# Effect of On-Street Pickup and Delivery on Level of Service of Arterial Streets

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**The effect of on-street pickup and delivery (PUD) of freight on arterial streets in central areas is analyzed. The data used were collected throughout the country and included PUD demand, parking patterns, and the impact of lane blockages on traffic. The purpose of the analysis was to develop a method by which on-street PUD operations could be incorporated into level-of-service analysis as well as to provide a mechanism by which to evaluate alternative goods-movement strategies. The findings of the research indicate that lane blockages by PUD vehicles, even at very low demand levels, have a considerable impact on traffic speed and level of service. Tables and charts by which this impact can be determined are presented, and some preliminary strategies that could improve arterial street performance are proposed.**

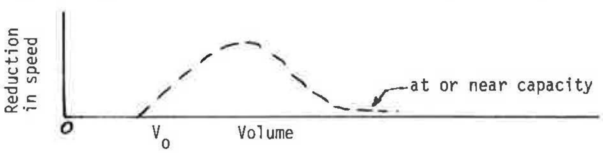
The on-street pickup and delivery (PUD) of freight is the major mode of accomplishing the transfer of materials in central areas. The vehicles used are primarily small and intermediate-sized trucks, which park at the curb or double-park as close to the destination as possible. Several cities, such as Boston and Phoenix, have alleys from which goods can be transferred. In most cities, however, this transfer occurs either at curbside on an artery or off the street in a loading dock or parking lot.

This paper presents an analysis of the effect of curbside and double-parked PUD operations on traffic speed and level of service for the type of streets on which these operations are dominant--arterial streets of two or more lanes per direction. The research on which this paper is based is drawn from a comprehensive study of on-street PUD operations including PUD demand production, parking patterns, and characteristic freight distribution patterns as well as traffic impact. Data for the study were collected in various cities in the United States.

## STUDY DESIGN

It is hypothesized that, at a certain low volume of traffic, a lane blockage does not affect flow speed. Furthermore, at very high traffic volumes (near capacity), the intersection so controls the flow that a blockage (except one right at the downstream intersection approach) does not affect speed. Figure 1 shows hypothesized volume versus speed reduction for a lane blockage: $V_0$ would be a threshold volume below which there would be no apparent effect.

**Figure 1. Hypothesized relation between volume and speed reduction.**




The study design for determination of traffic impact was to collect data on traffic blockages by PUD vehicles and use these data to calibrate NETSIM, a widely accepted traffic simulator. Then NETSIM was used to simulate the effect of PUD blockages under various traffic and street conditions. Since the study is restricted to arterial facilities of >2 lanes/direction, the findings would only apply to these larger facilities.

### Data Collection

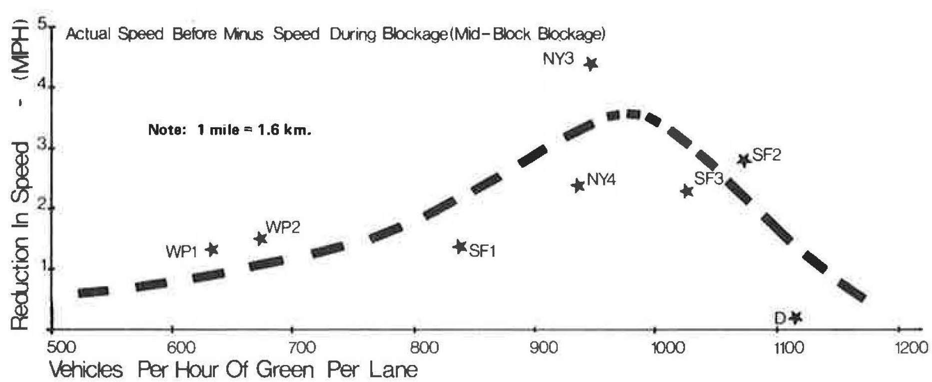
Field data for the study were collected by using 1-s time-lapse photography with a Super 8-mm camera mounted on rooftops, in office buildings, on fire escapes, and in other locations. Approximately 25 blockage cases were filmed throughout the country. Ten cases were selected for use for NETSIM calibration. The selection was based on volume level, duration and type of blockage, number of lanes, signal control, and the degree of influence the blockage had on street performance. Table 1 gives the 10 selected cases.

