GREENHOUSE GAS EMISSIONS AS AN IMPACT OF NEW ROAD UNDER RAILWAY ELEVATION PROJECT IN TAOYUAN, TAIWAN

Rahayu Kusumaningrum

Lecturer, Department of Civil Engineering, Brawijaya University
kusumaningrum_rahayu@yahoo.com

Abstract

Frequent occurrence of severe traffic congestion between Taoyuan City and Zhongli City has encouraged Taoyuan County Government to build elevated railway between these two cities. Besides, this plan also intended to merge all road signage by constructing new roads under the newly built elevated railway. Based on the environmental point of view, railway infrastructure improvement may be able to reduce the congestion and also emission. But the construction of new roads under it may result conversely, especially for the area neighboring the project. Therefore, the impact of railway elevation project parallel with the construction of new road on greenhouse gas emissions generated by road transport needs to be further studied.

This study integrates transportation planning model and emission estimation model in order to estimate CO\(_2\) emissions as an impact of road improvement and further shows the spatial distribution of emission in grid-based emission. Short-term and long-term period analysis were done both for Taoyuan County and the affected area. Short-term period analysis analyze the project’s impact on emission for short-term after the project is implemented. Meanwhile, long-term period analysis analyze the impact of the project 20 years later.

The results shows that in term of emission, the implementation of railway elevation project parallel with the construction of new roads generates the lowest CO\(_2\) emissions for whole Taoyuan County area both for short-term and long-term period analysis. In contrary, for project-affected area, the lowest emission is derived from the implementation of railway elevation project without construction of new roads both for short-term and long-term period analysis.

Keywords: Railway elevation project, road improvement, emission estimation model, grid-based emission, Taoyuan County

Introduction

In recent years, the need for mitigation of climate change has been more and more acknowledged. Climate change is one of the most serious environmental threats and global systemic risk facing the world today. Therefore, awareness of the global scale of emission of greenhouse gases has increased over the last few years. One of the most abundant greenhouse gases in earth’s atmosphere is carbon dioxide (CO\(_2\)). According to OECD (2002), scientists have noted that the average of CO\(_2\) content of the earth’s atmosphere is steadily increasing. Among many sources of CO\(_2\) emitters, transportation sector is one of the major emitters of CO\(_2\) that can not be trivialized, it contributes about 23% of total CO\(_2\) emissions worldwide (IEA Statistics, 2011).

This research focuses on Taoyuan County as the third largest populated county in Taiwan after Taipei County and Taipei City. It is located in the northwestern part of Taiwan. As the economy continues to grow and its population steadily increasing, with a monthly increases of about 1500 to 2000 people, the demand for transportation in Taoyuan County tends to increase correspondingly.

Based on the number of registered motor vehicles issued by the Ministry of Transportation and Communications R.O.C., the total number of motor vehicle in Taoyuan County by 2011 was 1,797,521 vehicles, with about 63.6% motorcycles, 31.5% passenger cars, and 1.1% trucks and buses. The use of private cars increases for about 0.7% by March 2012. Due to the great number of motor vehicles and the rapid growth of private cars, serious traffic congestion often happen along the main traffic corridor between Taoyuan City and Zhongli City, two core cities of Taoyuan County. The traffic congestion not only causes economic loss, but also environment pollution which can affect people’s health.
To deal with the severe traffic congestion, Taoyuan County government funded the project of Taiwan railway improvement which connects the urban development hub of Taoyuan City and Zhongli City. The removal of the conventional railway into elevated was the main concern of this project. This project not only aims to alleviate traffic congestion by improving the large-scale mass transportation infrastructure, but also to merge all road signage and intensified the traffic management. The merging of all road signage by constructing new roads under the new elevated railway was also expected to reduce the traffic congestion.

Based on the environmental point of view, the improvement of such a large-scale mass transportation infrastructure may be able to reduce the congestion and also emission. But the construction of new roads under it may result conversely. For the short-term period, the construction of new roads may be able to solve the problem of traffic congestion, which accordingly will also reduce the emission. But for the long-term period, the construction of new roads may encourage the purchase and use of more vehicles, which means the possibility of increase in congestion and emissions will also be higher.

Based on the background above, this research seeks to analyze the best planning that should be implemented in order to alleviate traffic congestion and more specifically to reduce the emissions that occur between the hub of Taoyuan City and Zhongli City, the two core cities of Taoyuan County.

