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A Study of Two-Fluid Model with Ring Road Simulation

THESIS

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MASTER OF SCIENCE

in Civil Engineering

by

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ABSTRACT OF THE THESIS

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The Two-fluid model has been used as a macroscopic method to evaluate urban network performance for decades. Different achievements have been made regarding to the use of the two-fluid model in city network and arterial street level. Data collected during peak hours is always used for parameter estimation, but how different congestion levels would affect the two-fluid model parameters has never been discussed. In this thesis, it is verified with ring road simulation data that under over-saturated or under-saturated traffic conditions, the two parameters, and n, cannot be properly estimated. Beijing data is used in the second part to verify that GPS data from cellphone can be used for verification of the two-fluid model. Two data collection methods are used here: one is time-based, and the other distance-based. It is proved that with traffic data collected during peak hours, distance-based data is more accurate to estimate the two-fluid model parameters.

Chapter 1: Introduction

Transportation has always been regarded as one of the most important components in a city. Mobility within any urban area can directly influence the quality of life, the increase of economics and the development of the city. With the growth happened in many cities, they are all facing with the problems of larger population and more congested traffic condition. Different techniques have been used to improve the transportation situation in a city but the difficulty is how to evaluate these techniques and how efficient the evaluation system is. A number of methods based on traffic flow theory and practice are used to evaluate the change happened in the performance of an intersection or an arterial.

Two-fluid model is one of them and has been used for decades as one way to test the performance of surface street network. By showing the relationship between trip time and stop time, a linear regression model can be generated. Two parameters n and T_m are used as the measurements describing relative quality of different traffic systems. One way using two-fluid model is to compare network performance before and after some changes happened in several years in same district such as change in land use from residential to mixed use, change of intelligent traffic light design, change of road design from one-way to two-way traffic and other conversions. The other way is to make comparison between various traffic networks in different districts, cities or even countries and to evaluate the network performance comprehensively. With the measurements of two-fluid model parameters, traffic conditions can be compared vertically and horizontally and changes can be made in order to build a better traffic network.

As a macroscopic modeling technique it provides the measurement of the quality of traffic service in a street network, which is independent of concentration. Comparing with other theory, two-fluid model is much easier to be implemented that data can be relatively easier collected for model generation. This is also one of the reasons that two-fluid model has been widely used for the last 35 years. All the variables used in the two-fluid model represents the network-wide averages taken over a given period of time. Under this circumstances, many reality conditions cannot be avoided and they all may affect the evaluation results, which represent the two parameters in two-fluid model. It has been verified that the network conditions can be represented by a single vehicle appropriately sampling the network, so that driver behavior, network features and other variables all have effect on the two-fluid model parameters.

Geometric and traffic control features of a street network play an important role in the quality of service provided by a network. Different studies have been made discussing about the relationships between specific features and the two-fluid model parameters, including lane miles per square mile, number of intersections per square mile, average signal cycle length and so on. But one of the network features has never been discussed about before, that if the congestion level of the network. What is the relationship between the network congestion level and two-fluid model parameters? How will different traffic congestion level affect the accuracy of two-fluid model parameters? Is there any boundary for the congestion level when using two-fluid model as the network evaluation method? In the former papers, congested traffic condition is a basic requirement when collecting the experiment data. But how to define the congestion level and how the accuracy of two-fluid model will be affected when having an over saturated traffic should be more carefully studied.

In order to answer this question, computer simulation will be used to study about the different congestion level. Comparing to field data, computer simulation has many advantages. It is easier to simulate conditions that may not happen in the field and it can also provide a more clear and easy-controlled network, so that different congestion level can be set up. Different from the normal two-fluid simulation setup with a generic grid network, a ring road is programmed in Matlab as the most basic and simple traffic network in this paper. The network is simply a one-way ring road with traffic signal at the end/start point of ring road. Different numbers of vehicles will be assigned on the ring road and based on the car-following model (optimal-velocity model is used here), vehicles will keep sampling on the ring road until the end of the simulation. Different traffic congestion levels are used in the model to measure the reaction of parameters from two-fluid model. With the use of ring road simulation in this paper, different driver behaviors are avoided. Meanwhile, as the most simple traffic network performance, only traffic congestion level will be considered as the objective, and all other traffic features will be eliminated in this paper. The change of vehicle number, signal setting and road length are the three variables that will be used to provide the network with different congestion levels. And based on different congestion levels, two-fluid model will be generated and discussed, two parameters will be evaluated for their efficiency and accuracy.

Chapter 2: Literature Review

Herman and Prigogine first raised the two-fluid model up in 1979. Traffic in a city network can be differentiated as two traffic fluids: one part composed of the moving cars and the other of cars that are stopped as a result of congestion, traffic signals, stop signs, and other traffic control devices. A number of field studies were made for two-fluid model and indicated that urban street network can be characterized by two parameters, n and . These parameters have been estimated using observations of stopped and moving times gathered in each network. Chase car technology is used in data collection with chase cars following randomly selected cars in designated networks. Runs have been broken under two ways, one is into one- or two-mile trips, and the other one is one- or two-minute trips. The running time and total trip time for each one- or two-mile/minute trip are from the observations for the parameter estimation. With the analysis of observations made in many cities in the United States and even worldwide in later papers, it was found out that the log of stop time per unit distance is linearly related to the log of trip time per unit distance and with this relationship, we can describe the traffic efficiently and simply. Two-fluid model is an important result from Prigogine and Herman’s (1971) kinetic theory of traffic flow and it works as the theoretical basis for the result of the linearly relationship between trip time and stop time.

Two-fluid model applied under town traffic with two assumptions:

Extending the ideas in the kinetic theory of traffic, similar as the analogy with the Bose-Einstein condensation, the average running speed in a street network is proportional to the fraction of vehicles that are moving:

$$= \quad (\quad) \quad (1)$$

: average speed of the moving cars

: average maximum running speed in the network system

: fraction of the cars that are moving

: parameter representing the quality of traffic service in a network

Considered as a type of ergodic condition, the fraction of the time stopped for a vehicle circulating in the network is equal to the average fraction of stopped cars in the system over the same time period:

$$= (-)(2)$$

: fraction of the cars that are moving

: running time per unit distance

T: trip time per unit distance

Under these two assumptions, we get the final equation for the model:

$$= \quad - \quad \frac{1}{+1} \quad \frac{}{+1} (3)$$

T_s: stop time per unit distance

T_m: average minimum trip time per unit distance

T: trip time per unit distance

Based on the theory, an urban network can be characterized by the (, n) pair of values. A further description of traffic in towns including concentration and flow in the fraction of the stopped vehicles was also given as:

$$= \quad = \quad (1 - (-)^{\frac{1}{+1}})^{\frac{1}{}} \quad (4)$$

q: traffic flow

: average maximum concentration when traffic jams in the system

With the basic functions and derivation process given for the two-fluid model, possible applications of two-fluid model in further transportation studies were discussed in different aspects including relationship between two-fluid model and driver behaviors, influence of network features on the model, application of two-fluid model with field studies and parameters estimated by computer simulation.

Herman (1984) examined the validity of the theoretical assumptions underlying two-fluid model. Two useful parameters were used to describe the character of a traffic network system. The parameter is the average minimum trip time per unit distance, and it represents the trip time that might be experienced by an individual vehicle alone in the network with no stops. Since it is unlikely to measure this parameter directly, that any vehicle try to drive through the network with no other traffic late at night may still need to stop at red traffic signal or stop sign. A higher value of will indicate a lower speed, which means a poorer operation. Another parameter n is a measure of the resistance of the network to degraded operation with increased demand. Parameter n must be greater than zero that the usual cause for increased stop time is the increased congestion, and when congestion is high, vehicles when moving, travel at a lower speed than they do when congestion is low. Graphically from the figure or analytically from equation:

$$\frac{}{} = \left\{1 - \left[\frac{}{+1}\right] \left(\frac{}{}\right)^{\frac{1}{+1}}\right\}^{-1} \quad (5)$$

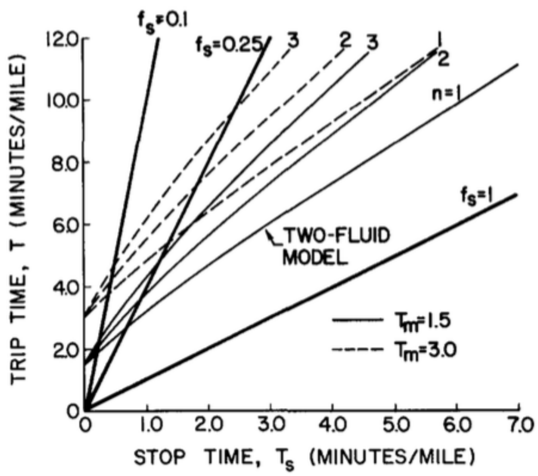

Figure 1. The Trip Time versus Stop Time Relation of the Two-fluid Model (Herman,1984)

Bigger n,   represent a worse traffic network with lower average speed, because a steeper slope means trip time is more sensitive to the increase of stop time, which indicates that the network deteriorates more rapidly during congestion. One more parameter has been discussed in the paper is when using concentrations of the vehicles stopped,k_s, and moving,k_r, to define

= (—) (6)

There is parameter p measuring the quality of the traffic network system as it determines the fraction of vehicles stopped for a given partial concentration.

In the two-fluid model, experiments were designed in particular study areas to verify two assumptions for the model and also to calculate the parameters for the model. Four experiments were designed in four different test areas with various numbers of drivers following other vehicles and circulating in the arranged areas for 1 hour during the peak (or rush) hour. With the test data and the use of uniform sampling intervals, it is verified that traffic is ergodic. The reasonableness of the first assumption is also tested. With the trip time and stop time observations made worldwide, two-fluid model trends for different cities were plotted and the relationship between n, and the significant difference among various trends for different cities were discovered.

Other than the theoretical studies about two-fluid model, different variables that have effect on the parameters of two-fluid model have also been well studied. How extreme driver behaviors influence the two-fluid model is one of the subjects that has been discussed in several papers. It is first stated by Herman that driver behavior will directly affect the parameters for two-fluid model. Herman, Malakhoff (1987) designed different experiments consisted of collecting trip time-stop time data with three different types of driver behaviors' vehicles circulating simultaneously in the same area, which are: aggressive, normal-chase car and conservative in CBD in Roanoke and Austin. Conservative driver can be identified with low acceleration and deceleration rates, minimal land changing, delayed starting at intersections, excessive defensive driving, slowing when coming to a long-lasting green light, stopping on amber when possible, and rejecting many gaps at stop signs and aggressive driver is reverse. Normal-chase car is considered as the normal driver behavior on the road, which used chase-car technology to represent. This paper made both vertical comparisons between different driver behaviors in the same area and horizontal comparisons between experiments in Roanoke and Austin. It also found out that in Austin, there are more aggressive drivers based on the two parameters of two-fluid model.

It is statistical significant of the different trends under various driving behaviors. For both networks studied, the normal trend generally lied between the conservative and aggressive and conservative trend approached the normal trend at off-peak periods, aggressive at peak periods. The results discussion mainly emphasized the similarity of driver behavioral conditions is needed for comparing the quality of traffic service in various networks, or in the use of two-fluid model, which chase-car method can be treated as the common technique. This also led to a new topic that with the use of two-fluid model, different driver behaviors can be identified and this can also be linked with traffic safety study.

Vinaya (2013) proposed another more detailed study with a behavioral framework based on individual trade-off behavior to explain the two-fluid model phenomenon. A behavioral framework is presented to understand the two-fluid model, in which three parameters were found and tested to affect the characteristics of the two-fluid model perceived crash likelihood factor (beta), perceived impact factor (k) and the crash weighting factor (w). Vinayak and Anurag attempted to evaluate corridor level operations using the parameters of the two-fluid model for arterial corridors and brought to light correlations between the two-fluid model parameters and crash rates, indicating that these parameters may have some potential as safety surrogates on arterial streets.

In lieu of this, it is crucial to understand the relationships between specific features and the two-fluid parameters. This information helps to identify specific measures that improve traffic flow and provides a means to compare the relative improvement. This also used to recalculate the two-fluid model regularly to monitor the performance of the network.

