World Academy of Science, Engineering and Technology
International Journal of Transport and Vehicle Engineering
Vol:13, No:1, 2019

Application of AIMSUN Microscopic Simulation Model in Evaluating Side Friction Impacts on Traffic Stream Performance

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***Abstract*—**Side friction factors can be defined as all activities taking place at the side of the road and within the traffic stream, which would negatively affect the traffic stream performance. If the effect of these factors is adequately addressed and managed, traffic stream performance and capacity could be improved. The main objective of this paper is to identify and assess the impact of different side friction factors on traffic stream performance of a hypothesized urban arterial road. Hypothetical data were assumed mainly because there is no road operating under ideal conditions, with zero side friction, in the developing countries. This is important for the creation of the base model which is important for comparison purposes. For this purpose, three essential steps were employed. Step one, a hypothetical base model was developed under ideal traffic and geometric conditions. Step two, 18 hypothetical alternative scenarios were developed including side friction factors such as on-road parking, pedestrian movement, and the presence of trucks in the traffic stream. These scenarios were evaluated for one, two, and three lane configurations and under different traffic volumes ranging from low to high. Step three, the impact of side friction, of each scenario, on speed-flow models was evaluated using AIMSUN microscopic traffic simulation software. Generally, it was found that, a noticeable negative shift in the speed flow curves from the base conditions was observed for all scenarios. This indicates negative impact of the side friction factors on free flow speed and traffic stream average speed as well as on capacity.

***Keywords*—**AIMSUN, parked vehicles, pedestrians, side friction, traffic performance, trucks.

I. Introduction

ROAD traffic congestion creates great challenges for the majority of urban areas, mainly in the developing countries. Congestion has significant impacts on traffic stream performance; it increases delay and travel time; reduces travel speed, mobility and reliability of the road network. Congestion occurs when travel demand exceeds the road's capacity during peak hours. It also may occur during events that cause temporary reductions in capacity. These events can be the results of vehicle crashes, vehicle breakdown, work zones, and more. In addition to these planned and unplanned events, driver behavior and side friction factors can negatively impact traffic stream performance. Side friction factors can be characterized as roadside activities that interfere with traffic flow on the travelled way. It includes, but not limited to, on road parking, curb side bus stops, pedestrian movements, slow moving vehicles and on road stopping vehicles. These factors are not included in the Highway Capacity Manual (HCM) analysis and models. The analysis procedures and methodologies in the HCM were based on empirical research conducted in United States of America under homogenous steady traffic conditions with high levels of motorization and zero level of interference [1]. Therefore, they cannot be applied to the developing countries where the prevalent traffic conditions are significantly different.

In this paper an attempt was made to identify and assess the impact of different side friction factors on traffic stream performance of a hypothesized urban arterial road. Hypothetical data were assumed for three reasons. The first reason is because roads operating under ideal conditions, with zero side friction, in the developing countries are almost nonexistent. Creating a base model out of ideal conditions is important for comparison and analysis purposes. Second, obtaining consistent/repeatable field data for analysis is difficult because the travel direction, congestion, traffic streams, traffic types, and even traffic movements at one location change daily in the heavy populated well-traveled areas. The third reason is because side friction factors had to be isolated and analyzed separately to determine their significance to the flow of traffic. To achieve the objective of this study, three steps were employed. Step one, a hypothetical base model under ideal traffic and geometric conditions was developed. Step two, 18 hypothetical scenarios were developed including different side friction factors. These scenarios were evaluated for different lane configurations and under different traffic volumes. Step three, the impact of side friction in each scenario was evaluated using Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks (AIMSUN) microscopic traffic simulation software on speed/flow models. These factors were found to have a significant impact on free flow speed and capacity.

II. Literature Review

Various studies have been conducted to evaluate side friction impacts on traffic flow characteristics in developing countries. Munawar [1] studied the effect of side friction factors on capacity and speed at urban arterial roads in Indonesia. He found that there are significant differences between the actual speed/capacity and the predicted speed/

