Analysis on Calculation of Vehicle Operating Cost (VOC) Before and After Flyover & Road Widening Operation at Gedangan Intersection in Sidoarjo Regency

R Endro Wibisono¹, Purwo Mahardi²
¹² Program Study of Civil Engineering, Engineering Faculty, Universitas Negeri Surabaya.

Abstract. The main road that connects the city of Sidoarjo to Surabaya is the intersection of Gedangan. By 2018 it has reached saturation by having a poor service level. More severe conditions will occur in the next 10-20 years. One of the government's efforts to overcome the problem of congestion, damage structure is the construction of flyover or other alternatives by widening the road. The purpose of this study is to determine the characteristics of the traffic and to save vehicle operating costs before and after the construction of a flyover at the Gedangan intersection. The method for predicting Vehicle Operating Costs (BOK) is to use PCI method. This study predicts Vehicle Operating Costs (BOK) to determine cost savings. The scenario for predicting BOK is that 80% of the vehicle volume will pass the Fly Over, and 20% still use the existing road. The results showed that the cost savings of Vehicle Operational Costs (BOK) of existing roads compared to the use of flyover in 2019 was IDR 15 Billion. In 2039 the savings are IDR 77 Billion. Another discussion is that if the road is only widened without flyover, then the BOK cost savings in 2019 will be IDR 4 Billion and in 2039 it will be IDR 27 Billion.

1. Introduction

The main road that connects the city of Sidoarjo to Surabaya is the Gedangan intersection. Transportation problems that occur include congestion, damage to road pavement structures, reduced age of road plans and increased accident rates. “As road surface conditions deteriorate (through increased roughness and rolling resistance and reduced traction capability) vehicle operating costs per tonne-kilometer increase due to higher fuel consumption, reduced speeds and higher service/repair costs. Terrain characteristics affect road alignments (gradient and curvature) which will oil/lubricant reduce vehicle speeds and also increase operating costs” [1]. Traffic performance at the Gedangan intersection is increasing because there are several intersections on the road. The intersection can connect the cities of Sidoarjo and Surabaya. Conditions on the road are deemed uncomfortable and unsafe due to mixed traffic between cities, especially heavy vehicles with local traffic such as cars and motorbikes. Because the capacity of the vehicle is high enough so that the road cannot accommodate vehicles again a few years later. Because the Gedangan intersection is the main road that connects between cities, it can be ascertained that many vehicles are moving their vehicles at a high enough speed. The diversity of types of vehicles that pass through this road, the speed of the speeding vehicles is quite high and the many damages to the road pavement at some point resulting in frequent accidents.

Congestion (delay) also often occurs on the road because of the high number of vehicles. If viewed from an economic standpoint, the delay experienced by the vehicle is the cost that must be paid by the vehicle user due to delay (traffic) while in terms of time, vehicle users will be longer to reach the
destination. “One of the major areas of an economic feasibility assessment of a major highway project is the impact on vehicles operating cost (VOC)” [2]. The existence of this condition causes the conditions at the Gedangan intersection to require more serious handling, one of the government's efforts to deal with the above problems is the construction of flyovers. This flyover construction business is expected to provide comfort and a sense of security for road users especially in terms of time and cost. Vehicle operating costs (VOC) include on fuel, tires, maintenance and depreciation cost of a vehicle[3].

Before the physical implementation of development, it is necessary to know whether or not the flyover is feasible through a feasibility study. a feasibility study will be carried out on the construction of flyovers at the Gedangan intersection in terms of traffic and economic aspects. The purpose of this study was to determine the characteristics of traffic before and after the construction of flyovers at the Gedangan intersection, the difference in time and cost savings before and after the construction of flyovers at the Gedangan intersection, the feasibility of overpassing (flyover). Rolling resistance occurs between tires and roads[4], some of the causes of tire inflation below which can increase tire warming and resistance can affect safety.[5]

![Figure 1 Situation Map of Gedangan Intersection In Sidoarjo Regency.](image)

Performance of Gedangan Intersection in 2018, the signalized intersection of saturation already has value 0.89 in 2018 or in other word has LOS D (between 0.8 until 1). The prediction of signalized intersection performance in 2028 showed that DS value reached>1. 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. “Calculation of capacity based on the Indonesian Road Capacity Manual (MKJI 1997) uses Equation (1) which exists C = Co x FCw x FCSP x FCSF” [6]. The delay at Gedangan signalized intersection, every vehicle has a 50% chance or more to queue at the un signalized intersection. The more severe conditions will occur in the next 10-20 years.
If it is planned using Fly Over in Sidoarjo intersection, indeed we need to think the concept maturely to serve the vehicles flow from north to south and vice versa. “For now, the current structure implies that the total number of miles driven by all vehicles on the road will change from one scenario to the next based on the breakdown of number and type of vehicles purchased. Some of the most significant features of the model are that large cars” [7]. 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 model includes empiric, mechanic, deterministic or probabilistic formula. (Bien, 1993).