**Table 1. NETSIM validation cases.**

| City | No. of Lanes per Direction | Direction | Vehicles per Hour of Green per Lane[a] |
|---|---|---|---|
| Dallas | 3 | One-way | 1100 |
| San Francisco | 2 | One-way | 1000 |
| | 2 | One-way | 1100 |
| | 2 | One-way | 1000 |
| | 2 | One-way | 800 |
| White Plains, NY | 2 | Two-way | 700 |
| | 2 | Two-way | 650 |
| New York City | 3 | One-way | 800 |
| | 2 | Two-way | 950 |
| | 2 | Two-way | 1000 |

[a]Represents volume conditions during blockage.

**Figure 2. Speed reduction caused by lane blockage in the various cities studied.**



Travel-time data were collected from the films over the affected section (usually one block). Stops were not recorded because of the difficulty of accurately counting locked-wheel stops at a time lapse of 1 s.

Figure 2 shows the impact on speed caused by the lane blockage. It should be noted here that none of the cases shown is an approach-lane blockage at the downstream intersection. Thus, in the cases shown, the intersection characteristics still control the capacity of the block, and it would be expected that speed reduction resulting from the blockage would be directed toward zero as volume approaches capacity (1400-1500 vehicles/h of green/lane).

The principal reason for not considering filmed cases was that the volume past the blockage was too low to provide a measurable impact. The second reason for eliminating certain cases was that other environmental factors--such as cross-street congestion, automobile double parking or other-side-of-street parking, and bus breakdown in the moving lane--controlled arterial flow more than did the lane blockage.

**Figure 3. Family of blockage configurations (* denotes location of lane blockage).**

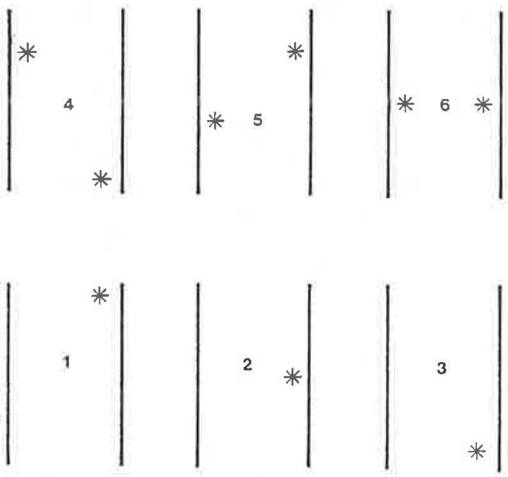
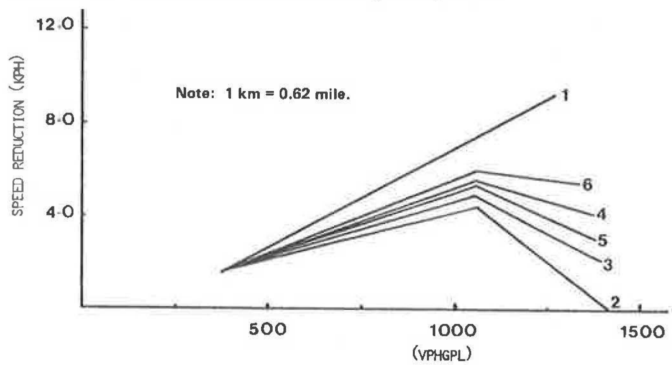



**Figure 4. Speed reduction for various blockage configurations.**




## Analysis Method

NETSIM simulations were designed and run for each case given in Table 1, and relations were developed between simulated conditions and actual field conditions, including signal progression and split, turning volumes, and pedestrian interference levels. Since NETSIM was not created to simulate lane blockages by trucks, the development of relations between simulated and actual conditions was essential in interpreting the further simulations that would be made for the various traffic volumes, street sizes and types, and lane-blockage configurations.

