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# TRANSIT ORIENTED DEVELOPMENT PERFORMANCE ASSESSMENT TOWARDS LOW CARBON DEVELOPMENT: A CASE STUDY OF TOKYO

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**ABSTRACT**

A multitude of efforts towards low-carbon transportation development foster concentration strategies around reducing vehicular emissions. Extensive literature is looking for strategies linked to how the built environment might be improved to reduce GHGs together with vehicular transportation, which reveals the importance of coordinating the balance of high-density urban areas development for low-carbon transportation. In this research, we focus on the integrating both transit and development in TOD areas. We aim to contribute to constructing an interaction network between TOD areas, and combine the PoI data to provide a refined method for analyzing the stability of integrated development of urban functions and traffic intensification which could help provide strategies to vehicular emissions.

**Keywords:** Transit Oriented Development, Low-carbon transportation, land-use and transport integration, sustainability

**NONMENCLATURE**

| *Abbreviations* | |
|---|---|
| GHG | Greenhouse gas emissions |
| VMT | Vehicle miles traveled |
| TOD | Transit oriented development |
| TRB | Transportation research board |
| PoI | Point of Interest |

*Symbols*

## 1. INTRODUCTION

Transportation makes up 16% of Global greenhouse gas emissions (GHG) with a 33% average growth rate from 1990 to 2010[1]. A multitude of efforts towards low-carbon transportation development foster concentration strategies around reducing vehicle miles traveled (VMT), which is closely related to vehicular emissions[2, 3]. Moreover, in recent studies, the reduction in driving is commonly reported that correlates with the population density in statistical estimation[4]. Extensive literature is looking for strategies linked to how the built environment might be improved to reduce GHGs together with vehicular transportation[5]. The large areas around the transit hubs support functions developing by the high-density land-use pattern previously mentioned. Land use and transport are strictly inter-linked. So, these Areas developed around the station are regarded as — "lifestyle supporters."[6], which could represent the primary urban function.

### *1.1 Transit Oriented Development for low-carbon city*

Transit oriented development is a strategy focusing on these areas promoted for more than 20 years in several cities of the world as a sustainable and low-carbon urban mobility policy[7]. TOD is a strategy to adapt to growing urban populations and reduce the impact on transportation networks and the

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environment. It aims to provide a range of services within walking distance and regional accessibility by high-quality public transport that reduce driving by up to 85%[8]. It is widely accepted that focusing on dense station areas can help evaluate more efficiently the functions of each city area and link through the track line and make the connections between the various regions of the city clearer, which considered to conducive to guiding low carbon traffic behavior [4].

### *1.2 Urban development inequality and vehicle traffic*

In the early urban development, investment is mostly used in the construction of transportation infrastructure with the compression of public service facilities and public space. Lack of function has caused the new development zone to become a sleeping city that attracts people with convenient transportation and low housing prices. The inequality will ultimately lead to an increase in the flow of vehicles in various regions of the city[9], which intensifies as the increasing convenience of regional public transportation and the lack of urban functions. The main reason for a resident to leave for other places is precisely the disparity, that is, inequality. As previously analyzed, this inequality requires not only the functional characteristics of the region but also the accessibility of public transpor[10]t.

This research, therefore, tries to contribute to constructing a traffic interaction network between TOD areas, and combine the PoI data to provide a refined method for analyzing the stability of integrated development of urban functions and traffic intensification which could help provide strategies to reduce vehicle travel and vehicular emissions.

## 2. *MATERIAL AND METHODS*

As mentioned in the previous section, the critical Point for reducing vehicular emissions is about integrating both T (transit) and D (development), we believe that a wholesome policy and planning for a region must address two issues: firstly, to measure the stability of transit and development within the areas around the transportation hub; secondly, to identify those areas where the urban function of those places needs improvement.

### *2.1 TOD area identification and function definition*

For the first issue, the boundaries of TOD areas should be identified. As argued by previous studies, TOD is expected to provide a comfortable and safe walking environment, which is the key component of any TOD[11]. Therefore, combining with integration of land

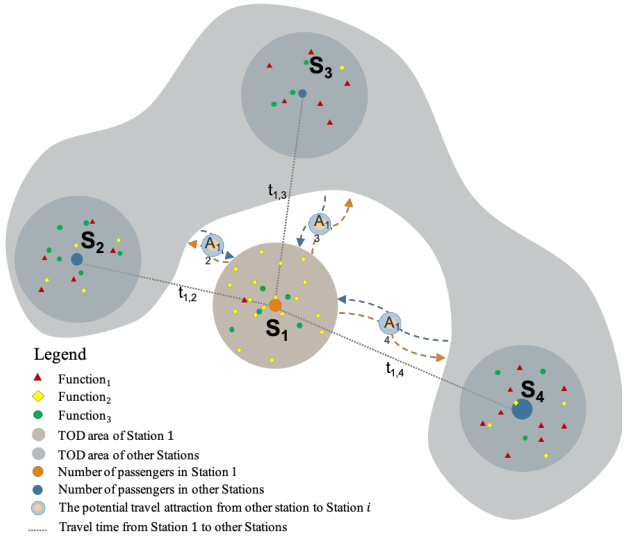


Fig 1. Potential travel attraction of Station 1

use, transport and walking environment, we argue that a walkable distance(500m)[12] from one station is identified to be the range of TOD area.