Ayadh (1986), Ardekani et al. (1992) and Bhat (1994) selected various network features and estimated regression models to understand the effects of these network features on and n. Seven network features are selected by Ayadh (1986), which are lane miles per square mile, number of intersections per square mile, fraction of one-way streets, average signal cycle length, average block length, average number of lanes per street, and average block length to block width ratio. Through a regression analysis, two models are selected showing the relationship between and n with selected network features:

$$= 3.59 - 0.54\ {}_{6} \quad (7)$$

$$= 0.21 + 2.97\ {}_{3} + 0.22\ {}_{7} \quad (8)$$

where C_3 is the fraction of one-way streets, C_6 the average number of lanes per street, and C_7 the average block length to block width ratio. More features are used by Ardekani et al. (1992), and the relationship between these features and two-fluid model parameters are summarized in the following table.

Table 1: Effect of Various Network Features on the Two-fluid Model

Network Features	T_m	n
Fraction of one-way streets		+
Average number of lanes per street	-	-
Signal Density		-
Average speed limit	-	
Fraction of actuated signals		-
Fraction of approaches with good progression	-	
Average block length to block width ratio		+

The '+' and '-' signs indicate positive and negative effects respectively on and n as the associated factor increases. Although selecting different features may change the regression model, the basic relationship has been showed in the table. It can be used for its potential practical application to choose to modify network features in order to improve the traffic performance.

Further study about two-fluid model includes the validation of the use of two-fluid model in network performance, relationship with safety. Jones and Farhat (2004) verified the possibility of the use of two-fluid model on arterial street scale. Two challenges were pointed out for the use of two-fluid model: the difficulty of routine collection of two-fluid data of trip time and stop time per unit distance for vehicles traveling in a system; the inability to examine the quality of traffic at scales other than the network level. This paper verified that two-fluid model as a scalable model can not only examine the quality of traffic on the arterial street before and after changes to an arterial street, but also the potential networked effects from a localized change. Two-fluid model is also applied to compare network performance over time and after a recent major modification. In Phong and Stephen (2007) paper, two-fluid model was chosen to assess the quality before and after the traffic change happened in the City of Fort Worth. Comparison of two-fluid model parameters was made in three different cities: Arlington, Dallas and Fort Worth. and n were used as the significant proof for describing the current and previous network statement; the decrease of these two parameters can be regarded as the improvement in the traffic network performance.

Chapter 3: Two-fluid Model with Ring Road Simulation Data

Two-fluid model has been studied for over 30 years and it has been proved that the use of two-fluid model is quite extensive. Mostly it is used with macroscopic data to evaluate the traffic network performance in a local network or on an arterial street. Microscopic data has been used to simulate two-fluid model before to build the similar traffic condition, so that it can be used before any change happened in the real traffic network. But there is still some questions concern with two-fluid model that has not been discussed about. If two-fluid model can still work under extremely congested, which is over-saturated traffic condition; if traffic data from different congestion level will lead to different two-fluid model or it will directly influence the accuracy of the parameters. In this chapter, these questions will be discussed in order to better understand two-fluid model.

Computer simulation has many advantages over field data in the study of network models and it has been used quite often in the study of two-fluid model. Conditions not found in the field can be evaluated and new control strategies can be easily tested and especially for two-fluid model, the entire vehicle population in the network can be used in the estimation of the model parameters comparing to the small sample used in the chase car studies. TRAF-NETSIM (Mahmassani et al. 1984), a microscopic traffic simulation model has been used successfully with the two-fluid model. Most of the simulation work to-date has used a generic grid network in order to isolate the effects of specific network features on the two-fluid parameters (FHWA 1993). Typically, the simulated network has been a 5*5 intersection grid made up entire of two-way streets. Traffic signals are at each intersection and uniform turning movements are applied throughout.

Different from normally used method to calibrate the simulation to two-fluid model, ring road is used in this paper. Car following model is used to build the ring road in Matlab, with one traffic signal set on the ring road. Other network features are all excluded on this ring road, including driver behaviors. The network is closed that vehicles are not allowed to leave the network, thus maintaining constant concentration during the simulation run. The trip histories of all the vehicles circulating in the network are aggregated to form a single (T_r, T) observation for use in the two-fluid parameter estimation. With the use of this ring road simulation, vehicle number, road length, simulation time and signal setting can be changed. Different concentration can be achieved by changing these variables and how two-fluid parameters will be influenced will be discussed later.

The basic setting of this ring road traffic network is designed with 20 vehicles keep running on a 1500 feet ring road for 3600 seconds simulation time. When changing different variables, different traffic condition can be achieved. In this paper, in order to achieve different congestion level, simulation time, signal setting and road length are set as constant vehicle number will be changed from 5 to 50.

Optimal Velocity Model

Optimal Velocity Model is used to describe the driver behavior and the car following pattern in order to simulate the real traffic following pattern. Masako (1998) proposed this optimal velocity model (OVM) based on a dynamical equation

$$\ddot{x}_n(t) = a\{V(x_{n+1}(t) - x_n(t)) - \dot{x}_n(t)\} \quad (9)$$

where t is time and x_n is a position of the nth car. Cars are numbered so that the $(n+1)^{th}$ car precedes the n^{th} car. The driver feels the headway $x_{n+1}(t) - x_n(t)$ and determines an optimal velocity $(\;\; _{+1}(\;) - \;\; (\;))$. It is best to drive a car with the optimal velocity but in general a deviation exists between the optimal velocity and a real one. The driver responds to the deviation

$$\Delta V = \; (\;\; _{+1}(\;) - \;\; (\;)) - \; \dot{} (\;) \quad (10)$$

and diminishes it by giving an acceleration ΔV to the car. The coefficient expresses the sensitivity of the driver.

In traditional car following model, the introduction of 'delay' is necessary and essential to understanding traffic dynamics, but this delay including not only the observed delay time T of car motion but also the known physical or mechanical response time τ. With this delay time, we have the following equation for OVM:

$$\ddot{}(\; + \tau) = \; \{ \; (\;\; _{+1}(\;) - \;\; (\;)) - \; \dot{} (\;)\} \quad (11)$$

In order for the analysis, 1.2s is used as the reaction time and 1.6s used as τ. The fundamental code for this ring road with OVM applied is built by Candy Kwan and the detailed explanation and the detailed code of this OVM is described Candy Kwan's thesis (2015). Here, it is simply used as the fundamental traffic network in order to get the simulation data for two-fluid model generation.

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As discussed above, optimal velocity model is used for car-following model here, and all the basic parameters setting are based on the real world data, which represent the average condition of local traffic network in California. All the parameters used for network building are listed in the following table.

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Jam spacing	25 feet
Free flow speed	65 ft/s
Coefficient of friction	0.7
Gravity of Earth	32.17 ft/s2
Maximum acceleration	9.8425 ft/s2
Deceleration	13.1234 ft/s2
Maximum velocity	66 ft/s
Minimum velocity	22 ft/s
Reaction time	1.2 s
Time step	1.2 s
Intersection length	20ft
Reaction Time	1.2 s
τ	1.6 s

Based on general traffic light design data in California, signal timing is designed as constant, green light for 23 seconds, yellow light for 3 seconds, red light for 32 seconds and all red for 2 seconds. All the vehicles will travel on the ring road and will decide to stop or keep going when running into yellow light based on optimal velocity model. Detail information about the vehicle travel pattern and choice for dilemma zone will not be discussed here. Only the requisite data will be used for two-fluid model regression.

For the purposed of the two-fluid model, distance, travel time and stopped time are the only essential information to be collected. In this simulation part, only one method for data collecting is used which is two-minute method. For real world data, two stop watch will be used to record time, one to time up two minutes while the other stop watch is used to measure stopped time. Also, the trip odometer reading is recorded for the beginning and the end of the two minutes. In order to simulate this data collecting process, time and distance will be counted in the following way. Vehicle velocity and travelling distance are recorded during the simulation process every 1.2 second time step. When the velocity is equal to zero, it is considered as vehicle stopped and the velocity above zero considered as vehicle running.

Simply by counting the number of velocity equals to zero during every 100 time gap (which represents 2 minutes), we can get the stop time, and velocity above zero, running time is also counted. Based on the previous experiments for two-fluid model, the total simulation time is set as 3600 seconds (60 minutes). When processing data for two-fluid model use, the running time and stop time for each vehicle is calculated every one hundred 1.2 seconds time gap, which represents 2 minutes. Running time and stop time will be counted based on the velocity and distance travelled during 2 minutes period will also be calculated here. Another method for data collection is distance base, in which running time and stop time is calculated every one-mile travelling. This method will apply in Chapter 4 for Beijing data and for this simulation data, ring road is used as the traffic network, one-mile method doesn't apply.

3.3 Two-fluid Model Simulation

In this part, different congestion level will be applied in the simulation, and data representing under-saturated, saturated and over-saturated traffic conditions will be generated. Equation 3 in Chapter 2 represents the two-fluid model that will be discussed. To get the two parameters T_m and n, the following equations will be used.

$$= \frac{1}{+1} \qquad + \frac{}{+1} \qquad (12)$$

$$= \quad + \qquad (13)$$

$$n = 1/(1-B) \quad (14)$$

$$= \quad /(1 - \quad) \quad (15)$$

The curvilinear relationship between trip time and stop time per unit distance can be obtained by equation 14 and 15.

3.3.1 Different Congestion Level

In order to answer the above questions about two-fluid model, including how two-fluid model parameters will react to different congestion level, different numbers of vehicle numbers will be used. Since it is a ring road network model, different congestion level will not be defined by density or concentration. Congestion level will be decided by the ratio of stationary demand over supply (Jin and Yu, 2015),

$$= \frac{\min\{Vk_0,C\}}{\min\{C,(K-k_0)W\}} \quad (16)$$

Where V is the free-flow speed, W is the shock wave speed in congested traffic, K is the jam density and C is the capacity.

Based on Table 2, we have V=65ft/s=44.3mph, τ=1.6s, s_j=25ft, $= \frac{1}{}$ =221.2vpm, we can get Q(k) = $\min\{Vk, \frac{1}{\tau}(1 - \}$ = $\min\{44.3 \ , 10.7(211.2 - \}$, Capacity C=1820.2 vph, $= \frac{\min\{44.3 \ ,1820.2\}}{\min\{1820.2,10.7(211.2-k)\}} = \frac{}{}$. And we get the congestion level based on . The traffic light design is used for parameter $\pi_0 = \frac{}{}$ = 0.5 and the result for congestion level reflected by the different vehicle number is showed in Table 3. Based on the urban network traffic data in California and the congestion level table below, we set the ring road length 1500 feet and vehicle number 20 as the standard for peak hour traffic. In order to get different congestion level, keep the ring road length as 1500 feet and change vehicle number to 5,15, 20, 30, 40 and 50 that represent from under-saturated traffic to over-saturated traffic condition.

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Number of Vehicles	Density	Congestion Level		
5	17.6	0.43	Under Saturated	$[0-\pi_0)$
15	52.8	1.07	Saturated	$[\pi_0-1)$
20	70.4	1.21	Saturated	$[\pi_0-1)$
30	105.6	1.61	Saturated	$[\pi_0-1)$
40	140.8	2.41	Over-Saturated	$(\frac{1}{\pi_0}-\infty)$
50	176	4.83	Over-Saturated	$(\frac{1}{\pi_0}-\infty)$

Different congestion level will be used and if two-fluid model can be generated under these congestion level will also be discussed. When different number of vehicles are assigned on the ring road, different number of data point will be collected, range from 150 to 1200. Since the data size is already big enough, the difference in the number of data points in each model can be considered to have no influence in the results.

3.3.2 Two Fluid Model

All the data generated by ring road simulation use second/feet as unit. To match up with the two-fluid model used in former papers, all the data were converted to minute/mile to calculate and . Based on the congestion level in Table 3, 5 vehicles are assigned on the 1500 feet ring road to simulate light (under-saturated) traffic condition. Using equation 12, linear regression model between and is obtained. Figure 2 shows a plot of versus and the linear regression equation. We got the linear regression function = 0.33 + 0.29 with ^{2}=0.445. Using equation 14 and 15, we get n=0.41, T_m=1.59, so that = − 1.39 $^{0.29}$ is the two-fluid model generated by n and T_m.

