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The Application of Integrated Multimodal Metropolitan Transportation Model in Urban Redevelopment for Developing Countries

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Abstract

Urban redevelopment is an important way for city evolution especially in metropolitans where the limitation of land resource becomes a bottleneck to farther development. However, redevelopment can bring a number of perturbations on transportation system, even though it improves the efficiency of land use. Many cases can be found to cause or exacerbate traffic congestion because of redevelopment especially in developing countries. Urban redevelopment scenario might be erroneous without accurate travel forecasting and traffic impact evaluation. To avoid the negative impact on traffic under redevelopment, an effective transportation model is needed to forecast accurate travel demand, and effective traffic impact evaluation measures are also needed based on output of the transportation model to compare scenarios and complete scenario planning. Developing countries often lack robust transportation planning models and effective evaluate measures to address urban development and redevelopment.

In this paper, based on the differences of transportation system and travel demand forecast between urban development and redevelopment, we propose an integrated multimodal metropolitan transportation model to meet the requirements of urban redevelopment forecast, and develop an evaluation index system for scenario planning to compare traffic impact of urban redevelopment scenarios quantitatively. To illustrate recommendations for developing countries, we use state of Maryland in the United States as a case study to demonstrate forecast accuracy of the integrated transportation model and also show the traffic evaluation for redevelopment scenario planning. The results indicate that the integrated multimodal metropolitan transportation model can get better fitness and it is easy to assess which scenario can reduce traffic congestion using the evaluation index system.

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1. Introduction

City development is a constantly building and updated metabolic process. Two fundamental ways of cities evolve are urban development and urban redevelopment (a reconstruction on a previously developed area). Currently, with rapid development of urbanization, redevelopment has become imperative for metropolitan areas where the limitation of land resource becomes a bottleneck to further development. Redevelopment can not only reuse and improve land use efficiency, but also update the original land use (including land type, land structure, and so on) and make efficient use of regional land layout possible. And many redevelopments have been put into effect to maintain the urban vitality and transform urban function. Two examples are London Docklands redevelopment and the Huangpu River redevelopment in Shanghai of China (He and Wu, 2005). Especially in developing countries such as China, most big cities including Shanghai, Beijing are carrying out urban redevelopment projects (Leaf, 1995).

However, urban land redevelopment will inevitably bring some impact on transportation system when changing the land use to improve efficiency. It might be conducive to public transportation and relief traffic congestion such as London Docklands redevelopment, or may cause traffic problem and even lead to or exacerbate traffic congestion such as the Shanghai Huangpu River redevelopment. Actually in developing countries such as China, there are more cases causing traffic congestion because of redevelopment. For example, the large-scale redevelopment of Central Business District (CBD) in Beijing in 21st century once brought heavy traffic to this region due to the emergence of a large number of tall buildings, which made residents and employees “unable to enter or unable to go out” at peak time. Another example in Beijing is the reconstruction of the old town Haidian into Zhongguancun, and it also caused traffic congestion and became one of the most congested areas (BMICPD, 2009).When analyzing cases that cause traffic congestion, it is relatively easier to find that fail to coordinate the development of land reuse and transportation thereby traffic demand exceeding the capacity of transportation facilities after redevelopment (Wang et al., 2011). Why did these situations occur? The root lies in the urban redevelopment planning (Shen, 1997).

On one hand, lack of adequate transportation models that can reflect the relationship between land use and transportation properly, the traffic forecast is inaccurate. This problem mainly happens in developing countries. For example, the transportation model in china is traditional four steps model focusing on urban areas and person trip without an integrated land-use and transportation model. Specifically, the transportation model of Shanghai still use gravity model and growth factor model for trip distribution, and logarithm method for mode choice(Lu et al., 2008); the multi-level models of Beijing are, respectively, planning model and micro-simulation model without a valid combination(Li et al., 2008). Overall, there are some deficiencies: (a) targeting at personal trips only, without considering the regional passenger travel and freight movement; (b) Static analysis of travel demand forecasting without variance over time of day; (c) aggregated model with few discrete travel behavior studies. Meanwhile, there are a number of redevelopments in progress. With inaccurate travel demand modeling, traffic congestion forecasts are inaccurate. Therefore, it is very important for developing countries like China to improve the transport model and adopt the integrated land-use and transportation model to obtain the real travel demand for the redevelopment in the future.

On the other hand, there is no strict traffic impact analysis for redevelopment plans to examine and adjust the scenarios during planning stage. This is another problem found commonly in developing countries. For example, in China, traffic impact analysis (TIA) system is introduced to the project implementation phase (MOHURD, 2010) for reducing the impact to traffic, but there are no traffic impact analysis required during planning stage. And also, there are no systematic traffic evaluation measures for redevelopment planning in both developing countries and developed countries. The analysis result with one or two measures is not enough to support decision making. Therefore, sometimes the scenarios of redevelopment are unreasonable and bring traffic congestion. And the negative impacts are usually found after their implementation which is too late to adjust the land reuse. In China, even if the impact is detected after planning but before implementation, corresponding improvement is to make to the traffic facilities, but it is hard to feedback to planning stage to adjust land use scenario. Actually, the best way to avoid the unreasonable redevelopment is examining the traffic impact of the redevelopment scenarios during planning stage. Therefore, for better coordination between land use and transportation, in addition to a well-designed transportation model, an effective evaluation measures system is also required for urban redevelopment.

