Economic Approach to Allocating Curb Space for Urban Goods Movement

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The curb lane on urban street systems is subject to severe user competition. The primary competitors are the static users (parked vehicles) and dynamic users (vehicular traffic and surface transit). In downtown areas, the pickup and delivery of goods are almost exclusively done at curbside and, thus, goods-movement vehicles must compete with the other curb space users. Standards for the allocation of curb space for pickup and delivery (PUD) vehicles are nonexistent. The purpose of this paper is to present a method for determining curbside spatial requirements for PUD vehicles. The method outlines a process whose solution answers the question, Given a set of conditions, what are the curbside spatial requirements for PUD vehicles that would keep the total costs to society (the relevant portions) to a minimum? "Society" includes vehicular traffic, carriers, shippers, curbside automobile parkers, surface transit, and the community at large. This paper presents the components of each societal group that would be affected by varied spatial allocations at curbside and outlines the method for searching out the least cost solution. In addition to the method presentation, a case study is put forward to show that application of the least cost principle does in fact give results that are practical and implementable on urban street systems.

The vast majority of pickup and delivery (PUD) vehicles destined to the downtown area park at curbside to transfer goods. The demand for use of this curb space is high and supply is limited. The management of curb space and the rational allocation of this space among the competing users to satisfy specific needs thus become a critical issue. In one case, the need might be expediting traffic flow; in another, it might be increasing curbside automobile parking to promote local business interest; in yet another instance, a need might be to specifically provide loading zones for PUD vehicles. A lack of recognition of the need to adequately accommodate such vehicles contributes to overall downtown congestion (2).

The approach to curb use allocation described herein is based on the quantification of costs resulting from the allocation of space to the competing users. Specifically, it deals with the determination of dollar equivalents of the impacts of curb use allocation between PUD vehicles and other users. The outcome of the method application would be to allocate curb space to keep costs to society (the relevant portions) to a minimum. These costs include traffic and carrier costs, as well as automobile parking costs and the costs to the public at large.

WHO COMPETES FOR CURB SPACE USE?

In downtown areas, two basic pressures govern curbside usage: to allow parking for all or certain types of vehicles (static users) or to prohibit parking in favor of the more efficient movement of traffic on the street (dynamic users). These two basic user populations compete for use of the limited curb space. The competing users for curb space are not always in severe conflict with each other because of the natural temporal separation in user need patterns. Figures 1 and 2 show typical user demand patterns of curb space. Demand is measured by arrival patterns of these potential users. Although all data are characteristic of downtown Brooklyn, it is believed to be generally representative of large urban central business districts (CBDs).

WHEN DOES COMPETITION OCCUR?

The general identification of conflicting users of curb space in time is required. Before 7:00 a.m., curb demand in the CBD is relatively low for all users. However, just after 7:00 a.m. and continuing to about 10:00 a.m., dynamic user demand for curb space becomes significant. During this period, several static users' demands also show peaking especially in the non-shopping-related automobile populations. The 7:00 a.m. to 10:00 a.m. period is one of multiple conflicts in downtown areas; surface transit competes with other elements of moving traffic. Subgroups of the static user population are in competition with each other, and an overall high degree of dynamic and static user competition on a group user basis also exists.

The period between 10:00 a.m. and 4:00 p.m. is one when the static users mainly compete with each other for curb space usage. The amount of double parking, circulating, and the like that result depends on the severity of this competition. From 4:00 p.m. to 7:00 p.m., the

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dynamic users again show heavy demand patterns and the static user groups show relatively low demand characteristics during this period. The 4:00 p.m. to 7:00 p.m. period is, therefore, less difficult in resolving conflicts than the 7:00 a.m. to 10:00 a.m. period because of the relative absence of static-user competition.

In view of this information, three distinct conflict periods (CPs) can be defined for evaluation: (a) CP 1 is from 7:00 a.m. to 10:00 a.m.; (b) CP 2 is from 10:00 a.m. to 4:00 p.m.; and (c) CP 3 is from 4:00 p.m. to 7:00 p.m. There is sufficient difference in curb space user demand in these three conflict periods to warrant separate consideration from the curb management viewpoint, at least in initial phases of the evaluation.