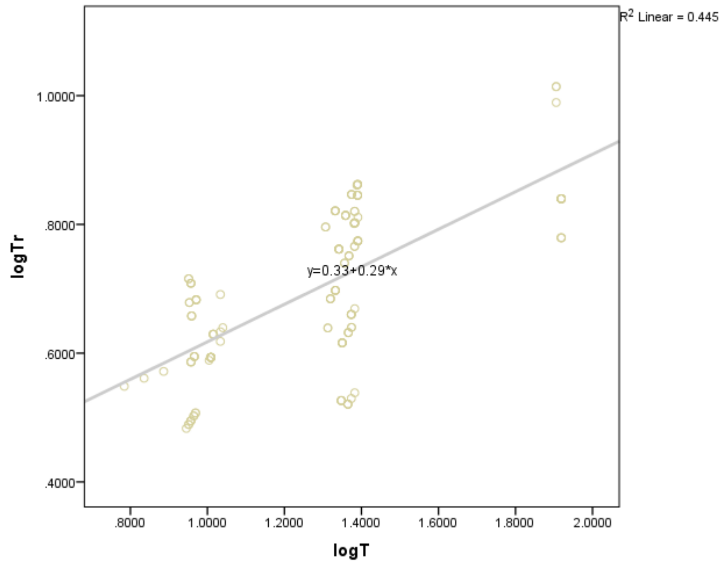

Figure 2: Regression Curve with Under-saturated Traffic to Calculate Two-Fluid Model

Similar as the data process with 5 vehicles simulation, we can get the linear regression model with 20 and 40 vehicles running on the 1500ft ring road shown in figure 3 and 4.

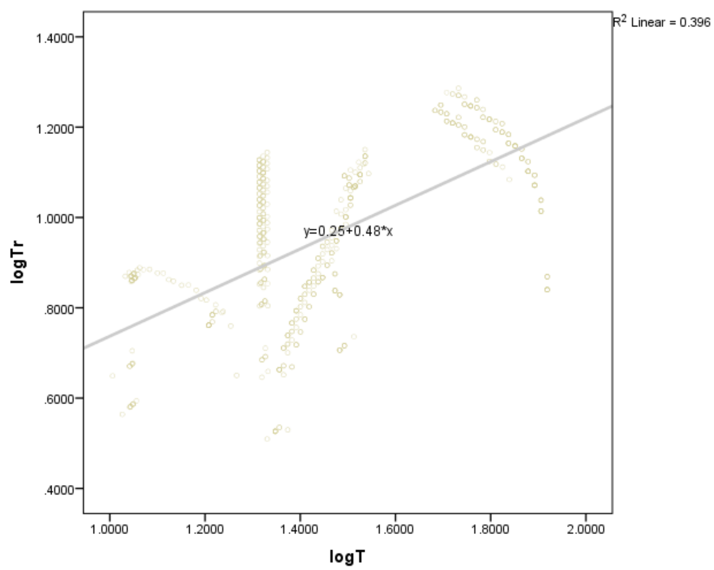

Figure 3: Regression Curve with Saturated Traffic to Calculate Two-Fluid Model

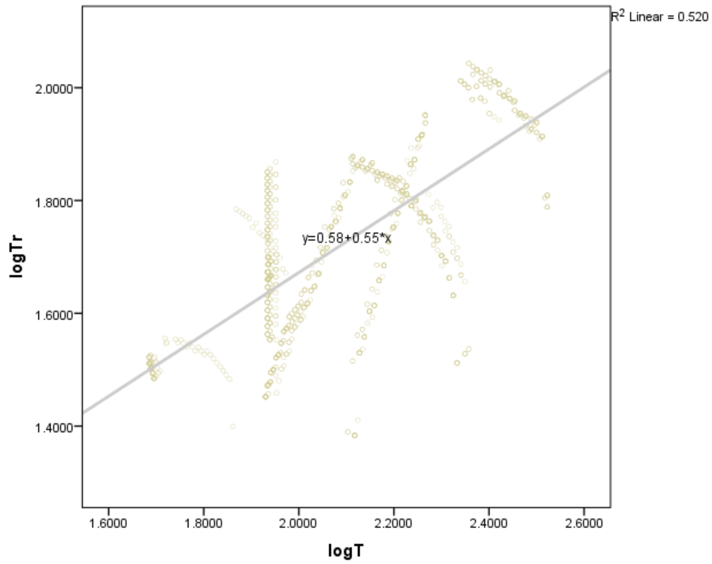

Figure 4: Regression Curve with Over-saturated Traffic to Calculate Two-Fluid Model

T_m and n can also be generated by using the linear regression model and equation 14 &15. Result for these three linear regression model and corresponding two-fluid model and the two parameters are summarized in table 4.

Table 4: Regression Terms and Two-fluid Model Parameters

Congestion Level	Regression Terms		Two-fluid Model Parameters		Two-fluid Model
	A	B		n	
Under-saturated	0.33	0.29	1.59	0.41	$= \quad - 1.39 \; ^{0.29}$
Saturated	0.25	0.48	1.62	0.92	$= \quad - 1.28 \; ^{0.52}$
Over-saturated	0.58	0.55	3.60	1.22	$= \quad - 1.78 \; ^{0.55}$

In the above figures, ^{2} evaluated from each models are quite low comparing with those in the original studies. The main reason for this issue is that with ring road simulation, traffic light is the only network feature that directly control and influence each vehicle trajectory, all other network features are excluded. Even though numbers of vehicles are assigned on the ring road, but the trip time, stop time and distance data are sometimes reduplicated. Different number of vehicles can only define the congestion level, but cannot provide with enough effective data point for model regression.

The parameter is the average minimum trip time per unit distance and it has been found to range from 1.5 to 3.0 min/mile, with smaller values typically representing better operating conditions in the network. The other parameter n is a measure of the resistance of the network to degraded operation with increased demand. The value of n varies from 0.8 to 3.0 based on former field studies. Comparing to this two range, we can tell the parameter and n generated from under-saturated and over-saturated traffic condition are either out of range. This might indicate that two-fluid model will not validate under not congested traffic condition. This can also be verified from figure 5,6 and 7.

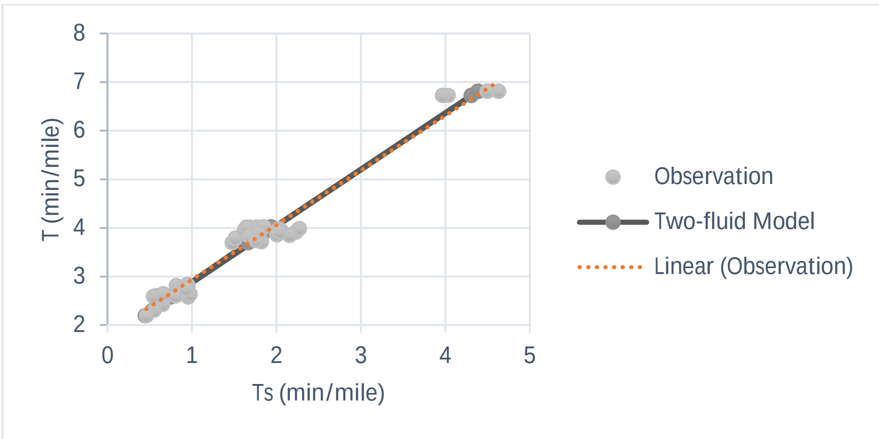

Figure 5: Two-fluid Model with Under-saturated Traffic Condition

The observation data points represents data from ring road simulation, special distribution exists in this data set. Either both stop time and trip time per unit distance are rather small, or rather big. When both variables are rather small, it means vehicles running on the ring road with free flow speed (speed limit). When both variables are rather big, it means vehicles are waiting for the traffic light. With under-saturated traffic data, vehicles driving trajectory cannot represent the average network performance. Even with the whole network data, two-fluid model cannot be generated with this data set.

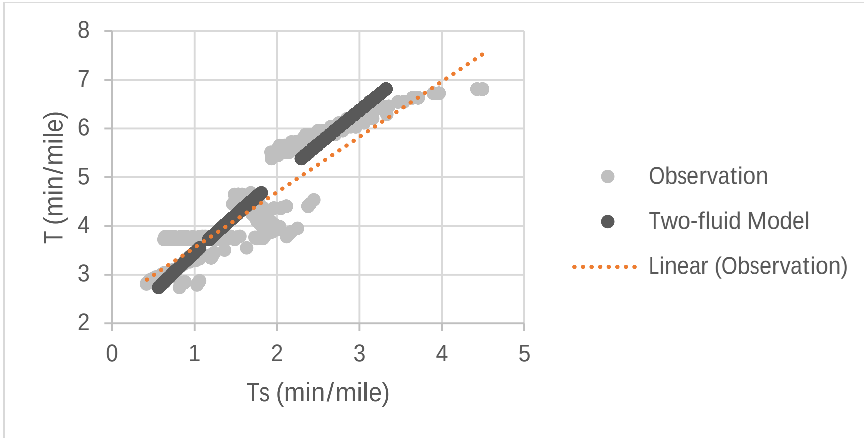

Figure 6: Two-fluid Model with Saturated Traffic Condition

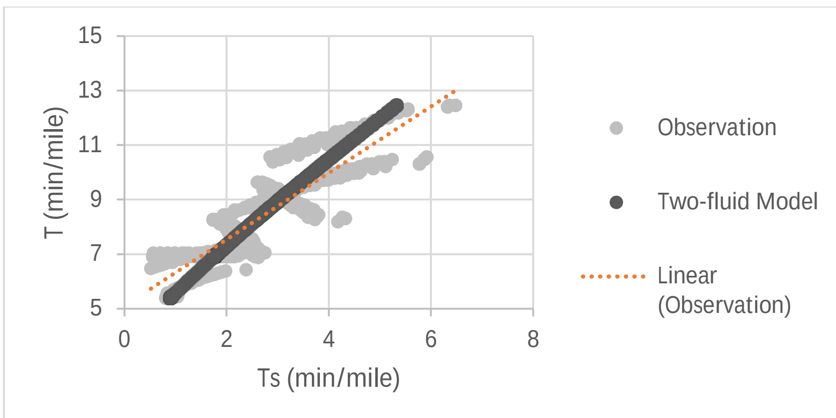

Figure 7: Two-fluid Model with Over-saturated Traffic Condition

Different from the situation with under-saturated traffic, when traffic is over-saturated, no special relationship between stop time and trip time is found. However, simply under super congested traffic condition, two-fluid model cannot be used to evaluate the network performance that it cannot represent the normal traffic condition.

It is verified that only data from congested traffic condition can be used to calculate two-fluid model. Sampling data simply from under-saturated or over-saturated traffic condition are not validated for two-fluid model generation. If over-saturated traffic condition happens occasionally during the peak hour, parameters for two-fluid model will be slightly influenced.

Chapter 4: Two-fluid Model Application in Beijing, China

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Two-fluid model is a macroscopic theory of traffic flow focused on the relationship between stop time and trip time per unit distance and all the variables are defined at the network level, as average taken over a specific period of time in a specified local network area. Since variables in the model are all network-level averages, to estimate the parameters, one approach is to obtain observations of such network-level average from aerial photographs (Ardekani & Herman, 1987). In order to get the overall network-level average, this approach is quite complicated requiring time, effort and cost. In reality, most of past papers related to two-fluid model used "chase car" technique, with one or more vehicles sample the network by passively following random vehicles in the area (Herman & Ardekani, 1984) to get the experiment data.

"Chase car" technique tries to use as few vehicles as possible to obtain data, which can represent the overall network performance. By having experiment vehicles chase random vehicles in the traffic, more traffic data can be observed and different driver behaviors may be included in the whole dataset. This method can avoid having any single vehicle's character to dominate and reflect the overall network in a certain extent. But the same time when using "chase car" technique, several factors are uncontrollable. If more drivers in a certain district are aggressive or conservative, experiment data will also be affected by this extreme driver behavior and the parameter of two-fluid model will be biased. Also, since vehicles being followed are chose randomly, a data collector is always needed in the car to record the stop time, trip time and also the odometer reading, drivers cannot do both recording and driving simultaneously.