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capacity. New formulas for calculating speed and capacity taking into consideration the most commonly observed side friction factors in Indonesia were recommended. Rao and Rao [2] evaluated side friction impact on free flow speed in India. They reported a reduction in FFS of 57% and 67% at bus stop locations and at on street parking locations respectively. Patel and Joshi [3] tested the effect of various side friction factors on capacity of urban arterial roads in India. It was found that the capacity and speed of urban arterial roads are greatly affected by lane width, presence of non-motorized vehicles and side friction factors. Iin [4] used VISSIM, microscopic simulation software, to study the delay caused by side friction under heterogeneous traffic conditions in Indonesia. He found that side friction increased delay per vehicle by 34%. Chand et al. [5] studied the impact of curb side bus stops on capacity at arterial roads in India. It was found that there was a reduction of 8% to 13% in capacity. Sudipta and Sudip [6] developed a Road Side Friction Index (RSFI) to quantify the impact of side friction generated from road side markets on performance of two-lane rural roads in India. In another study, Sudipta and Sudip [7] proposed a methodology to quantify the effect of side friction factors generated in road side markets. Five levels of service (LOS) were recommended, the threshold values were based on operational speed and freedom to maneuver as measures of effectiveness. Salini et al. [8] proposed speed prediction models under different levels of side friction including bus stops, pedestrians and on street parking. Fee studies were conducted to evaluate side friction impacts on traffic flow characteristics in developed countries. Aronsson and Bang [9] developed speed prediction models by analyzing factors that affect speed on urban roads in Sweden. They found that side friction factors including parked vehicles, roadside premises, and unprotected road users negatively impacts traffic stream speed. Lee et al. [10] conducted a study on undivided three lane roadways in Virginia. They found that the probability of lane-changing violations increases at curbside bus stops which will inversely affect traffic performance.

III. Methodology

In this study, an attempt was made to evaluate the impact of various side friction factors on traffic stream performance of a hypothesized urban arterial road. This study differs from the previously mentioned studies by analyzing each friction factor separately. Each friction factor was studied under different number of lanes and under different traffic conditions. The selected side friction factors were the most frequently observed factors on urban arterial roads in developing countries.

***Step One*:** The base model development is essential to compare the performance of an unimpeded traffic stream to the performance of a traffic stream with side friction factors. The base model, in this case, is a hypothetical arterial segment of 500 meters in length. It was constructed under ideal traffic and geometric conditions where the side friction is assumed to be zero and the geometric characteristics are under standard values as indicated by the HCM for a design speed of 80 Km/hr and a base capacity of 1900 pcphpl [11].

***Step Two*:** 18 hypothetical alternative scenarios were created to reveal the effects of different side friction factors on traffic flow. These scenarios were tested under various levels of congestion with traffic volumes ranging from low to heavy. They were also evaluated using one, two and three lane configurations. Side friction factors were assembled into two groups: external factors, which included the presence of pedestrians and parked vehicles; and internal factors which included the presence of trucks in the traffic stream. Six scenarios were created for each lane configuration including two scenarios with varying percentages of pedestrians walking parallel to the road (10 and 20%), two scenarios with varying percentages of trucks (10 and 20%), and two scenarios with varying percentages of parked vehicles (two and three percent). Table I shows a summary of the hypothetical side friction scenarios that were created.

***Step Three*:** The side friction impact in each scenario was evaluated using speed flow models and AIMSUN microscopic traffic simulation software. Free Flow Speed (FFS) and capacity were the selected measures of effectiveness as they are the main operational characteristics that describe the traffic stream performance. The HCM defines the FFS as "the average speed of vehicles on a given facility, measured under low-volume conditions, when drivers tend to drive at their desired speed and are not constrained by control delay". Also, the HCM defines capacity as "the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions" [11].

TABLE I
Summary of the Hypothetical Side Friction Scenarios

Scenario	Pedestrian (%)	Trucks (%)	Parked Vehicles (%)
Base Model	0	0	0
One Lane			
1	10	0	0
2	20	0	0
3	0	10	0
4	0	20	0
5	0	0	2
6	0	0	3
Two Lanes			
7	10	0	0
8	20	0	0
9	0	10	0
10	0	20	0
11	0	0	2
12	0	0	3
Three Lanes			
13	10	0	0
14	20	0	0
15	0	10	0
16	0	20	0
17	0	0	2
18	0	0	3

A. Simulation Software

Microscopic traffic simulators are probably the most available traffic analysis tools that can reasonably imitate the flow of individual vehicles in a large traffic network. They enable transportation engineers and planners to develop and compare different scenarios under varying traffic flow conditions. AIMSUN is one of the Transportation Simulation System (TSS) packages that can perform traffic modeling, planning, and simulation. Car following and lane changing models imbedded in the AIMSUN simulation software were used to compare the hypothetical scenarios to the base model. Although several parameters in the imbedded models can be modified to represent specific driving environments, the default setting was used for all scenarios in this study.