OVERVIEW OF PUD PROCESS

Before we discuss the curb space allocation method, the PUD process as it generally occurs in a large CBD needs to be briefly characterized. The basic operational characteristics (e.g., dwell times, trip generation, and parking patterns) are necessary inputs to the model. The values presented in the following sections were collected in the Brooklyn CBD; however, we believe that the values presented are reasonable estimators for most large CBDs.

Parking Patterns of PUD Vehicles

Observations from 686 samples in downtown Brooklyn showed that 98 percent of all PUD vehicles were parked within 30 m (100 ft) of the destination establishment. This pattern was followed independently of curb parking regulations. If a driver did not find a curb parking space within 30 m (100 ft) of his or her destination, he or she would double park to pick up or deliver goods. This parking pattern is a result of driver habit, truck security, and efficient truck operations.

Dwell Times

Data on vehicle dwell time for pickup and delivery of goods by land use were also collected. Table 1 gives the summary of findings. Two dwell times are shown for the other retail or commercial land use because the legality of parking had a significant effect on length of stop. For the other land uses, no significant differences were found.

Trip Generation

The analysis of the number of PUD vehicle trips generated by sample sites in a large CBD was done by Loebl (12). His work demonstrated that the number of PUD vehicles generated by a retail or commercial establishment is a function of the number of different commodities typically picked up and delivered to that establishment in an average week (Monday through Friday). This number of different commodities was defined as the specialization index of the establishment and was labeled C. Table 2 (12) gives the specialization indexes for retail and specialty establishments. Dividing Loebl's weekly generation by 5 to get daily generation gives $T = -3.3 + 1.8C$ where C = specialization index of the site. For example, an appliance store would be expected to generate $-3.3 + (1.8 \times 3) \cong 2$ PUD trips on the average day.

OVERVIEW OF ECONOMIC RATIONALE

A decision to allocate a portion of the curb space in the CBD for loading and unloading of goods will inherently result in impacts to varied interest groups. Providing no space for goods movement at curbside increases the probability of a double-parked PUD vehicle that would adversely affect traffic flow. The provision of a segment of curb space (in time) for goods movement would reduce the traffic impact but increase the impact on the curbside parkers who must seek alternate accommodations. If the quantification of these varied impacts can be brought to a common basis, then a curb use allocation governed by the minimization of this denominator should be possible. Such a minimum-impact allocation procedure could be justifiable as a rational tool for CBD application.

The base to which the varied impacts will be reduced in this study is equivalent dollars because data are available to attempt such a quantification of impacts. The object, therefore, would be to choose a curb allocation scheme based on a set of given conditions that would keep the costs of impacts on society to a minimum. The cost to society for allocating curb spaces to PUD vehicles can be expressed as

$$C(s) = c_1(s) + c_2(s) + c_3(s) + \ldots \quad (1)$$

where $c_i(s)$ = cost to interest group i of allocation spaces. Because the individual $c_i(s)$'s in equation 1 are not all analytically expressible, the procedure for finding the minimum cost solution would be to evaluate C(s) for increasing values of s (beginning with s = 0) until the minimum C(s) is achieved.

IDENTIFICATION OF SOCIETAL COSTS

A PUD vehicle arrives and the driver, seeing no available parking space for his or her vehicle within search range, double parks. This paper will first evaluate the costs associated with S = 0 (no allocation). The cost of dislocating one or more automobile parking spaces from curbside to accommodate the PUD vehicle or vehicles at the curb is then determined for various sizes of loading zones.

Cost of Zero Allocation

The cost of an illegally double parked PUD vehicle is borne by the affected traffic and the community through increased delays, air pollution, and road user costs. It has not been substantiated that accident rates vary with vehicle speeds [between 16 and 40 km/h (10 and 25 mph)] typical of urban street system conditions (4, 5); therefore, this element has been omitted at this time for evaluating costs of alternatives.