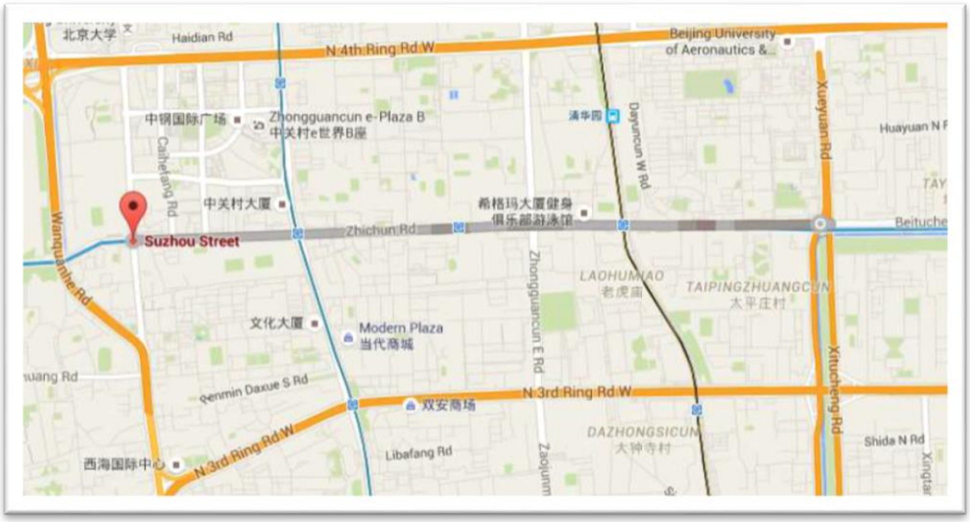
Comparing to “chase car” technique, in this paper, simple vehicles tracks are used to generate two-fluid model. When sampling the network, GPS recording app is used to record the total trip trajectory. Several vehicles are used to sample conditions in the network for a specific duration. Taxi drivers were hired as the testers for the experiments. The reason for choosing taxi drivers is that they are professional and are more familiar with the city traffic condition, that they can easily control their driving behavior to be a more normal driver representing the average driving condition. GPS recording app is used in this situation, drivers only need to turn on the app right before driving. It will automatically begin to record the date, time, longitude, latitude, distance, speed and bearing. With this method only one driver is needed for both driving and data collection. And they have more power to control the whole experiment in different aspects. It has been verified that “aggregating the trip histories of 10 to 20 test vehicles over 10 to 15 minutes yield parameter estimates very close to the true value” (James & Hani, 1994). The experiment in this section is designed with 4 taxi drivers, sampling in the assign network at peak hour in Beijing and each trip is around 20 minutes. Accumulating these 4 data sets, two-fluid model will be generated.

The biggest difference of the use of manual record by data collector and smart recording with GPS app is that data will be recorded and assorted in totally different ways. When collect the data with collectors, they will use one-mile as a distance base or one-minute (sometimes two-minutes) as a time base to record the data. When having one-mile distance as the base, the collector read the odometer to determine when a mile has been traveled and two stopwatches are used to measure the total trip time and stopped time during that one mile.

Similarly when using time as the base, one stopwatch is used to time up to certain time and the other stopwatch measures the stopped time, meantime, odometer readings are recorded at the beginning and end of each time period. Whichever method is using need to be determined before the experiment, but it is also possible to use these two methods simultaneously. On the other hand, when using GPS recording app to record the trip trajectory, neither time base nor distance base need to be considered. App will simply record all the data including time, distance and speed every one second. In order to use the data in the study of two-fluid model, further data processing is needed. The trip history of single vehicle need to be divided into a series of short trip, microtrips, based on either time or distance unit. Better aspect of using GPS recording is that whether time or distance base is used does not need to be decided before the experiments and a comparison of the use of different measure unit can be made. In addition, with speed being recorded, it is more accurate to measure the stop time comparing to manual records.

In this study Beijing is selected as the study area. Recent years, Beijing is going through a high-speed development and the traffic congestion has been one of the major problems in the city development process. In this study we try to use two-fluid model to evaluate traffic performance in Beijing and same time with dataset from relatively congested condition in Beijing, it will also be detected if two-fluid model will still exist under over-saturated traffic condition.

Haidian District is selected as the experiment area, figure 10 shows exact the street that was assigned for data collection. To ensure that the model reflected the average operation conditions, standard weekdays not designated as holidays were selected. For the purposes of this project, data collection occurred on November 15th, 2013 during the peak hour from 17:52 to 19:12.



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As discussed in the previous section, two kinds of dataset can be used when generating two-fluid model, one is distance base and the other is time base.

It has been discussed that trip time and stop time over a fixed distance are two of the three principal variables for a two-fluid model relation (the third one is running time). For distance base method, the collection of data with the form of trip time and stop time indicates a good connection between the distance base method and the underlying theory of two-fluid model. When using distance base microtrip, small fraction of stop time will appear more frequently than large fraction of stop time over the same time period. And also, when the traffic is more congested, fewer data points can be generated comparing to time base method because the trip time per unit distance will be much longer than a free flow traffic network.

When using time base, vehicle’s stop time may be overestimated, since during the fixed time period, if the vehicle is not moving, no running time will be generated and trip time is equal to stop time, this data point may influence the estimation of two-fluid model parameters. One way to alleviate such error is by extending the length of time unit. The advantage of using time base is that no matter what the congestion level is, no time data will be missed and a certain number of time data will be collected. Same time, using time base method will address another problem that under more congested traffic condition, distance change will be less sensitive to the time change. In order to assure the veracity of the parameter estimation, the accuracy of distance change measurement is quite important. Comparing to chase car methodology, with the use of odometer reading for distance change, GPS data can provide more accurate distance data.

These two methods will both be used in the data processing. A Matlab program is coded to generate the data point from GPS recording app into the format of 1-kilometer distance base and 2-minute time base microtirps (because all the data are collected in Beijing, metric measurement is used in this section).

Stop time is considered as the absolute cessation of motion of the test vehicle. In chase-car technology, whether vehicle stopped or running will be judged by the recorder. In this experiment, it will be considered when the speed is zero, and those time will be calculated as stop time.

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Two data processing methods will be used here and comparison between them will also be stated in this part. For the time-base data set, original data point is 35, but two of them are outliers. When vehicles running during relatively over-saturated traffic time, vehicles tend to move forward slowly, when the GPS app recording this time period, the speed is slightly above zero and distance is extremely small, which means that a small stop time is associated with a short moving distance. This kind of situation has to be excluded from the data set. For the distance-base data set, since it is peak hour, distance is shorter than other traffic time, comparing to the 35 data points with time-base measurement, only 14 data points are collected for distance-base data.

Similar as the process dealing with simulation data, linear regression model between $\log T_r$ and logT is built and parameters for two-fluid model are estimated.

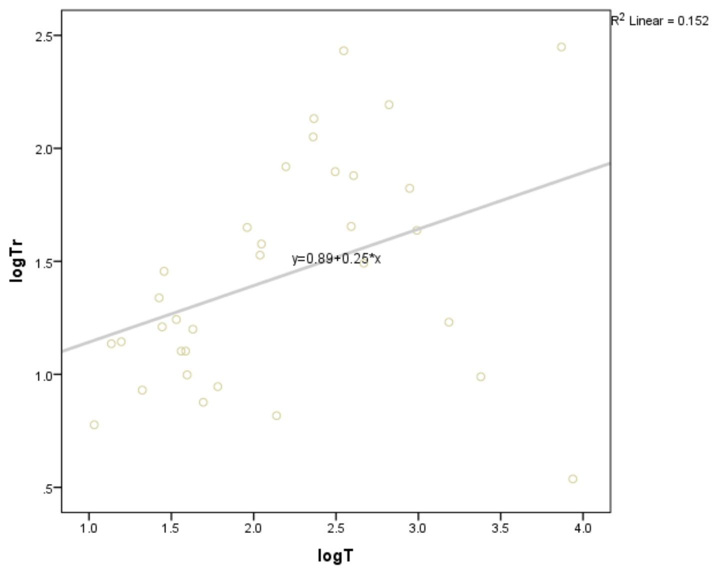

Figure 9: Regression Curve with Time-base Data to Calculate Two-Fluid Model

Based on figure 9, the ^{2} for time-base data is quite small, suggests that the model explains approximately 15.2% of the variability in the response variable logT. F-test and residuals plot are used to evaluate the model. F-statistic tests for a significant linear regression relationship between the response variable $\log T_r$ and the predictor variable logT. P-value for the F statistic of the hypotheses test that the corresponding coefficient is equal to zero or not.

Here, the p-value of the F-statistic is 0.025 less than 0.05, so this term is significant at the 5% significance level given the other terms in the model.

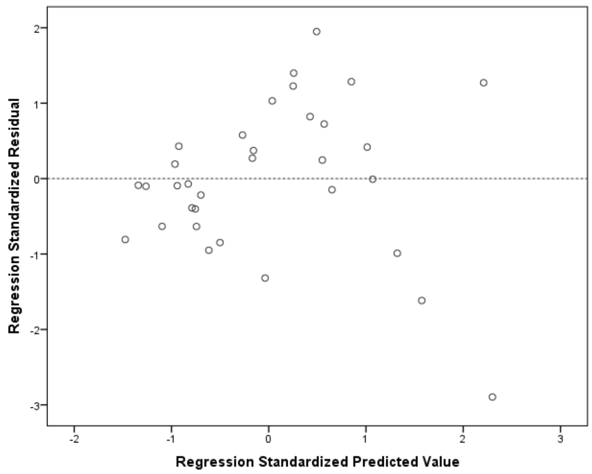

Figure 10: Residuals Plot for Regression Curve with Time-base Data

In order to validate the model, residual plot is also used here to tell whether the observed error (residuals) is consistent with stochastic error. For random error, the residuals should not be either systematically high or low, but should be centered on zero throughout the range of fitted values. The residuals should fall in a symmetrical pattern and have a constant spread throughout the range. For the residual plot above, the residuals distribute centered on zero but does not show a perfect symmetrical pattern that with regression standardized predicted value below zero, residuals are mostly smaller than zero, for predicted value range from 0 to 1, most residuals are greater than zero. This residuals plot indicates that this linear regression model might not be able to use to calculate two-fluid model parameters.

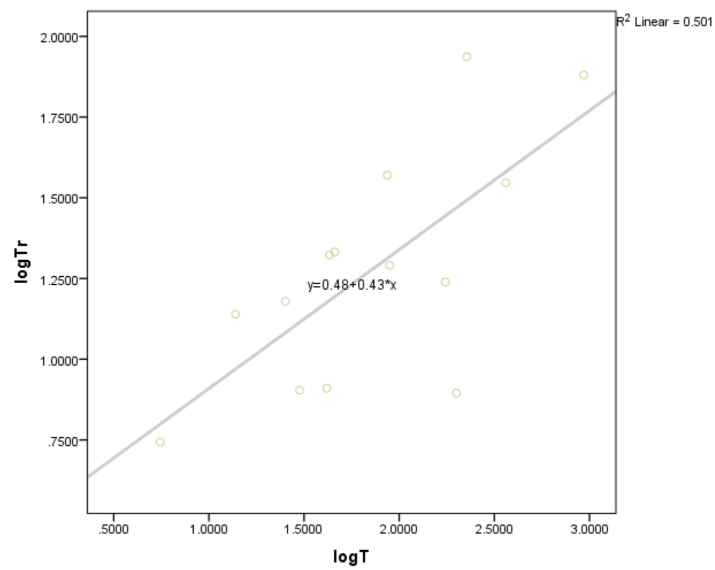

Figure 11: Regression Curve with Distance-base Data to Calculate Two-Fluid Model

Regression Curve for and with distance-base data is presented in figure 11. Different from the regression result for time-base data, ^{2}=0.501, which represents that more than 50% of can be explained by with equation = 0.48 + 0.43 .

