Effects of vehicle classes and lanes positions on microscopic traffic flow

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ABSTRACT
There are many simulations in microscopic traffic flow, but few of them concern some small but important features. Therefore, we observed traffic flow at a crossroad in Utsnomiya, Japan and test the significance of three small features, such as traffic loads for different size of vehicles, effect of lane position and effect of the vehicle type at the front row. With the observation and corresponding statistical analysis, we could calculate the relative traffic load for two different vehicle types and verify that the lane position and the vehicle type at the front row influence the processed traffic load of the lane significantly.

1. INTRODUCTION
Urban area traffic is crazy. These days, large cities are suffering heavy traffics and car accidents. The heavy traffics of the cities are mainly due to its heavy population and the large quantity of goods transported, but sometimes inefficient traffic policies cause the problem. Therefore, there have been tons of research papers about traffic flow observations and simulations to support solving this problem. Particularly, the traffic at crossroads is heavily researched, but there are some relevant features that previous research papers are commonly missing. For example, most of the previous research does not consider effects of lane positions. We expect our vehicle can move faster in the first lane, but many research papers do not apply this rules. Also, the loads of different size of vehicles are not measured well though they are represented in the research papers. Thus, in this paper, we will do naturalistic observation of traffic flow at a crossroad in Japan and try to point out some important features that the previous research did not addressed clearly.

Previous Research in Traffic Simulation
According to Pursula [1], the use of computer simulation started when D.L. Gerlough published his dissertation: "Simulation of freeway traffic on a general-purpose discrete variable computer" in 1955. With the old history of this field, it has several distinct approaches to simulate the traffic. Among the approaches, most urban transportation simulations are network related. In networks, one has to combine different kinds of intersections and links. This makes the simulation quite complicated, so there are programs dealing with only isolated intersections and road sections to avoid being too complicated.

These simplified microscopic simulation models often uses poorly measured constants for vehicle types and driver behaviors, and researchers who benchmark these simulations also do not have verified hypotheses or values to deal with these variables. For example, Brockfeld et al [2] tested several microscopic traffic flow models with a publicly available dataset. They used optimization method to determine the best parameters for predicting the dataset with each model. However, it is questionable whether benchmarking with the optimized parameters is appropriate or not.

Therefore, there are increasing demands in investigation of multiple vehicle classes and services and driver behaviors. Jayakrishnan et al [3] argues that how comprehensive urban network simulation environments will be, is influenced by their capabilities to handle multiple vehicle classes, and they discuss the state of the art in such simulations. However, they did not make any hypotheses or analysis arguments on this issue with their data analysis. Thus, in this paper, we collect the real world crossroad traffic dataset, and we make and test hypothesis for these simplified simulations to give them brief but concrete basis.

Figure 1 the observed crossroad in Utsunomiya, Japan

2. METHODS
As stated above, we will focus on testing some hypotheses, about the crossroad traffic, that were not examined meticulously in the previous papers. For the data collection, we used a webcam installed at a crossroad in Utsunomiya, Japan. The crossroad has medium traffic that can be seen at crossroads of middle sized city in U.S. and three lanes: two for straight crossing and one for right turn. We counted vehicles that passed the crossroad in a certain

time period and in each lane. Furthermore, we observed not only the number of vehicles, but also the type of vehicle that was at the front position in each lane. Because of the importance of the counts in this paper, it is important to have clear operational definitions. We summarized our operational definition in figure 2.

1. We divide the observed cars into two categories: small vehicle and large vehicle. Small vehicle includes sedans, SUVs and small trucks. Large vehicle stands for buses, large trucks and vehicles whose size is over two sedans.
2. We capture the image of the webcam every 8-9 seconds.
3. We count the number of vehicles that passed the stop line during the two image capture period right after the signal changed red to green.
4. If an illegal driving is detected in an image or if there are no cars in either the first or the second lane, we discard the case.
5. Vehicle at front position means the first vehicle in the given lane.

Figure 2 Operational Definitions for counting vehicles

With the above observation rules, we collected data during two hours (9AM-10AM, local time) over the course of four days (Oct 11th, 12th, 14th and 15th). The collected data consists of 100 crossing records, and a crossing record has numbers of each class vehicle that passed in the three lanes and types of vehicles at the front position in the lane. We discarded some observation records because some of them violated the operational definition and the others were difficult to recognize due to sun light, heavy traffic, etc.

3. RESULTS

3.1 Observation 1: Loads of vehicle types

Considering that a small vehicle can speed up faster than a large vehicle, it is natural that the large vehicle will put more traffic load than the small vehicle. However, the degree of relative load is not well-known because it is not sure whether the acceleration capability is only factor or not. Drivers are usually cautious when they are at crossroads, so there are more factors than we can imagine. Therefore, we calculate relative traffic loads for vehicle types.

First, we can assume that the load of the small vehicle is one because there are only two types and we compute the relative load. With the assumption, we calculated the average number of the small vehicle that can pass when there are no large vehicles. We will call this as average load capacity (AVC). Table 1 is the descriptive statistics when we compute AVC from the dataset.

Table 1 descriptive stat. for Average Load Capacity in the dataset

N	108.00	Standard Deviation	1.27
Mean	5.02	Sample Variance	1.61
Standard Error	0.12	Skewness	-0.37

After the AVC calculation, we apply it to the below formula. Because the crossroad environment is identical, if there is a reduction in number of small vehicles passing, it is caused by the large vehicle traffic load. The below formula is expression of it.

$$(\text{large vehicle load}) = \frac{(\text{AVC}) - (\#\text{of small vehicle})}{(\#\text{of large vehicle})}$$

When we applied the above formula to the rest of crossing records with AVC is 5.02, we could obtain table 2.

