DESIGN GUIDELINE OF TREES PLANTING ALONG THE ROADSIDE CONSIDERING IMPACTING OF THE CO2 EMISSION DISPERSION BY VEHICLES

Abstract Dissertation

DESIGN GUIDELINE OF TREES PLANTING ALONG THE ROADSIDE CONSIDERING IMPACTING OF THE CO2 EMISSION DISPERSION BY VEHICLES

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Abstract

This Ph.D. research focuses on evaluating the design of trees planting on the roadside in impacting the dispersion of CO_2 emitted from transportation. This research provides the alternative design of trees planting in urban roadside that can improve level air quality exposed CO_2 emission. The result can support urban planners, government, or other stakeholders to solve the decreasing air quality due to CO_2 emission dispersion. Computational Fluid Dynamics (CFD) was used to simulate the spread of CO_2 and analyze air quality in some design trees planting. So, the first research is investigating the CO_2 dispersion emitted from transportation in the study area with trees planting and without tree planting on the roadside. The result confirms the effect of tree planting on air quality exposed to CO_2 dispersion that emitted from transportation.

After confirming trees planting impact on CO2 dispersion, the next step is providing row positions of trees planting. This second research evaluates the four-row position of trees planting to the road-air quality from CO_2 emission. Trees can plant as a one-row position in the middle of the road. Trees also can plant as double-row positions on both sides of the road as a barrier between road, roadside, and building.

Thirdly, this research predicts CO_2 dispersion in different design trees planting patterns. This stage carried out five design of tree planting patterns based on the row position, avenue-tree layout, and space. These designs of trees planting can be effective in increasing air quality if the trees species chosen are appropriate. The selection of the trees is related to the tree's crown shape. So, the last step of this research is analyzing the crown shape of trees planting on the roadside to improve air quality. This study provides five tree's crown shape. Therefore, the design of trees planting patterns can improve air quality exposed to CO_2 emission from transportation optimally.

Keywords: *CO_2 emission, Computational fluid dynamics, trees planting pattern, design trees planting, air quality.*

I. Introduction

Currently, motor vehicle numbers in urban areas always increase every year. Indonesia, as a developing country, has a high of motor-vehicle number, so there is much congestion that can found in the road. Motor vehicles were increased by 300% since the 2008-2018 (Statistics Bureau of Indonesia, 2019). This condition causes degradation in air quality because it will produce CO_2 emissions from gasoline and diesel usage as fuel.

Transportation is the primary source of CO2 emission in the air. It will disperse 34% of the total CO_2 in the air every day (Sullivan *et al.*, 2004; Jie, 2011; EPA, 2016). CO_2 from transportation spread quickly to the roadside, which is a facility for pedestrians who want to travel in public space that separates from roadway vehicles. But currently, Co2 dispersion that effects road-air quality can harm pedestrians. High CO_2 concentration can have a devastating effect on human health, such as headaches, sleepiness, stuffy air, stale, poor concentration, loss of attention, increased heart rate, etc.

Based on that, this research es expected to deliver the contribution for the body of knowledge by 1) Investigating the CO_2 dispersion emitted from transportation in the study area with trees planting and without tree planting on the roadside. This research confirms the effect of tree planting on the roadside to the distribution of CO_2 emitted from transportation so that it can be comparative data of air quality in a study area with trees and a study area without trees. 2) Evaluating the row position of trees planting to the road-air quality from CO_2 emission. ; 3) Predicting CO_2 dispersion in different design trees planting patterns. This design can be applied in roadside that has chronic congestion to improve air quality. So that the results can be used in the tree-side planting design to get the maximum function in improving air quality.

Therefore, the main body in this research divided into four chapters (*Figure 1*). The first discussion displays investigating the CO_2 dispersion emitted from transportation in the study area with trees planting and without tree planting on the roadside. The next discussion is evaluating the row position of trees planting to the road-air quality from CO_2 emission. After that, the next section is predicting the CO_2 dispersion in different trees planting patterns based on some parameters design.