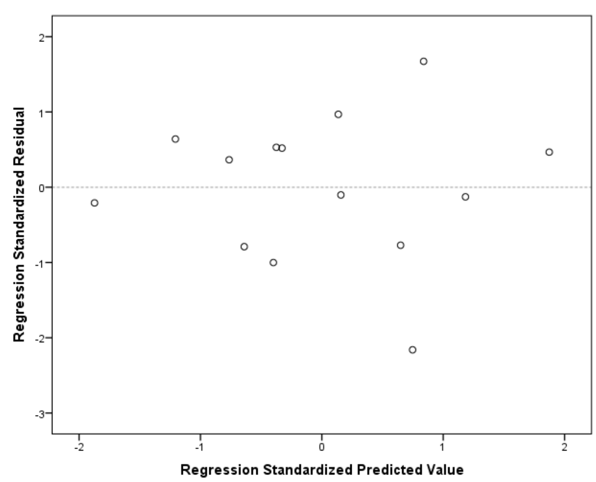

Figure 12: Residuals Plot for Regression Curve with Distance-base Data

Based on F-statistics and Residuals plot in figure 12, it can be verified that there is linear relationship between and .

Parameters for two-fluid model are calculated based on the linear regression model and equation 14&15. Results are shown in table 5 and figure 13&14.

Table 5: Regression Terms and Two-fluid Model Parameters (Beijing)

Data Collection	Regression Terms		Two-fluid Model Parameters		Two-fluid Model
	A	B		n	
Time-base	0.89	0.25	3.25	0.33	= − 2.43 0.25
Distance-base	0.48	0.43	2.32	0.75	= − 1.62 0.43

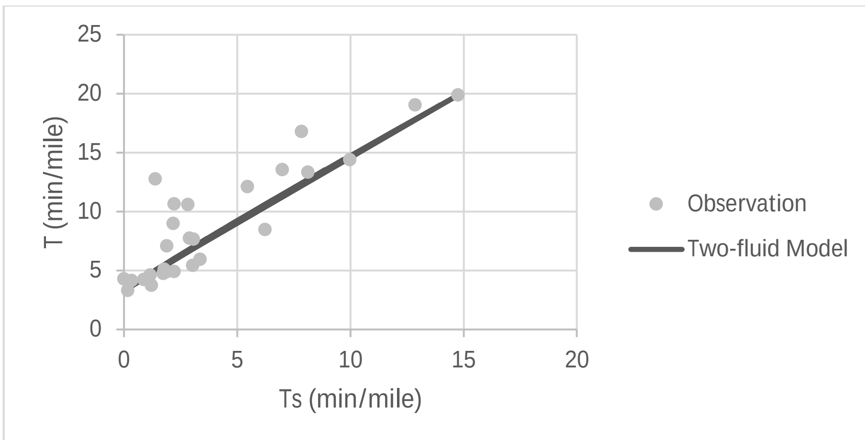

Figure 13: Two-fluid Model with Time-base Data

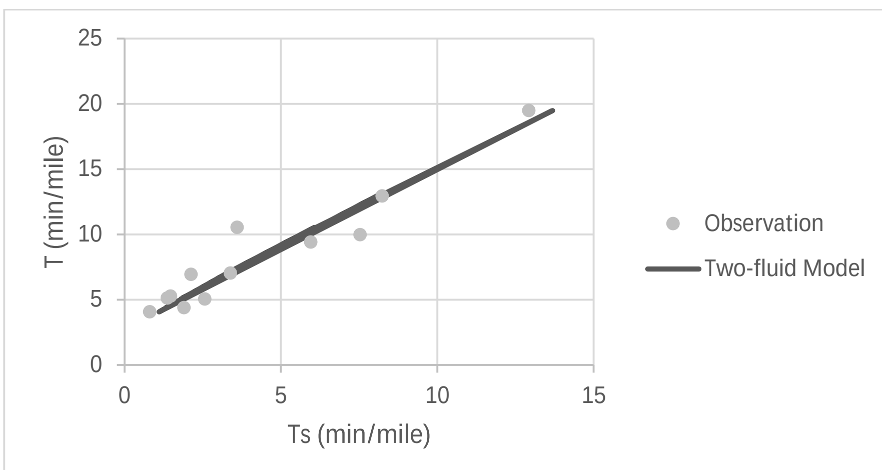

Figure 14: Two-fluid Model with Distance-base Data

Two-fluid model generated based on distance-base data is much more reliable comparing to the model generated by time-base data. Some of time-base data has been delated in data predicting since stop time is overestimated, trip time and stop time per unit distance cannot be used as a pair to represent the normal condition. Distance-base data works well in estimating two-fluid model parameters and although less data point can be used, the data is more reliable.

A new way for data collecting is used in this chapter and it has been verified to be accurate for estimating parameters of two-fluid model. When the traffic condition is congested, traffic data is always collected for two-fluid model. Distance-base data can represent the traffic condition more efficient comparing to time-base data.

Chapter 5: Summary and Conclusions

Main idea of this thesis is to verify if traffic data collected from over-saturated condition can be used to predict two-fluid model. Based on the analysis with the ring road simulation data, two-fluid model is quite sensitive to different data set from different traffic conditions. When having data from under-saturated or over-saturated traffic condition, no linear relationship between and exists, which means that two-fluid model cannot be predicted using data collected under these two traffic conditions. Even collecting data from saturated traffic (peak hour) in the former papers, over-saturated situation might still exist. It is also verified that small amount of over-saturated condition during data collecting process will not influence the parameters of two-fluid model dramatically, but how to identify this situation still needs to be carefully studied in the future.

Beijing data is used to verify if the new data collection method can also work in generating two-fluid model and also how time-base and distance-base data processing method will influence the relationship between trip time and stop time per unit distance. It is proved that the with the use of GPS data from individual phones, parameters of two-fluid model can be easily calculated, but how individual driver behavior affects the model may still need to be discussed. For the comparison of time-base and distance-base data processing method, two problems are addressed here. First, for time-base data, how congested the traffic network is will play an important role in data analysis. One way to prohibit outliers is that stop time may be calculated based on other variables instead of the time when speed equal to zero. The other is use time-base data under less congested traffic condition for two-fluid model generation. Second, for distance-base method, longer data collection period need to be applied for a more accurate model generation. Above all, based on current experiments, distance-base data collection method is more accurate and stable.

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Appendix A: Ring Road Simulation Raw Data

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Ts (sec)	Tr (sec)	Distance (ft)	Ts/D (s/ft)	Tr/D (s/ft)	T/D (s/ft)
15	85	4112.08	0.00364779	0.0206708	0.02431859
38	62	2583.22	0.01471032	0.02400105	0.03871138
44	56	2006.59	0.02192775	0.02790804	0.04983579
32	68	3102.13	0.01031549	0.02192042	0.03223592
49	51	2895.19	0.01692462	0.01761542	0.03454005
47	53	2668.6	0.01761223	0.0198606	0.03747283
18	82	3103.13	0.00580059	0.02642493	0.03222553
40	60	2635.21	0.01517906	0.02276858	0.03794764
46	54	1954.59	0.02353435	0.02762728	0.05116162
34	66	3127.31	0.01087196	0.0211044	0.03197636
51	49	2921.19	0.01745864	0.01677399	0.03423262
54	46	2616.6	0.02063747	0.01758007	0.03821753
19	81	3129.08	0.00607207	0.0258862	0.03195828
41	59	2661.2	0.01540658	0.02217045	0.03757703
49	51	1928.6	0.02540703	0.02644405	0.05185108
38	62	3100.68	0.01225538	0.01999561	0.03225099
51	49	2973.19	0.01715329	0.01648062	0.03363391
35	65	2590.6	0.01351038	0.02509071	0.0386011
20	80	3129.05	0.00639172	0.02556687	0.03195858
43	57	2687.19	0.01600185	0.02121175	0.03721359
50	50	1902.6	0.02627983	0.02627983	0.05255966
40	60	3125.84	0.01279656	0.01919484	0.0319914
36	64	3375.36	0.01066553	0.01896094	0.02962647
36	64	2162.51	0.01664732	0.02959524	0.04624256
23	77	3103.01	0.00741216	0.02481462	0.03222677
44	56	2739.19	0.01606314	0.020444	0.03650714
53	47	1850.6	0.02863936	0.02539717	0.05403653
49	51	3071.22	0.01595457	0.01660578	0.03256035
36	64	3479.31	0.01034688	0.01839445	0.02874133
38	62	2110.54	0.01800487	0.02937637	0.04738124
15	85	4145.44	0.00361843	0.02050446	0.02412289
36	64	2557.24	0.01407768	0.02502698	0.03910466
43	57	2032.59	0.02115527	0.02804304	0.04919831
30	70	3102.4	0.00966993	0.02256318	0.03223311
48	52	2869.19	0.01672946	0.01812358	0.03485304

66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4060.66	0.00418651	0.02044003	0.02462654
39	61	2609.21	0.01494705	0.02337872	0.03832578
45	55	1980.59	0.0227205	0.0277695	0.05049001
32	68	3127.78	0.0102309	0.02174066	0.03197156
49	51	2895.19	0.01692462	0.01761542	0.03454005
48	52	2642.6	0.01816393	0.01967759	0.03784152
18	82	3129.11	0.00575243	0.02620553	0.03195797
40	60	2635.21	0.01517906	0.02276858	0.03794764
47	53	1954.59	0.02404596	0.02711566	0.05116162
35	65	3101.31	0.01128555	0.02095889	0.03224444
49	51	2947.19	0.01662601	0.01730462	0.03393063
33	67	2616.6	0.01261179	0.02560575	0.03821753
19	81	3129.08	0.00607207	0.0258862	0.03195828
42	58	2661.19	0.01578241	0.02179476	0.03757717
49	51	1928.6	0.02540703	0.02644405	0.05185108
37	63	3126.68	0.01183364	0.02014917	0.03198281
57	43	2947.19	0.01934046	0.01459017	0.03393063
35	65	2590.6	0.01351038	0.02509071	0.0386011
21	79	3103.06	0.00676751	0.02545874	0.03222625
43	57	2713.19	0.0158485	0.02100848	0.03685698
51	49	1876.6	0.02717681	0.02611105	0.05328786
41	59	3072.71	0.01334327	0.01920129	0.03254456
35	65	3453.36	0.01013506	0.01882225	0.02895731
36	64	2136.51	0.01684991	0.02995539	0.0468053
37	63	4171.51	0.00886969	0.01510244	0.02397213
36	64	2531.27	0.01422211	0.02528375	0.03950586
41	59	2058.59	0.01991654	0.02866039	0.04857694
29	71	3102.6	0.009347	0.02288403	0.03223103
47	53	2843.19	0.01653073	0.01864103	0.03517176
59	41	1731.23	0.03407982	0.02368258	0.0577624
17	83	4068.61	0.00417833	0.02040009	0.02457842
37	63	2583.23	0.01432315	0.02438807	0.03871123
44	56	2006.59	0.02192775	0.02790804	0.04983579
30	70	3128.13	0.00959039	0.02237759	0.03196798
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46	54	1980.59	0.0232254	0.0272646	0.05049001
33	67	3101.78	0.01063905	0.0216005	0.03223955
48	52	2921.19	0.01643166	0.01780096	0.03423262
54	46	2642.6	0.02043442	0.0174071	0.03784152
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40	60	2635.21	0.01517906	0.02276858	0.03794764
47	53	1954.6	0.02404584	0.02711552	0.05116136
35	65	3127.31	0.01119173	0.02078464	0.03197636
51	49	2921.19	0.01745864	0.01677399	0.03423262
33	67	2616.6	0.01261179	0.02560575	0.03821753
20	80	3103.08	0.00644521	0.02578084	0.03222605
42	58	2687.19	0.01562971	0.02158389	0.03721359
50	50	1902.6	0.02627983	0.02627983	0.05255966
38	62	3073.84	0.01236239	0.02017021	0.0325326
56	44	3025.19	0.01851123	0.01454454	0.03305578
36	64	2564.6	0.01403728	0.02495516	0.03899244
30	70	4257.35	0.00704664	0.01644215	0.02348879
34	66	2505.32	0.01357112	0.02634394	0.03991506
40	60	2084.58	0.01918852	0.02878278	0.04797129
27	73	3102.75	0.00870196	0.02352752	0.03222947
46	54	2817.19	0.01632833	0.01916804	0.03549636
56	44	1754.57	0.03191665	0.02507737	0.05699402
16	84	4075.23	0.00392616	0.02061233	0.02453849
36	64	2557.25	0.01407762	0.02502688	0.03910451
42	58	2032.59	0.02066329	0.02853502	0.04919831
29	71	3128.4	0.00926991	0.02269531	0.03196522
47	53	2843.19	0.01653073	0.01864103	0.03517176
65	35	1708.77	0.03803906	0.02048257	0.05852163
17	83	4086.64	0.0041599	0.02031008	0.02446998
37	63	2583.23	0.01432315	0.02438807	0.03871123
44	56	2006.59	0.02192775	0.02790804	0.04983579
31	69	3102.13	0.00999313	0.02224278	0.03223592
47	53	2895.19	0.01623382	0.01830623	0.03454005
47	53	2668.6	0.01761223	0.0198606	0.03747283
17	83	3129.12	0.00543284	0.02652503	0.03195787
40	60	2609.21	0.01533031	0.02299547	0.03832578
46	54	1980.59	0.0232254	0.0272646	0.05049001
33	67	3127.78	0.01055061	0.02142094	0.03197156
49	51	2895.19	0.01692462	0.01761542	0.03454005