IV. Results

A total of four individual simulation runs, each using different random seed number reflecting the traffic variation on the network each day, were executed for each scenario. This resulted in a total set of 76 runs. Although the specific computational time varied for each run, the average run time was about one hour for each scenario. The AIMSUN program produced outputs every 15 minutes. The results reflect the average of the comparative measures of effectiveness computed each of the four separate, scenario-specific runs. The negative impact of side friction factors on traffic stream operational characteristics was evaluated by analyzing the side friction's impact on FFS and capacity using the speed flow relationships.

Figs. 1-9 show the speed flow curves for a single, two and three lane traffic stream systems. The figures include the speed flow curve for the base model and the speed flow curves for the traffic stream including different side friction factors. The FFS was expressed by km/hr and the flow rate was expressed by passenger car per hour per lane (pcphpl). Generally, a noticeable negative shift in the speed flow curves from the base conditions can be seen in all figures. This indicates negative impact of the side friction factors on FFS and traffic stream average speed of the traffic stream as well as on capacity.

Figs. 1-3 illustrate the effect of side friction factors on a single lane traffic stream performance. Fig. 1 shows the impact of the presence of varying percentages of trucks in a single lane traffic stream. It may be seen that when compared to base conditions, the presence of 10% trucks in the traffic stream resulted in 8% reduction in FFS. It also resulted in reducing capacity to 1824 pcphpl with 4% reduction in capacity under base conditions. While the presence of 20 % trucks in the traffic stream had greater impact on FFS and capacity; it resulted in reducing the FFS to 68 km/hr and capacity to 1625 pcphpl. This corresponded to 15% reduction in FFS and 15% reduction in capacity when compared to the base conditions.

Fig. 2 shows the impact of the presence of varying percentages of pedestrians walking parallel to the road. It can be seen that the presence of 10% pedestrians in traffic stream negatively impacted traffic performance. It resulted in reducing the FFS to 68 km/hr and in reducing capacity to 1539 pcphpl. This corresponds to 15% reduction in FFS and 19% reduction in capacity when compared to the base conditions. While the presence of 20% pedestrians in traffic stream resulted in reducing FFS to 66.4 km/hr, it also reduced capacity to 1425 pcphpl. This corresponds to 17% reduction in FFS and 25% reduction in capacity when compared to the base conditions.

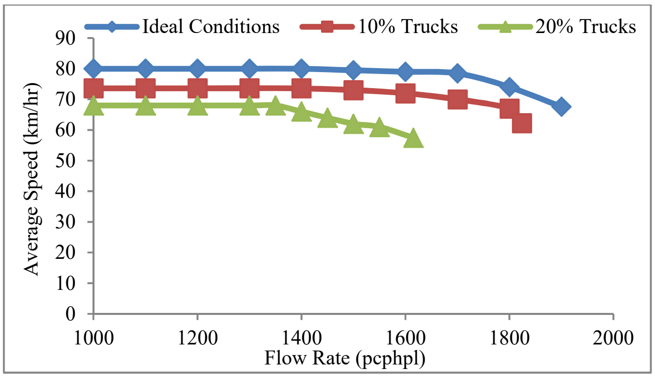

Fig. 1 Speed-Flow Curves for Single Lane Traffic Stream System with 10% and 20% Trucks

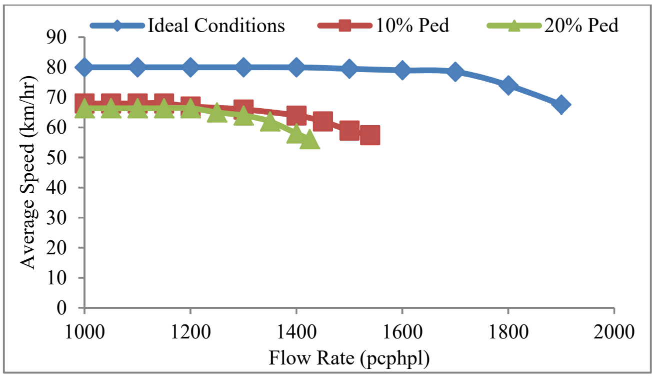

Fig. 2 Speed-Flow Curves for Single Lane Traffic Stream System with 10% and 20% Pedestrians

Fig. 3 shows the impact of having varying percentages of parked vehicles along the road. It can be seen that parked vehicles greatly affected traffic performance, just 2% parked vehicles resulted in reducing FFS to 56.8 km/hr and reducing capacity to 1520 pcphpl. This corresponded to 29% reduction in FFS and 20% reduction in capacity when compared to the base conditions while having 3% parked vehicles reduced FFS to 49.6 km/hr and reduced capacity to 1406 pcphpl with a 38% and 26% reduction in FFS and capacity, respectively when compared to the base conditions.