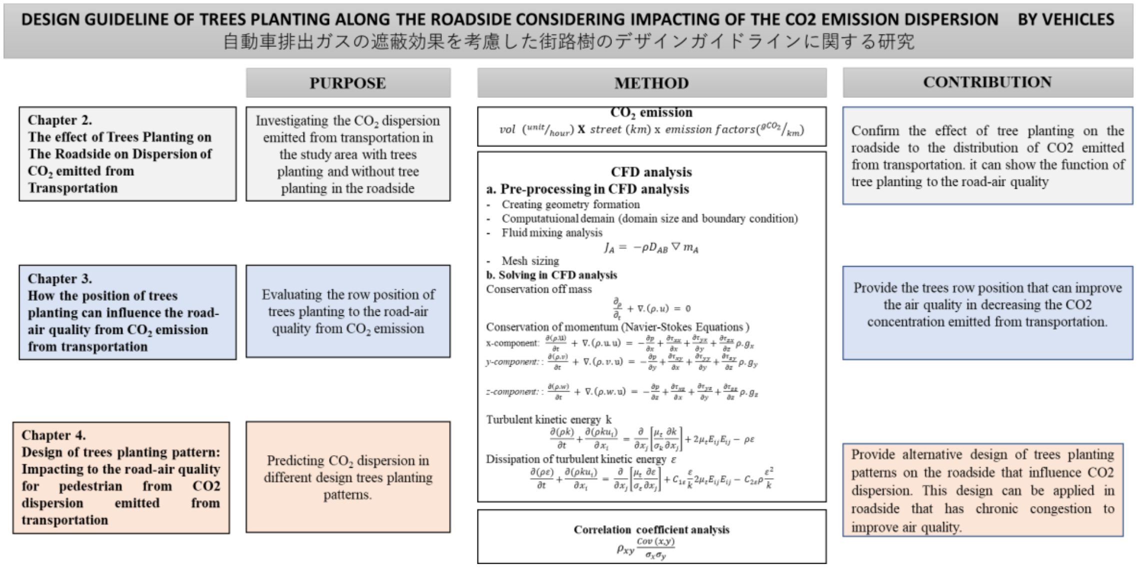


Figure 1 Research framework

1.2.1 The effect of trees planting on the roadside on the dispersion of CO2 emitted from transportation.

This chapter simulates the CO_2 dispersion in the real 3D modeling according to the actual physical condition. It is mean that the characteristic of the trees and buildings in the study area were built according to reality. This research displays the comparison of CO_2 dispersion in the study area without trees and with trees (*Figure 2)*.

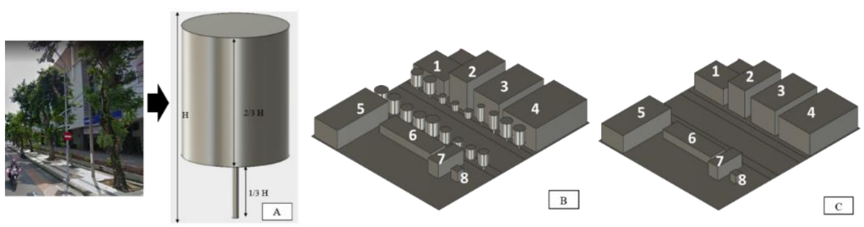


Figure 2 geometry of 3D modeling a) Trees modeling; b) study area with trees; c) study area without trees

This section appearance the distribution of CO_2 in the study area. *Figure 3* shows the comparison of CO_2 dispersion at several heights in both models. Based on that, the model with trees has a higher distribution value. At the height of 1.8 meters, the CO_2 distribution in the study area without trees is 19.2%%. While CO_2 spread by10.2% in the modeling with trees, this result shows that trees in the roadside can decrease CO_2 dispersion by 9% at an altitude of 1.8 meters. It is also displayed in another different height.

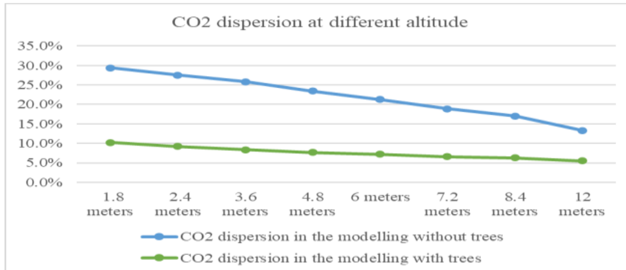


Figure 3 The comparison of CO_2 dispersion on the study area without trees and with trees.

Another result shows the CO_2 concentration on the road in both of modeling *(Figure 4)* and CO_2 concentration on the roadside (*Figure 5).* The result show that study area with trees can decrease CO_2 concentration on the road, but has higher CO_2 concentration on the roadside. While, study area without trees can decrease CO_2 concentration on the road and increase CO_2 concentration on the road. Trees can withstand the wind so that CO_2 is trapped in the area. This condition is not good for the pedestrian. Then it is necessary to design a better tree planting so that the roadside does not have high CO_2 concentrations.