Currently, there are a large number of literature on coordination between land reuse and transportation including integrated land use and transportation model (Hunt et al., 2005; Waddell, 2002; Wegener, 2004), and also a number of researches on traffic congestion countermeasures (Miller et al., 1999; Mohandas et al., 2009) as well as traffic impact analysis (Dey and Fricker, 1994; Litman, 2003). And many studies on scenario planning have emerged recently(Amer and Daim, 2013; Chakraborty and Mcmillan, 2015). But only few show specific application of integrated land use and transportation model in redevelopment scenario planning (Mishra et al., 2013b), and few study on the traffic congestion solution or traffic impact evaluation of redevelopment (Wang et al., 2013). There is lack of systematic approach in urban redevelopment planning to reduce traffic congestion with redevelopment in China and other developing countries. Since redevelopment is an important part to city evolution to alleviate congestion, it is imperative to improve the redevelopment methods for successful planning.

Therefore, the objective of this paper is to provide recommendations for developing countries for urban redevelopment planning so as to avoid traffic congestion taking lessons learned from developed countries. We proposed a two stage approach: first we adopt an integrated multimodal metropolitan transportation model (IMMTM) for urban redevelopment planning to obtain accurate forecast, and second we employ an evaluation index system for traffic impact analysis of urban redevelopment scenarios quantitatively. The proposed approach can provide current and predicted traffic situation, examine the effectiveness of improvement scenarios, evaluate the urban redevelopment plan, and support policy decision making for land use and transportation. In the next section, we analyze the difference between development and redevelopment, and also show the requirement of travel model and evaluation measures under redevelopment. In section 3, IMMTM are proposed to meet the requirement, and also the framework and advantage as well as its application are described. In section 4, the evaluation index system is developed for traffic impact analysis of urban redevelopment planning scenarios. After that, a case about Maryland Statewide Transportation Model is presented to demonstrate the application of the two stage approach in section 5. Conclusions and further research are summarized in the final section.

2. The problem in redevelopment

2.1. Deference between urban development and redevelopment

Urban redevelopment is the secondary development or a reconstruction on a previously built land, with or without land property change. In the neighborhood of urban redevelopment location, there exist transportation facilities as a medium of travel from origin to destination (Amekudzi and Fomunung, 2004). In the location where redevelopment is proposed also have a transportation system already in place. In contrast, urban development refers to new land use and transportation construction.

Once the land use changes, the activities involving households and employments will be different from the previously developed land, as a result, drive fundamental shifts in the trip generation, trip distribution, mode choice and the final trip assignment. The changed travel demand will bring a significant impact on the transportation system. The impacts on both external and internal of the redeveloped land traffic facilities come not only from the new trip production and attraction of the redeveloped land but also from changes in re-distribution of surrounding travel after redevelopment. Therefore, travel demand forecast and traffic impact evaluations for redevelopment are different from new development. In addition, redevelopment is usually required by city expansion and benefit maximization, so that redeveloped land is made full use (Imrie and Thomas, 1993; Turok, 1992). Hard to coordinate land reuse and transportation facilities improvement lead to traffic congestion after urban redevelopment.

2.2. Limited Application of Traditional Transportation Models for Redevelopment

Some parts in the traditional four-step model if not designed properly are not fit for redevelopment and may not reflect the traffic demand after redevelopment.

For trip generation, the factors in regression models which are commonly used to reflect the correlation between base year trip production and the independent variables are not appropriate to describe future year when the land use changes dramatically. And also category analysis model which is another common used model only consider the household size or income in some countries such as China, while in reality, the trip generation varies not only by household's size and income but also by trip purpose. Even if the household size and the trip purpose are the same, There are diversities of the trips numbers due to household income discrepancy before and after redevelopment. So a multilayer category analysis model is needed for the redevelopment model.

For trip distribution, the growth factor model and gravity model has limitation as an aggregate model. They cannot explain individual travel behavior and estimate impact of individual characteristics and their preferences as well as policy changes. For example, gravity model assumes that the trips produced at an origin and attracted to a destination are directly proportional to the total trip productions at the origin and the total attractions at the destination. And usually gravity model uses travel time as impedance to determine the probability of trip making. As a result, they cannot assess the future zone-to-zone trip interchanges accurately and produce reliable and consistent origin-destination (O-D) trip interchanges. And also they cannot reflect the more diverse personal travels and the more accurate requirements for forecast (Mishra et al., 2013a). So when the gravity model is employed, the trip distribution can be similar after redevelopment if land use is the same with before. This is unreasonable because the residents or employees after redevelopment which has nothing to do with before should have different choice of origin and destination. Therefore, a disaggregate approaches incorporating not only the travel time but also individual's demographic and socio-economic characteristics should be employed for urban redevelopment.