Figs. 4-6 illustrate the effect of side friction factors on the performance of a two lane traffic stream. Fig. 4 shows the impact of the presence of varying percentages of trucks in a two lane traffic stream. It can be seen that the FFS was reduced to 70.4 km/hr and the capacity was reduced to 1520 pcphpl when 10% trucks were added to the base traffic stream. This corresponds to 12% and 20% reduction in FFS and capacity when compared to the base FFS and base capacity respectively whereas, the FFS was reduced to 64.8 km/hr and the capacity was reduced to 1406 pcphpl when 20% trucks were added to the ideal traffic stream. This corresponded to 19% reduction in FFS and 26% reduction in capacity when compared to the base conditions.

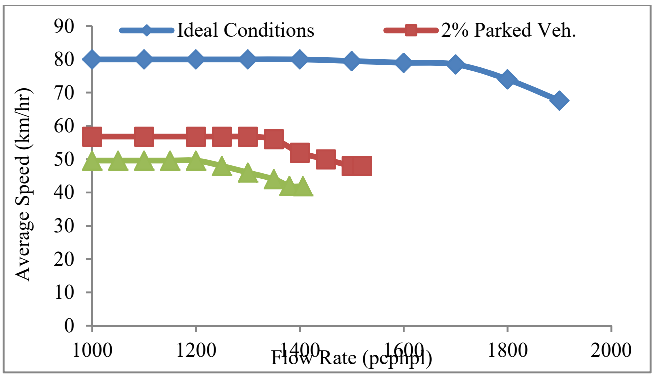

Fig. 3 Speed-Flow Curves for Single Lane Traffic Stream System with 2% and 3% Parked Vehicles

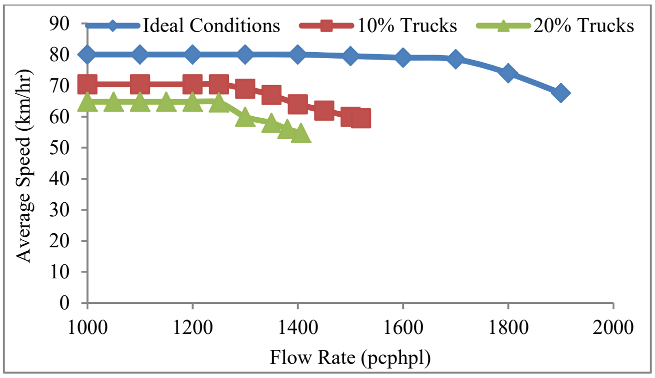

Fig. 4 Speed-Flow Curves for Two Lane Traffic Stream System with 10% and 20% Trucks

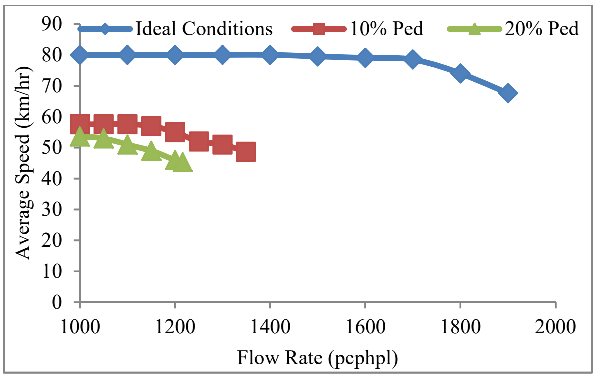

Fig. 5 Speed-Flow Curves for Two Lane Traffic Stream System with 10% and 20% Pedestrians

Fig. 5 illustrates the impact of the presence of varying percentages of pedestrians included near the traffic stream. Figure shows that the presence of 10% pedestrians near the traffic stream resulted in reducing the FFS to 57.6 km/hr. It also resulted in reducing capacity to 1349 pcphpl. Combined, this corresponds to 28% reduction in FFS and 29% reduction in capacity when compared to the base conditions. The presence of 20% pedestrians in traffic stream resulted in reducing FFS to 53.6 km/hr and it reduced capacity to 1216 pcphpl. This corresponds to 33 % reduction in FFS and 36% reduction in capacity when compared to the base conditions.