VOC was obtained from the calculation of every vehicle passing Gedangan intersection and predicted according to vehicle growth in Sidoarjo district. From the result, it could be multiplied to all aspects of costs ranging from materials and mechanic wage. Finally, the load cost a certain speed in the desired year could be determined. "Vehicle operating costs are the sum of running costs, and standing costs, which in detail consists of the following components: Motion costs (fuel consumption, lubricating oil consumption, vehicle repair and maintenance and vehicle depreciation) and Fixed Costs (Capital interest, Insurance and Overhead) [8]. "The Big Profit of Vehicle Operating Costs is the difference in vehicle operating costs and the time value on toll roads and alternative routes”[9]

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.

“The research focused only on the cost components that are most affected by pavement conditions, namely, fuel consumption, repair and maintenance costs, and tire wear” [10].

Total resistive forces acting on a vehicle is the sum of rolling resistance and aerodynamic drag (Hertz, unpublished material, 1982) and may be expressed mathematically as

\[ R_{total} = R_{roll} + R_{drag} \]

2. Literature Review

The procedure assesses the Vehicle Operating Costs (VOC) by a written regression between PCI and International [11]. Vehicle Operating Costs (VOC) is a value that states the number of costs incurred for vehicle operation. VOC consists of several components, namely:

Running cost may include, fuel cost, oil/lubricant cost, tire usage cost, maintenance cost (repair and maintenance, general overhaul), overhead costs (incidental expenses). Fixed cost, may include Insurance, Capital Interest, Depreciation (Vehicle Depreciation), Time Value

Vehicle Operating Costs (VOC) is a function of speed and distinguished for the toll road and the non-toll road of VOC. For VOC calculation, PCI model formula was used with road condition (road geometric) was relatively flat and types of vehicle used were released in 2007. [12]

The formula used in calculating Vehicle Operating Costs is based on fuel consumption for sedans, medium buses, large buses, mini trucks, and large trucks, is using formulas 1-5, the cost can be described as:

\[
\begin{align*}
\text{Sedan (PC)} & : Y = 0.037195S^2 - 4.19966S + 175.9911 \\
\text{Mini/Medium Bus} & : Y = 0.068465S^2 - 8.02987S + 340.6040 \\
\text{Large Bus} & : Y = 0.12922S^2 - 13.68742S + 541.0279 \\
\text{Mini Truck} & : Y = 0.06427S^2 - 7.06130S + 318.3326 \\
\text{Large Truck} & : Y = 0.11462S^2 - 12.85594S + 503.7179
\end{align*}
\]

Where:

\[ Y \quad = \quad \text{Fuel consumption (liter/1000 km)} \]
\[ S \quad = \quad \text{Running Speed (Km/Hour)} \]
The formula used of Engine Oil Consumption for non-toll roads is based on the PCI model method for sedans, medium buses, large buses, mini trucks, and large trucks, is using formulas 6-10, the cost can be described as:

\[
\begin{align*}
\text{Sedan (PC)} & : Y=0.00025S^2 + 0.02664S + 1.441710 \\
\text{Mini/Medium Bus} & : Y=0.00057S^2 - 0.06130S + 3.317530 \\
\text{Large Bus} & : Y=0.00030S^2 - 0.12968S + 7.062390 \\
\text{Mini Truck} & : Y=0.00048S^2 - 0.05608S + 3.073830 \\
\text{Large Truck} & : Y=0.00100S^2 - 0.11715S + 6.409620
\end{align*}
\]

The rates of tire wear on the Road Test vehicles are probably not representative of rates of tire wear on similar vehicles used in normal operations on the public highways [13]. The use for sedans, medium buses, large buses, mini trucks, and large trucks, is using formulas 11-16, the cost can be described as:

\[
\text{Passenger vehicle} \quad 1.94 \\
\text{Bus} \quad 1.10 \\
\text{Truck} \quad 1.10
\]