The travel delays caused by a double-parked PUD vehicle can be estimated by using the Urban Traffic Control System Simulator (UTCS-1). The UTCS-1, a microscopic-oriented program, can simulate the incremental effect on "normal" traffic operations of a blocked lane for given base conditions, such as traffic volume, block length, and cycle length (6).

The dollar cost of the delays attributable to the double-parked vehicle is calculated by applying a value of time to these delays. This paper assumes $2.20/h/person as the cost of time for passenger delays (automobile and public transit) and $6.00/h for truck drivers. The value of time has been shown to depend on trip purpose, income of traveler, and the size of a trip delay (7). The values used in this paper are representative of current findings and, in our opinion, reasonably conservative.

The increased operating costs due to incremental congestion are primarily attributable to the increased number of stops and starts caused by the blockage. This increased number of stops results from maneuvering as well as from missed progression in the signal system.

The UTCS-1 outputs data on the number of stops as well as average travel speed before, during, and after the blockage. Curry and Anderson, in a 1972 study (8), evaluated the increased cost of stopping and regaining speed. Because of the recent dramatic increase in operating costs, the values developed in that 1972 study have been increased by 50 percent to approximate 1976 conditions. The incremental operating cost of a blockage if a 25-km/h (40-mph) speed after stopping is assumed is about $6.00/1000 stops for automobiles, and $12.00/1000 stops for buses and trucks.

Incremental air pollution can be estimated from UTCS-1 output data by using an equivalent vehicle-kilometer of travel per minute of delay. If a vehicle spends 1 min of extra time on a block, then the amount of air pollutants emitted by that vehicle during that minute is the incremental pollution. The number of kilometers that this vehicle would travel in 1 min is equal to the speed before blockage times 1 min. Table and charts for air pollution give values per vehicle-kilometer of travel. The vehicle-kilometers of travel (actual) do not increase because of the blockage; therefore, the estimation of an equivalent vehicle-kilometer of travel is necessary. The quantity of incremental air pollution (carbon monoxide and hydrocarbons) after the equivalent vehicle-kilometers of travel have been calculated can be estimated from the research findings of Beaton, Skog, and Ranzieri (9). The U.S. Environmental Protection Agency's estimates for oxides of nitrogen for 1975 vehicles (typical mix) is about 3.2 g/km (1.99 g/mile) (13).

To quantify the economic impact of this increased pollution on the public at large, a dollar cost per unit of pollution is necessary. Pylyp's research (10) evaluated the cost to the community of these pollutants as they affect health, vegetation, residential property, and the like. The values recommended are as follows:

1. 0.0004 cent/g for carbon monoxide,
2. 0.04/cent/g for particulates,
3. 0.10 cent/g for sulfur dioxide,
4. 0.03 cent/g for hydrocarbons, and
5. 0.02 cent/g for oxides of nitrogen.

Some of these unit costs are applied to the incremental pollution to determine dollar impact.

Consumer costs are not included in the evaluation because these costs are reflected in the resultant cost to the carrier as part of the traffic stream. As was discussed in the section on parking patterns, there does not appear to be any measurable cost to the trucker if parking is or is not available (except for parking tickets).

Cost of Nonzero Allocation

The costs associated with allocating specific segments of the curb to trucks relate to the impact of dislocating automobile parkers from curbside plus the resultant impact incremental to moving traffic. This incremental impact should decrease as spatial allocation increases. The major portion of this cost is the cost of dislocating parkers from the curb and, as a result, the replenishment of an equivalent amount of off-street parking spaces (these vehicles cannot be displaced to other curb space because the supply of such spaces is not expandable). The cost of providing parking spaces for displaced parkers is construction cost, maintenance and operation cost, and land acquisition costs. These off-street parking spaces may be in garages or in parking lots.

The cost to the parker of being dislocated is primarily in time lost in parking and unparking the vehicle in an off-street facility as opposed to curbside parking. The other cost to the displaced curb parker is the additional parking fees paid for off-street parking. This cost, however, has already been included by the consideration of construction costs, maintenance costs, and the like for providing the additional off-street spaces that are paid for by parking fees. Thus inclusion of the incremental parking fees would be double counting.