On a typical one- or two-way arterial street, there are a variety of blockage configurations. For instance, on a one-way facility there could be a blockage upstream, midblock, or downstream or a downstream blockage on one side and a midblock blockage on the other side. There are, for all practical purposes, 64 different permutations of blockage configurations on a one-way street and 6 on a two-way street (in one direction), if one considers each block face to be made of three "cells" (upstream, midblock, or downstream) in which a blockage can occur. Each blockage configuration will affect traffic differently.

The analysis process defined six blockage configurations on a one-way street and three

**Table 2. Speed reduction for one-way arterials for various levels of PUD double-parking demand on both sides of street.**

| Volume (vehicles/h of green/lane) | Speed Reduction by No. of PUDs per Hour (km/h) | | | | |
|---|---|---|---|---|---|
| | 6 PUDs | 12 PUDs | 24 PUDs | 36 PUDs | 48 PUDs |
| 500 | 2.1 | 2.7 | 2.9 | 3.0 | 2.9 |
| 550 | 2.4 | 3.0 | 3.2 | 3.4 | 3.3 |
| 600 | 2.6 | 3.3 | 3.6 | 3.7 | 3.7 |
| 650 | 2.9 | 3.6 | 3.9 | 4.1 | 4.1 |
| 700 | 3.1 | 3.9 | 4.2 | 4.5 | 4.5 |
| 750 | 3.4 | 4.2 | 4.6 | 4.9 | 4.9 |
| 800 | 3.6 | 4.5 | 4.9 | 5.3 | 5.3 |
| 850 | 3.9 | 4.8 | 5.2 | 5.6 | 5.8 |
| 900 | 4.1 | 5.1 | 5.5 | 6.0 | 6.2 |
| 950 | 4.4 | 5.4 | 5.9 | 6.4 | 6.6 |
| 1000 | 4.7 | 5.5 | 5.9 | 6.5 | 6.8 |
| 1050 | 4.7 | 5.5 | 6.0 | 6.7 | 7.1 |
| 1100 | 4.6 | 5.5 | 6.1 | 6.9 | 7.4 |
| 1150 | 4.5 | 5.5 | 6.2 | 7.2 | 7.7 |
| 1200 | 4.5 | 5.5 | 6.2 | 7.4 | 8.1 |
| 1250 | 4.4 | 5.5 | 6.3 | 7.6 | 8.4 |
| 1300 | 4.3 | 5.5 | 6.4 | 7.8 | 8.7 |
| 1350 | 4.3 | 5.5 | 6.5 | 8.1 | 9.0 |
| 1400 | 4.2 | 5.5 | 6.6 | 8.3 | 9.3 |

Note: 1 km = 0.62 mile.

**Table 3. Speed reduction of two-way arterials for various levels of PUD double-parking demand on one side of street.**

| Volume (vehicles/h of green/lane) | Speed Reduction by No. of PUDs per Hour (km/h) | | | | |
|---|---|---|---|---|---|
| | 3 PUDs | 6 PUDs | 12 PUDs | 18 PUDs | 24 PUDs |
| 500 | 1.4 | 2.2 | 2.7 | 2.8 | 2.8 |
| 550 | 1.6 | 2.4 | 3.0 | 3.2 | 3.2 |
| 600 | 1.8 | 2.7 | 3.4 | 3.6 | 3.6 |
| 650 | 1.9 | 2.9 | 3.7 | 3.9 | 4.0 |
| 700 | 2.1 | 3.2 | 4.0 | 4.3 | 4.4 |
| 750 | 2.3 | 3.4 | 4.3 | 4.7 | 4.8 |
| 800 | 2.4 | 3.6 | 4.6 | 5.0 | 5.2 |
| 850 | 2.6 | 3.9 | 5.0 | 5.4 | 5.6 |
| 900 | 2.8 | 4.1 | 5.3 | 5.8 | 6.0 |
| 950 | 2.9 | 4.4 | 5.6 | 6.1 | 6.4 |
| 1000 | 3.3 | 4.8 | 6.0 | 6.4 | 6.7 |
| 1050 | 3.2 | 4.7 | 6.0 | 6.6 | 7.0 |
| 1100 | 3.1 | 4.6 | 6.0 | 6.7 | 7.3 |
| 1150 | 3.0 | 4.5 | 6.0 | 6.9 | 7.5 |
| 1200 | 2.9 | 4.4 | 6.0 | 7.0 | 7.8 |
| 1250 | 2.8 | 4.3 | 6.0 | 7.2 | 8.0 |
| 1300 | 2.7 | 4.2 | 6.0 | 7.3 | 8.3 |
| 1350 | 2.6 | 4.1 | 6.1 | 7.4 | 8.6 |
| 1400 | 2.5 | 4.0 | 6.1 | 7.6 | 8.8 |