Furthermore, in order to measure the development statue, the urban function feature of TOD areas should be identified. Due to the intensive development of cities, the actual types of urban activities are more diverse than the land use in urban planning of the same area, as an example, residential land will be mixed with retail, small catering, etc. Therefore, number of workers in job categories[13] or Point of Interest (PoI) [12]are tend to be used to evaluate the Land-use diversity the degree of which different land uses are located within close proximity of each other. For this research, a similar but more specific approach was chosen, where each POI category represents a type of activity taking place in TOD areas. The PoI classified as five clusters used in this research (Table 1).

Table 1. The defined POI clusters

| Cluster | Urban function |
|---|---|
| 1 | Catering services, stores, and Hotels |
| 2 | Transport distribution centers and warehouses, private warehouses, gas stations, factories, and crafts |
| 3 | Commercial corporations, banks, real estate agency, communication, newspaper, and broadcasting |
| 4 | Hospitals, social insurance, social welfare, all kinds of schools, research institute, skill classroom, government office |
| 5 | Travel agencies, amusement parks, gardens, public bathhouses and temples |

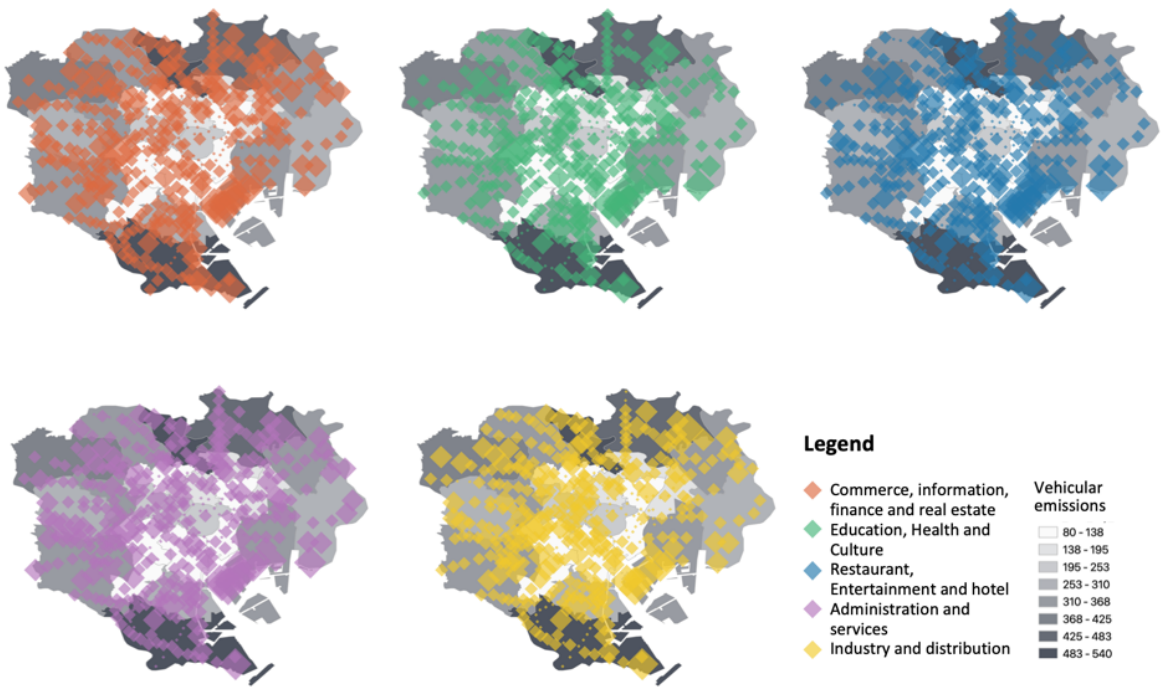


Fig 2. Potential travel attraction in five functions and vehicular emissions

### *2.2 TOD areas performance assessment*

In this research, we propose an attraction index to evaluate the potential traffic demand in TOD regions based on the adaption of potential models. Generally, the index is calculated based on the adapted Huff model[14] denoted by e.q (1):

$$A_i = \sum j \in [d_1 > d_{ij} > d_0] \quad A_{ij}$$
$$A_{ij} = \frac{S_j f(d_{ij})}{\sum_{k\in[d_{ik}\le d_0]} \quad S_k f(d_{ik})} \qquad (1)$$

Where $A_i$ denotes the potential travel demand from region $i$ within a distance threshold of $d_0$ and $d_1$, $A_{ij}$ denotes the attraction index of region $j$ to region $i$ with a travel distance of $d_{ij}$, $S_j$ denotes the supply of facility in region $j$, $f_{ij}$ denotes the distance decay function. Furthermore, we use the kernel density function to represent distance decay which can be denoted by e.q(2)

$$f(d_{ij}) = \begin{cases} \frac{3}{4}[1-(\frac{d_{ij}}{d_1})] & (d_{ij} \le d_1) \\ 0 & (otherwise) \end{cases} \qquad (2)$$

In addition, we set $d_0$ as 15 minutes and $d_1$ as 45 minutes for representing the potential long trip demands for a specific type of facilities.