The perceived cost of loss of business by the retailer when curb space is removed from shopper use is a cost that need only be evaluated for CP 2 because of the patterns associated with these users. This perceived cost can be neglected altogether if all off-street spaces are located in a manner such that the shopper patterns are unaffected. If the shoppers are displaced to an area undesirable to the parker or if the shoppers' needs are not satisfied, then the actual and not the perceived cost of loss of business must be considered. The concept, therefore, of replenishing parking spaces at desirable locations when they are removed from curbside for the accommodation of PUD vehicles is one that is consistent with CBD economic enhancement.

The difference in the parking and unparking time for curb and off-street spaces is a delay cost to the parker. The maneuvering time for entering and departing a parallel curb parking space has been shown to be about 1 min (11). The amount of time spent in an off-street facility will vary widely with the type of facility. For lots, the parking plus unparking time may be 2 to 4 min; the time would be as much as 10 min for large garages. The difference between the parking plus unparking time at the curb and at the off-street facility is translated into cost with the use of $2.20 as the value of time.

Providing off-street parking facilities for the automobile parker has the benefit of reducing to almost zero the circulating time usually consumed in the search for a curb parking space in the CBD. Depending on the downtown area this circulating time may or may not be significant. The value of this benefit would primarily be the time savings to the parkers times the value of their time in dollars. Another potential benefit to providing off-street parking would be the reduction in accidents while the automobiles are circulating on the street in search of a curbside parking space. Accidents are not included because savings are negligible compared to the other costs included (less than 0.001 accident/displaced automobile parker/year).

COMPARISON OF ALTERNATES

In the simplest sense, if the cost to society caused by double-parked PUD vehicles is not greater than the cost to displace automobiles from curbside, then the PUD vehicles should remain double parked. The displacement of curbside spaces will depend on the existing as well as short-term future traffic conditions on the street, for the severity of impact of a double-parked vehicle will increase with traffic volume. The higher the impact on traffic is, the more curbside spaces there will be that can be displaced to ensure that PUD vehicles do not double park.

The first step is evaluating the $S = 0$ condition to determine societal costs. If $C(0)$ is less than the cost of displacing two automobile spaces (one truck space) from curbside, then the least cost solution is $S = 0$ or no loading zone. If $C(0)$ is greater than the cost of displacing two curbside automobile spaces, then $C(S = 1, 2, 3, \ldots, n)$ are evaluated to find the value of S that minimizes $C(S)$.

APPLICATION OF LEAST COST APPROACH TO A CASE STUDY

The case study described is a street with three moving lanes for traffic in each direction and curbside parking. A 180-m (600-ft) block face was considered in the case study with 60-s cycle lengths and a 50-50 split. The PUD vehicle was double parked in the model at various points along the block face to evaluate the impact of double-parking location on resulting delays to moving traffic.

Cost of Zero Allocation

In the case study, the UTCS-1 was run for a simulation period of 4 min to achieve a stable flow of traffic. Then, a blockage was placed in the right lane for a period of 12 min, the typical double-parking dwell time (Table 1). The blockage was then removed from the lane and flow was allowed to resume in the three lanes along the block face for a period of 8 min to determine when "stable" conditions again prevailed. The volume to capacity ratio v/c was varied in different simulations to evaluate the effect of different traffic flows. v/c ratios of 1.0, 0.95, 0.85, 0.75, and 0.50 were tested.

Data for estimating incremental time delays, operating costs, and air pollutants were developed from the UTCS-1 simulations for various traffic volumes and different double-parking locations along the block face. Figure 3 shows the results of the simulation for incremental delays to traffic caused by the lane blockage. From Figure 3, one can see that the amount of incremental delay to the traveling public does vary with the v/c ratio and the location of the blockage.