Equations for Tire Usage:

\[
\begin{align*}
\text{Sedan (PC)} & : Y=(0.0008848S-0.0045333) \\
\text{Mini/Medium Bus} & : Y=(0.0012356S-0.0064667) \\
\text{Large Bus} & : Y=(0.0012356S-0.0064667) \\
\text{Mini Truck} & : Y=(0.0011553S-0.0005933) \\
\text{Large Truck} & : Y=(0.0011553S-0.0005933)
\end{align*}
\]

\[Y'=Y*\text{total tire price/1000km}\]

The use of Maintenance is based on the PCI model method, the cost can be described as:

\[
\begin{align*}
\text{Passenger vehicle} & : Y=(0.0000064S+0.0005567) \\
\text{Bus} & : Y=(0.0000320S+0.0020891) \\
\text{Truck} & : Y=(0.0000191S+0.0015400)
\end{align*}
\]

Where:

\[
\begin{align*}
Y' &= Y*\text{vehicle value (/1000 km)} \\
S &= \text{Running Speed (Km/Hour)}
\end{align*}
\]
The use of Maintenance hours for workers non-toll roads for sedans, medium buses, large buses, mini trucks, and large trucks, is using formulas 23-27, the cost can be described as:

Sedan (PC) : \( Y = (0.00362S + 0.36267) \) \( \text{(23)} \)
Mini/Medium Bus : \( Y = (0.02311S + 1.97733) \) \( \text{(24)} \)
Large Bus : \( Y = (0.02311S + 1.97733) \) \( \text{(25)} \)
Mini Truck : \( Y = (0.01511S + 1.21200) \) \( \text{(26)} \)
Large Truck : \( Y = (0.01511S + 1.21200) \) \( \text{(27)} \)

\( Y' = Y \times \text{hourly mechanic fee (per 1000 km)} \)

The use of Vehicle depreciation non-toll roads for sedans, buses, and trucks, is using formulas 28-30, the cost of can be described as:

\[ Sedan \ (PC) \ : \ Y = \frac{1}{2.5 \ S + 125} \] \( \text{(28)} \)

\[ Bus \ : \ Y = \frac{1}{8.756 \ S + 350} \] \( \text{(29)} \)

\[ Truk \ : \ Y = \frac{1}{6.129 \ S + 245} \] \( \text{(30)} \)

Where:

\( Y \) = Vehicle depreciation per 1000 km was multiplied with the vehicle price

\( S \) = Running Speed (Km/Hour)

The interest rate for sedans, buses, and trucks, is using formulas 31-33, the cost of can be described as:

\[ Sedan \ (PC) \ : \ Y = \frac{120}{500 \ S} \] \( \text{(31)} \)

\[ Bus \ : \ Y = \frac{120}{2500 \ S} \] \( \text{(32)} \)

\[ Truk \ : \ Y = \frac{120}{1750 \ S} \] \( \text{(33)} \)

In which:

\( Y \) = Interest rate per 1000 km was multiplied with 0.5 from vehicle value. Interest rate = 12%/year

\( S \) = Running Speed (Km/Hour)

Vehicle maintenance, depreciation, and interest are important, “interrelated components of the costs of vehicle ownership and operation. Maintenance parts and labor typically constitute 15-35 percent, and depreciation and interest 15-25 percent, of total costs excluding overhead; together they account for about the same proportion as fuel and tire consumption combined”[14].

3. Method

Surveys were conducted for primary data in the form of counting the total vehicles at Gedangan intersection. 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 Gedangan intersection. In addition, the secondary data was also used to support the calculation of traffic performance with data in the number of the vehicle in 2012 until 2016 in Sidoarjo. The number of vehicle calculation of each intersection compared to the growth rate of vehicle produced a degree of saturation that could
determine the Level of Service at each intersection. The maximum saturation degree than was predicted up to 10 years and the researchers predicted the Vehicle Operating Costs (VOC) profit after the Fly Over operation. "Before calculating the existing formulas, it is necessary to obtain data on fuel prices, lubricating oil prices, mechanic salary costs, tire/unit prices so that the VOC calculation results are accurate" [15]. By calculating VOC, it could be seen how much the cost-saving of VOC after Fly Over operation compared to before the operation.