For mode choice, there are limitations in most models although they are based on discrete choice modeling theory. First, the variables in traditional model are simply combinations of cost/income, travel time, walking time, and not include the traffic character and individual attributes. Second, the model structure is simple with several traffic modes (e.g. car, bus, and subway) and without considering the complex interactions between travel modes. So the mode choice models need to be improved to reflect changing individual attributes and traffic characteristics of redevelopment.

For trip assignment, consideration of both spatial and temporal distribution is crucial. When the lands are reused, the space-time characteristics of trips will be changed, changing the temporal and spatial pattern of traffic congestion. So it is crucial to distinguish the assignment by time of day. For example, an industrial land redeveloped into shopping center, the trips will concentrate in midday instead of morning peak hour. If the travel demands of a surrounding land are also industrial land, the redevelopment might be positive to relief traffic congestion; but if the surrounding land are also shopping center after redevelopment, it could be cause traffic congestion. Employing time of day assignment is necessary to embody the difference travel demand between before and after redevelopment. In addition, assigning specific user classes is also conducive to reflect the changes of transport facilities because of redevelopment.

Due to the above limitations of traditional transportation models, the prediction results are often inaccurate for urban redevelopment. Transportation planning will be unreasonable with inadequate travel demand modeling for redevelopment. Therefore, to meet the requirement of urban redevelopment and also overcome the above weakness of traditional models, we propose to employ an integrated multimodal metropolitan transportation model for urban redevelopment.

2.3. The insufficient traffic impact evaluation of redevelopment

Using travel demand model, one can obtain current and future transportation systems characteristics. Common measures are vehicle miles traveled(VMT) (Mishra et al., 2013b), vehicle hours traveled (VHT) and vehicle hours delay (VHD) (Dowling et al., 2004; Johnston and Ceerla, 1994; Mishra et al., 2011). VMT, VHT, and VHD are macroscopic measures making it hard to justify quantification of traffic congestion.

These measures are not enough to evaluate the redevelopment scenarios, so that the traffic impact analysis of redevelopment base on these measures is not fully or comprehensive to support decision making. More measures including traffic congestion evaluation measures are needed to introduce from a systematic evaluation perspective to infer traffic impact analysis of redevelopment planning scenarios.

3. The Integrated Multimodal Metropolitan Transportation Model

3.1. Brief overview

The limitations of the tradition four-step transport models are realized since 1970s, and further researches on disaggregate models are developed to improve the accuracy of forecasting (Akiva and Lerman, 1985; Walker and Ben-Akiva, 2011). Many theories and models have been used to study land use and transportation interaction since 1960s (Bertolini et al., 2005; Hunt and Simmonds, 1993; Miller et al., 1999; Wegener, 2004). Integrated multimodal metropolitan transportation models are not new and already applied in some metropolitan. For example, some MPOs in the United States are employing integrated land-use and transportation model for urban planning, and some states have developed the statewide models (Horowitz, 2006; Horowitz and Farmer, 1999), such as California (Outwater et al., 2010), Michigan (Nellet et al., 1996) and Maryland (Mishra et al., 2013b; Mishra et al., 2011). However, for developing countries such as China, the integrated regional transportation models are still in progress, and it is urgent to improve the transport model and adopt the integrated land-use and transportation model.

In this paper, Maryland statewide transportation model (MSTM) which is designed as a functional integrated land use-transportation model for analyzing transportation impacts in Maryland (Mishra et al., 2013b; Mishra et al., 2011) , is taken as an example to show the structure, advantage, and application of the integrated multimodal metropolitan transportation model.

3.2. The framework and components

The integrated multimodal metropolitan transportation models should integrate both land-use and transport compositions. The main parts are econometric model, land use model and transportation model, and they connect with each other. Figure 1 shows the basic framework and components of the integrated multimodal metropolitan transportation model (Wang et al., 2013).