Figure 4 was developed by using data from several simulations and calculating the annual cost of the blockage on the traffic stream (of one typical 12-min stop made daily) and on the community through increased air pollution. This figure shows the annual cost of one daily 12-min lane blockage for a family of conditions that can occur on a three-lane street with parking when an arriving PUD vehicle double parks in one of the travel lanes. The difference between the curves for CPs 1 and 3 and CP 2 in Figure 4 is that, in CPs 1 and 3, 5 percent buses (35 persons/bus) is assumed for calculations and, in CP 2, 2 percent buses (20 persons/bus) is assumed.

The term block section is defined as a 60-m (200-ft) section of the block face. This definition is desirable because, as presented previously, drivers will park their vehicles within 30 m (100 ft) of their desired destination, which implies a 60-m (200-ft) parking section for PUD vehicles.

Cost of Nonzero Allocation

The annual cost associated with displacing one curbside automobile space in downtown Brooklyn is approximately $1150 in CP 1 and CP 3, and $1050 in CP 2. These costs are derived from the assumptions presented previously.

Least Cost Solution

Finding the least cost solution is aided by transforming the impact on traffic of one typical double-parked vehicle into an equivalent number of curb spaces that could be economically displaced. Table 3 gives the impact on traffic of one daily double-parked PUD vehicle in terms of equivalent displaced automobile spaces (EDAS). Table 3 was developed by dividing the costs of impacts on traffic from Figure 4 by the cost of displacing one curbside automobile space (typical values presented previously). It is noted that the v/c ratio of 0.50 is the practical lower bound value below which, for this case study section (three lanes), the impact of double parking on traffic is not clearly identifiable.

On most block sections, the double-parking rate of PUD vehicles is rarely 1/h daily. Therefore, the actual number of double-parked vehicles as well as the resultant impact on traffic must be estimated. If a moving lane is blocked for T min in an hour, the impact on traffic can be conservatively estimated at T/12 times the impact of the standard 12-min lane blockage. A more elaborate explanation of this is available elsewhere (1). Within any 60-m (200-ft) block section, there are about five loading spaces for PUD vehicles in the moving lane. For typical retail or commercial activity, the average dwell time when the PUD vehicle is double parked is 11 min. The UTCS-1 simulations considered 12-min blockages after additional time for "parking" maneuvers was taken into account.

The moving lane is blocked when one or more PUD vehicles is double parked at any time. The five possible truck spaces for PUD vehicles in a 60-m (200-ft) section can be considered as five independent servers each with an exponential mean (though more precisely, a gamma mean in which A = 1.25) of 12 min. The independence of servers can be assumed because the portion of the dwell time that most detracts from this independence is internal time, which is a small portion of the total stay (3). For office buildings and retail food establishments, the internal time is independent of parking conditions because of the type of internal functions performed by the driver at these land uses.

It should also be noted that not all arriving PUD vehicles will double park; therefore, the double-parking population must first be extracted from the gross arrivals. If a Poisson arrival pattern for double-parking PUD vehicles within each hourly period is assumed, then the probability of having no double parkers in the system at any time can be readily estimated, given that no more than five such parkers can be accommodated at any one time. Table 4 gives these estimates.

Sample Block Segment

Applying the known information to develop curb space usage is now considered for a case study midblock segment [60 m (200 ft) long] that generates PUD vehicles. This block segment has two restaurants, two shoe stores, two clothing stores, a jewelry store, an appliance store, and a bank. Table 5 gives the arrival pattern of PUD vehicles to this block segment.

The procedure for determining curb usage based on the given conditions (traffic, street section, and PUD vehicle generation) is as follows. The overall PUD vehicle generation rate to the sample block section is determined for each hour of the typical day (only 7:00 a.m. to 7:00 p.m. need be considered). From this overall generation, the arrival rate for the double-parking population is calculated by using the findings from Figure 2, Table 2, and Table 4. By using the procedure outlined previously, one estimates the number of minutes in each hour that the moving lane is blocked due to a double-parked PUD vehicle. From this estimate, the equivalent 12-min impact is read directly from Table 4. The annual cost of the impact of double-parked PUD vehicles on traffic is the value read from Table 4 multiplied by the equivalent 12-min impacts in each hour. The total impact in the conflict period is thus the sum of the hourly impacts.