Note: 1 km = 0.62 mile.

blockage configurations on a two-way street to which all configurations could be reduced for traffic impact purposes. These are shown in Figure 3. As the block face is "divided" into three cells (upstream, midblock, or downstream) a multivehicle blockage in one cell would be represented by one blockage in that cell. The combination of blockages in different cells defines the configurations.

The various configurations shown in Figure 3 were simulated by NETSIM under various traffic volumes, and the results were adjusted by using data from field test cases. A standard block length of 122 m (400 ft) was used, and typical arterial street progression, traffic composition, and turning conditions were assumed. The characteristics of the simulations and the ranges studied are given below:

| Item | Range |
|---|---|
| Number of moving lanes | 2, 3, 4 |
| Directions | One-way, two-way |
| Volume/capacity ratio | 0.5, 0.7, 0.8, 0.85, 0.9 |
| Blockage durations (min) | 3, 7, 12, 20, 30 |
| Intersection characteristics | 10 percent right and left turns; moderate pedestrian volume; green time/cycle length ratio = 0.5 |
| Block length (m) | 122 |
| Other considerations | NETSIM does not consider (a) parking versus no parking (only moving lanes) or (b) variations in lane widths; 5 percent trucks |

Figure 4 shows the speed-reduction relation developed for the various possible blockage configurations.

Analysis of blockage cases from the field as well as of the NETSIM results showed that there was no consistent representation of the effect of the size of arterial, over the range studied (2-4 lanes/direction), on reduction in speed caused by lane blockage. This insensitivity to number of lanes was also found in a previous study (1). The findings in Figure 4 are therefore presented as a function of vehicles per hour of green per lane.

The probability of an arterial block being in any of the 64 (reduced to 6) configuration states is a function of the demand of PUD vehicles on that block. Therefore, theoretical probability matrices were developed for each configuration state under different PUD demand levels. As demand rises, the probability of the most severe configuration states also rises.

## Determining Speed Reduction and Level of Service

Tables 2 and 3 give the expected reduction in speed for a variety of traffic volumes and levels of PUD double-parking demand for one-way and two-way operation on arterial streets. Figures 5 and 6 show the expected resultant level of service on the arterial street under various levels of traffic and PUD demand. These levels of service would be more appropriate descriptors for an arterial segment (several blocks) than for an individual block, since a random PUD arrival pattern based on a uniform distribution along the block was assumed in the analysis process. That is, if a block has a very large downstream generator and little or no generation elsewhere, the tables given would underestimate the impact. On the other hand, should that major generator be midblock, an underestimate would be expected.

The level of service was determined by combining the no-blockage volume-speed curve from the simulation results with a general relation between arterial volume and level of service (2). Figure 7 shows this combination. The method used to find the level of service caused by PUD blockages is as follows: The hypothetical volume determines the no-blockage speed, which in turn is reduced by appropriate values from Table 2 (or Table 3). The resultant location of the point defines the appropriate impact level of service.

