IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received February 25, 2019, accepted March 9, 2019, date of publication March 21, 2019, date of current version April 26, 2019.

Digital Object Identifier 10.1109/ACCESS.2019.2906216

A Simulation-Based Approach to Determine the Location of Dedicated Transit Lane

QIAOWEN BAI, ZHAOWEI QU, XIANMIN SONG, AND SHUAI XIONG
School of Transportation, Jilin University, Changchun 130022, China

Corresponding author: Xianmin Song (songxm@jlu.edu.cn)

This work was supported by the National Natural Science Foundation of China under Grant 51278220.

ABSTRACT This paper is concerned with proposing a decision-making model to determine the suitable type from curbside and offset transit lane, mainly for a double-lane auxiliary road. The significant difference between these two types is the location of the weaving segment. A comparison analysis was first conducted to discuss traffic operations at weaving segments. Then, a decision-making model using random forest technique was developed based on output volume, delay, and the number of person from 1 261 260 VISSIM micro-simulation scenarios which evaluated varying occupancy of a transit vehicle, occupancy of a general vehicle, transit traffic volume, general traffic volume, cycle lengths, green time splits, and ratio of right-turning flow. The results reveal that when determining transit lane options: 1) general traffic volume is the most significant variable; 2) the impact of occupancy of a general/transit vehicle is so small that can be ignored; and 3) signal cycle, general, and transit volume have a negative effect on selecting offset transit lane, but signal splits and right-turning ratio have a positive effect. This paper provides a better understanding of offset transit lane operation and offers a simple determination to select suitable transit lane type for a particular traffic scenario using five input data needs, without the need for complex hand calculations.

INDEX TERMS Transportation, transit lane, micro-simulation, random forest.

I. INTRODUCTION

The transit lane, as an important transit preferential treatment, can improve bus reliability, as well as enhance the customer experience. Transit lanes may be located in different locations on a street adjacent to the curb, or down the center. Among them, the curbside transit lane is the most widely used, because it avoids the construction of center platforms and also has its differing, flexible uses throughout the day [1]. But in practice, traffic engineers discover that flourishing street trees, without enough headroom for travelling buses, may seriously affect running buses adjacent to the curb, as shown in FIGURE 1. Thus they design offset transit lanes, one lane away from the curb, to ensure the bus operation. These offset transit lanes are different from those commonly used in New York City, USA, where the lane next to the curb only serves parking and loading vehicles [2]. Here, curb lanes can serve right-turning traffic as well as few through traffic. And general vehicles do not need to briefly enter the transit lane to make right turns. After using it for a while, engineers notice that offset transit lanes can improve operational efficiency of buses and right-turning vehicles, especially for traffic scenarios with high right-turning volume. Therefore, decision makers in many cities begin to install offset transit lanes along a street with high right-turning volumes, such as Shanghai, Dalian, Suzhou and Changchun in China (see FIGURE 2).

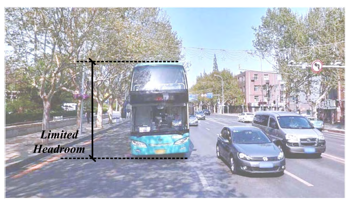


FIGURE 1. Limited headroom for buses caused by flourishing street trees.

Nowadays, offset transit lanes have been recorded in Manual on Urban Road Traffic Management [3]. The manual only points that an offset transit lane can reduce delays due to eliminate conflicts between buses and right-turning vehicles at the entering approach of an intersection. However, it will also increase a weaving segment before and after a bus stop. There is no accepted criterion for the installation and usage of the offset transit lane. Traffic operations on streets with offset

The associate editor coordinating the review of this manuscript and approving it for publication was Bin Yu.

(a) (b)

FIGURE 2. Offset transit lane used in Shanghai and Dalian. (a) Xizang Nanlu (Shanghai) and (b) Gao'erji Lu (Dalian).

transit lanes is expected to be different from that with curbside transit lanes. Traffic engineers and transit planners are in great need of developing new guidance for determining suitable transit lane options considering different traffic scenarios.

