The Urban Transportation System and Fuel Consumption of Metropolitan and Large Cities In Java

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ABSTRACT

The urban transportation system includes the number of private passenger cars, private buses and motor cycles, public buses and public passenger cars, goods transportation vehicles, road length, and route length. The fuel consumption is greatly influenced by the city typology (land use management, population size, population density, RGDP). Both transportation and fuel consumption are very strategic because they are related with the local, national, and global-scale economy and environment. The data were analyzed by using a multivariate-multivariable analysis, including a co-relational analysis, Biplot and a multivariable regression analysis. Metropolitan and large cities in Java have the following characteristic: city typology, transportation system, bigger fuel consumption than medium cities. The effect of the population on the fuel consumption is very great. The urban transportation that can make efficient fuel consumption: small percentage and number of vehicles (private and goods vehicles), route efficiency, the public transportation services with a large capacity, grid road network, land use management (compact). The fuel consumption is influenced by the urban transportation system and city typology. All integrated influential variables can reduce fuel consumption, can reduce subsidy on the fuel consumption, can increase health, and increase state economy.

Key words: city typology, fuel consumption, Java, transportation system, urban transportation.

1. INTRODUCTION

State that the concept of sustainable transportation becomes both a foundation and challenge for effective development and implementation [18]. One of the challenges of sustainable transportation is the urban resource conserving mobility [4], [5] or by developing a transportation mobility strategy in the country [24].

Improving the city transportation system, especially that is triggered by the increase of private vehicle ownership and usage negatively has some impacts on the city, like traffic jams and accidents, space usage, environmental preservation (exhaust gas emission, air pollution, energy resource exploitation, etc.). This occurs in large cities of both developed and developing countries, like Rio de Jenaio, Mexico City, Jakarta, New Delhi, and Bangkok.

States that sustainable transportation is related to collective and integrated management of fossil fuel consumption, vehicle exhaust gas emission, safety, traffic jams and social economy towards future sustainability without causing problems for future generations around the world [23]. Therefore, an environment-based transportation is needed by taking potential environmental implications and impacts into consideration, especially air pollution, noise pollution and energy consumption. These impacts trigger the sustainable urban city transportation system, which is a concept involving several systems and is cross-disciplinary and requires a holistic analysis.

Biplot is a multivariate multivariable statistics technique which can be displayed visually to simultaneously demonstrate the $n$ observed object and the $p$ variable on a two dimensional space for the variable and observed object characteristics and the relative position between observed objects with the analyzable variable. So, the Biplot can show the relationship between variables, the relative similarities between observed objects, as well as the relative position between the observed object and the variable [13].
2. LITERATURE REVIEW

According to [6], with respect to fossil fuel consumption in the United States, 80% of the transportation sector is taken up by land transportation, 20-30% uses truck and buses. [9] Considers trucks carrying goods consume up to 30-40% of the transportation fossil fuel consumption. In Indonesia, the national economy growth has increased the number of private vehicle ownership and usage in the city area. Private vehicle ownership has increased significantly compared to public transportation, therefore also increasing fossil fuel consumption. According to [12], to reduce fossil fuel consumption, we need to reduce the number of private vehicles. In reality, the number of private vehicles in Indonesia actually rises each year. The number of vehicles and fossil fuel consumption in Indonesia during 1983-2003 can be seen in Figure 1 [8].

![Figure 1. Number of Vehicles in Indonesia 1983-2003](image)

In the United States, between 1970 and 1995, there was a large gap between the supply or production of fossil fuel and the need for fossil fuel for transportation. This fact is considered worrying because the transportation sector is currently heavily reliant on unrenewable fossil fuel that is rare and decreasing. Declining supplies affect the rising price of fossil fuel, impacting the creation of wide external factors towards the national social-economy condition. In Indonesia, the growth of fossil fuel need is bigger than the government’s capability in providing subsidies [21]. Some developing country governments are forced to provide subsidies for the people to be able to access the rising prices of fossil fuels. Figure 2 shows energy consumption in Indonesia based on their resources [8].