From Table 5, the societal impacts in CP 1, CP 2, and CP 3 are 10.8, 2.7, and 0.1 EDAS respectively. Therefore, in CP 3, the least cost solution would be to have zero allocation because to provide one truck space would be to incur a societal cost of at least 2.0 EDAS. However, in CP 1 and CP 2, the least cost solution may or may not be zero allocation and can only be determined by further calculations.

Table 6 gives a summary of the calculations for CP 1 and CP 2 to determine societal costs and thus the least cost solution. In CP 1, one can see that, as zone size S increases, traffic impact decreases and displaced parking impact increases. The least cost solution in CP 1 is to have a loading zone capable of accommodating two PUD vehicles at the same time. In CP 2, the least cost solution is to provide no space for PUD vehicles even though this is the period when most of these vehicles pick up and deliver their goods.

OVERVIEW

Changing policy to establish curbside loading based on least cost could find justification in cities that must improve air quality (as traffic delay decreases so do air pollution emissions). However, to improve this environmental aspect, local governments, most of which are

Figure 1. Typical nongoods curb space demand patterns.

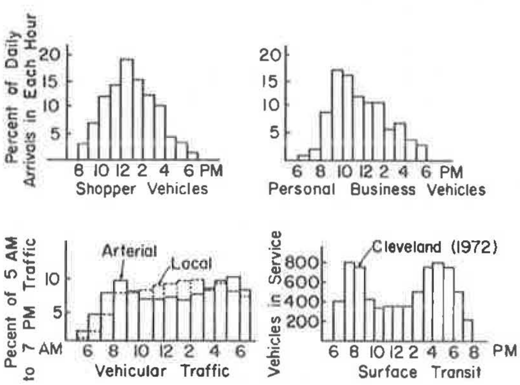

Figure 2. Selected hourly PUD vehicle arrival patterns by land use in Brooklyn CBD.

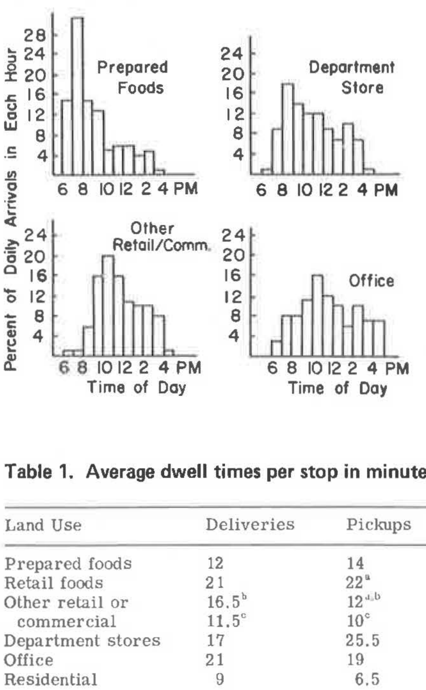

Table 1. Average dwell times per stop in minutes.

Land Use	Deliveries	Pickups	All
Prepared foods	12	14	12
Retail foods	21	22[a]	21
Other retail or	16.5[b]	12[a,b]	15.5[b]
commercial	11.5[c]	10[c]	11[c]
Department stores	17	25.5	18
Office	21	19	20
Residential	9	6.5	8

[a]Estimated from very small sample.
[b]Legal curb parking.
[c]Illegal curb parking.

Table 2. C-values for retail and specialty establishments.

Type of Establishment	C-Value	Type of Establishment	C-Value
Prepared foods	5	Fabrics	3
Shoes	3	Banks	4
Clothing	4 to 5[a]	Appliances	3
Furniture	3	Electrical and camera	3
Jewelry	3	Retail foods	4 to 7[a]
Department store	15	Flowers	3
Wigs	3	Liquor store	4
Drug store	6 to 8[a]	Miscellaneous	3
Stationery	2		

[a]Size dependent.