54	46	2642.6	0.02043442	0.0174071	0.03784152
19	81	3103.11	0.00612289	0.02610285	0.03222573
41	59	2661.2	0.01540658	0.02217045	0.03757703
48	52	1928.6	0.02488852	0.02696256	0.05185108
36	64	3074.68	0.01170854	0.02081517	0.03252371
50	50	2999.19	0.01667117	0.01667117	0.03334234
34	66	2590.6	0.01312437	0.02547672	0.0386011
46	54	3280.56	0.014022	0.0164606	0.0304826
36	64	3479.26	0.01034703	0.01839472	0.02874174
39	61	2110.56	0.01847851	0.02890228	0.04738079
26	74	3102.86	0.00837937	0.02384897	0.03222833
45	55	2791.19	0.01612216	0.01970486	0.03582701
54	46	1778.58	0.0303613	0.02586333	0.05622463
37	63	4080.67	0.00906714	0.01543864	0.02450578
35	65	2531.29	0.01382694	0.02567861	0.03950555
40	60	2058.58	0.01943087	0.0291463	0.04857717
27	73	3128.6	0.00863006	0.02333312	0.03196318
46	54	2817.19	0.01632833	0.01916804	0.03549636
58	42	1731.23	0.03350219	0.02426021	0.0577624
16	84	4094.59	0.0039076	0.02051487	0.02442247
36	64	2557.25	0.01407762	0.02502688	0.03910451
43	57	2032.59	0.02115527	0.02804304	0.04919831
30	70	3102.4	0.00966993	0.02256318	0.03223311
46	54	2869.19	0.0160324	0.01882064	0.03485304
66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4086.64	0.0041599	0.02031008	0.02446998
38	62	2583.22	0.01471032	0.02400105	0.03871138
44	56	2006.59	0.02192775	0.02790804	0.04983579
31	69	3128.13	0.00991007	0.02205791	0.03196798
48	52	2869.19	0.01672946	0.01812358	0.03485304
47	53	2668.6	0.01761223	0.0198606	0.03747283
18	82	3103.13	0.00580059	0.02642493	0.03222553
40	60	2635.21	0.01517906	0.02276858	0.03794764
46	54	1954.59	0.02353435	0.02762728	0.05116162
34	66	3075.31	0.0110558	0.02146125	0.03251705
48	52	2973.19	0.01614428	0.01748963	0.03363391
54	46	2616.6	0.02063747	0.01758007	0.03821753
39	61	3321.62	0.01174126	0.01836453	0.03010579
36	64	3453.31	0.01042478	0.01853294	0.02895772

37	63	2136.54	0.01731772	0.02948693	0.04680465
24	76	3102.95	0.00773458	0.02449282	0.0322274
44	56	2765.19	0.01591211	0.02025177	0.03616388
52	48	1803.09	0.02883938	0.02662097	0.05546035
31	69	4085.07	0.00758861	0.01689078	0.02447938
33	67	2505.34	0.01317186	0.02674288	0.03991474
40	60	2084.56	0.0191887	0.02878305	0.04797175
26	74	3128.75	0.00831003	0.02365162	0.03196165
45	55	2791.19	0.01612216	0.01970486	0.03582701
55	45	1754.57	0.03134671	0.02564731	0.05699402
37	63	4101.18	0.00902179	0.01536143	0.02438323
35	65	2531.29	0.01382694	0.02567861	0.03950555
41	59	2058.58	0.01991664	0.02866053	0.04857717
28	72	3102.6	0.00902469	0.02320634	0.03223103
45	55	2843.19	0.01582729	0.01934447	0.03517176
59	41	1731.23	0.03407982	0.02368258	0.0577624
16	84	4094.59	0.0039076	0.02051487	0.02442247
36	64	2557.24	0.01407768	0.02502698	0.03910466
43	57	2032.59	0.02115527	0.02804304	0.04919831
29	71	3128.4	0.00926991	0.02269531	0.03196522
47	53	2843.19	0.01653073	0.01864103	0.03517176
66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4060.66	0.00418651	0.02044003	0.02462654
39	61	2609.21	0.01494705	0.02337872	0.03832578
45	55	1980.59	0.0227205	0.0277695	0.05049001
32	68	3075.78	0.01040387	0.02210821	0.03251208
47	53	2947.19	0.01594739	0.01798323	0.03393063
48	52	2642.6	0.01816393	0.01967759	0.03784152
36	64	3383.83	0.01063883	0.01891348	0.02955231
35	65	3427.36	0.01021194	0.01896503	0.02917698
36	64	2162.51	0.01664732	0.02959524	0.04624256
23	77	3103.01	0.00741216	0.02481462	0.03222677
44	56	2739.19	0.01606314	0.020444	0.03650714
50	50	1827.96	0.0273529	0.0273529	0.05470579
47	53	3088.9	0.01521577	0.01715821	0.03237398
36	64	3479.31	0.01034688	0.01839445	0.02874133
38	62	2110.54	0.01800487	0.02937637	0.04738124
24	76	3128.86	0.00767053	0.02429	0.03196052
44	56	2765.19	0.01591211	0.02025177	0.03616388

53	47	1778.58	0.02979905	0.02642558	0.05622463
31	69	4106.59	0.00754884	0.01680226	0.0243511
33	67	2505.34	0.01317186	0.02674288	0.03991474
40	60	2084.56	0.0191887	0.02878305	0.04797175
26	74	3102.75	0.00837966	0.02384981	0.03222947
44	56	2817.19	0.0156184	0.01987796	0.03549636
56	44	1754.57	0.03191665	0.02507737	0.05699402
37	63	4101.18	0.00902179	0.01536143	0.02438323
36	64	2531.27	0.01422211	0.02528375	0.03950586
41	59	2058.59	0.01991654	0.02866039	0.04857694
28	72	3128.6	0.00894969	0.02301349	0.03196318
46	54	2817.19	0.01632833	0.01916804	0.03549636
59	41	1731.23	0.03407982	0.02368258	0.0577624
17	83	4068.61	0.00417833	0.02040009	0.02457842
37	63	2583.23	0.01432315	0.02438807	0.03871123
44	56	2006.59	0.02192775	0.02790804	0.04983579
30	70	3076.13	0.00975251	0.02275587	0.03250838
46	54	2921.19	0.01574701	0.01848562	0.03423262
45	55	2668.6	0.01686277	0.02061006	0.03747283
34	66	3429.19	0.00991488	0.01924653	0.02916141
56	44	2999.19	0.01867171	0.01467063	0.03334234
35	65	2590.6	0.01351038	0.02509071	0.0386011
21	79	3103.06	0.00676751	0.02545874	0.03222625
43	57	2713.19	0.0158485	0.02100848	0.03685698
49	51	1853.12	0.02644189	0.02752115	0.05396305
40	60	3091.85	0.01293724	0.01940586	0.0323431
35	65	3453.36	0.01013506	0.01882225	0.02895731
36	64	2136.51	0.01684991	0.02995539	0.0468053
23	77	3128.95	0.00735071	0.02460889	0.0319596
44	56	2739.19	0.01606314	0.020444	0.03650714
51	49	1803.09	0.02828478	0.02717557	0.05546035
47	53	3111.26	0.01510642	0.0170349	0.03214132
36	64	3479.31	0.01034688	0.01839445	0.02874133
39	61	2110.54	0.01847868	0.02890256	0.04738124
25	75	3102.86	0.00805708	0.02417125	0.03222833
44	56	2791.19	0.01576389	0.02006313	0.03582701
54	46	1778.58	0.0303613	0.02586333	0.05622463
31	69	4106.59	0.00754884	0.01680226	0.0243511
34	66	2505.32	0.01357112	0.02634394	0.03991506

40	60	2084.58	0.01918852	0.02878278	0.04797129
27	73	3128.75	0.00862964	0.023332	0.03196165
45	55	2791.19	0.01612216	0.01970486	0.03582701
56	44	1754.57	0.03191665	0.02507737	0.05699402
16	84	4075.23	0.00392616	0.02061233	0.02453849
36	64	2557.25	0.01407762	0.02502688	0.03910451
42	58	2032.59	0.02066329	0.02853502	0.04919831
29	71	3076.4	0.0094266	0.02307892	0.03250553
45	55	2895.19	0.01554302	0.01899703	0.03454005
65	35	1708.77	0.03803906	0.02048257	0.05852163
32	68	3496.8	0.00915122	0.01944635	0.02859757
50	50	2973.19	0.01681695	0.01681695	0.03363391
33	67	2616.6	0.01261179	0.02560575	0.03821753
20	80	3103.08	0.00644521	0.02578084	0.03222605
42	58	2687.19	0.01562971	0.02158389	0.03721359
47	53	1878.49	0.0250201	0.02821415	0.05323425
37	63	3094.21	0.01195782	0.02036061	0.03231843
56	44	3025.19	0.01851123	0.01454454	0.03305578
36	64	2564.6	0.01403728	0.02495516	0.03899244
21	79	3129.01	0.00671139	0.0252476	0.03195899
43	57	2713.19	0.0158485	0.02100848	0.03685698
50	50	1827.96	0.0273529	0.0273529	0.05470579
40	60	3114.9	0.0128415	0.01926226	0.03210376
35	65	3453.36	0.01013506	0.01882225	0.02895731
37	63	2136.51	0.01731796	0.02948734	0.0468053
24	76	3102.95	0.00773458	0.02449282	0.0322274
43	57	2765.19	0.01555047	0.02061341	0.03616388
52	48	1803.09	0.02883938	0.02662097	0.05546035
47	53	3111.26	0.01510642	0.0170349	0.03214132
36	64	3479.26	0.01034703	0.01839472	0.02874174
39	61	2110.56	0.01847851	0.02890228	0.04738079
25	75	3128.86	0.00799013	0.02397039	0.03196052
44	56	2765.19	0.01591211	0.02025177	0.03616388
54	46	1778.58	0.0303613	0.02586333	0.05622463
37	63	4080.67	0.00906714	0.01543864	0.02450578
35	65	2531.29	0.01382694	0.02567861	0.03950555
40	60	2058.58	0.01943087	0.0291463	0.04857717
28	72	3076.6	0.00910096	0.02340246	0.03250341
44	56	2869.19	0.01533534	0.0195177	0.03485304

