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Alternative transit-oriented development evaluation in sustainable built environment planning

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ABSTRACT

Following the increase in urban population density and house prices in the 1970s, urban residents began searching for satisfactory living environments. With the construction of highways and advancements in motor vehicle technology, urban development began extending to suburban regions, a phenomenon which is referred to as urban sprawl. The negative external effects caused by urban sprawl, including inefficient land use and pollution, highlight several problems such as the disjunction between urban land use and transportation. To achieve sustainable transportation and resolve the aforementioned problems, we established the transit-oriented development (TOD) evaluation criteria and formulated the TOD site selection standard, which fulfills the principle of sustainable transportation. Thus, a solution to problems related to urban sprawl is proposed, which may serve as a reference for planning units in devising relevant processes.

The fuzzy Delphi method was adopted to select TOD evaluation criteria satisfying the principle of sustainable transportation, and the fuzzy analytic network process (FANP) was applied to determine the weights of relevant planning criteria. The results show that all nine TOD evaluation criteria for sustainable transportation were supported by an expert consensus in the first phase of the study, indicating that all of the selected criteria were critical in the TOD evaluation. In the second phase, according to the weighted evaluation criteria, the environmental carrying capacity in high-density development was the most crucial evaluation criterion, whereas the least critical criterion was equality in residence accessibility. Finally, through the use of a geographical information system, the performance of each station on the Ankeng Line of the New Taipei City mass rapid transit (MRT) system was evaluated according to the TOD evaluation criteria. Combining the evaluation with the weighted sums of the FANP revealed that Xinhe Elementary School MRT station was the optimal station for TOD. Accordingly, built environment planning should be undertaken to develop the urban area surrounding this station. The findings of this study may provide a reference for planning units in undertaking future TOD projects under the principle of sustainable transportation.

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1. Introduction

Following the increase in urban population and immigration, overcrowding and urban sprawl began occurring because of urban developments. The negative external effects of urban sprawl include air pollution from motor vehicles, longer commuting times because of traffic congestion, overuse of land resources caused by low-density and leapfrog development, and driver safety (Peiser,

1989). To solve these external problems, scholars have suggested applying the concept of sustainable development to resolve the impact of urban development. In *Our Common Future*, the [World Commission on Environment and Development of the United Nations \(1987\)](#) defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (p. 10). This effectively defines the goal of sustainable development as achieving equality among generations in using resources. Practicing sustainable development requires simultaneously satisfying the economic, social, and environmental dimensions of development. On applying the concept of sustainable development in connecting urban transportation and land use, scholars have advocated adopting the

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principle of sustainable transportation, which requires promoting transportation behaviors and involves the following subgoals: (a) Economic efficiency: Transportation resources must be used efficiently to maximize their effects and facilitate economic development in other areas. (b) Environmental sustainability: Decisions regarding transportation behaviors must consider the external effects of transportation such as air pollution, noise, and traffic accidents. Additionally, transportation infrastructure developments must not exceed the environmental carrying capacity in order to prevent irreparable damage to the natural environment. (c) Social equity: Promoting transportation behaviors must involve fair consideration of the benefits to all people and cater to the needs of vulnerable groups. Transit-oriented development (TOD) emphasizes integrating urban land use with public transportation. In other words, urban residents must be able to accomplish their daily living activities entirely through using public transportation and without relying on privately owned motor vehicles (Wey & Chiu, 2013). Thus, the use of motor vehicles would be reduced, effectively preventing urban sprawl and lowering air pollution. In addition, the traffic volume of public transportation systems would increase, thereby promoting the economic efficiency of such systems. However, the concept of diversity, such as diversified land use and levels of habitability, must be stressed for such developments to be successful (Blowers, 1993; Calthorpe, 1993). Accordingly, the objective of this study was to fulfill sustainable development through coordinating transportation and land use behaviors. Because the developmental concepts of TOD are related to the goals of sustainable transportation, TOD was considered a suitable planning approach for promoting sustainable transportation.

This study was conducted to establish TOD evaluation criteria based on the principles of sustainable transportation to enable effectively selecting mass rapid transit (MRT) stations in Taipei for future TOD projects. To combine theories with practice, the Ankeng line of the New Taipei City MRT system was selected as the research target. The most suitable station on Ankeng Line for TOD was determined according to the principles of sustainable transportation, and built environment plans were formulated for developing the urban area around that station.