**Figure 5. Level of service for lane blockages on one-way arterials.**

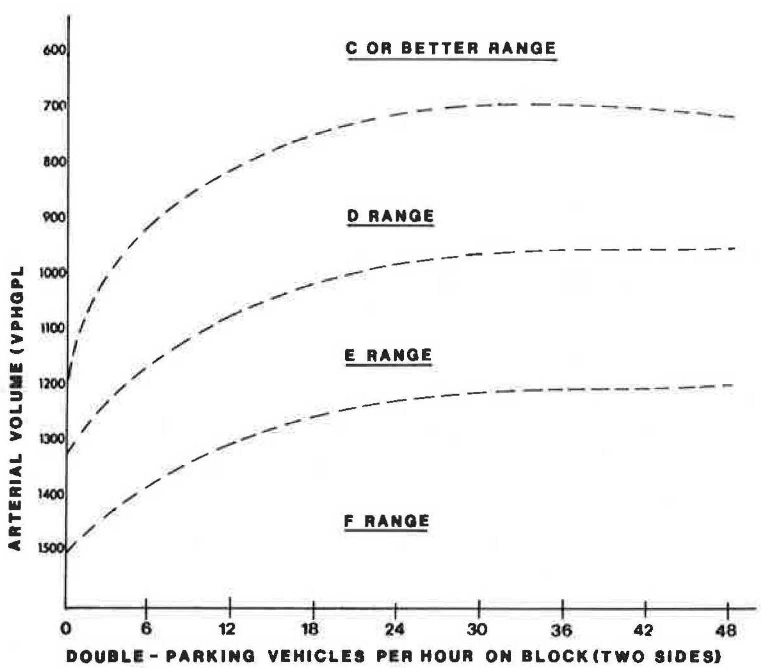


Figure 6. Level of service for lane blockages on two-way arterials.

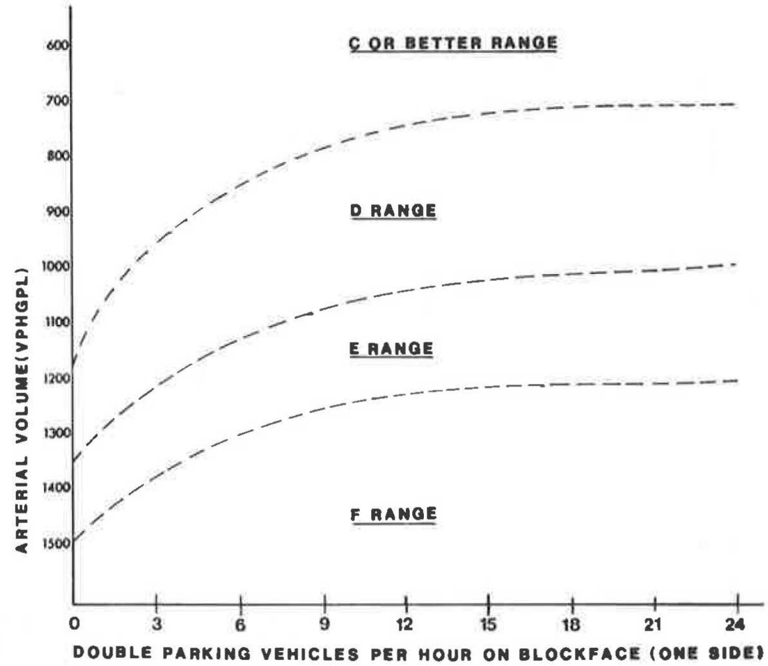
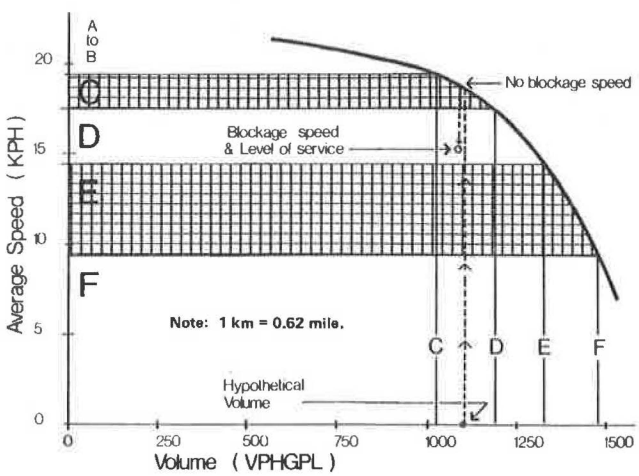



Figure 7. Determination of level of service.