Fig. 6 shows the impact of having varying percentages of parked vehicles along the road. Observations suggests that 2% parked vehicles negatively influenced the traffic stream by reducing FFS to 50.4 km/hr (37%) and reducing capacity to 912 pcphpl (50%) from base conditions while 3% parked vehicles further reduced FFS to 46.4 km/hr (42%) and reduced capacity to 741 pcphpl (61%) from base conditions.

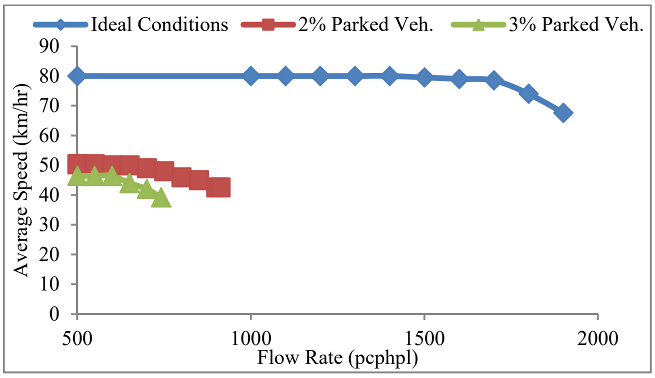

Fig. 6 Speed-Flow Curves for Two Lane Traffic Stream System with 2% and 3% Parked Vehicles

Figs. 7-9 demonstrate the effect of side friction factors on a three-lane traffic stream performance. Fig. 7 shows the impact of truck presence on a three-lane traffic stream. 10% trucks in the traffic stream resulted in reducing FFS to 60.8 km/hr (24% reduction) from the FFS under base conditions. Truck presence also resulted in reducing capacity to 1216 pcphpl (36% reduction) from capacity base conditions. Increasing the truck presence to 20% yielded results that are more impactful. With 20 % trucks in the traffic stream, the FFS and capacity decreased to 56.8 km/hr (29% reduction) and 1102 pcphpl (42% reduction), respectively.

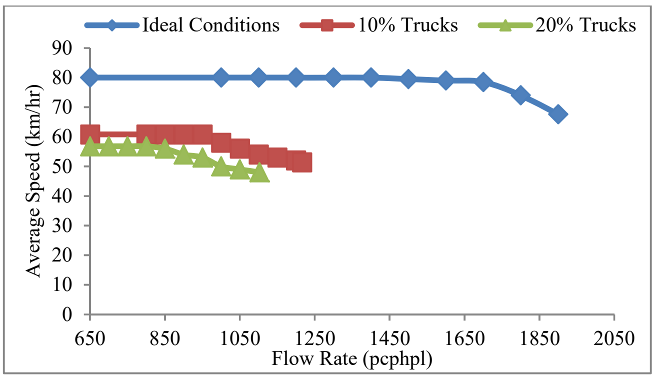

Fig. 7 Speed-Flow Curves for Three Lane Traffic Stream System with 10% and 20% Trucks

Fig. 8 shows impact of the presence of varying percentages of pedestrians in the traffic stream. The presence of 10% pedestrians in the traffic stream negatively impacted traffic performance. It resulted in reducing the FFS to 50.4 km/hr (37%) and reducing capacity to 1102 pcphpl (42%). Increasing the pedestrian presence to 20% reduced the FFS to 45.6 km/hr (43%) and the capacity to 988 pcphpl (48%).

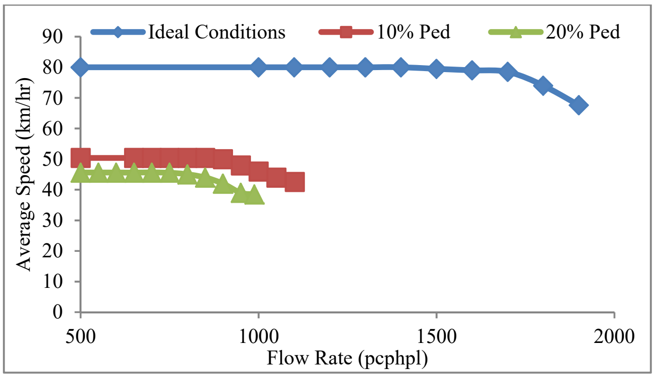

Fig. 8 Speed-Flow Curves for Three Lane Traffic Stream System with 10% and 20% Pedestrians