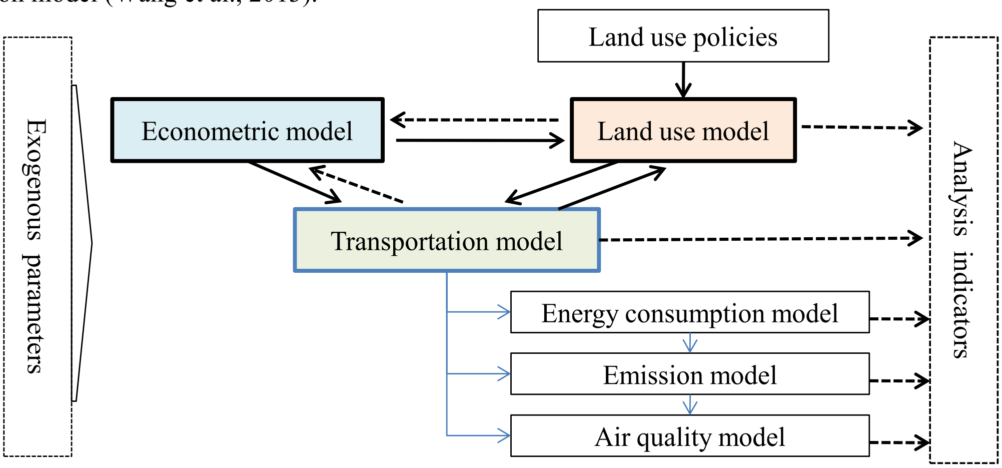


Fig. 1. Framework of the Integrated Model

The specific transportation models are different in MPOs with various compositions and structures. MSTM is based on the traditional four-step transport model with significant improvements: (a) categorize the traditional four-step model into several modules; (b) contain multiple components covering region and urban wide passenger and freight movements; (c)introduce time of day allocation to get the traffic situation during morning and afternoon peak hour as well midday; (d)adopt disaggregate methods and market segments in trip generation and distribution (e.g. using destination choice model to replace gravity model). The structure of MSTM is displayed in Figure 2 (Wang et al., 2013).

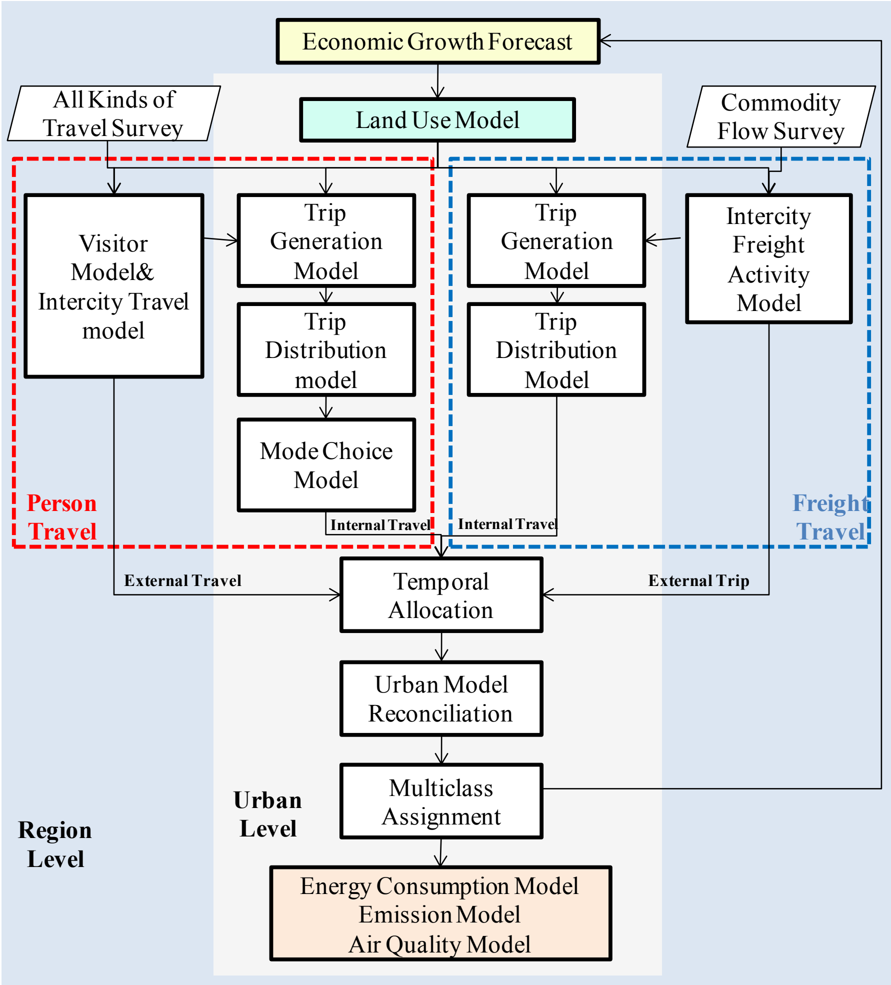
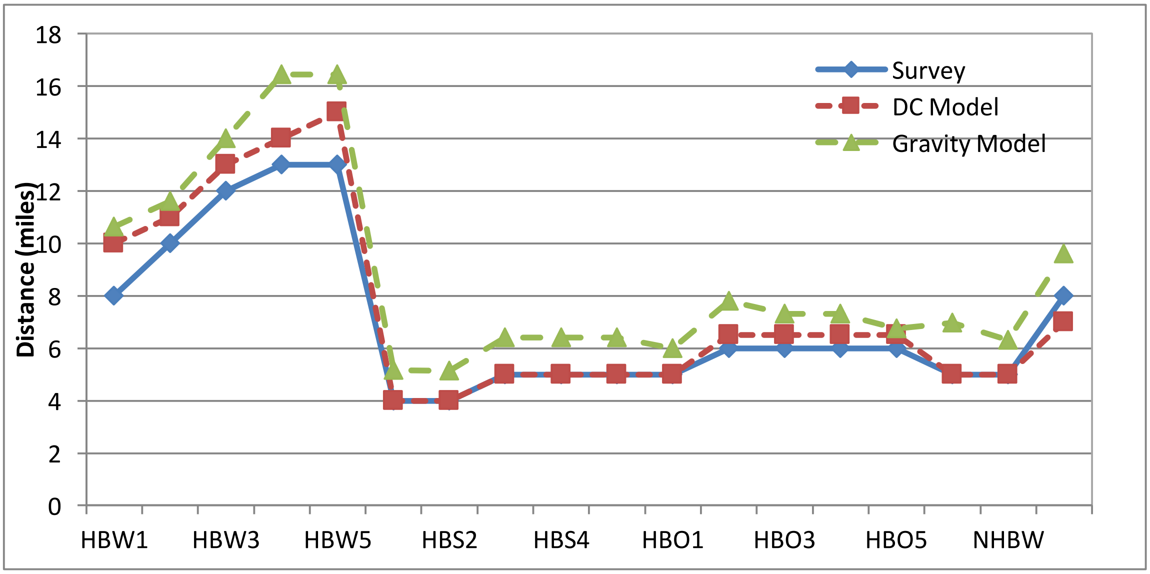