![Figure 2. Energy Consumption in Indonesia Based on Resources](image)

Because road transportation consumes fossil fuel the most, reaching 70% (for developing countries) [15], and even in Australia energy needs for transportation reaches 80% [17], this transportation sub-sector requires attention in several policies, planning and research. According to [1], the fossil fuel consumption for each vehicle’s transportation needs is different. The calculation for each vehicle’s fossil fuel consumption can be seen in Table 1.
According to [10], the effect of city growth developing through a concentric typology or a single city center saves fossil fuel consumption more than a city typology with several city centers. This is in accordance with [12], and [11], the city form influences energy use. There is a conservative view stating that the current land use will not change much even if there is a change in the public transportation system. According to [22], the empirical reality always proves that land use has a strong correlation to city transportation because the land use determines the size and distribution of movement, influencing travel movement, transportation modes used and fossil fuel consumption.

The impact of land use on fossil fuel consumption is not only caused by the type of land use, but also the influence of the intensity in using the land of which can be demonstrated through population density. Rising population density allows higher possibility for mixed use to happen. Areas with lower population density have higher per capita fossil fuel use, on the contrary, areas with high population density have lower per capita fossil fuel use. The land use and transportation cycle can be seen in Figure 3.

Figure 3 shows the relation between fossil fuel/capita and population density in cities, by sampling 84 cities in the world [16]. The study conducted by [2],[3], shows that rising population density in West Europe does not always lower vehicle ownership which would lower fossil fuel consumption, but the people or population’s travel route in the city is more determining. Likewise, according to [7], studying cities in Asia (including Indonesia), fossil fuel consumption has a low correlation with population density. Research in Indonesia shows that fossil fuel consumption is influenced by travel patterns, meanwhile travel patterns are influenced by the location of activity centers (residences, shopping centers, offices, schools, hospitals, etc.) [20].
3. METHODOLOGY RESEARCH

The data analysis will involve many variables and indicators, so a multivariate multivariable analysis, that is an application method that deals with large number of measurement (more than one independent variable and one dependent variable) of the objects simultaneously conducted. The proposed analysis of the relationship between transportation system and fuel consumption of the cities in Javais made in accordance with the theoretical framework as illustrated in Figure 4.

![Figure 4. Theoretical Framework for Urban Transportation Model System and Fuel Consumption of Metropolitan and Large City In Java](image)

4. ANALYSIS

4.1. Fossil Fuel Consumption Characteristics in Cities in Java

The analysis results show that large and medium-sized cities can be grouped together and are positioned opposite of the direction of the line, meaning that large and medium-sized cities share similarities in fossil fuel consumption (petrol, diesel oil and both), in that they have low consumption of petrol fuel, diesel oil and both, whereas metropolitan cities (Semarang, Tangerang, Surabaya, Bekasi and Bandung) are spread out, meaning that each city is different in its fossil fuel consumption. Bandung has the highest petrol fuel consumption. Tangerang and Semarang has the highest diesel fuel consumption, the highest two types of fuel consumption is Surabaya, with almost equal percentages of petrol and diesel fuel consumption. The Biplot fossil fuel consumption analysis results can be seen in Figure 5 below.

![Figure 5. Biplot Fossil Fuel Consumption Analysis Results](image)

4.2. City Transportation System Characteristics in Java

Large cities are within the middle group. This shows that large cities have the following transportation system characteristics: a) road length, b) road condition (good, fair, damaged, very damaged), c) goods vehicles (trucks), d) public transportation vehicles (buses and public passenger cars), e) route length of public transportation, f) personal vehicles (buses, passenger cars, motorcycles) are not too apparent when compared to metropolitan cities. The Biplot city transportation system analysis results can be seen in Figure 6 below. Metropolitan cities consisting of: Semarang, Surabaya, Bandung, Bekasi and Tangerang have different prominent transportation system characteristics. This is evident from their spread out positions. Semarang has the longest road length. Surabaya has the largest number of public passenger cars, motorcycles and trucks. Bekasi has a prominent number of private passenger cars. Bandung has prominent public passenger cars, truck and motorcycles.
4.3. City Typology Characteristics in Java

The variables of city typology consists of the number of population, the nett area (area based on the width of developed areas), population density (based on developed areas), and RGDP (based on current prices). Analysis results show that there is grouping of the position and proximity between objects of city typology in Java. This shows that there are resemblances or similarities, meaning the cities have a relatively similar city typology. Cities grouped together are medium-sized and large cities. These cities have similar city typology, which is a low population number, low population density, low PRDB and low developed area. Metropolitan cities are widely spread or not grouped together, meaning each city has a different prominent city typology. Bandung has a high population density nett, Surabaya has the highest number of population and RGDP, and Semarang has the largest area. The Biplot city typology analysis results can be seen in Figure 7 below.