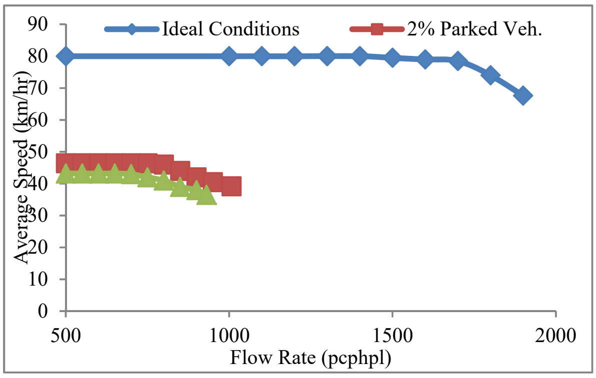

Fig. 9 Speed-Flow Curves for Three Lane Traffic Stream System with 2% and 3% Parked Vehicles

Finally, Fig. 9 shows the impact of having varying percentages of parked vehicles along a road with three lanes of traffic. Parked vehicles greatly affected traffic performance and reduced FFS by an average of 44.5% and it reduced capacity by an average of 48.5%. This suggest that motorists travel at almost half the speed and reach almost half the flow when as little as 2 or 3% of the vehicles in the area are parked near the three-lane travel way.

V. Summary and Conclusion

Traffic stream characteristics are influenced by various factors such as surface type, lane width, drivers' behavior, drivers' driving skills, and side friction factors. Side friction factors can be defined as all those road side activities that interfere with traffic flow on the travelled way. It includes on road parking, bus stops, pedestrian movements, slow moving vehicles and on road stopping vehicles. If the effect of these factors is adequately addressed and managed, traffic stream performance and capacity could be improved. The main objective of this paper is to identify and assess the impact of different side friction factors on traffic stream performance of a hypothesized urban arterial road. Hypothetical data were assumed to create a baseline that would aid in identifying traffic side friction factors that are difficult to separately observe in developing countries because roadway operations are inconsistent and sometimes not repeatable. For the purpose of this study, three essential steps were employed. Step one; develop a hypothetical base model under ideal traffic and geometric conditions. The base model was needed for comparison purposes. Step two, create 18 hypothetical alternative scenarios. The side friction factors analyzed included on-road parking, pedestrian movement and the presence of trucks in the traffic stream. These factors were found to have a significant impact on FFS as well as on capacity. Each scenario was evaluated for one, two and three lane configurations and under different levels of congestion. Step three; evaluate the impact of side friction in each scenario on speed flow models using AIMSUN microscopic traffic simulation software. The overall results from the study are shown in Table II.

TABLE II
SIDE FRICTION REDUCTION RESULTS

	2% Parked	3% Parked	10 % Truck	20 % Truck	10% Peds.	20% Peds.
One Lane FFS Reduction	29%	38%	8%	15%	15%	17%
One Lane Capacity Reduction	20%	26%	4%	15%	19%	25%
Two Lane FFS Reduction	37%	42%	12%	19%	28%	33%
Two-Lane Capacity Reduction	50%	61%	20%	26%	29%	36%
Three-Lane FFS Reduction	42%	47%	24%	29%	37%	42%
Three-Lane Capacity Reduction	46%	51%	36%	42%	43%	48%

When compared to the base model for single lane system, the presence of 10 to 20% trucks reduced the FFS by 8 to 24% and reduced capacity by 4 to 42%. The number of lanes and percentage of trucks governed the percent reduction. Generally speaking, reduction in FFS and capacity is greatest when both the number of lanes and truck percentages increase.

The presence of pedestrians (10-20%) walking parallel to the road reduced the FFS by 15 to 42% and reduced capacity by 19 to 48%. Finally, parked vehicles greatly affected traffic performance. Just 2% parked vehicles resulted in reducing FFS anywhere from 29 % to 42%. The reduction in capacity ranged from 20% to 46%. A similar negative affect was observed with 3% parked vehicles, which reduced FFS by 38 to 47% and capacity by 26 to 61%.

Concerning capacity, the number of lanes were more a factor than pedestrian and truck presence. The greatest reduction in capacity occurred under the two-lane configuration. This suggests that the most damaging combination of side friction factors to traffic flow is parked cars near two-lane configurations.

The results also reveal the most volatile friction factor, as noted by the biggest change in percentage points from one configuration to the next, is truck percentages, changes in truck percentages affected the greatest change in traffic flow. Therefore, the results from this study indicate that limiting truck access (when possible) and on-street parking will likely produce greater traffic flow and longer lasting FFS.

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