In recent years, many previous scholars prefer to develop micro-simulation models to conduct traffic operation analysis on dedicated transit lanes, because it would allow for modification and control without having extraneous and unexplanatory variables [4]. The HCM also introduced micro-simulation analysis approaches and their proper applications from 2010 edition [5]. Different from collecting actual traffic data, there is no need to change traffic facilities in reality and it is quite easy for scholars to address a broader range of geometric and traffic conditions. Thus micro-simulation models are quite useful in analyzing operational impacts of a vast array of design alternative for managed lanes like dedicated transit lane. Many previous studies have certainly offered informative results. Chen used a Vissim-based approach to study the impacts of dedicated transit lanes on the capacity of a weaving segment on an urban expressway, including center transit lane with off-on-ramp and curbside transit lane with on-off-ramp/off-on-ramp [6]. And then a capacity reduction factor, considering the influence of bus exiting and entering flow ratio, bus ratio, and bus exiting and entering length, is formulated as a generalized function for the weaving segment with center transit lane [7]. According to the simulation results, they also proposed a regression model to estimate the capacity of a weaving segment with a center transit lane. The model is applicable and easy to use with an acceptable accuracy [8]. Zhu et al also used Vissim software to evaluate dedicated transit lanes in Beijing Western 3rd Ring-Road Expressway. Results showed that center transit lane slightly outperformed the curbside transit lane [9]. Ye paid more attention on the impact of access traffic on the operational efficiency of curbside transit lane and he recommended the length of weaving area by simulation results [10]. Sun et al designed a Vissim-based simulation platform to study the operating characteristics of the buses and cars on urban roads and gave the thresholds of traffic volume for using dedicated transit lanes [11]. Lou also determined the length of the skip line between the dropped transit lane and the through mixed-traffic lane based on the result of micro-simulation [12].

Similarly, it is also very hard to have comparison analysis of traffic operation on a street with curbside and offset transit lane in the same traffic condition by collecting actual data. According to the methodology on operation analysis above, this paper is intended to develop an analytical procedure to evaluate the operational efficiency on both offset and curbside transit lane by micro-simulation-based approach, and propose a decision-making model to determine the appropriate type for different traffic scenarios.

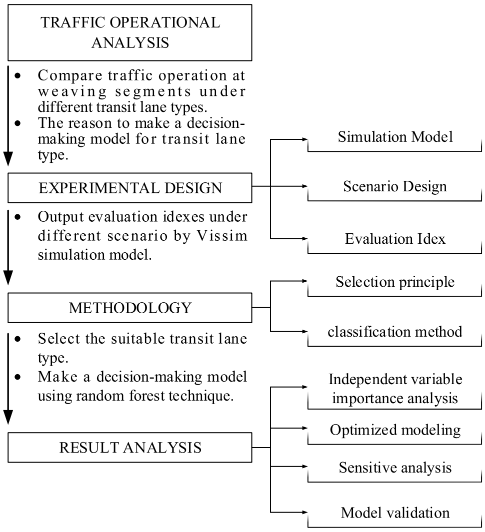


FIGURE 3. Conceptual graph of the study.

Figure 3 gives the conceptual graph presenting different components of the study. Firstly, traffic operations near the entering approach and the bus stop and are analyzed for streets with offset/curbside transit lane. Then a micro-simulation experiment for different traffic scenarios is conducted by Vissim com programming with Visual Basic script. According to simulation results and selection principles introduced, the random forest technique is used to select the important variable and conduct the transit type classification and prediction for different traffic scenarios. At last, the paper presented conclusions and recommendations. The findings in this study will offer a better understanding of offset transit lane operation and provide references for traffic engineers and decision makers to decide whether the offset transit lane is applicable in a particular traffic scenario.

II. TRAFFIC OPERATIONAL ANALYSIS

FIGURE 4 illustrates right-turning routes when a curbside or offset transit lane is installed. For a curbside transit lane street, the transit lane is often dropped at the entering approach to allow general traffic sharing the curbside lane and making their right turns. So weaving conflicts between buses and general vehicles mainly happen at the entering approach of an intersection. Drivers of right-turning traffic need to maneuver vehicles with the gap search, drive through the transit traffic flow. With the increasing of right-turning demands, the transit traffic operation will be increasingly disturbed by merging flows. Thus buses may be severely delayed. What is worse, if an intersection is signalized, the entrance of the

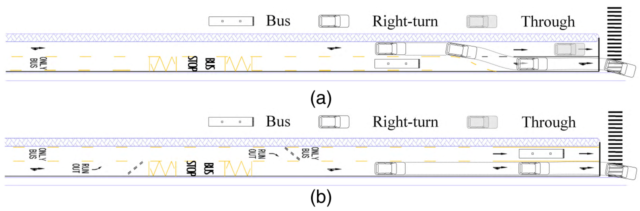


FIGURE 4. Right-turning routes on streets with different types of transit lane. (a) Curbside transit lane and (b) offset transit lane.

shared lane will be blocked by the queued through vehicles in the adjacent through lane. Under this situation, right-turning vehicles cannot enter the shared lane despite the availability of space. Even though they successfully enter the shared lane, the buses waiting for a green phase will still block their right-turning routes. When the right-turning flow has a high volume, following buses may be influenced as well. (See FIGURE 5 (a)) In contrast, there is no such weaving segment at the entering approach on an offset transit lane street, general traffic travelling on curbside lane can directly make right turns at an intersection without any delay to running buses. Of course, at a signalized intersection, right-turning vehicles may be also blocked by the queued through vehicles as shown in FIGURE 5 (b)).