58	42	1731.23	0.03350219	0.02426021	0.0577624
31	69	3535.37	0.00876853	0.01951705	0.02828558
48	52	2947.19	0.0162867	0.01764393	0.03393063
54	46	2642.6	0.02043442	0.0174071	0.03784152
19	81	3103.11	0.00612289	0.02610285	0.03222573
41	59	2661.2	0.01540658	0.02217045	0.03757703
46	54	1904.02	0.02415941	0.02836105	0.05252046
35	65	3096.1	0.01130454	0.02099415	0.0322987
50	50	2999.19	0.01667117	0.01667117	0.03334234
34	66	2590.6	0.01312437	0.02547672	0.0386011
20	80	3129.05	0.00639172	0.02556687	0.03195858
42	58	2687.19	0.01562971	0.02158389	0.03721359
48	52	1853.12	0.02590226	0.02806078	0.05396305
37	63	3117.85	0.01186715	0.02020623	0.03207338
56	44	3025.19	0.01851123	0.01454454	0.03305578
36	64	2564.6	0.01403728	0.02495516	0.03899244
22	78	3103.01	0.00708989	0.02513688	0.03222677
42	58	2739.19	0.015333	0.02117414	0.03650714
50	50	1827.96	0.0273529	0.0273529	0.05470579
40	60	3114.9	0.0128415	0.01926226	0.03210376
36	64	3453.31	0.01042478	0.01853294	0.02895772
37	63	2136.54	0.01731772	0.02948693	0.04680465
23	77	3128.95	0.00735071	0.02460889	0.0319596
44	56	2739.19	0.01606314	0.020444	0.03650714
52	48	1803.09	0.02883938	0.02662097	0.05546035
31	69	4085.07	0.00758861	0.01689078	0.02447938
33	67	2505.34	0.01317186	0.02674288	0.03991474
40	60	2084.56	0.0191887	0.02878305	0.04797175
26	74	3076.75	0.00845048	0.02405135	0.03250183
43	57	2843.19	0.01512386	0.0200479	0.03517176
55	45	1754.57	0.03134671	0.02564731	0.05699402
29	71	3571.62	0.00811956	0.01987893	0.0279985
47	53	2921.19	0.01608933	0.01814329	0.03423262
47	53	2668.6	0.01761223	0.0198606	0.03747283
18	82	3103.13	0.00580059	0.02642493	0.03222553
40	60	2635.21	0.01517906	0.02276858	0.03794764
44	56	1929.66	0.02280194	0.02902066	0.0518226
33	67	3097.61	0.01065337	0.02162958	0.03228295
48	52	2973.19	0.01614428	0.01748963	0.03363391

54	46	2616.6	0.02063747	0.01758007	0.03821753
19	81	3129.08	0.00607207	0.0258862	0.03195828
41	59	2661.2	0.01540658	0.02217045	0.03757703
46	54	1878.49	0.02448775	0.02874649	0.05323425
35	65	3120.21	0.01121719	0.02083193	0.03204912
50	50	2999.19	0.01667117	0.01667117	0.03334234
35	65	2590.6	0.01351038	0.02509071	0.0386011
20	80	3103.06	0.00644525	0.025781	0.03222625
41	59	2713.2	0.01511131	0.02174554	0.03685685
49	51	1853.12	0.02644189	0.02752115	0.05396305
37	63	3117.85	0.01186715	0.02020623	0.03207338
35	65	3427.36	0.01021194	0.01896503	0.02917698
36	64	2162.51	0.01664732	0.02959524	0.04624256
22	78	3129.01	0.00703098	0.02492801	0.03195899
43	57	2713.19	0.0158485	0.02100848	0.03685698
50	50	1827.96	0.0273529	0.0273529	0.05470579
47	53	3088.9	0.01521577	0.01715821	0.03237398
36	64	3479.31	0.01034688	0.01839445	0.02874133
38	62	2110.54	0.01800487	0.02937637	0.04738124
24	76	3076.86	0.00780016	0.02470051	0.03250067
43	57	2817.19	0.01526344	0.02023293	0.03549636
53	47	1778.58	0.02979905	0.02642558	0.05622463
27	73	3630.83	0.00743632	0.0201056	0.02754191
46	54	2895.19	0.01588842	0.01865163	0.03454005
66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4060.66	0.00418651	0.02044003	0.02462654
39	61	2609.21	0.01494705	0.02337872	0.03832578
43	57	1955.39	0.0219905	0.0291502	0.05114069
31	69	3098.81	0.01000384	0.02226661	0.03227045
47	53	2947.19	0.01594739	0.01798323	0.03393063
48	52	2642.6	0.01816393	0.01967759	0.03784152
18	82	3129.11	0.00575243	0.02620553	0.03195797
40	60	2635.21	0.01517906	0.02276858	0.03794764
45	55	1904.01	0.02363433	0.0288864	0.05252073
33	67	3122.1	0.01056981	0.02145991	0.03202972
48	52	2973.19	0.01614428	0.01748963	0.03363391
33	67	2616.6	0.01261179	0.02560575	0.03821753
20	80	3103.08	0.00644521	0.02578084	0.03222605
41	59	2687.2	0.01525752	0.02195594	0.03721346

47	53	1878.48	0.02502023	0.0282143	0.05323453
35	65	3120.21	0.01121719	0.02083193	0.03204912
56	44	2999.19	0.01867171	0.01467063	0.03334234
35	65	2590.6	0.01351038	0.02509071	0.0386011
21	79	3129.05	0.0067113	0.02524728	0.03195858
42	58	2687.19	0.01562971	0.02158389	0.03721359
49	51	1853.12	0.02644189	0.02752115	0.05396305
40	60	3091.85	0.01293724	0.01940586	0.0323431
35	65	3453.36	0.01013506	0.01882225	0.02895731
36	64	2136.51	0.01684991	0.02995539	0.0468053
23	77	3076.95	0.00747493	0.02502478	0.03249972
42	58	2791.19	0.01504735	0.02077967	0.03582701
51	49	1803.09	0.02828478	0.02717557	0.05546035
26	74	3682.16	0.00706107	0.0200969	0.02715797
45	55	2869.19	0.01568387	0.01916917	0.03485304
59	41	1731.23	0.03407982	0.02368258	0.0577624
17	83	4068.61	0.00417833	0.02040009	0.02457842
37	63	2583.23	0.01432315	0.02438807	0.03871123
41	59	1981.19	0.02069463	0.02978008	0.05047471
30	70	3099.76	0.00967817	0.02258239	0.03226056
46	54	2921.19	0.01574701	0.01848562	0.03423262
45	55	2668.6	0.01686277	0.02061006	0.03747283
17	83	3129.12	0.00543284	0.02652503	0.03195787
39	61	2609.21	0.01494705	0.02337872	0.03832578
44	56	1929.66	0.02280194	0.02902066	0.0518226
31	69	3123.61	0.00992441	0.02208983	0.03201424
47	53	2947.19	0.01594739	0.01798323	0.03393063
54	46	2642.6	0.02043442	0.0174071	0.03784152
18	82	3103.11	0.00580063	0.0264251	0.03222573
40	60	2661.2	0.01503081	0.02254622	0.03757703
46	54	1904.01	0.02415954	0.0283612	0.05252073
33	67	3122.1	0.01056981	0.02145991	0.03202972
50	50	2973.19	0.01681695	0.01681695	0.03363391
33	67	2616.6	0.01261179	0.02560575	0.03821753
19	81	3129.08	0.00607207	0.0258862	0.03195828
41	59	2661.19	0.01540664	0.02217053	0.03757717
47	53	1878.49	0.0250201	0.02821415	0.05323425
37	63	3094.21	0.01195782	0.02036061	0.03231843
56	44	3025.19	0.01851123	0.01454454	0.03305578

36	64	2564.6	0.01403728	0.02495516	0.03899244
22	78	3077.01	0.0071498	0.02534928	0.03249908
41	59	2765.19	0.01482719	0.02133669	0.03616388
50	50	1827.96	0.0273529	0.0273529	0.05470579
24	76	3747.1	0.00640495	0.02028235	0.0266873
44	56	2843.19	0.01547557	0.01969619	0.03517176
56	44	1754.57	0.03191665	0.02507737	0.05699402
16	84	4075.23	0.00392616	0.02061233	0.02453849
36	64	2557.25	0.01407762	0.02502688	0.03910451
40	60	2007.04	0.01992985	0.02989477	0.04982462
28	72	3100.5	0.0090308	0.02322206	0.03225286
45	55	2895.19	0.01554302	0.01899703	0.03454005
65	35	1708.77	0.03803906	0.02048257	0.05852163
17	83	4086.64	0.0041599	0.02031008	0.02446998
37	63	2583.23	0.01432315	0.02438807	0.03871123
42	58	1955.39	0.02147909	0.0296616	0.05114069
30	70	3124.81	0.00960058	0.02240136	0.03200195
46	54	2921.19	0.01574701	0.01848562	0.03423262
47	53	2668.6	0.01761223	0.0198606	0.03747283
17	83	3103.13	0.00547834	0.02674719	0.03222553
38	62	2635.22	0.01442005	0.02352745	0.0379475
44	56	1929.66	0.02280194	0.02902066	0.0518226
31	69	3123.61	0.00992441	0.02208983	0.03201424
48	52	2947.19	0.0162867	0.01764393	0.03393063
54	46	2642.6	0.02043442	0.0174071	0.03784152
19	81	3129.11	0.00607201	0.02588595	0.03195797
40	60	2635.21	0.01517906	0.02276858	0.03794764
46	54	1904.02	0.02415941	0.02836105	0.05252046
35	65	3096.1	0.01130454	0.02099415	0.0322987
50	50	2999.19	0.01667117	0.01667117	0.03334234
34	66	2590.6	0.01312437	0.02547672	0.0386011
20	80	3077.06	0.00649971	0.02599884	0.03249855
40	60	2739.19	0.01460286	0.02190429	0.03650714
48	52	1853.12	0.02590226	0.02806078	0.05396305
23	77	3783.82	0.00607851	0.02034981	0.02642832
43	57	2817.19	0.01526344	0.02023293	0.03549636
54	46	1778.58	0.0303613	0.02586333	0.05622463
37	63	4080.67	0.00906714	0.01543864	0.02450578
35	65	2531.29	0.01382694	0.02567861	0.03950555

39	61	2032.92	0.01918423	0.0300061	0.04919033
27	73	3101.09	0.00870662	0.02354011	0.03224673
44	56	2869.19	0.01533534	0.0195177	0.03485304
58	42	1731.23	0.03350219	0.02426021	0.0577624
16	84	4094.59	0.0039076	0.02051487	0.02442247
36	64	2557.25	0.01407762	0.02502688	0.03910451
40	60	1981.19	0.02018989	0.03028483	0.05047471
28	72	3125.76	0.00895782	0.0230344	0.03199222
45	55	2895.19	0.01554302	0.01899703	0.03454005
66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4060.66	0.00418651	0.02044003	0.02462654
38	62	2609.23	0.01456368	0.0237618	0.03832548
43	57	1955.39	0.0219905	0.0291502	0.05114069
30	70	3124.81	0.00960058	0.02240136	0.03200195
47	53	2921.19	0.01608933	0.01814329	0.03423262
47	53	2668.6	0.01761223	0.0198606	0.03747283
18	82	3129.12	0.00575242	0.02620545	0.03195787
39	61	2609.21	0.01494705	0.02337872	0.03832578
44	56	1929.67	0.02280183	0.02902051	0.05182233
33	67	3097.61	0.01065337	0.02162958	0.03228295
48	52	2973.19	0.01614428	0.01748963	0.03363391
54	46	2616.6	0.02063747	0.01758007	0.03821753
19	81	3077.08	0.00617469	0.02632366	0.03249834
40	60	2713.2	0.01474274	0.02211411	0.03685685
46	54	1878.49	0.02448775	0.02874649	0.05323425
21	79	3826.85	0.00548754	0.02064361	0.02613115
43	57	2791.19	0.01540562	0.0204214	0.03582701
52	48	1803.09	0.02883938	0.02662097	0.05546035
31	69	4085.07	0.00758861	0.01689078	0.02447938
33	67	2505.34	0.01317186	0.02674288	0.03991474
37	63	2058.81	0.01797155	0.0306002	0.04857175
25	75	3101.56	0.00806046	0.02418138	0.03224184
43	57	2843.19	0.01512386	0.0200479	0.03517176
55	45	1754.57	0.03134671	0.02564731	0.05699402
37	63	4101.18	0.00902179	0.01536143	0.02438323
35	65	2531.29	0.01382694	0.02567861	0.03950555
40	60	2007.03	0.01992995	0.02989492	0.04982487
27	73	3126.5	0.00863585	0.02334879	0.03198465
44	56	2869.19	0.01533534	0.0195177	0.03485304