Fig. 2. Structure of the Integrated Multimodal Metropolitan Transportation Model

The transportation module is the major component, but regional economy growth and land use modules are also closely linked to steps of transportation module. And trip assignment results can reflect the various economy and land use policies and scenarios. This structure also separates the trips in regional and urban areas to capture the impact of regional traffic on the city center, such as external trips and bypass trips. Passenger travel and freight movement are analyzed in both regional and urban level independently and assigned to the network in the end. It also contains a time allocation step to integrate the multi-level study area and passenger and freight movements.

3.3. Advantage of IMMTM and its application

The IMMTM (e.g. MSTM in this case) can overcome the limitations of traditional transportation model and has advantage for estimating traffic congestion for urban redevelopment. Specifically, the trip production rates are not only by income and workers of households but also by region and trip purpose. The multilayer category analysis suits to forecast the trips of different households after redevelopment model. For trip distribution, destination choice model (DC model) is adopted to predict the probability of choosing any given zone as the trip attraction end. DC model has a better fitness than gravity model (see Figure 3) (Mishra et al., 2013a).



Note: DC Model is destination choice model; HBW refers to Home Based Work; HBS refers to Home Based Shopping; HBO refers to Home Based Other; NHBW refers to Non Home Based Work; the numbers after HBW, HBS, and HBO refers to income level with "1" being the lowest income category

Fig. 3. Comparison of Average Trip Lengths between Models

For mode choice, a nested logit model is used, and separate utilities are developed to represent the traffic conditions by time of day. In the utility function, auto operating cost, tolls and parking cost are considered for driving alone and share ride, and walking time and transfer time are considered in bus related mode. For assignment, temporal allocation can get respective daily trip matrices to derive peak and off-peak trip matrices for network assignment. This is helpful to reflect the temporal re-distribution due to redevelopment, which is important to evaluate the traffic impact. And also multiclass assignment are employed to get all kinds of vehicles in the highway network (Ye, 2010), which is contribute to analyze the influence of the freight.

Besides, the model is integrated into a package including script files for each step. And a total running file such as a batch file is given to run the models by double clicking this file. With the basic model, it is easy to examine scenarios through changing the input files, so it is convenient for redevelopment planning. IMMTM provides reasonable estimations depicting different patterns of future development with changing key measures of transportation performance.

4. The traffic evaluation measures system

As a tool, the integrated models provide huge output data of trip distribution and assignment. For better use of the output, systematic traffic evaluation measures are needed to do the traffic analysis of scenarios.

4.1. The basic performance measures for Comparison

There is no systematical measures to evaluate traffic impact during planning stage, so we summarize the basic performance measures for the redevelopment scenarios' comparison and evaluation.

Since the measures are for planning stage and the data source is from macroscopic traffic demand forecasting and not the real-time traffic status, the performance functions presented in the paper focus on evaluating the general road network status. The purpose is to compare travel patterns with and without redevelopment to learn the influence. So the measures need to meet the following four requirements: (a) aim at the whole road network excluding microscopic indexes specific to a certain section or intersection; (b) obtain from output of travel demand forecast model; (c) can be compared between different scenarios for subsequent impact analysis; (d) include both spatial and temporal measures reflecting traffic congestion.

For the output of trip distribution, average trip length (ATL) is used to compare travel patterns. Generally, longer trips are negative to reduce traffic congestion. For mode choice, auto mode shares (AMS) can report the dependence on cars. For traffic assignment, vehicle hours traveled (VHT) and vehicle miles traveled (VMT) reflect the traffic status over space and time, respectively. To measure traffic congestion, vehicle hours delayed (VHD) and congested lane miles (CLM) are computed. However, VHD and CLM cannot tell the congestion level, so the absolute measures are needed. Here, we get two absolute measures: "vehicle hours delayed ratio" (VDI) using VHD divided by VHT; "congested lane miles ratio" (CLMR) using CLM divided by the total lane miles. Through VDI and CLMR, we can know how heavy the traffic is. The indicators are shown in Figure 4.