4.4. Fossil Fuel Consumption Model of Metropolitan and Large Cities in Java

Petrol fuel consumption highly influences total fuel consumption, yet not so for diesel fuel. Diesel fuel has a low and negative effect on total fossil fuel consumption. The higher the petrol fuel consumption, the higher the total fossil fuel consumption, but the higher the value of diesel fuel, the lower the value of fossil fuel consumption. City typology influences the city transportation system. The effect of the city typology on fossil fuel consumption for metropolitan cities are far bigger compared to the effect of the city transportation system on fossil fuel consumption. The higher the value of city typology is, the higher the fossil fuel consumption will be. The higher the value of the city transportation system is, the lower the fossil fuel consumption will be. The metropolitan city population density nett and developed areas variables have the biggest impact on city typology. The same applies for the transportation system variable: route length, good condition of roads, public passenger cars and motorcycles have a big impact on the city transportation system.
The population size in metropolitan cities is much higher than large and medium-sized cities, so fossil fuel consumption in metropolitan cities is much higher compared to large cities and medium-sized cities. Rising fossil fuel consumption in metropolitan cities is influenced more by the rise of RGDP rather than the rise of population. The higher the population, the higher the value of city typology, and this will raise fossil fuel consumption. The same applies for a rise in RGDP in metropolitan cities, where the higher the RGDP is, the higher the fossil fuel consumption will be. Population density in metropolitan cities has a big effect on city typology, so the higher the population density is, the higher the fossil fuel consumption will be.

The rise of the value of city typology is influenced more by the population number, population density nett and developed area as well as RGDP. So if the population size, population density nett and developed area as well as RGDP rise, the value of city typology also rises, therefore increasing fossil fuel consumption. In reality on the field, metropolitan cities have a higher population density nett, a wider developed area and a higher RGDP compared to large cities and medium-sized cities. Metropolitan cities generally have a wider administrative area than other cities but also a higher population density, so fossil fuel consumption, if viewed from the number of vehicles by the length of the road and population density nett divided by the city’s branches, has a smaller angle. The longer the roads is, the lower the value of the transportation system will be. This will increase fossil fuel consumption.

The number of motorcycles in metropolitan cities is higher than any other private vehicles. Although the fossil fuel consumption, especially petrol fuel, per motorcycle is smaller than for passenger cars, but the impact of motorcycles toward private vehicles is high, therefore, increasing petrol fuel consumption with the increasing number of motorcycles. The number of private passenger cars vehicles greatly affect private vehicles, meaning the higher the MPP vehicles are, the higher the value of private vehicles and the higher the value of the transportation system will be, which will eventually reduce fossil fuel consumption. The data analysis using PLS has produced Bootstrapping, and has produced an impact model of the city transportation system on fossil fuel consumption which can be seen in Figure 8 below.

The metropolitan cities in Java fossil fuel consumption model can be explained as below:
If the length of the road increases in value by 1 unit, the system’s value will decrease 0.427. If trucks increase in value by 1 unit, the system’s value will increase 0.356. If the route length increases in value by 1 unit, the system’s value will increase 0.999. If the road network patten increases in value by 1 unit, the system’s value will increase 0.182.

The road condition is classified into good roads, fair roads, damaged roads and non-damaged roads. If the road condition increases in value by 1 unit, the system’s value will increase by 0.282. If the good road condition increases in value by 1 unit, the road condition value will increase by 0.855. If the fair road condition increases in value by 1 unit, the road condition value will increase by 0.591. If the damaged road condition increases in value by 1 unit, the road condition value will increase by 0.088. If the very damaged road condition increases in value by 1 unit, the road condition value will decrease by 1.510. A good road condition greatly impacts the road condition value.
The public vehicle value is formed from public buses and public passenger cars. If public buses increase by 1 unit, the public vehicle value will decrease by 0.213. If public passenger cars increase by 1 unit, the public vehicle value will increase by 0.927. The private vehicle value is formed from private buses, private passenger cars and motorcycles. If private buses increase by 1 unit, the private vehicle value will increase 0.343. If private passenger cars increases by 1 unit, the private vehicle value will increase by 0.205. If motorcycles increase by 1 unit, the private vehicle value will increase by 0.658.