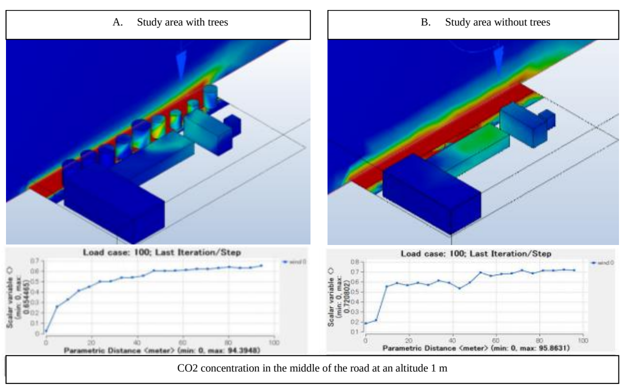


Figure 4 CO_2 concentration in the middle of the road and roadside between the area with trees and area without trees

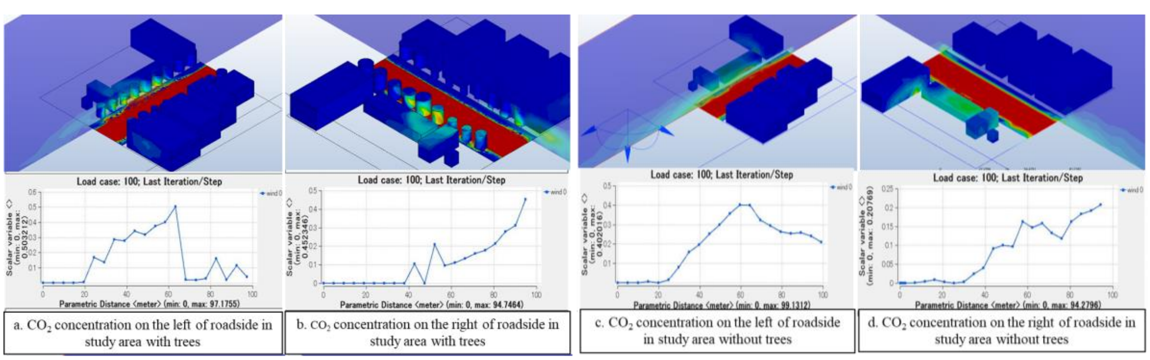


Figure 5 CO_2 concentration in the right and left of the roadside

3. How positions of trees planting can influence the dispersion of CO2 emission from transportation.

This section discusses the influence of some design positions of trees planting on dispersing CO_2. This section provides four position of trees planting on the roadside. This study considers some trees planting position in some road of Surabaya City. *Figure 6* shows the position of trees planting in this section.

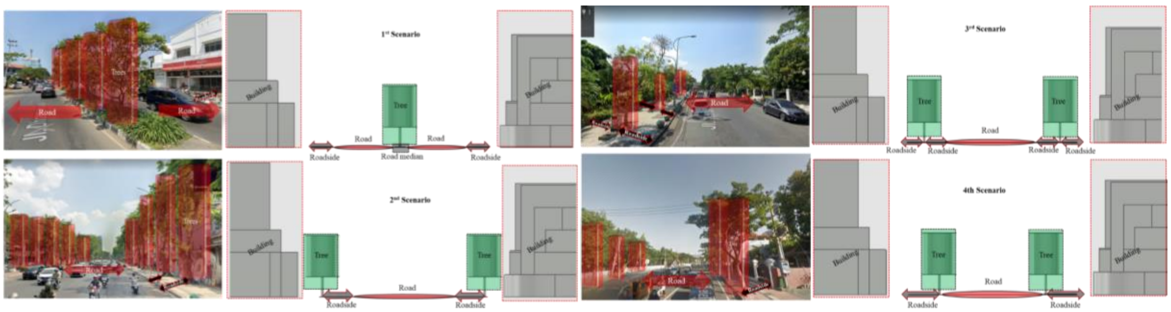


Figure 6 The position of trees planting in Surabaya city

The following figure shows the result of CO2 dispersion simulation at different altitude. The result displays that some row position is not effective in improving the air quality from the distribution of CO_2 emission. Therefore, this study evaluates this row position to get the best row position of trees planting in dispersing CO_2. Based on that figure, 2nd scenario has the highest CO_2 concentration. Then among the four scenarios, 4th scenario, which is trees, are planted on the roadside as a barrier between road and roadside, has the lowest CO_2 dispersion than others scenario. 4th Scenario can disperse 33.1% of CO_2 emission at an altitude 1.8 meters. It's mean that this position of trees planting can decrease CO_2 dispersion of 13.1%.