VOC was obtained from the calculation if every vehicle passed the Gedangan intersection and predicted according to vehicle growth in Sidoarjo district. Then the result could be multiplied to all aspects of costs ranging from materials and mechanic wage. Finally, the load cost a 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:

Without flyover construction at Gedangan intersection, its performance is getting worse from the existing year (2018). The saturation degree will be higher, the queues getting longer, and the length of vehicles will stop at Gedangan intersection. This will increase the vehicle operating costs if passing Gedangan intersection with the current condition.

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 flyover would be constructed later.

Fly Over at Gedangan intersection of Sidoarjo with a distance of 0.8 km is assumed can be operated in 2020. 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 flyover consisting of 14,829 passenger cars and 8,345 heavy vehicles (truck and bus) in 2018. While the assumption that Fly Over has operated, the number of vehicles passing through the flyover are 14,457 passenger cars and 8,271 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 using the planned flyover are presented. The following is presented in Table 1
### Table 1. Cost Saving of VOC of Gedangan Intersection for 20 Years ( IDR )

| Year | Existing VOC | VOC of Widening | VOC of Fly Over | Savings of the Existing – Fly Over | Savings of the Existing – Widening |
|------|--------------|-----------------|-----------------|------------------------------------|------------------------------------|
| 2019 | 45947349226  | 41273203836     | 30093059939     | 15854289286                       | 4674145389                        |
| 2020 | 48303852014  | 43052346208     | 30724203172     | 17579648841                       | 5251505805                        |
| 2021 | 49715855959  | 44213885051     | 31384274099     | 18331581860                       | 5501970907                        |
| 2022 | 52437385772  | 46254835736     | 3208409758      | 20348976014                       | 6182550036                        |
| 2023 | 54058158211  | 47584337475     | 32807309342     | 21250848869                       | 6473820735                        |
| 2024 | 57217395669  | 49933733910     | 33621296377     | 23596099291                       | 7283661758                        |
| 2025 | 59085384632  | 51460764658     | 34421386155     | 24663998476                       | 7624619973                        |
| 2026 | 62773140502  | 54174949776     | 3535798694      | 27415341807                       | 8598190725                        |
| 2027 | 64934807816  | 55934679727     | 36294831072     | 28639976743                       | 9000128089                        |
| 2028 | 69265804255  | 59082070352     | 37307012851     | 31958791403                       | 1018373902                        |
| 2029 | 71777601481  | 61116437498     | 38312273089     | 33465328391                       | 10661163982                       |
| 2030 | 76898658492  | 64780597710     | 39515384936     | 37383273556                       | 12118060782                       |
| 2031 | 79829622959  | 67139749212     | 40645918247     | 39183704712                       | 12689873746                       |
| 2032 | 85931540559  | 71423415142     | 41949097036     | 4398243523                        | 1450819016                        |
| 2033 | 89366771591  | 74167523662     | 43298151271     | 46068620319                       | 15199247929                       |
| 2034 | 96702067861  | 79198063098     | 44783817435     | 51918250426                       | 17504004763                       |
| 2035 | 100747488208 | 82399530635     | 46225520364     | 54521967843                       | 18347957572                       |
| 2036 | 109657745031 | 88336167702     | 48017079615     | 61640665415                       | 21321577328                       |
| 2037 | 114446801178 | 92082618102     | 49652086524     | 64794714653                       | 22364183075                       |
| 2038 | 125406414531 | 99126634415     | 51597558413     | 7380856117                        | 26279780115                       |
| 2039 | 131109814958 | 103524588489    | 53570862187     | 77338952770                       | 27585226469                       |

**Figure 2.** Relationship Diagram of the existing VOC, road widening VOC, Total Fly Over, and cost-saving of VOC/year
5. Conclusion

Total Vehicle Operating Costs (VOC) of the existing road in 2019 is IDR 45 Billion and in 2039 is IDR 131 Billion. Total Vehicle Operating Costs (VOC) of road widening in 2019 is IDR 41 Billion and in 2039 is IDR 103 Billion. Total Vehicle Operating Costs (VOC) of Fly Over in 2019 is IDR 30 Billion and in 2039 is IDR 53 Billion. The results show that the cost-saving of Vehicle Operating Costs (VOC) of the existing road compared to the flyover existence in 2019, the cost saving is IDR 15 Billion and in 2039 the cost-saving is IDR 77 Billion. If the road is only widened without flyover, then the cost saving of VOC in 2019 is IDR 4 Billion and in 2039 is IDR 27 Billion.

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

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