Literature Review

Projects Overview

Experiencing rapid industrial and commercial development that also accompanied by rapid population growth especially in Taoyuan City and Zhongli City, the two core cities of Taoyuan County, makes the transportation infrastructure that has been available is no longer sufficient. Therefore, Taoyuan County government strives to improve the main artery for the western line of Taiwan Railway Administration which connects these two cities. Currently, the railway section along Taoyuan City and Zhongli City will be improved by the Ministry of Transportation to promote the metropolitan area of Taiwan Railway Administration “MRT” by convert it into elevated railway.

The starting point of the elevated railway project was undertaken at Yingge Station and Taoyuan Station, the western line of Taiwan Railway, mileage of about K53+350, southward to Zhongli station. The overall planning of this project include preliminary works, drop excavation, overhead works, and station works.

Related Works

The increase of transport in the 20th century was closely linked to the use of fuel which also will affect the increase in greenhouse gas emission. Greenhouse gas emission is one of the causes of climate change. In order to mitigate the climate change that getting more serious from year to year, various models and emissions estimation methods have been studied and investigated by researchers over the years, as follows:

1. C. Borrego et al. (2000) in “Impact of road traffic emissions on air quality of the Lisbon region” have studied the emission of CO, NOx, and VOC produced by road traffic in the area of Lisbon by using high spatial and temporal resolution emission estimation approaches. Emissions from four vehicle types and three road classes were observed. The emission factor used was derived
from default emission factors handbook provided by European Commission.

2. Kyoungho Ahn and Hesham Rakha (2008) in “The effects of route choice decisions on vehicle energy consumption and emissions” have investigated whether traveling along a longer but faster routes results in energy and/or air quality improvements or not. They used microscopic and macroscopic emission estimation tools to estimate the emission factors of HC, CO, NOx, and CO₂ for different vehicle type. VT-Micro model and the comprehensive modal emissions model (CMEM) were used to estimate microscopic level emission. While for macroscopic level, the Environmental Protection Agency’s (EPA) MOBILE6 was utilized. But they concluded that MOBILE6 can produce erroneous in evaluating the environmental impacts of traffic operational projects, given that they ignore transient vehicle behavior along a route.

3. Yu Zhou et al. (2010) in “The impact of transportation control measures on emission reductions during the 2008 olympic games in Beijing, China”. In this research they investigated the effects of temporary transportation control measures during the event on urban motor vehicle emissions. Grid-based emission inventories with micro-scale vehicle activities and speed-dependent emission factors were developed to measure the emission of volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxides (NOx) and particulate matter with an aerodynamic diameter of 10 mm or less (PM10) before and after the event.

4. Chun-Hsiung Liao et al. (2011) in “Carbon dioxide emissions and inland container transport in Taiwan” have predicted the trend of carbon dioxide (CO₂) emissions produced by inland container transport during the time period of 1998–2008. The CO₂ emissions from inland container transport were estimated based on the methodology provided by IPCC Guidelines for generating national greenhouse gas emission for road transport sector.

**Methodology**

Basically, the overall methods of this research can be divided into three main parts, i.e.: transportation modeling, emission estimation model, and the integrated model between the two.

**Transportation Demand Modeling**

Transportation demand modeling in this study was based on the model developed by THI consultants inc. that trusted by Taoyuan County government to run the railway elevation project (see Figure 3). The only focus in this research was traffic assignment process, the last step of the classical transportation modeling.

**Traffic Zoning**

In this research, the study area was divided into 509 zones where zone 1 up to zone 464 were located in Taoyuan County, while the zones apart from that were located outside Taoyuan County, such as Taipei City and Hsinchu City.

**Road Network**

Established using highly detailed traffic zones with a scale 1/25,000 makes the road network built for Taoyuan County closer to the real network. The road network used in this research was created based on the situation in 2011 which also projected for the situation in 2031. According to the project plan of Taoyuan County Government Transportation Bureau, there were some roads that exist in 2011 but not in 2031 and also there were some roads that have not been built in 2011, but will exist in 2031.
The term “new road” here means road that will be constructed under the elevated railway, it will be located align with the railway from Taoyuan City to Zhongli City. Based on the report derived from Taoyuan County Government Transportation Bureau, there are 73 new roads that will be built.

Traffic Assignment

The traffic assignment model was used to estimate the flow of traffic on a network. It determines the allocation of trips between origin and destination by a particular mode to a route (corresponding network), and estimates the link travel times and related attributes that were the basic for benefits estimation and air quality impact.

Figure 5. Traffic flow of Taoyuan County in 2011

In this research there were three modes considered i.e., car, motorcycle and freight, so that the analysis used was based on multi-modal multi-class assignment (MMA) using user equilibrium method.