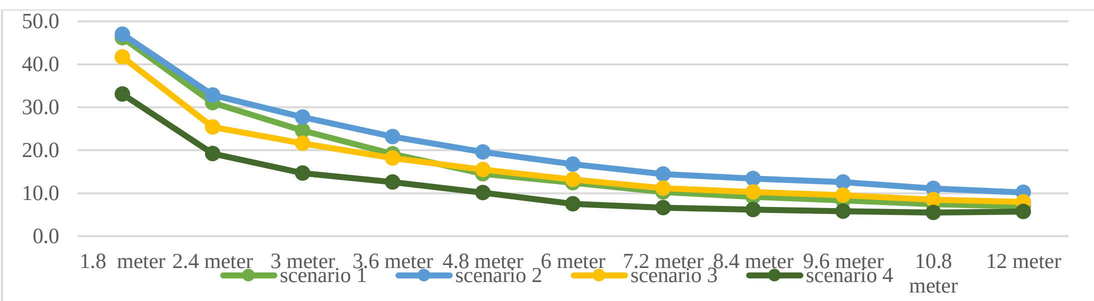


Figure 7. CO2 dispersion in some scenario of trees planting position at an different altitude

On the other result, this section also shows the analyses of air quality in different tree's row position (*Table 1)*. Air quality is indicated by CO_2 concentration in the study area. This analysis use standard from Wisconsin Department of health service (2019).

Table 1 Level of air quality

The standard of CO_2 concentration in the air		CO2 level (%)			
Level of air quality	CO2 concentration	1st scenario	2nd scenario	3rd scenario	4th scenario
Good air quality (Normal background concentration in outdoor ambient air)	>0.04% (400 ppm)	90.5	89.1	90.2	92.4
Good air quality (minimal CO2 concentrations in indoor spaces) exchange	0.04%-0.1% (400-1,000ppm)	1.4	1.5	1.1	1.3
Poor air quality (Complaints of drowsiness and poor air)	0.1%-0.2% (1,000-2,000 ppm)	3.2	2.5	2.7	1.6
Poor air quality (Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate, and slight nausea may also be present.	0.2%-0.5% (2,000-5,000 ppm)	5.0	6.9	6.0	4.7

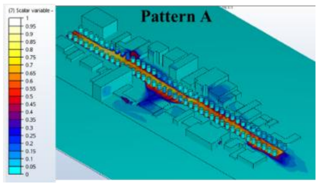
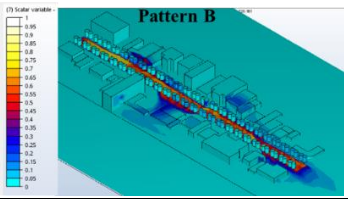
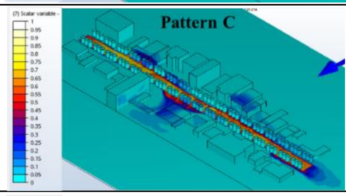
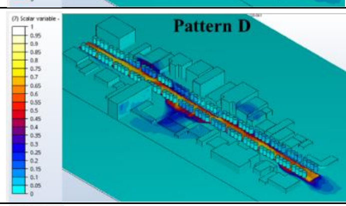
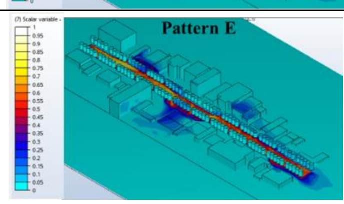
Table 1. shows that 4^{th} scenario has the highest good level air quality than other scenarios, which is 92.4% good air quality. While, scenario that has lower percentage of good air quality is 2^{nd} scenario, which is 89.1%. Then 1^{st} and 3^{rd} scenario have similar value of good air quality in outdoor. On the other side, the scenario that has lower percentage of poor air quality is 4^{th} scenario. This scenario only has 6% area that has poor air quality. While, poor air quality in 2^{nd} scenario is 9%, which is the highest area than other scenario.

The conclusion of this section shows that the 4th scenario is better in improving air quality. This scenario plants the trees in the double-row position as a barrier between roadside and road.

4. Impact the design of trees planting patterns on the roadside to the near-road air quality from CO2 dispersion emitted from transportation

This section discusses some design of trees planting patterns to improve the near-road air quality. This chapter displayed five scenarios of trees planting patterns according to some parameters design, which is the position, the avenue-tree layout, and space. So, it can predict the CO_2 dispersion in different design trees planting patterns. It will provide some alternatives design of trees planting patterns on the roadside that influence CO_2 distribution. This design can be applied in roadside that has chronic congestion to improve air quality.