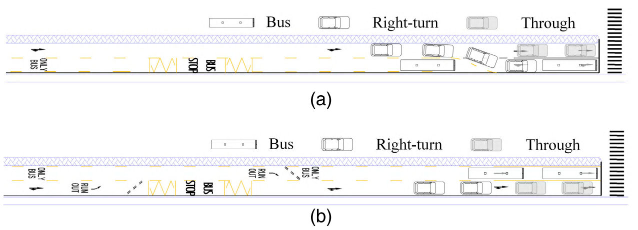


FIGURE 5. Effects on right-turning vehicles using different types of xtransit lane. (a) Curbside transit lane and (b) offset transit lane.

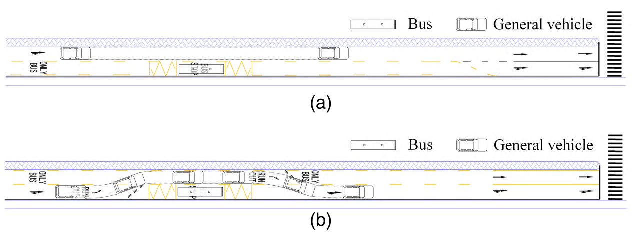


FIGURE 6. Effects on right-turning vehicles using different types of transit lane. (a) Curbside transit lane and (b) offset transit lane.

In addition to the entering approach of an intersection, traffic operation near a bus stop are quite different for streets with different types of transit lanes. Buses travelling on a curbside transit lane can stop and board passengers at a bus stop without ever leaving their travel lane. General traffic has no impact on the bus approaching and leaving the bus stop, as shown in FIGURE 6(a). However, when offset transit lanes are used, special design attention must be given to weaving segments before and after a bus stop, as shown in FIGURE 6(b). The bus bulb cannot be installed because the lane next to the curb still serves travelling traffic. These buses have to leave the travel lane and stop on the curbside lane to provide boarding service. After then, they will change the lane and continue to travel on offset transit lanes. As for general traffic, it is allowed to briefly enter the offset transit lane so as to overtake boarding buses at the bus stop. But they must leave the transit lane and come back to the curbside lane after passing through the bus stop. It is easier for general traffic to have lane changings in these weaving segment because a serving bus that board passengers has no speed. Certainly, when no bus is present, general traffic can keep travelling on the curbside lane and pass the bus stop without lane changings. In order to make it easy for drivers of general traffic to know where they should have lane changings, some traffic engineers designate weaving segments using a double dotted white line, arrow markings, as well as a stenciled "RUN OUT" marking. FIGURE 7 illustrates the example of pavement markings used in Dalian, China.

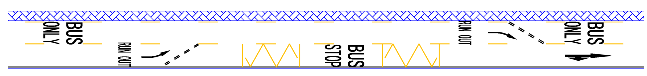


FIGURE 7. Pavement markings for offset transit lane used in Dalian, China.

It is hard to say which type of transit lane is better. An offset transit lane do not produce a weaving segment at the entering approach of an intersection, but it may lead to more weaving segments near a bus stop. A curbside transit lane can provide less weaving segment, but right-turning vehicles have more opportunities to be blocked and their overflow can even affect bus operation. In fact, different types of transit lane should be applied in different traffic scenarios, which depends on the traffic flow volumes and signal control schemes. It is necessary to offer a simple determination to select suitable transit lane type for a particular traffic scenario.

III. NOTATIONS

To facilitate the presentation of the modeling process, key notations to be used hereafter are listed in TABLE 1.

IV. EXPERIMENTAL DESIGN

In this study, experiments were conducted by using VISSIM COM programming with Visual Basic script. Vissim, as a micro-simulation software, does well in modeling transit operations and driving maneuvers at weaving segments [6]. Visual Basic will help to simulate automatically and enhance the efficiency of the simulation process.

A. SIMULATION MODEL

Vissim simulation models should be developed first including traffic network objects, desired speed distributions and transit stop time.