Emission Estimation Model

Emission factor used in this research was developed by the cooperation of Ministry of Transportation and Communications, THI consultant, and Chung-Hua Institution for Economic Research, Taiwan. Seven road classes with varying speed were observed. On-road fuel consumption measurements integrate with laboratory measurements by using the U.S. Federal Test Procedure (FTP) was done in order to obtain a set of emission factor that sensitive to vehicular speeds and highway classes.

Integrated Model

Integrated Model

Integrated Model

To demonstrate the spatial distribution of emission in Taoyuan County area, the area of Taoyuan County was divided into 1053 grids, each of which was 1 km x 1 km. Road links emissions resulted were further transformed into grid-based emissions. Information provided in each grid cell includes grid ID, area, and total CO\textsubscript{2} emission per km\textsuperscript{2} (kg/day). The total CO\textsubscript{2} emission in kg/day per km\textsuperscript{2} was the result of multiplication between travel time, traffic flow, and emission factor for each link.

Scenario

Three conditions were observed in this research both for short-term and long-term period either for whole Taoyuan County area and project-affected area (a zone with a distance of 2 km around the project).

Short-term period analysis analyze the project’s impact on emission for short-term after the project was implemented in 2011. Meanwhile, long-term period analysis analyze the impact of the project in the year 2031.

Current condition scenario

This scenario describes the emission in Taoyuan County in 2011 before the railway elevation project implemented. Whereas for 2031, it describes the emission where there was no railway elevation project implemented in Taoyuan County area.
Elevated with no new road scenario
This scenario describes the emission when the railway elevation project was implemented both for year 2011 and 2031. This scenario assumes that the project has been completed in 2011 and further projected to 2031 as the target year. There were 17 railroad crossings that removed as a result of railway elevation project implementation.

Elevated with new road scenario
Basically this scenario was the same as “elevated with no new road” scenario. The difference was that in this scenario there were 73 newly constructed roads located at the original location of railway before elevation.

Travel Demand
The travel demand used for all scenarios in 2011 and 2031 were 2,859,686.44 PCU and 3,546,934.83 PCU, respectively.

Results
In this research, overall emission of Taoyuan County area was analyzed first. Followed by the emission analysis of project-affected area to better see the impact of railway elevation project implementation.

Due to the absence of changes in travel demand used, meaning that the travel demand used is fixed for all scenarios. Therefore, the emphasis in this research is the difference between each scenario that compared in each analysis.

Moreover, emission has a strong relationship with traffic. The more dense the traffic, the higher the fuel consumption. Consequently, the emission will also be higher.

Taoyuan County Area
Short-Term Period
The current emission pattern of Taoyuan County or the emission in Taoyuan County in 2011 before the railway elevation project implemented shows that the more toward downtown, CO₂ emissions generated by road transport is getting worse. The darker the color of the grid, the worse the emissions that occur in the area.

Figure 7 shows that the distribution of vehicle emissions in Taoyuan County are more concentrated in the center of Taoyuan City and Jhongli City, two core cities of Taoyuan County. More than 9,500 kg of CO₂ per km² emitted in a single day in almost all of these two areas.

Based on the results, it shows that the total CO₂ emission in Taoyuan City and Jhongly City is about 783,283.453 kg/day and 781,978.503 kg/day in 2011, respectively. This is understandable because the center of Taoyuan City and Jhongli City is the hub of urban development in Taoyuan County area which currently experiencing rapid industrial and commercial development. While the total emission of current condition scenario in Taoyuan County area is the highest that is 5,528,165.272 kg/day.

In case the railway elevation project has been completed in 2011 where there are 17 railroad crossings removed, the total CO₂ emission of Taoyuan County is reduced by 1.90% from the current condition. Figure 8 is shown to better see the difference between current condition scenario and elevated railway with no new road scenario. Figure 8 (a) showing areas which are experiencing an increase in the number of emission, while Figure 8 (b) showing areas which are experiencing a decrease in the number of emission.
Greenhouse Gas Emissions as ….

Figure 8. Elevated with no new road scenario (a) Areas that experienced an increase in emissions, (b) Areas that experienced a decrease in emissions

Removal of these crossings makes north–south traffic more smoothly. Traffic congestion that previously occurs because of the existence of these crossing has been reduced. Therefore, the emissions are also lower.

The lowest emission is obtained from elevated with new road scenario with 5,524,718.91 kg/day or decreased about 6.23% from the current condition. It happens not only because removal of 17 railroad crossings, but also because there is no change in travel demand within each scenario while the road capacity increases as a result of the construction of new roads.

