDR 38,910,424,749 and in 2039 is IDR 124,801,476,584
- The results show that the cost saving of Vehicle Operating Costs (VOC) of the existing road compared to the fly over existence in 2019, the cost saving is IDR 37,941,324,952 and in 2039 the cost saving is IDR 240,232,694,488
- If the road is only widened without fly over, then the cost saving of VOC in 2019 is IDR 9,084,204923 and in 2039 is IDR 72,107,188,198.

The above show that Vehicle Operating Costs (VOC) is higher while operating at the existing road than at fly over. So that the cost saving generated on the fly over operation is more efficient (large profit).
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