Figure 3. Incremental traffic delays per 12-min blockage.

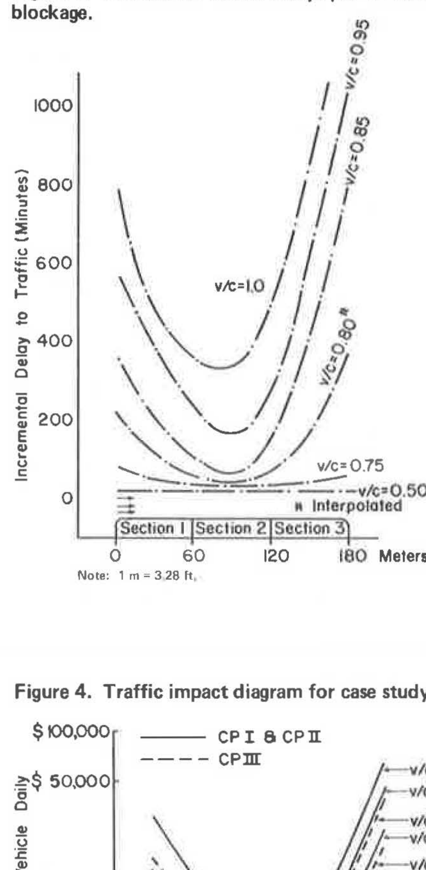

Figure 4. Traffic impact diagram for case study.

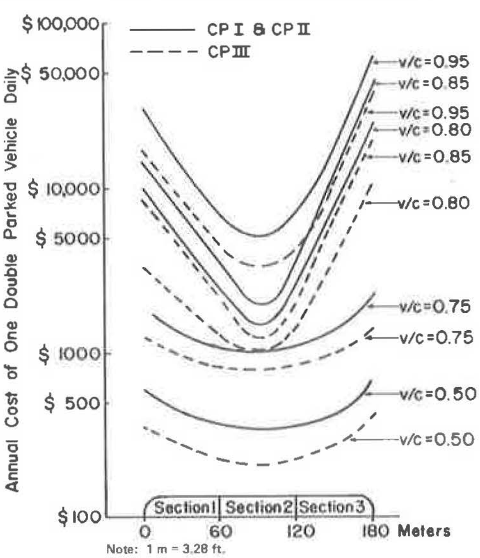

Table 3. Curb space equivalents of traffic impact of one 12-min double-parked goods vehicle daily in CBD.

Conflict Period	v/c ratio	EDAS Section 1 Block	EDAS Section 2 Block	EDAS Section 3 Block
1 and 3	1.00	17	10	27
	0.95	11	5	17
	0.85	6	2.4	11
	0.80	5	1.7	7
	0.75	1.1	1.0	1.2
	0.60	0.7	0.6	0.9
	0.50	0.3	0.2	0.3
2	1.00	10	6	15
	0.95	6	2.8	10
	0.85	3.3	1.3	6
	0.80	1.6	1.0	3.1
	0.75	0.7	0.6	0.5
	0.50	0.2	0.2	0.2

Note: v/c ratios of 0.80 and 0.60 were interpolated.

Table 4. Estimates of lane blockage by arrival rate.

Double Parker Arrival Rate Per Hour[a]	P(0)[b]	1 - P(0)	Minutes Occupied	T/12
0.5	0.90	0.10	6	0.5
1.0	0.82	0.18	11	0.9
2.0	0.67	0.33	20	1.7
3.0	0.54	0.46	27	2.3
4.0	0.43	0.57	34	2.8
5.0	0.34	0.66	40	3.3
6.0	0.25	0.75	45	3.8
7.0	0.18	0.82	49	4.1
8.0	0.12	0.88	53	4.4
9.0	0.08	0.92	55	4.6
10.0	0.05	0.95	57	4.8

[a]25 percent of arrivals double park from 6:00 a.m. to 8:00 a.m.; 37 percent double park from 8:00 a.m. to 9:00 a.m.; and 49 percent double park after 9:00 a.m. (1).
[b]Probability of no lane blockage.