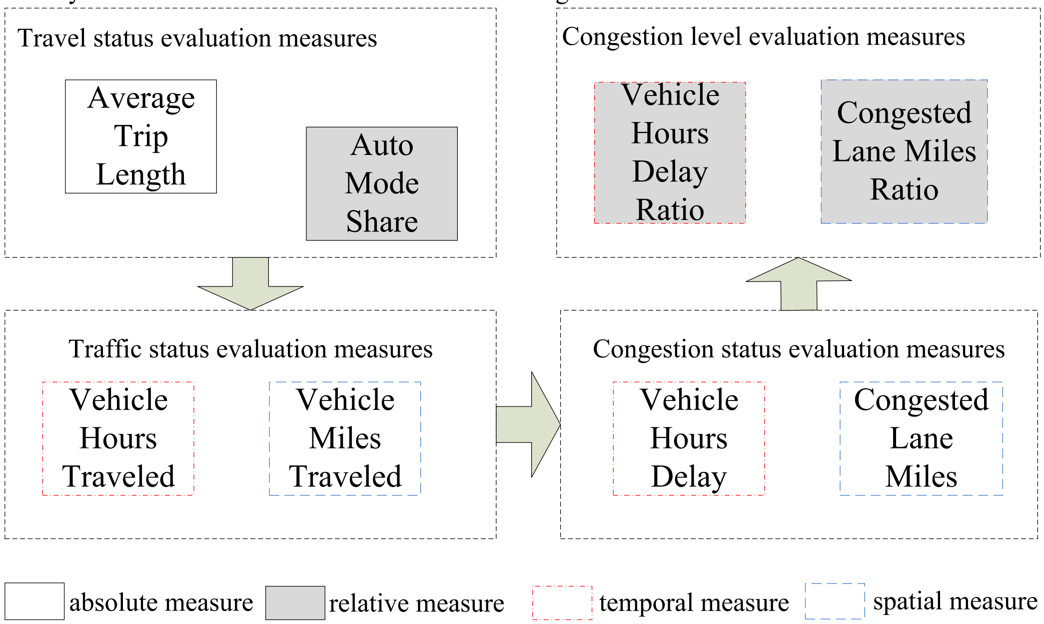


Fig. 4. The Basic Performance Measures

4.2. The competitive measure for traffic congestion

With the basic performance measures, we can compare scenarios to explore travel behavior. But these measures are not enough to figure out the impact to traffic congestion because values of measures usually do not increase or decrease at the same time compared to the baseline. For example, compared to without redevelopment, the results of redevelopment scenario are VDI increasing (which means more time loss due to congestion) and CLMR decreasing (which means less congested lane miles). Then it is hard to say whether the redevelopment relief traffic congestion. This situation is common in scenario planning (see the case study section). Therefore, a competitive measure is needed to judge the impact of redevelopment to traffic congestion.

Here, based on VDI and CLMR, we propose "Space -time Congestion Rate" (STCR) as a competitive measure to evaluate the congestion level of highway network. The formulation of STCR is as follow:

$$STCR = \alpha \cdot VDI + \beta \cdot CLMR \tag{1}$$

Where, VDI is the vehicle hours delay ratio of the highway network, equal to VHD divided by VHT; CLMR is the congested lane miles ratio, equal to the congested lane miles of the network divided by the total lane miles. α and β are weight coefficients, and $\alpha + \beta = 1$.

The values of α and β depend on the service object of the measure STCR. If target to exam the travelers' time loss caused by congestion, α can be bigger thanβ, and if target to exam the congested lanes ratio, β can be more than 0.5. Here, service for the planners, we suggest the same weight 0.5 for VDI and CLMR. Once the weights are fixed, then we can compute the STCR under scenarios. If the STCR of redevelopment is larger than without redevelopment, it means the traffic is more congested. Using STCR is easy to do the impact analysis on traffic congestion and choose the scenario which brings least traffic congestion.

5. Case Study

In this paper, a case study is presented to demonstrate the application of the integrated multimodal metropolitan transportation model and the proposed measures to evaluate the redevelopment scenarios planning. As a representative of the integrated multimodal metropolitan transportation model, MSTM is employed to determine the forecast of redevelopment scenarios. The traffic impacts of these scenarios are evaluated by basic and competitive measures.

5.1. Background and the redevelopment scenarios

With the growth of traffic congestion, the U.S. government proposed the strategy of "smart growth" to advocate coordination between transportation and land use since the mid of the 20th century. And "smart growth" also emphasizes redevelopment of existing community. Transit-oriented development (TOD) which focuses the development of housing and employment around the transit stations has been identified as one of the "smart growth" tools that aim to address the problem of traffic congestion. Federal, state and local agencies in the U.S put in more efforts to promote TOD (Cervero, 2004).