Two modeled streets were created as traffic network objects: one with curbside transit lane, the other with offset transit lane. The modeled street is a basic auxiliary road with

TABLE 1. Parameters and variables.

Type parameters:	
i	The type of transit lane. (i=0: curbside transit lane, i=1: offset transit lane)
Input variables:	
Occ^t	Occupancy of a transit vehicle (*person/veh*) (The number of passengers that are in the transit vehicle when entering the VISSIM network.)
Occ^g	Occupancy of a general vehicle (*person/veh*) (The number of passengers that are in the general vehicle when entering the VISSIM network.)
r	The ratio of right-turning vehicles on the lanes for general traffic.
C	Signal cycle time of the signalized intersection. (*s*)
δ	Percent of green time.
V^t_{input}	Transit traffic volume input when entering the VISSIM network. (*veh/h*)
V^g_{input}	General traffic volume input when entering the VISSIM network. (*veh/h*)
$V_{input}(i)$	Total traffic volume input under type i when entering the VISSIM network. (*veh/h*)
Evaluation variables:	
$V_{output}(i)$	Total traffic volume output under type i when leaving the VISSIM network. (*veh/h*)
$D(i)$	Average delay per person under type i (*s*)
$P_{input}(i)$	The number of person input under type i when entering the VISSIM network.(*person*)
$P_{output}(i)$	The number of person output under type i when leaving the VISSIM network.(*person*)

two travelling lanes, which is normally used in many cities, as is shown in Fig 3. The simulated street is 500 meters long and lane widths are kept to the standard 3.5 meter.

The desired speed distribution is one of the most important parameters in Vissim model and it has a significant impact on the roadway capacity and achievable travel speeds [13]. In order to define desired speed distributions, a field survey was conducted at Xi'an Avenue in Changchun to collect speed data for both transit and general traffic in low demand condition. FIGURE 8 illustrate the calibrated desired speed distributions. The minimum and maximum values for the distribution of transit traffic are 35km/h and 60km/h, those for general traffic are 40km/h and 65km/h.

The transit stop times are determined by setting dwell time distributions in Vissim. According to the analysis of dwell time data for buses at bus stop Chongqing Lu and Renmin Guangchang during peak hour, a normal distribution

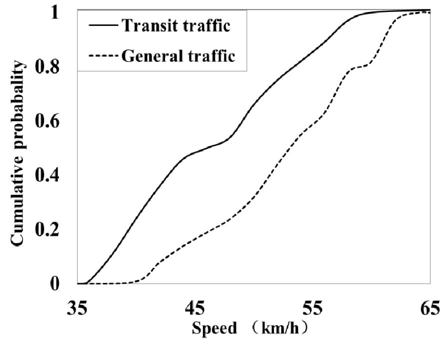


FIGURE 8. Desired speed distribution for transit and general traffic.

is calibrated by giving a mean value 16*s* and standard deviation 4*s*.

B. SCENARIO DESIGN

In order to provide guidance to select an appropriate transit lane configuration while considering different traffic conditions, detailed scenarios should be designed for the micro-simulation implementation. Seven variables, including transit volume V^t_{input}, occupancy of a transit vehicle Occ^t, general traffic volume V^g_{input} occupancy of a transit vehicle Occ^g, right-turn ratio r, cycle length C, and percent of green time δ, are identified for the design of different scenarios.

According to the Code for Design of Bus Exclusive Lanes System in Shanghai [14], a dedicated bus lane can be applied along the street where transit volume is higher than 40veh/h during the peak hour. And two parallel transit lanes should be considered if transit volume reach 160veh/h. Thus the transit volume range is 40veh/h-160veh/h. Table 2 provides all the ranges and increment values for simulated variables. The possible combination of these seven variables will provide $7\times9\times13\times4\times11\times7\times5$=1,261,260 scenarios. Considering the stochastic traffic input, five different random seeds were used in each scenario. At last, totally 6,306,300 simulations were performed to collect the required data.

The simulation time horizon was 4200 seconds and the first 600s was the warming time.

C. EVALUATION INDEX

Traffic volume and delay are always used to evaluate the traffic state. In this study, traffic volumes output when leaving the VISSIM network $V_{output}(i)$ were collected and it was compared with input traffic volumes $V_{input}(i)$ to determine whether the road could serve all input traffic. Considering that a bus can carry much more passengers than a general car,

TABLE 2. Range values for simulated variables.