If the population increases by 1 unit, the typology value will increase by 1.017. If the population density increases by 1 unit, the typology value will increase by 1.787. If developed area increase by 1 unit, the typology value will increase by 1.172. If RGDP increases by 1 unit, the typology value will increase by 0.321.

Fossil fuel consumption in cities in Java can be explained as follows: if the typology increases by 1 unit, fossil fuel consumption will rise up to 1.097 kilo liters per year, but if the system increases by 1 unit, fossil fuel consumption will decrease 0.138 kilo liters per year. So the above explanation can be put into the following equation:

\[
\text{Road Condition} = 0.855 \times \text{Good Road} + 0.591 \times \text{Fair Road} + 0.088 \times \text{Damaged Road} - 1.510 \times \text{Very Damaged Road} \quad (1)
\]

\[
\text{Public Vehicles} = -0.213 \times \text{Public Buses} + 0.927 \times \text{MPU} \quad (2)
\]

\[
\text{Private Vehicles} = 0.343 \times \text{Private Buses} + 0.205 \times \text{MPP} + 0.658 \times \text{Motorcycles} \quad (3)
\]

\[
\text{System} = -0.427 \times \text{Route Length} + 0.182 \times \text{Road Network Pattern} + 0.282 \times \text{Road Condition}
\]

\[
+ 0.203 \times \text{Public Vehicles} - 0.131 \times \text{Private Vehicles} + 0.999 \times \text{Route Length} + 0.356 \times \text{Goods Cargo}
\]

\[
+ 0.421 \times \text{City Typology} \quad (4)
\]

\[
\text{City Typology} = 1.017 \times \text{Population} + 3.378 \times \text{Net Population Density} + 1.172 \times \text{Net Area} + 0.321 \times \text{RGDP} \quad (5)
\]

\[
\text{Fossil Fuel (outer)} = 0.944 \times \text{Petrol} + 0.104 \times \text{Diesel Fuel} \quad (6)
\]

\[
\text{Fossil Fuel (inner)} = 1.097 \times \text{City Typology} - 0.944 \times \text{System} \quad (7)
\]

The number of public passenger cars strongly influences public vehicles, the more public passenger cars are, the higher the value of public vehicles and the higher the value of the transportation system will be. This will eventually lower fossil fuel consumption. Public transport buses have a relative (negative) effect on the metropolitan cities transportation system. The more buses are, the lower the value of public vehicles will be, and also the lower the transportation system value is, therefore increasing fossil fuel consumption. This is caused by the number of public transport buses that is lower than the required amount.

The route length in metropolitan cities greatly affects the city’s transportation system. The longer the route length of city public transportation (wider service area of public transportation) is, the higher the transportation system value will be, which will lower the fossil fuel consumption. Good road conditions in metropolitan cities greatly affects the city transportation system, the longer the good road condition is, the higher the transportation system value will be, which will lower fossil fuel consumption. Goods transportation has a fair effect on the city transportation system.

The dependent variable is fossil fuel consumption (petrol and diesel oil) and the independent variables are city typology (population size, net area, population density nett, RGDP) and transportation system (road length, road network pattern, number of public vehicles, number of private vehicles, number of goods vehicles, road length based on road condition (good, fair, damaged, and very damaged).

5. CONCLUSION

The city transportation system and city typology have reciprocal effects. Fossil fuel consumption in metropolitan cities are more influenced by the city typology (population size, net area, nett population density, RGDP) than by the city transportation system. This is because the currently available transportation system has not been provided well and the management of land use has not been implemented well.
The city transportation system consuming fossil fuel efficiently is a city transportation system with public transportation services using large capacity vehicles, efficient routes, low percentage and number of vehicles (private and goods), road network pattern using grid, and a compact land use. The transportation system consuming a lot of fossil fuel is the city transportation system providing small capacity public transportation services, inefficient routes, high percentage and number of vehicles (private and goods), a radial road network pattern, and a land use that is not compact (for example: Semarang, Bandung, Tangerang).

REFERENCES