59	41	1731.23	0.03407982	0.02368258	0.0577624
16	84	4068.61	0.00393255	0.02064587	0.02457842
36	64	2583.26	0.01393588	0.0247749	0.03871078
41	59	1981.18	0.02069474	0.02978023	0.05047497
28	72	3125.76	0.00895782	0.0230344	0.03199222
46	54	2895.19	0.01588842	0.01865163	0.03454005
66	34	1708.77	0.03862427	0.01989735	0.05852163
17	83	4086.64	0.0041599	0.02031008	0.02446998
37	63	2583.22	0.01432321	0.02438817	0.03871138
43	57	1955.39	0.0219905	0.0291502	0.05114069
31	69	3098.81	0.01000384	0.02226661	0.03227045
47	53	2947.19	0.01594739	0.01798323	0.03393063
48	52	2642.6	0.01816393	0.01967759	0.03784152
18	82	3077.11	0.00584964	0.02664838	0.03249803
39	61	2687.21	0.01451319	0.02270012	0.03721332
45	55	1904.02	0.02363421	0.02888625	0.05252046
20	80	3874	0.00516262	0.02065049	0.02581311
42	58	2765.19	0.01518883	0.02097505	0.03616388
50	50	1827.96	0.0273529	0.0273529	0.05470579
47	53	3088.9	0.01521577	0.01715821	0.03237398
36	64	3479.31	0.01034688	0.01839445	0.02874133
36	64	2084.73	0.01726842	0.03069942	0.04796784
24	76	3101.92	0.00773714	0.02450095	0.0322381
43	57	2817.19	0.01526344	0.02023293	0.03549636
53	47	1778.58	0.02979905	0.02642558	0.05622463
31	69	4106.59	0.00754884	0.01680226	0.0243511
33	67	2505.34	0.01317186	0.02674288	0.03991474
38	62	2032.9	0.01869251	0.0304983	0.04919081
25	75	3127.09	0.00799465	0.02398396	0.03197861
43	57	2843.19	0.01512386	0.0200479	0.03517176
56	44	1754.57	0.03191665	0.02507737	0.05699402
37	63	4075.22	0.00907926	0.01545929	0.02453855
34	66	2557.29	0.01329532	0.02580857	0.0391039
40	60	2007.01	0.01993014	0.02989522	0.04982536
27	73	3126.5	0.00863585	0.02334879	0.03198465
45	55	2869.19	0.01568387	0.01916917	0.03485304
59	41	1731.23	0.03407982	0.02368258	0.0577624
17	83	4094.59	0.00415182	0.02027065	0.02442247
36	64	2557.23	0.01407773	0.02502708	0.03910481

41	59	1981.19	0.02069463	0.02978008	0.05047471
30	70	3099.76	0.00967817	0.02258239	0.03226056
46	54	2921.19	0.01574701	0.01848562	0.03423262
45	55	2668.6	0.01686277	0.02061006	0.03747283
17	83	3077.12	0.00552465	0.02697327	0.03249792
37	63	2661.21	0.01390345	0.02367344	0.03757689
44	56	1929.66	0.02280194	0.02902066	0.0518226
18	82	3938.64	0.00457011	0.02081937	0.02538947
41	59	2739.19	0.01496793	0.02153921	0.03650714
49	51	1853.12	0.02644189	0.02752115	0.05396305
40	60	3091.85	0.01293724	0.01940586	0.0323431
35	65	3453.36	0.01013506	0.01882225	0.02895731
35	65	2110.65	0.01658257	0.0307962	0.04737877
22	78	3102.2	0.00709174	0.02514345	0.03223519
42	58	2791.19	0.01504735	0.02077967	0.03582701
51	49	1803.09	0.02828478	0.02717557	0.05546035
47	53	3111.26	0.01510642	0.0170349	0.03214132
36	64	3479.31	0.01034688	0.01839445	0.02874133
36	64	2058.79	0.017486	0.03108622	0.04857222
24	76	3127.56	0.00767371	0.02430009	0.03197381
43	57	2817.19	0.01526344	0.02023293	0.03549636
54	46	1778.58	0.0303613	0.02586333	0.05622463
31	69	4080.66	0.00759681	0.01690903	0.02450584
34	66	2531.36	0.01343152	0.02607294	0.03950446
39	61	2032.88	0.01918461	0.03000669	0.0491913
25	75	3127.09	0.00799465	0.02398396	0.03197861
44	56	2843.19	0.01547557	0.01969619	0.03517176
56	44	1754.57	0.03191665	0.02507737	0.05699402
16	84	4101.19	0.00390131	0.02048186	0.02438317
35	65	2531.26	0.01382711	0.02567891	0.03950602
40	60	2007.04	0.01992985	0.02989477	0.04982462
28	72	3100.5	0.0090308	0.02322206	0.03225286
45	55	2895.19	0.01554302	0.01899703	0.03454005
65	35	1708.77	0.03803906	0.02048257	0.05852163
17	83	4034.65	0.0042135	0.0205718	0.0247853
36	64	2635.21	0.01366115	0.02428649	0.03794764
42	58	1955.39	0.02147909	0.0296616	0.05114069
17	83	3990.08	0.00426057	0.02080159	0.02506215
40	60	2713.19	0.01474279	0.02211419	0.03685698

47	53	1878.49	0.0250201	0.02821415	0.05323425
37	63	3094.21	0.01195782	0.02036061	0.03231843
56	44	3025.19	0.01851123	0.01454454	0.03305578
33	67	2538.71	0.01299873	0.02639136	0.03939008
21	79	3102.43	0.00676889	0.02546391	0.0322328
41	59	2765.19	0.01482719	0.02133669	0.03616388
50	50	1827.96	0.0273529	0.0273529	0.05470579
40	60	3114.9	0.0128415	0.01926226	0.03210376
35	65	3453.36	0.01013506	0.01882225	0.02895731
36	64	2084.7	0.01726867	0.03069986	0.04796853
22	78	3127.92	0.00703343	0.0249367	0.03197013
42	58	2791.19	0.01504735	0.02077967	0.03582701
52	48	1803.09	0.02883938	0.02662097	0.05546035
29	71	4085.02	0.00709911	0.01738058	0.02447968
32	68	2505.46	0.01277211	0.02714072	0.03991283
37	63	2058.76	0.01797198	0.03060094	0.04857293
24	76	3127.56	0.00767371	0.02430009	0.03197381
43	57	2817.19	0.01526344	0.02023293	0.03549636
54	46	1778.58	0.0303613	0.02586333	0.05622463
37	63	4106.61	0.00900986	0.01534112	0.02435099
33	67	2505.31	0.01317202	0.0267432	0.03991522
39	61	2032.92	0.01918423	0.0300061	0.04919033
27	73	3101.09	0.00870662	0.02354011	0.03224673
44	56	2869.19	0.01533534	0.0195177	0.03485304
58	42	1731.23	0.03350219	0.02426021	0.0577624
16	84	4042.6	0.00395785	0.02077871	0.02473656
35	65	2609.23	0.01341392	0.02491156	0.03832548
40	60	1981.19	0.02018989	0.03028483	0.05047471
16	84	4021.61	0.00397851	0.02088716	0.02486566
40	60	2687.21	0.01488533	0.02232799	0.03721332
46	54	1904.02	0.02415941	0.02836105	0.05252046
35	65	3096.1	0.01130454	0.02099415	0.0322987
50	50	2999.19	0.01667117	0.01667117	0.03334234
54	46	2564.68	0.02105526	0.01793596	0.03899122
20	80	3102.6	0.00644621	0.02578483	0.03223103
40	60	2739.19	0.01460286	0.02190429	0.03650714
48	52	1853.12	0.02590226	0.02806078	0.05396305
37	63	3117.85	0.01186715	0.02020623	0.03207338
56	44	3025.19	0.01851123	0.01454454	0.03305578

34	66	2512.74	0.01353105	0.02626615	0.03979719
21	79	3128.2	0.00671313	0.02525414	0.03196727
41	59	2765.19	0.01482719	0.02133669	0.03616388
50	50	1827.96	0.0273529	0.0273529	0.05470579
46	54	3088.9	0.01489203	0.01748195	0.03237398
56	44	3077.19	0.01819842	0.01429876	0.03249718
36	64	2486.79	0.01447649	0.02573599	0.04021248
22	78	3127.92	0.00703343	0.0249367	0.03197013
43	57	2791.19	0.01540562	0.0204214	0.03582701
52	48	1803.09	0.02883938	0.02662097	0.05546035
49	51	3111.26	0.01574925	0.01639207	0.03214132
36	64	3479.25	0.01034706	0.01839477	0.02874183
37	63	2058.82	0.01797146	0.03060005	0.04857151
25	75	3101.56	0.00806046	0.02418138	0.03224184
43	57	2843.19	0.01512386	0.0200479	0.03517176
55	45	1754.57	0.03134671	0.02564731	0.05699402
37	63	4049.21	0.00913758	0.01555859	0.02469618
33	67	2583.27	0.01277451	0.02593612	0.03871063
40	60	2007.03	0.01992995	0.02989492	0.04982487

Appendix B: Raw Data for Beijing

Raw Data at peak hour in Beijing on November 15th, 2013

Time-base (2 minutes)					Distance-base (1000 meters)					
Tr	D	Ts	Ts/D	T/D	¢Ŋ	5	¢	¢ă	¢ăк5	¢к5
66	265.562	54	0.203	0.451	мпм	ффуфнр	мфс	рр	лфлрр	лфмфс
114	973.485	6	0.006	0.123	мпл	мллпфор	мфм	рм	лфлр	лфмф
75	415.616	45	0.108	0.288	мтр	ффффсс	пун	олт	лфолт	лфпун
74	658.608	46	0.069	0.182	фн	ффофсм	мут	фр	лфлфр	лфмуу
58	237.522	62	0.261	0.505	ту	ффрфлрпр	ту	л	л	лфлту
47	241.001	73	0.302	0.497	мту	ффофрм	нрт	тф	лфлтф	лфнру
0	5.29781	120	22.65	22.65	мну	ффпфпп	опф	ннм	лфннн	лфор
110	773.852	10	0.012	0.155	нпп	ффтфтп	тнр	пум	лфпун	лфтнс
53	591.807	67	0.113	0.202	мнл	фуффтп	мрл	ол	лфло	лфмрм
93	1147.06	27	0.023	0.104	моп	фуyфср	нрф	мнр	лфмнс	лфнсм
120	750.593	0	0	0.159	нру	ффтфтн	офн	моп	лфмоп	лфофн
72	419.271	48	0.114	0.286	фл	фусфнн	ост	нтт	лфну	лфотн
37	223.254	83	0.371	0.537	ммс	ффрфтр	ммс	л	л	лфммс
4	62.709	116	1.849	1.913	фн	ффуффп	мсо	тм	лфлтм	лфмсо
95	759.606	25	0.032	0.1579						
91	358.217	29	0.08	0.334						
29	67.222	91	1.353	1.785						
88	303.606	32	0.105	0.395						
17	133.165	103	0.773	0.901						
64	191.54	56	0.292	0.626						
31	161.756	89	0.55	0.741						
11	109.688	109	0.993	1.094						
90	696.754	30	0.043	0.172						
76	676.581	44	0.065	0.177						
39	168.952	81	0.479	0.71						
78	630.287	42	0.066	0.19						
107	252.155	13	0.051	0.475						
95	302.239	25	0.082	0.397						
66	652.702	54	0.082	0.183						
32	379.123	88	0.232	0.316						
0	1.63753	120	73.28	73.28						
52	541.72	68	0.125	0.221						

120	1033.96	0	0	0.116						
81	856.994	39	0.045	0.14						
88	453.257	32	0.07	0.264						