Elements	Variable						
	V^t_{input} (*veh/h*)	Occ^t (*person/veh*)	V^g_{input} (veh/h)	Occ^g (*person/veh*)	r	C (s)	δ
Range	40-160	20-100	200-1400	1.2-1.8	0-1	60-180	0.3-0.7
Increments	20	10	100	0.2	0.1	20	0.1

more people will enjoy benefits when a bus is released rather than a car. Thus the average delay per person $D(i)$ is recorded and the number of person input upstream $P_{input}(i)$ and output downstream $P_{output}(i)$ are counted as well. It equivalently provides a greater weight to the transit traffic, which also accords with the aim of the plan for Bus forward. Noted that $D(i)$ do not include passenger stop times at bus stops.

V. METHODOLOGY

A. SELECTION PRINCIPLE

A better transit lane type should serve larger traffic volume and produce smaller traffic delay. According to the specific selection procedures shown in Algorithm 1, the suitable transit lane type can be selected for different scenarios.

Algorithm 1 Selection Principle

Input $V_{output}(i)$, $P_{output}(i)$, $D(i)$, $j=0$
for $i=0$ **to** 1
  if $V_{output}(i) < V_{input}(i)$
    $j=i+1+j$
  else
    $j=-i-1+j$
end
  if $j=1$
    $type = offset$
  elseif $j=-1$
    $type = curbside$
  elseif $j=3$
    if $P_{output}(1)=P_{output}(0)$
      if $D(1) < D(0)$
      $type = offset$
      else $type = curbside$
    elseif $P_{output}(1) > P_{output}(0)$
    type= offset
    else type=curbside
  elseif j=-3
   if $D(1) < D(0)$
    $type = offset$
    else $type = curbside$

First of all, a comparison analysis between $V_{input}(i)$ and $V_{output}(i)$ is conducted. If $V_{input}(i)$ is larger than $V_{output}(i)$ under $i=0$ rather than $i=1$ or larger under $i=1$ rather than $i=0$, all input volumes can be output under one type, but cannot be fully output under the other one. It is clear that the type with fully output is the better one because it can meet the traffic demand.

If $V_{output}(i)$ is smaller than $V_{input}(i)$ under both $i=0$ and $i=1$, it indicates that two types are both hard to solve the traffic demand. Considering the greater weight to the transit traffic, $P_{output}(i)$ is introduced to conduct comparison analysis. Certainly, the type with large $P_{output}(i)$ should be selected. When $P_{output}(0)$ is equal to $P_{output}(1)$, $D(i)$ should also be taken into consideration. And the type with smaller $D(i)$ is the better one. Once two values of $D(i)$ are the same, curbside transit lane will be selected in view of its common use in the street. This was relatively rare, however.

If $V_{output}(i)$ are not smaller than $V_{input}(i)$ under both $i=0$ and $i=1$, both two types of transit lanes can meet the traffic demand. Limited to input traffic volume, $V_{output}(i)$ *and* $P_{output}(0)$ have no significant difference. At this time, the type with smaller $D(i)$ is the best choice.

The resulting transit lane types for each of the 1,261,260 scenarios were reviewed and a classification model will be developed to mine possible potential trend. Seven variables that produce different scenarios are data feature. Each scenarios corresponds to a suitable transit type based on selection principle. The model will help to provide a simple determination and select the suitable transit lane type for different traffic scenarios.

B. CLASSIFICATION METHOD

At first, many classification techniques were attempted to solve the problems such as random forest, decision tree, Fisher discriminant analysis, support vector machine and artificial neural work. It is found that only the random forest technique could obtain performance evaluation over 90%, as shown in TABLE 3. Therefore, in this study, the random forest technique was used to conduct the transit type classification and prediction for different traffic scenarios.

TABLE 3. Classification accuracy using different techniques.

classification technique	accuracy
random forest	95%
decision tree	82%
Fisher discriminant analysis	73%
support vector machine	85%
artificial neural work	87%

Random forest, proposed by Breiman, is one of the most recent and promising machine learning techniques for classification and regression tasks [15]. It operates by constructing a multitude of decision trees at training time and outputting the prediction class according to the maximum votes by individual predictions. The random forest has strong generalization ability due to the generalization error obtained by the unbiased estimation model [16]. It also has advantage in selecting significant variables from a set of variables and avoiding over fitting to their training set. In this study, the random forest was implemented using R-Studio.