Table 2 descriptive stat. for Large Vehicle Load in the dataset

N	92.00	Standard Deviation	1.11
Mean	1.78	Sample Variance	1.23
Standard Error	0.12	Skewness	-0.22

According to the calculation, the large vehicle load (LVL), 1.78, is 78% larger than the small vehicle load (SVL), 1. When we consider that the large vehicles are at least twice larger than the small ones, the LVL is relatively small. Addtionally, we may conjecture that the large vehicles are efficient in transportation at crossroads because they have twice bigger rooms and put only 78% more load on the crossroads. However, it should be noted that LVL's standard deviation is large, so we need to examine more samples to make it certain.

3.2 Observation 2: Effect of lane position

Based on the calculated LVL and SVL, we will determine whether the first and the second lane have different capability in processing traffic load (TL). The lane position gives different environment to drivers, so the traffic load capacity of each lane may be different. Therefore, examining it may suggest insights into its simulation.

We calculated the processed traffic load (PTL) with the below formula for every crossing records.

$$(\text{PTL}) = (\text{SVL}) \times (\#\text{of small vehicle}) + (\text{LVL}) \times (\#\text{of large vehicle})$$

Table 3 the t-test result of the hypothesis: the first lane can handle more traffic load than the second lane (alpha=0.05)

	1st lane PTL	*2nd lane PTL*
Mean	5.266	4.796
Variance	1.496	1.394
Observations	100.000	100.000
df	99.000	
t Stat	3.451	
P(T<=t) one-tail	0.000	
t Critical one-tail	1.660	

With the calculated PTL, we tested a hypothesis: the first lane can handle more traffic load than the second lane. Table 3 is the result of the paired t-test.

According to the t-test result, we can claim that the first lane can process more TL than the second lane can. We guess that this result happened because the first lane suffers less interference from lane changing or slower vehicles/drivers.

3.3 Observation 3: Effect of vehicle type at the front row

Moreover, we collected data that can verify whether the vehicle type of the front row affects the PTL of the lane. We usually experience large vehicle's blocking of signal lights, especially if we drive a small vehicle. In that case, the small vehicle driver has no choice but to wait for the large vehicle's moving and see the light. In other words, the small vehicle drivers cannot anticipate when the light will change or whether there are objects on the crossroad. Under the assumption of these situations can affect the PTL, we analyzed it as below.

During the data collection, we recorded the vehicle type of the front row of each lane. Also, we calculated the PTL based on the LVL and SVL. Thus, we could get the averaged PTL for the two cases: the case when a small vehicle is at the front and the case when a large one is there. We made a hypothesis: if a small vehicle is at the front row, PTL of this case will be larger than that of the other case. We performed a t-test using two-sample assuming unequal variance. Table 4 is the result.

Table 4 the t-test result of the hypothesis: if a small vehicle is at the front row, PTL of this case will be larger than that of the other case (alpha=0.05)

	PTL when small vehicle at front	*PTL when large vehicle at front*
Mean	5.121	4.498
Variance	1.533	0.962
Observations	171.000	29.000
df	45.000	
t Stat	3.036	
P(T<=t) one-tail	0.002	
t Critical one-tail	1.679	

With the t-test result, we can argue that the vehicle type at the front row influence on the PTL of the lane. We think this result shows the effect of blocking of the signal light and forward crossroad situation.

4. Discussion

So far, we analyzed the traffic flow data that is observed at a crossroad in Japan. There are vast research papers about the microscopic traffic simulation at crossroads, but they often miss some important features in their modeling. Thus, we performed three observations and corresponding statistical analysis to present some of the missing features.

First, the relative traffic load calculation shows that large vehicles that are as twice large as small vehicles do not put the same degree of traffic load on the crossroad. While the room of the large vehicles is 200% of the small ones', their traffic load is only 178% of the small vehicles. However, it should be noticed that the standard deviation of the LVL is relatively big, so further data collection should be done to make this result more concrete. Second, we found out that the lane position influences on its traffic load capacity. Our analysis suggests that the first lane can handle more traffic load than the second lane can. We suppose that this happened because the first lane gets less interference like slower drivers/vehicles and lane changes. Finally, we revealed that the vehicle type at the front row affects the lane traffic load capacity. We could see that the PTL when a small vehicle is at front row is larger than that of the other case. We guess that this is resulted because of large vehicle's blocking of forward situation.

These observation results can be changed with different settings. For example, if we adopt three vehicle types, not binary, the results will change greatly. Also, we guess that the observation time might influence on the result because drivers may behave differently. Additionally, the traffic policy that is different across societies may affect the result. For example, the crossroad we observed does not permit left turn unlike the similar crossroads in Pittsburgh, U.S. If the left turn is possible, the observation result would be changed: the first lane would not be the best lane in handing traffic load.

With the above observations, we can say that the result of the simulations that abstracts small but relevant features is not realistic. To our knowledge, there are few microscopic simulations that differentiate the lane position or the vehicle types at the front row. However, we can see that these features are relevant to the traffic flow in our daily life: we often encounter drivers complaining the large vehicle's blocking of forward situation and changing their lanes to the first one to get less interference in their driving. Thus, it would be recommendable to validate the underlying assumptions of the current traffic simulations to make them more realistic.

5. REFERENCES

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