ASSESSMENT OF RESULTS

Figures 5 and 6 show that PUD activities can have a significant detrimental effect on level of service on the arterial street. It should be noted that a single 122-m (400-ft) block face can process 40 PUD operations in a blocked lane. Thus, the PUD demand levels shown are not worst-case conditions of PUD demand. In addition, initial work in this area (2) showed no measurable relation between block length and traffic impact from PUD operations over the range of typical arterial blocks [100-200 m (325-650 ft)]. Therefore, the rates of PUD double-parking demand given in this paper are PUD demand/122 m/h. This implies that the results would be transferable to other block lengths without much loss of accuracy.

Various studies have shown that PUD vehicles will double-park where curbside parking is not available or park in a curbside moving lane when no parking or standing is allowed. The percentage of such vehicles relative to total block PUD generation is 30-40 percent, a sizable amount.

When the amount of PUD activity is very small, the maximum throughput of a downtown arterial street will be reduced from about 1450 to about 1325 vehicles/h of green/lane (more likely about 1200). This reduction of 9-18 percent must be viewed as the minimum effect of PUD operations on system throughput. The range of effects grows larger as PUD demand grows.

Because PUD activity is regular and not a random occurrence, drivers expect certain delays and avoid specific streets as not being on the minimum-impedance path from origin to destination. Therefore, since the volume never reaches the hypothesized level unless this arterial section remains on the minimum path, the hypothetical impact may never occur. However, traffic engineers who calculate downtown street capacity without giving a great deal of attention to the assessment of the generation of on-street PUD operations are avoiding a key determinant of street-segment capacity and quality of flow.

OPTIONS TO IMPROVE LEVEL OF SERVICE

The way to improve traffic performance is to minimize conflict. To do this, the traffic engineer or planner should be fully aware of the elemental characteristics of good traffic movement. A traffic signal cannot be timed adequately unless an elemental characteristic of pedestrians--walking speed--is known. An intersection cannot be analyzed unless various elemental characteristics of the traffic stream--volume, speed, and discharge rates--are known. Knowledge of the elemental characteristics of goods movement--demand, arrival patterns, and parking patterns--seems to me to be the basic element in improving level of service. Acquisition of this knowledge and understanding by traffic engineers and planners will result in the ability to develop realistic strategies by which to lessen conflicts and improve level of service at specific problem locations.

Some of the strategies that I perceive to be realistic and that will be tested during further phases of the research from which this paper is drawn are

1. Reducing approach-lane blockages by various means, such as short loading zones, relocation of bus stops to the near side, placement of hydrants (if flexibility exists), and provision of loading space at corners on cross streets;
2. Altering the PUD demand pattern (through enforcement, consolidation, and other means) to reduce conflicts in selected time periods;
3. Providing (by purchase or rent) off-street loading space (lots) for PUD vehicles on the most critical arterial sections; and
4. Restriping selected arterials to allow for 4.5- to 5.0-m (15- to 16-ft) double-parking curb lanes where possible [a facility with three 3.7-m (12-ft) travel lanes and two 4-m (13-ft) curb lanes could be restriped to be three 3-m (10-ft) travel lanes and two 5-m (16-ft) curb lanes].

There are more simple and more exotic strategies to be used in addressing the problem of PUD impact on traffic flow. This paper, which is based on a limited amount of data, presents an initial, systematic way of relating the variables of urban goods movement to the variables of arterial traffic flow. In a time when maximum efficiency is being sought for existing traffic facilities, the proper recognition and treatment of on-street goods movement, as presented here and in future research efforts, can go a long way toward achieving that goal.

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