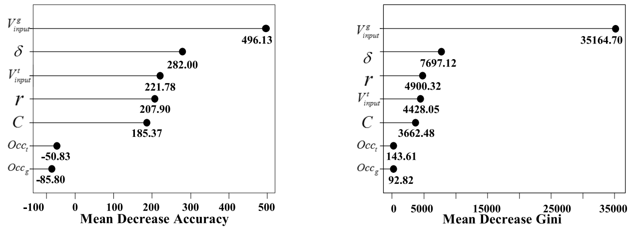
VI. RESULT ANALYSIS

A. INDEPENDENT VARIABLE IMPORTANCE ANALYSIS

In the R-Studio, Mean Decrease Accuracy and Mean Decrease Gini diagrams are introduced to measure the importance of each covariate. The mean Decrease Accuracy is the total decrease in prediction accuracy if values of a variable are replaced by random values. The larger a mean decrease accuracy value is, the more important a variable will be. Differently, Gini index shows the node impurity, as calculated by equation (1). A small Gini index means a high node purity. The Mean Decrease Gini represents the total decrease in node impurities from splitting on the variable, averaged over all trees [17]. The larger a mean decrease Gini value is, the more important a variable will be.

$$Gini = \sum_{k=1}^{K} p(k) \cdot [1 - p(k)] = 1 - \sum p(k)^2, \qquad (1)$$

where $p(k)$ is the probability of an item labeled with class k in the set.



(a) (b)

FIGURE 9. Ranking variable importance that associated with transit type selection by random forest.

FIGURE 9 gives ranking variable importance that associated with transit type selection by random forest. Both of these two indices shows that V^g_{input} is the most important variable. And it is also clear that two indices of Occ_t and Occ_g are far less than other factors. The impact of Occ_t and Occ_g is so small that can be completely ignored. To simplify the random forest construction and reduce the interference of unimportant covariates, Occ_t and Occ_g are not taken into consideration in the following classification. As a result, the prediction accuracy was slightly improved from 95.67% to 96.10%.

B. OPTIMIZATION MODELING

There are two parameters mainly affecting random forest model: the number of variables tried at each split (*mtry*) and the number of trees (*ntree*). In aforementioned model, these two parameters are set to be default (*mtry=2, ntree=500*). However, using default parameters may not lead to the best prediction performance. Thus parameter adjustments should be conducted to achieve optimization modeling.

In order to determine the optimal value for *mtry*, random forests were implemented by stepwise adding a variable and the *mtry* with the lowest OOB estimate of error rate was the optimum value. The default value (*mtry=2*) is not optimal with OOB = 0.0407, and *mtry=3* can obtain the best result with OOB = 0.0322.

Next, the optimum value for *ntree* should be calculated in the case of *mtry=3*. FIGURE 10 illustrates that the OOB estimate off error rate tend to be stable when *ntree* is larger than 600. And the error rate will be the lowest when *ntree=659*. From the above, random forests with *mtry=3* and *ntree=659* can achieve the most promising prediction accuracy.

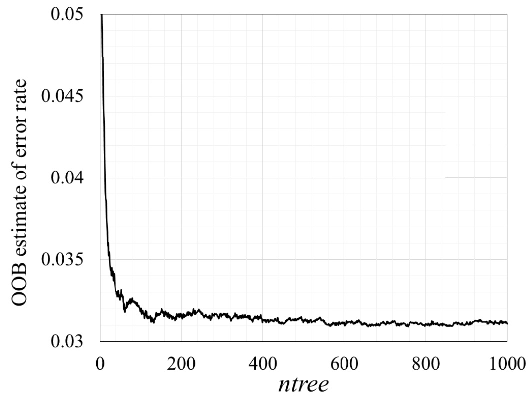


FIGURE 10. Relationship between ntree and OOB estimate of error rate.

TABLE 4 gives the confusion matrix of the optimal random forest model. It can be clearly seen that the model shows outstanding performance, no matter for curbside or offset transit lane. The prediction accuracy is improved again from 96.10% to 96.93%. Tree sizes distributions are illustrated in FIGURE 11. The number of nodes in each decision tree is quite different. The smallest number of tree nodes is 1380, and the largest value is 1802.

TABLE 4. Confusion matrix of the optimal random forest model.

		actual		class error
		curbside	offset	
predicted	curbside	15499	486	0.0304
	offset	590	18460	0.0309

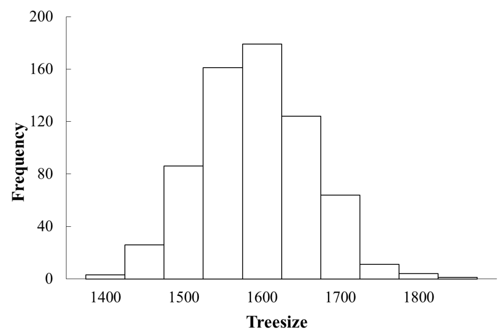


FIGURE 11. The distribution of tree sizes.