To establish the research model, the fuzzy Delphi method was first applied to select the criteria through administering questionnaires to a panel of experts. Subsequently, the criteria deemed suitable for establishing the evaluation model were determined. Second, the fuzzy analytic network process (FANP) was adopted to assign weights to the criteria derived from the expert questionnaires. Finally, a geographic information system (GIS) was used as an analytical tool to designate an appropriate index for each criterion. An index map of the studied region was constructed to form the basis for scoring each station according to the evaluation criteria. The scores of each criterion were then multiplied by the weighted values to identify the optimal station according to the highest score on the TOD evaluation criteria. Finally, a built environment plan was formulated for developing the urban area near the selected station.

2. Literature review

Transportation planning and strategies affect not only the landscape style and land use of a city, but also the relationship between urban sprawl and population density (Peiser, 1989). In summary, urban sprawl in Taiwan is due to inappropriate urban development planning and management. Specifically, an excess of urban development projects has caused rapid urban expansion, as well as the inadequate and inefficient use of public facilities. In the urban housing market, vacancy rates and house prices in urban centers have been exorbitant. The proliferation of private motor

vehicles also contributed to exacerbating the urban sprawl.

Collectively, the aforementioned problems originated from inappropriate transportation and land use. To solve these problems, scholars have suggested that philosophy of urban development must shift toward one of sustainable development, and urban and transportation infrastructure planning must follow the comprehensive consideration of environmental sustainability, social equity, and economic efficiency. Unrestrained use of natural resources for economic development has created a shortage of resources and damaged the natural environment, thus prompting the emergence of sustainable development concepts. Sustainable development is aimed at preventing shortages of usable natural resources for future generations while pursuing economic development. Therefore, when using resources, efficiency must be emphasized, wastage must be avoided, and renewable resources must be utilized extensively (World Commission on Environment and Development, 1987; Blowers, 1993; Meijer, Adriaens, Linden, & Schik, 2011).

Sustainable transportation can be regarded as an operations approach to the sustainable development of transportation systems. Sustainable transportation requires balancing the environmental, social, and economic dimensions in transportation behaviors. On the environmental dimension, transportation authorities must consider the externality of transportation behaviors in its decision-making, such as air pollution, noise, and traffic accidents. Moreover, the development of transportation infrastructure must not exceed the carrying capacity of the natural environment. On the social dimension, promoting transportation behaviors must involve fair consideration of the benefits to all people and cater to the needs of vulnerable groups such as elderly adults, people with disabilities, and disadvantaged groups. Finally, on the economic dimension, transportation resources must be used and maintained efficiently by minimizing resource use in order to maximize efficiency (Zhao, 2010).

Sustainable transportation requires the development of sustainable transportation behaviors in all three of these dimensions. Most of the aforementioned green transportation strategies have focused on environmental sustainability. Therefore, to promote sustainable transportation, social equity and economic efficiency must also be considered to balance the three dimensions of sustainable transportation behaviors.

The concept of TOD is derived from urban planning theories that emerged in response to urban sprawl including smart growth, new urbanism, and sustainable development. Smart growth involves controlling urban growth through flexible management approaches. The principles of smart growth include high-density development, mixed land use, redeveloping the old regions in cities, constructing accessible pedestrian spaces, and diversifying the selection of transportation vehicles. Grant and Tsenkova (2012) stressed that using encouragement management approaches (e.g., floor area incentives and flexible partitions), in contrast to growth management approaches, to achieve the goals of smart growth provides more flexibility and incentives to decelerate urban sprawl. New urbanism emphasizes diversity in designing cities, including diversifying traffic, which involves the coexistence of pedestrians, public transportation, and cars. Additionally, this concept accentuates localizing communities and focusing on specialization in order to project a city image of closeness and diversity, thereby reducing the use of private transportation vehicles and orienting future cities toward sustainable development.

Calthorpe (1993) introduced the concept of TOD, defining it as “moderate and high-density housing, along with complementary public uses, jobs, retail and services, concentrated in mixed-use developments at strategic points along the regional transit systems.” In particular, Calthorpe addressed the importance of

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