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The influence of integrated space–transport development strategies on air pollution in urban areas

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ABSTRACT

The phenomenon of urban sprawl has strong impacts on transport performance and accessibility and causes an increase of air pollution. Effective control of urban sprawl requires an integrated approach comprising urban transport and land-use planning. Current research is insufficient to demonstrate the effects of urban sprawl on travel behavior and air pollution emission. The present paper examines the potential of an integrated approach on space–transport development strategies with the aim of increasing accessibility and reducing air pollution. A combination of space and transport strategies has been simulated for the rapidly expanding city of Surabaya. A comparative analysis of the impact of those cases indicates the promising potential alternatives to minimize the phenomenon. The transport options considered are combinations of Public Transport (PT), comprising Mass Rapid Transit (MRT), Light Rapid Transit (LRT), and Bus Rapid Transit (BRT). The options for urban structure include a compact zone development for the city, as formulated by the city planning agency, and a polycentric city set-up based on a job-housing balance aimed at minimizing the house-job distance. The results indicate that the polycentric city structure has the potential to make public transport work successfully for the city of Surabaya. This city structure creates a trip demand pattern which matches citizens' PT preferences. Compared to the current situation, the combination of such a city structure with an expansion of PT systems would lead to a considerable improvement of transport performance, i.e. a PT mode share, a mean commute distance, and a significant reduction in emissions.

Introduction

Rapid expansion of city areas is occurring world-wide. The phenomenon of urban sprawl plays an important role in the build-up of urban areas, and it refers to a complex pattern of land use, transportation patterns, and social and economic development, influencing living conditions. Urban sprawl is characterized by a rapid expansion of residential area at the outskirt of the town, causing a spatial mismatch of jobs and residential dwellings, further causing imbalance in transport with high dependence on automobile (Duncan, 1989). Banister (1996) looked at integrating activities into high density areas and

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land-use mixes in order to reduce vehicular travel. Some effects of this phenomenon are the increase of automobile dependence, air pollution, automobile accidents, and pedestrian injuries and fatalities (Frumkin, 2002).

Since the beginning of the 20th century, urban sprawl has been identified in most Indonesian cities. It reflects a pattern of urban development with increasing settlement growth in the suburbs. The phenomenon of urban sprawl occurs in the city of Surabaya as case study area, are characterized by an estimated 38% of the population lives in the suburbs (Statistic Bureau of Surabaya City, 2010); most of them commute every day to work in the central urban area. This extensive growth in economic and residential development has significant consequences for mobility. Traffic congestion in the city of Surabaya has strongly increased since the late 1990s; predominantly due to increasing numbers of motorcycles and private cars. Current mode choice by residents: private car (30%), motorcycle (62%), and other vehicle types (8%, mostly minibuses). This situation results in significant increase of time, cost and productivity losses, and an increase in air pollution. Sustainable transportation linked to spatial planning is a major consideration for improving mobility. Such a strategy is expected to change modal split from private vehicles to public transport, to reduce the amount of air pollution from motorized vehicles, and to lessen travel time and distance. Private road transport is currently a substantial source of environmental pollution and traffic congestion in urban areas.

Another strategy, taking into consideration urban structures, based on compactness, was expected to produce lower levels of pollutant emissions, particularly CO_2 emissions, as well as fuel usage, travel distance and travel time (Marquez and Smith, 1999). They explained the influence of city structure on air quality by developing a framework consisting of various components, including a GIS database, a land use-transport-environment module and an airshed model. Stone (2008) revealed that large metropolitan regions rank higher on a quantitative index of sprawl than spatially compact metropolitan regions. This study has promoted land use strategies concentrating on more compact urban areas, intended to solve problems related to urban air quality by technological emission controls. Martins (2012) also presented a sustainable urban structure related to air quality. The impact of various urban growth patterns on air quality of the Porto urban region in Portugal has been assessed by applying the MM5-CAMx modeling system. The analysis concluded that an urban structure with sprawl has a high level of pollutants. On the other hand, a compact structure has a dense population, and increasing pollution (per space unit) due to the high concentration level. He indicated that consideration of land use strategies, such as the compact regions is designed to increase urban air quality.

Regarding transport strategies, numerous studies have been conducted on transport demand management (TDM) with the aims of reducing the air pollution from motor vehicles. The effectiveness of two demand management measures, i.e. road pricing and the vehicle quota scheme (VQS), was revealed as instrumental in controlling both congestion and automobile ownership (Chin, 1996). Mitchell (2005) explained that there was a significant level of environmental inequality in Leeds, in the UK. Briefly, environmental inequality was reduced by an analysis of transport strategies with natural fleet renewal and road-user charges. The changing modal split from private vehicles to public transport and decreasing travel demand are benefits in promoting emission control technology and clean fuel. These studies on transport strategies, such as TDM and the promotion of technology to control emission, found that those strategies were insufficient to control the phenomenon of urban sprawl.

Regarding travel behavior and pollution emissions, studies have focused on the impact of mode choice on energy consumption and pollution emission. Coefficients of energy consumption and emissions are influenced by the different sizes and ages of engines (Chiou et al., 2009; Chiou and Chen, 2010). These authors have designed an integrated model for cars and motorcycles, assessing choice behavior related to ownership, type and usage. They have proposed potential reductions of air pollution particularly HC and CO emissions by manipulating variables, such as an increase of ownership and user costs, and improving transit services. Nejadkoorki et al. (2008) have developed an approach for modeling CO_2 emissions related to traffic-generated emissions for major roads in Norwich, in the UK. They suggested that urban restructuring, developing road networks, and changing traffic demands would reduce air pollutions. Early studies focused on the structure of vehicles and travel behavior to minimize air pollutions. They indicated the need to consider the integration of urban development and transport systems to reduce air pollutions.

An integrated model to reduce air pollution by the improvement of transport technology was applied in Beijing, China. An intelligent transport management system could mitigate the proportion of pollution from vehicles and improve emission performances (Costabile and Allegrini, 2008). Loo and Chow (2011) explained that an analytical framework focusing on population patterns and job relocation policies has been applied in Hong Kong. The framework was intended to quantify potential commuting savings and environmental benefits by employing different job policies with different rates and patterns of population decentralization. Loo and Chow (2011) also discovered that modification of the urban form with three spatial job policies, and job decentralization had significant effects on shortening commuting patterns and the realization of a sustainable transportation in the city. Their previous research (Loo and Chow, 2008) demonstrated that providing good public transport should be connected with the new growth areas due to the increase of attractiveness of working in those areas. The improvement of public transport aims to increase connections in the new growth areas and to reduce their dependency on the city center. However, the above studies were not clearly addressing the importance of integrated space–transport development strategies in minimizing air pollution and contributing to sustainable urban transportation with a design of various urban structures.

An insufficient number of studies have considered the integration of urban planning and transport systems as the reduction of air pollution. Therefore, this study focuses primarily on the design of integrated space–transport development strategies which will not only reduce congestion, but also have a significant impact on air emissions. In this study, an integrated