C. SENSITIVE ANALYSIS

The random forest, a black box prediction method, is difficult to provide an easy understanding of the functional relations between predictors. In this study, partial dependence plots are used to investigate these relations as shown in FIGURE 12. The sensitive analysis is conducted based on graphical visualizations of the marginal effect of a given variable on an outcome. The function being plotted is defined as equation(2) [18].

$$\tilde{f}(x) = \frac{1}{n} \sum_{v=1}^{n} f(x, x_{vC}), \qquad (2)$$

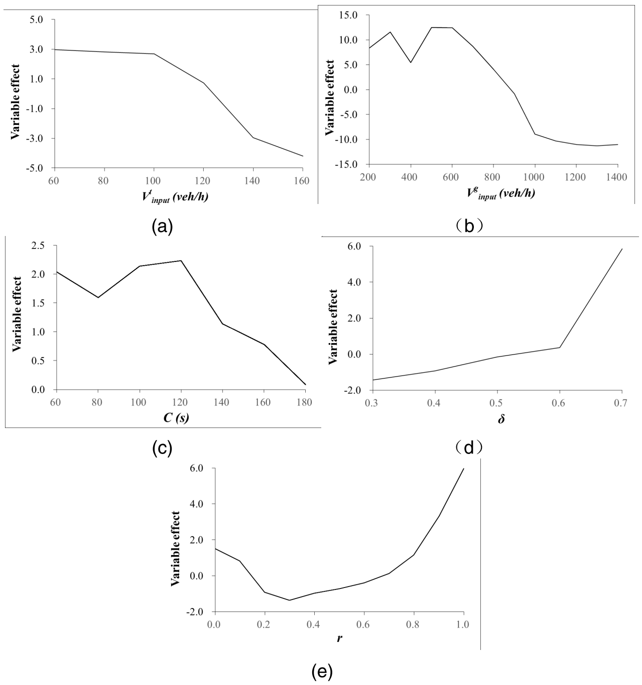


FIGURE 12. Partial effect of different variables on the offset transit lane selection.

where x is the variable for which the partial dependence is sought, and x_{iC} is other variables in the data. And $f(x)$ can be calculated by equation (3)

$$f(x) = \log p_k(x) - \frac{1}{K}\sum_{w=1}^{K} \log p_w(x), \tag{3}$$

where K is the number of classes, k is the class to focus on, and $p_w(x)$ is the proportion of votes for class w

FIGURE 12 illustrates the marginal effect of δ, C, r, V_{input}^{t} and V_{input}^{g} on selecting offset transit lane. It can be clearly seen that V_{input}^{t} and V_{input}^{g} have negative effect as their increasing. This is because a street with offset transit lane has one more weaving area than that with a curbside transit lane. More traffic volumes will lead to more weaving conflicts. For right-turning ratio, the r larger than 0.7 is suitable for offset transit lane. When right-turning traffic volume is large, different from curbside transit lane, an offset transit lane will make them cross the intersection more quickly without effect of buses waiting for green phase at the entering approach. As for the aspect of signal control, it is clear that the split δ has positive effect on selection result when it increases. And a cycle around 120 seconds performs well. It will have a sharp decrease after then.

D. MODEL VALIDATION

In order to verify the developed model, other 2880 scenarios are designed as shown in Table 5. Similarly, simulation experiments will also be conducted by VISSIM COM programming with Visual Basic script so as to obtain

TABLE 5. Range values for simulated variables in model validation.

Elements	Variable				
	V_{input}^{t} (veh/h)	V_{input}^{g} (veh/h)	r	C (s)	δ
Range	50-130	250-1250	0.13-0.88	63-188	0.33-0.63
Increments	20	200	0.25	25	0.1

evaluation values. And Algorithm 1 will still help to select the better type. Then the selection results by Algorithm 1 will be compared with those obtained from the developed model.

TABLE 6. The confusion matrix of the test data.

		Actual		Precision
		curbside	offset	
Predicted	curbside	1096	114	90.58%
	offset	102	1568	93.89%
Recall		91.49%	93.22%	

According to the confusion matrix shown in Table 6, both precision rates and recall rates are higher than 90 percent and the accuracy rate is 92.50%. In addition, the ROC (receiver operating characteristic) curve was drawn as well, as shown in FIGURE 13. It is an effective method to measure the classifier performance. The value of AUC (Area under the Curve of ROC) varies between 0 and 1, and 1 represents perfect performance. For these test data, the AUC value is 0.924, which shows that the developed model does well in predicting the suitable transit lane type.