## *3. STUDY AREA AND DATA SOURCE*

In order to analyze the attraction of different facility types in each region, in this research we collect road network from Digital Road Map road network, railway network from National Land Numerical Information and PoI data from TelePoint data. The number TOD region in this research is extracted from the whole railway 20 stations with the famous DBSCAN clustering method. In Tokyo 23 wards there are 413 TOD regions. For each TOD region, we extract the facilities by a 500-meter road network buffer and group the facilities into five clusters. For the vehicle miles traveled, we use the result in our previous research[15].

## *4. RESULTS AND DISCUSSION*

### *4.1 Potential travel attraction of TOD areas*

Our application of TOD areas performance assessment mode to the Tokyo 23 wards revealed differences among the five urban function clusters (Table 2). Generally, 'Education, Health and Culture' exhibited a smaller variance than the other clusters, varying between 1.258 and 3.842, with an average value of 2.24. In contrast, 'Industry and distribution' had the highest variance, ranging between 1.141 and 4.32, but with a lower average value (2.275).

Table 2 Descriptive statistics of travel attraction

| | Minimum | Maximum | Mean | Std. |
|---|---|---|---|---|
| Cluster 1 | 1.2578 | 3.8419 | 2.2396 | 0.4242 |
| Cluster 2 | 1.1413 | 4.3197 | 2.2750 | 0.4662 |
| Cluster 3 | 1.0764 | 4.1300 | 2.3009 | 0.4661 |
| Cluster 4 | 1.3591 | 4.0113 | 2.2381 | 0.4409 |
| Cluster 5 | 1.1107 | 4.0859 | 2.2958 | 0.4545 |

### *4.2 Correlation in potential travel attraction and vehicular travel*

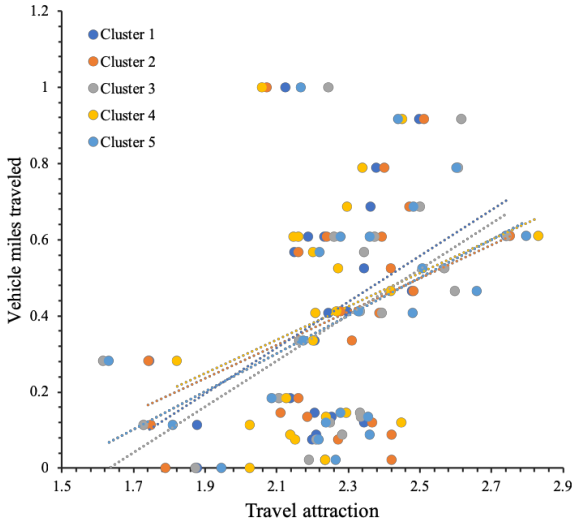


Fig 3. Correlation in travel attraction and vehicular travel

In order to identify the similarities in potential travel attraction and vehicle miles traveled, we conducted a correlation analysis using Pearson correlation and Kendall correlation. The indicator 'vehicular emissions' does correlate with the potential travel attraction in five clusters (Fig. 3). A significant correlation can be identified between 'vehicle miles traveled' and 'travel attraction of cluster 3'.

## *5. DISCUSSION*

In this research, we propose a TOD areas performance assessment mode to evaluate the stability of the integrated development of urban functions and traffic intensification. We find that, although Tokyo has the denser and more sophisticated transit-oriented development system than if not most cities in the world, the urban function in Tokyo TOD areas generally lacks in 'Restaurant, Entertainment and hotel.' Compared with the areas in city centers, remote areas still need to pour attention into the lagging functional development (Fig. 2).

In terms of the vehicular emissions, the potential travel attraction does have a significant impact on it. The areas with reliable travel potential are identified to be located in the wards with high vehicular emissions. To reduce integral vehicular emissions, it is crucial therefore to improve the public facilities and increase urban functional diversity in the wards with the lagging functional development mainly 'Commerce, information, finance and real estate' and 'Restaurant, Entertainment, and hotel.'

## *6. CONCLUSIONS*

The current paper presents a holistic approach to the analysis of the potential travel attraction of TOD areas. This approach combines the traffic interaction network and PoI data for analyzing the stability of integrated development of urban functions, and traffic intensification which is found correlate with vehicle miles traveled.


## ACKNOWLEDGEMENT

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