Table 2 CO2 dispersion in five scenarios

The scenario of trees planting pattern	Parameters of trees planting pattern	CO_2 dispersion at an altitude of 1.8 m
	Position of trees row: Double rows Space of trees: Hedgerow Avenue-tree layout: CVF: 21.3%	34.1% of CO2 can disperse in pattern A at an altitude of 1.8 meters. The range of CO2 concentration in this simulation starts from 0-0.82% (0-8200 ppm) at an altitude of 1.8 meters. The total area that has poor air quality in this pattern, which has CO2 concentration by >0.1% (>1000 ppm), is 4.35% of the total area at an altitude of 1.8 meters
	Position of trees row: Double rows Space of trees: Hedgerow Avenue-tree layout: CVF: 26.6%	Pattern B can distribute CO2 by 28.6% at an altitude of 1.8 meters. The range of CO2 concentration in this simulation starts from 0-0.78% (0-7800 ppm) at an altitude of 1.8 meters.
	Position of trees row: Double rows Space of trees: Hedgerow Avenue-tree layout: CVF: 28.8%	30.1% of CO2 emission can disperse in pattern C at an altitude of 1.8 meters. The range of CO2 concentrations in the simulation start from 0-0.77% (0-7700 ppm) at an altitude of 1.8 meters.
	Position of trees row: Double rows Space of trees: Hedgerow Avenue-tree layout: CVF: 29.8%	Pattern D can distribute CO2 by 32.3% at an altitude of 1.8 meters. The range of CO2 concentrations in the study area starts from 0-0.79% (0-7900 ppm) at an altitude of 1.8 meters.
	Position of trees row: Double rows Space of trees: Hedgerow Avenue-tree layout: CVF: 32%	Pattern E can spread CO2 by 30.06% at an altitude of 1.8 meters. This pattern has CO2 concentrations in the range from 0-0.79% (0-7900 ppm) at an altitude of 1.8 meters. 4.0% of the total area at an altitude of 1.8 meters has a poor air quality level, which has >0.1% (>1000 ppm) of CO2 concentration.

the conclusion of trees planting design that can improve air quality is pattern B. Pattern B can decrease CO_2 dispersion by 28.6%. It indicates that pattern B with the double-row position, hedgerow space with one by one tree planting (26.6% CVF), can decrease 8% of CO_2 dispersion in the study area compared with others. Hence, the area that has poor air quality in this pattern only 3.86% with the Co2 concentration range of 0-0.78%

令和２年７月 30 日

学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

DESIGN GUIDELINE OF TREES PLANTING ALONG THE ROADSIDE CONSIDERING IMPACTING OF THE CO2 EMISSION DISPERSION BY VEHICLES

(和訳：自動車排出ガスの遮蔽効果を考慮した街路樹のデザインガイドラインに関する研究)

２．論文提出者 (1) 所　属　環境デザイン学 専攻

(2) 氏(ふり)　名(がな)　NURUL(ぬらる) AINI(あいに)

３．審査結果の要旨（600～650 字）

NURUL AINI 氏の学位請求論文は「自動車排出ガスの遮蔽効果を考慮した街路樹のデザインガイドラインに関する研究」である。地球温暖化問題を背景として、都市デザインの分野において、自動車排出ガスの遮蔽効果の高い街路樹の形状とその配置計画について検討し、道路沿道の歩行者環境の向上に向けた街路樹のデザインガイドラインの在り方を検討した、新規性の高い研究である。

道路景観のデザインガイドラインを扱った既存研究では、住民参加型による景観まちづくりに関する研究や、法規制に基づく街並み景観の在り方を論じた研究が大半であり、地球温暖化問題を背景に、自動車由来の二酸化炭素の遮蔽効果に注目したデザインガイドラインの研究はほぼ皆無である。本研究ではインドネシアのスラバヤ市を事例として取り上げ、まず道路沿いにある街路樹による自動車排出ガスへの遮蔽効果をシミュレーションにより検討し、街路樹の位置や形状と自動車から排出される二酸化炭素の空間分布との関係を可視化した。さらに、街路樹の配列パターンが排出された二酸化炭素の空間分布に及ぼす影響を検証した。これらの一連のミクロなシミュレーション研究に基づいて、道路空間上の歩行者に対して、安全性の高い大気環境を確保するための街路樹のデザインガイドラインを定量的な根拠とともに提案した。

NURUL AINI 氏は、本学在学中に、学位論文の参考論文として、査読論文３編（ESCI と SCOPUS）を公表した。なお、副論文として国際会議１編、査読論文１編(ESCI)がある。本審査委員会は、NURUL AINI 氏が優秀な研究業績を挙げており、博士（工学）の学位に値すると判定した。

４．審査結果　(1) 判　定（いずれかに○印）　(合　格)・　不合格

(2) 授与学位　博　士（ 工学 ）