Table 5. Estimating impact of PUD vehicles by displaced curbside automobile parking spaces.

Critical Period	Time Period	v c Ratio[a]	Gross Generation Rate Per Hour[b]	Double Parker Arrival Rate Per Hour	Equivalent 12-Min Impacts	EDAS
1	7:00 a.m. to 8:00 a.m.	0.85	3.1	0.8	0.7	1.7
	8:00 a.m. to 9:00 a.m.	0.95	2.7	1.0	0.9	4.5
	9:00 a.m. to 10:00 a.m.	0.85	4.7	2.3	1.9	4.6
	Total					10.8
2	10:00 a.m. to 11:00 a.m.	0.75	4.9	2.4	2.0	1.2
	11:00 a.m. to 12 noon	0.60	4.1	2.0	1.7	0.5
	12 noon to 1:00 p.m.	0.70	3.0	1.5	1.3	0.6
	1:00 p.m. to 2:00 p.m.	0.55	2.6	1.3	1.1	—
	2:00 p.m. to 3:00 p.m.	0.50	2.7	1.3	1.1	—
	3:00 p.m. to 4:00 p.m.	0.70	1.9	0.9	0.8	0.4
	Total					2.7
3	4:00 p.m. to 5:00 p.m.	0.75	0.2	0.1	0.1	0.1
	5:00 p.m. to 6:00 p.m.	0.75	—	—	—	—
	6:00 p.m. to 7:00 p.m.	0.50	—	—	—	—
	Total					0.1

[a]v/c ratio past the sample block face in one direction.
[b]Using Table 2 and Figure 2.

Table 6. Identifying the least cost solution.

Conflict Period	Zone Size	Traffic Impact (EDAS)	Displaced Parking Impact (EDAS)	Total Impact (EDAS)
1	0	10.8	0	10.8
	1	5.8	2	7.8
	2[a]	0.5	4	4.5
	3	0	6	6.0
2	0[a]	2.7	0	2.7
	1	2.3	2	4.3

[a]Least cost solution in respective conflict period.

economically strained, would have to explicitly accept in principle to construct off-street automobile spaces as defined in the methodology. Actually, in our opinion, the establishment of loading zones based solely on least cost will result in an overall increase in the on-street automobile parking supply over current conditions.

There are several assumptions in the method, one of which is the assigning of a value to time. A higher value of time would place more pressure for the removal of additional curbside automobile spaces. The methodology does not restrict itself in any way, and the only reason for the use of any figures, costs, and the like in this paper is to show that reasonable results would be attainable when typical characteristics were assumed.

One potentially important by-product of the approach described in this paper concerns the impact of traffic as a function of block length. Figure 3 shows how the location of a double-parked vehicle affected delays. Although only 180-m (600-ft) block length was evaluated in the case study, the findings have implications concerning the inefficiency that is built into street systems that have short block lengths. One notable street system is that of Manhattan where the block lengths on the major arteries are only 60 m (200 ft). Congestion from goods movement in Manhattan has prompted studies to achieve more efficient operation. It may not be that goods movement process is inefficient but that the very short block lengths contribute disproportionately to the congestion where, in another CBD with the same goods movement activity, resultant congestion would be less severe because of longer block lengths.

This least cost approach is not directly sensitive to environmental considerations in terms of relative weight. This is a problem faced by most economic-based solutions to transportation problems. One method of circumventing this limitation would be to develop a "perceived cost" of air pollution and input this cost into the total cost function.

Goods movement has to be treated as one element in the urban transportation picture and not be treated as an entity. The least cost approach to solving curbside spatial allocation responds to this principle. The approach is one whose rationale can be identified. It is an economic rationale, a least cost approach for a given set of conditions. The method for finding this least cost solution does reflect reasonable curb management conclusions for the CBD. For roadways with high v/c ratios, the least cost solution shows that ensuring no double parking in travel lanes by PUD vehicles can be justified and, on low volume streets, that the installation of loading zones by removing on-street automobile space is a questionable practice.

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