To better see the difference between current condition scenario and elevated railway with new road scenario, Figure 9 was featured. Figure 9 (a) showing areas which are experiencing an increase in the number of emission, while Figure 9 (b) showing areas which are experiencing a decrease in the number of emission.

Figure 9. Elevated with new road scenario (a) Areas that experienced an increase in emissions, (b) Areas that experienced a decrease in emissions
Greenhouse Gas Emissions as ….

**Long-Term Period**

Figure 10. Pattern of emission in Taoyuan County in 2031 without railway elevation project

In accordance with the spatial distribution of emission in 2011, the emission distribution of current condition in 2031 where there is no railway elevation project implemented in Taoyuan County area looks much more severe as shown in Figure 10. Grids with dark color look more intense, mainly for the downtown area and the area around freeway and expressway.

Figure 11. Taoyuan County total CO₂ emission in 2031

The emission pattern for each scenario in 2031 is the same as the pattern of the emission for each scenario in 2011. The highest vehicular emission is derived from current condition scenario with 7,715,725.537 kg/day. Removal of 17 railroad crossings in elevated no new road scenario makes the total emission of Taoyuan County lower for this scenario. The total CO₂ emission for this scenario is 7,713,282.933 kg/day, means that it decreased by 0.03% from current situation. Then, the lowest emission is obtained from elevated with new road scenario with 7,695,705.559 kg/day. It means that emission for this scenario is decreased by 0.23% and 0.26% from elevated no new road scenario and from current condition scenario, respectively. The reduction happens not only because removal of 17 railroad crossings, but also because there is no change in travel demand within each scenario while the road capacity increases as a result of the existence of new roads.

**Project-Affected Area**

In order to better see the impact of railway elevation project implementation on Taoyuan County area, small area surrounding the project is observed. A zone with a distance of 2 km around the project is defined as the area affected by the project. Further away from the project site, the smaller the impact of the project. Determination of the affected area is based on links which experienced more than 10% increase and decrease both in traffic flow and CO₂ emission after the implementation of railway elevation project.

Figure 12. Project-affected area

**Short-Term Period**

Figure 13. CO₂ emission of project-affected area in 2011

Figure 13 shows that for short-term period, the total emission of elevated with new road scenario in project-affected area is the highest that is 1,479,140.196 kg/day. The lowest emission is derived from the implementation of elevated with no new road scenario with 1,460,672.12 kg/day. Railway elevation project implementation, which also means the removal of 17 railroad crossings, is able to help in alleviating the emissions that occur under current conditions. Removal of these crossings makes north – south traffic more smoothly. Traffic congestion that previously occurs because of the
existence of these crossings has been reduced. Therefore, the emissions are also lower.

Increase in road capacity as a result of the construction of new road and no change in travel demand supposed to make the emission lower for elevated with new road scenario. But in fact, emission resulting from this scenario is the highest for the project-affected area. It may happen because some motorists change their route as a result of new roads constructions. As an example, some links connected and located close to new roads are experiencing decrease in traffic flow, which means also decrease in emission; while new roads are experiencing increase both in travel flow and emission.

### Long-Term Period

![Graph showing CO2 emission increase percentage for different scenarios.]

**Figure 14.** Long-term CO2 emission for project-affected area

The results of these comparisons are described in emission increase percentage for each scenario from 2011 to 2031 as shown in Figure 14 above. The highest percentage of emission increase occurs in current condition scenario, reaching 64.17%. The lowest emission is obtained from elevated with no new road scenario. Implementation of this scenario is able to reduce the emission in Taoyuan County by 2.76% from current condition for long-term period. Although there is no change in travel demand used for each different scenario, it may happen because some motorists change their route as a result of new roads constructions. In general, motorists will choose routes that minimize their travel time which also minimize cost they should spend.

### Conclusions and Recommendations

#### Conclusion

1. For whole Taoyuan County area:
   a. For short-term period analysis, implementation of railway elevation project that accompanied by construction of new roads generates the lowest CO2 emissions that is 5524718.91 kg/day, which means it reduce the emission by 0.06% from the current condition.

2. For long-term period analysis, the lowest emission is also obtained from elevated railway with new road scenario with only 39.30% emission increase from 2011 to 2031 because there is no change in travel demand used.

#### Recommendations

In term of emission, to better see the impact of railway elevation project implementation in Taoyuan County area, the following recommendations should be made for future research, i.e:

1. Change in travel demand which means modification in O-D matrix for elevated with no new road scenario and elevated with new road scenario both for 2011 and 2031 conditions should be conducted.

2. Another type of greenhouse gases, such as H2O, CH4 and N2O generated by road transport may be observed.

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