Maryland also chooses smart growth and proposes TOD as a way of concentrating development at transit stations to boost transit ridership. In 2008, the Maryland state government signed legislation designed to facilitate the designation of transit-oriented development (TOD) areas (MDOT, 2008). The definition of TOD adopt in the legislation is "a dense, mixed-use deliberately-planned development within a half-mile of transit stations that is designed to increase transit ridership". In other words, through redevelopment the TOD area (within a half-mile around existing railway stations) attracts the future growth of activities (housing and/or employment) to increase transit ridership. The scenarios of TOD are the redevelopment scenarios which need to quantify the traffic impacts. The TOD locations are showed in Figure 5, and the purple area including Washington area and Baltimore area is the impact analysis area(Wang et al. 2016).

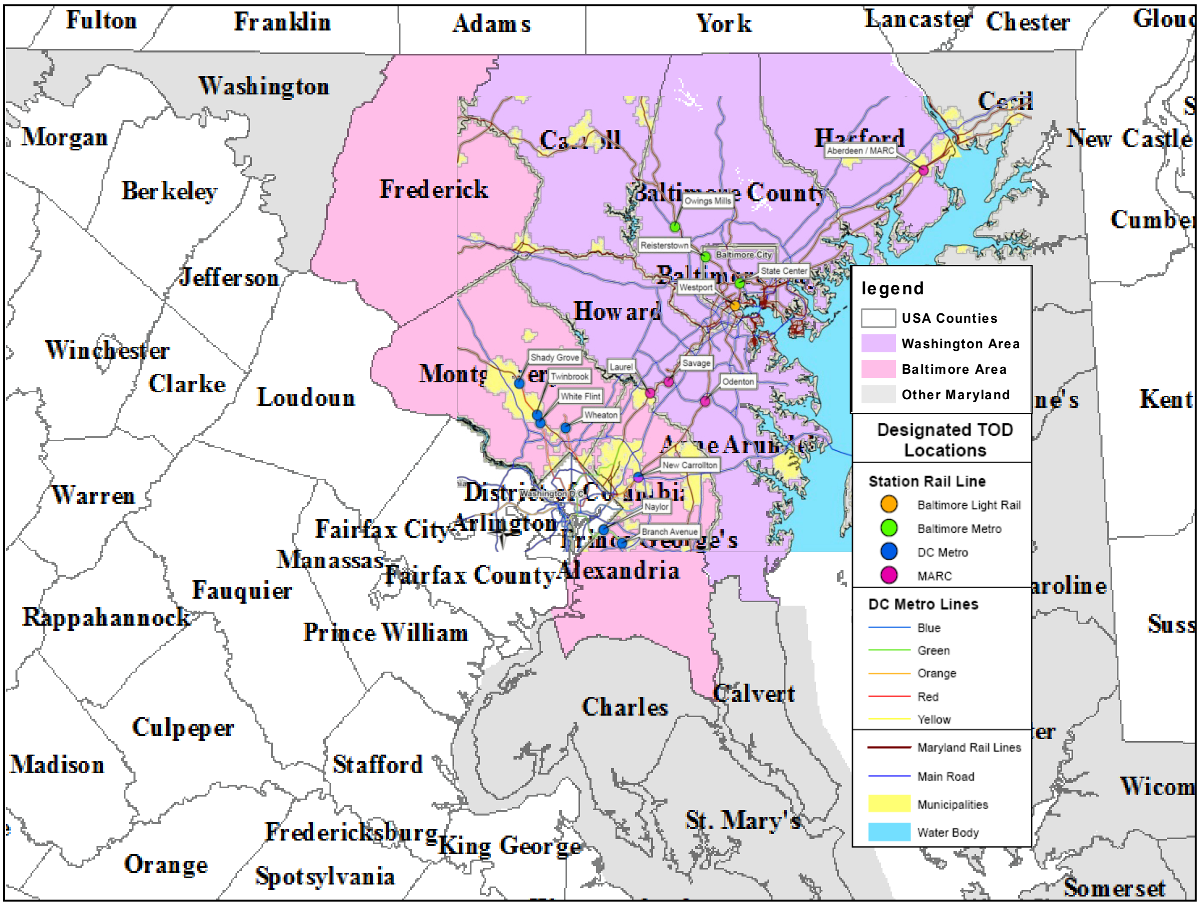


Fig. 5. Map of the Study Area

MSTM can estimate transportation performance of different patterns of future development. It is anticipated to be combined with statewide economic and land use scenarios of the future, and also the 2030 base model was developed with consideration towards each locality's constrained long-range plan (CLRP) (Mishra et al., 2013b; Mishra et al., 2011). The CLRPs were developed in conformity with federal requirements that funding sources be identified for all strategies and projects included in long range plans. The CLRP plans here are used as the baseline without redevelopment. In the model, 957 transportation analysis zones (TAZs) are located within the study area.

The TOD scenarios are developed by reallocating the growth of households or employment under CLRP. As a result, a certain percentage of non-transit area growth is reallocated and concentrated into TOD traffic zones (total 84TAZs) and other transit zones (total 167 TAZs) served by a rail transit station. The total growth of households or employment in the entire region is the same as CLRP, and growth allocation is modeled after the CLRP scenario plans. The location and specifications of all transportation facilities remain the same in each scenario (Wang et al., 2016).