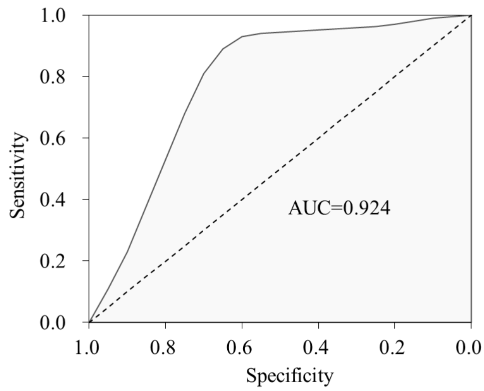


FIGURE 13. The ROC curve for test data.

VII. CONCLUSION AND RECOMMENDATIONS

This study focusses on two types of transit lane: curbside and offset, mainly for a double-lane auxiliary road. The significant difference between these two transit lane types is the location of weaving segments. For a street with curbside transit lane, weaving conflicts between transit and general traffic occurs at the entering approach of the intersection. In contrast, there is no such conflict on an offset transit lane street. Weaving segments are located before and after a bus stop. However, it is easier for general traffic to change lanes because a bus boarding passengers stops at the bus stop.

According to traffic evaluation indexes obtained from micro-simulation under 1,261,260 traffic scenarios, the suitable type was selected to each traffic scenarios by Algorithm 1. Then random forest technique classified the transit lane type by seven variable and three evaluation indexes. Some major tentative conclusions can be summarized as followings.

(1) The optimized random forest model have 659 decision trees and 3 variables at each split. The accuracy of the model can be up to 96.93%.

(2) General traffic volume V_{input}^{g} is the most important variable, and transit traffic volume input V_{input}^{t}, the ratio of right-turning vehicles on the lanes for general traffic r, the cycle time of the signalized intersection C, the percent of green time δ should be taken into consideration as well.

(3) Occupancy of a general/transit vehicle has least impact on transit type selection and they are enough to be ignored.

(4) Signal cycle, general and transit volume have negative effect on selecting offset transit lane, but signal splits and right-turning ratio have positive effect

This study is based on a large dataset of traffic scenarios and has enough training samples. The test dataset with 92.5% accuracy also proves the validation of the proposed model.

Our findings give an interesting insight into the selection of transit lane type for an auxiliary road. Once traffic engineers or decision makers obtain five traffic variables, it is easy for them to determine the transit lane type using the developed model in this study, without the need for complex hand calculations. Except an auxiliary road, the decision-making model can also provide reference on installing transit lane for some double-lanes streets without left-turning traffic. This information is essential for gaining more understanding on installing curbside and offset transit lanes, which can be applied for improving our design guidelines.

However, the studied object is limited to an auxiliary road or double-lanes streets without left turning traffic flows. Traffic operation on a street with three or more lanes may be a little different, especially when installing an offset transit lane. In this case, general traffic travelling on the center lane is allowed to cross the offset transit lane at the entering approach of an intersection and have lane changes to curbside lane to finish their right-turning movements. In addition, general traffic can also select to come back to the curbside lane or merge into the center lane after briefly entering the offset transit lane at a bus stop. These difference will make traffic maneuvers a little more complex. Therefore, the research will continue to analyze configurations with three or more lanes on the streets and determine the suitable transit lane type for different traffic scenarios.

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QIAOWEN BAI received the bachelor's degree in traffic engineering from Jilin University, Changchun, China, in 2014, where he is currently pursuing the Ph.D. degree with the School of Transportation. His research interests include traffic flow theory, traffic control theory, traffic organization, and traffic big data.

ZHAOWEI QU received the Ph.D. degree from the School of Transportation, Jilin University, Changchun, China, where he is currently a Professor and Ph.D. Supervisor. His current research interests mainly include traffic control theory, traffic organization, traffic big data, and intelligent transportation systems.

XIANMIN SONG received the M.Sc. and Ph.D. degrees in traffic engineering from Jilin University, Changchun, China, in 2005 and 2008, respectively, where she is currently an Associate Professor with the School of Transportation. Her research interests include intelligent traffic control, traffic flow theory, and traffic big data.

SHUAI XIONG received the bachelor's degree in traffic engineering from Jilin University, Changchun, China, in 2015, where he is currently pursuing the master's degree with the School of Transportation. His research interests include traffic flow theory and traffic control theory.