At first, considering more jobs around transit station can get more transit ridership, the first TOD scenario is proposed named "Emp35%": 35% of the total employment growth shift to the TOD zones and other transit zones respectively, while the household growth is remains same as in the CLRP. And then through traffic impact analysis, the results are not good, so scenario 2 and 3 are given. Scenario 2 compared to scenario 1, it reallocates both the growth of households and employment, named "Emp&Res35%". Compared to scenario 1, scenario 3reallocates the growth of households instead of employment, named "Res 35%".

5.2. The Traffic Impact Analysis and Results for Scenarios

The travel demand of the TOD scenarios is forecasted using MSTM. After setting up and running the model of TOD scenarios, we get the output of each step such as the origination and destination trips between TAZs for different purpose and the network with assigned vehicles. And then we use model scripts to compute the values of basic measures. For example, we sum the output of mode choice (the trips of all purpose for all auto modes including driving alone and sharing ride) to compute AMS; using the column “Congestion Time” and “total volume” of the assignment results to obtain the VHT. Finally, we get the value of basic measures of daily trips under TOD scenarios, and compare them to the baseline. The results are showed in Table 1.

Table 1. The Changes of the Basic Evaluation Measures under Redevelopment Scenarios

The basic evaluation measures	**Without redevelopment: CLRP**	**Redevelopment scenario 1: Emp35%**	**Redevelopment scenario 2: Emp&Res35%**	**Redevelopment scenario 3: Res35%**
ATL	15.52miles	+0.30%	-0.42%	-0.60%
AMS	93.70%	-0.42%	-0.80%	-0.40%
VHT	5,369,291vehicle hours	+0.08%	-1.84%	-1.95%
VMT	140,259,440vehicle miles	-0.21%	-2.27%	-1.92%
VHD	2,038,880vehicle hours	+4.96%	+0.01%	-8.80%
CLM	2,912 miles	+0.40%	-5.73%	-6.42%
VDI	0.38	+4.9%	+1.9%	-7.0%
CLMR	0.18	+0.4%	-5.7%	-6.4%

Under redevelopment scenario 1, the auto mode share decrease so the vehicle miles travelled also decrease, while the average trip length increase and more vehicle hours travelled. This also implies that using VMT and/or VHT cannot support the decision making. That is why the traffic congestion status evaluation measures VHD and CLM are introduced. VHD and CLM are increased, so the highway network is more congested under scenario 1 than without redevelopment.

Under redevelopment scenario 2, the auto mode share and trip length are smaller, and so do VMT and VHT, but VHD increased a little. This is true that some links in this area are more congested while other links are less congested due to the activities including households and employment are concentrated to the TOD areas. As a result, VDI increases and CLMR decreases. Hence, the competitive measure STCR is needed to evaluate the impact to traffic congestion. According to formulation (1), STCR of baseline is 0.280, and STCR under redevelopment scenario 2 is 0.278. So, the scenario 2 has a little positive to reduce traffic congestion.

Under redevelopment scenario 3, all the basic measures are decreased, so it is will not exacerbate the traffic congestion in general. STCR (0.261) is much smaller than the baseline and the other two scenarios. The three redevelopment scenarios all tell us relocating households are better than relocating employments. This is related to the fact that there are already more jobs than households in the transit areas. Relocating households can make the job and households more balance or more mixed land use.

Therefore, all the traffic evaluation measures in the system are necessary to judge the impact. Through the comparison of the measures between scenarios, it is easy to see the traffic impact of each scenario, and find the best scenario which will be less congested than without redevelopment. And not all TOD redevelopment scenarios can reduce congestion.

6. Conclusions

Based on the existing land use and transport facilities, urban redevelopment is an important part of city evolution that can bring negative or positive impact to transportation. The principal reason causing traffic congestion after redevelopment is unreasonable planning without an accurate travel demand forecasting model and effective evaluation system. The first problem usually exists in developing countries such as China, but the second problem also happens in other developing countries. This paper provided a two stage approach for the reasonable redevelopment planning and decision making in developing countries.

Step one is for the first problem, the framework and components of IMMTM is introduced for redevelopment using MSTM as an example, followed by the advantage and better fitness. Step two is for the second problem, traffic evaluation measures system including basic and competitive measures is proposed. And application of the model and these measures is given by taking the TOD redevelopment scenarios of Maryland in the U.S. as a case study. The model is employed to quickly obtain the forecast of redevelopment scenarios in the case study, and the measures are used to do the traffic impact analysis and scenarios comparison.

From case study, we can see that MSTM is a suitable tool to assess scenario planning and contribute to evaluation tools. The basic traffic evaluation measures are necessary to reflect traffic impact on different aspects, but sometimes cannot reveal the whole impact to traffic congestion, so a competitive measure STCR is effective to judge the impact and support the decision making. The traffic evaluation measure system can fill the gap of traffic impact analysis. But because of data limitation, we couldn't show the application in urban redevelopment of developing countries, rather used MSTM as a platform to demonstrate the proposed methodology. The research presented in this paper can serve as a tool for developing countries to examine the impact of urban redevelopment scenarios.

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