ON-STREET PARKING METER BEHAVIOR

Aaron Adiv
Wanzhi Wang

Center for Transit Research and Management Development
University of Michigan Transportation Research Institute
2901 Baxter Road
Ann Arbor, MI 48109

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FINAL REPORT

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16. Abstract

This study employed empirical data about use of on-street parking meters to examine questions of parking behavior, violations, enforcement, and revenue. The City of Ann Arbor, Michigan was used as a case study.

This study utilizes two sources of data: (1) historical data about parking meter performance for a period of over twenty years, 1965-1986; (2) a survey of selected on-street parking meter sites in downtown Ann Arbor.

The study found a high level of parking meter violations and a low level of enforcement. About one in three parked vehicles violated meter regulations,while only one in twenty (5.9%) was issued a citation. In spite of these facts, the study concludes that, for the most part, on-street parking meters efficiently performed the task of allocating a limited supply of preimum short-term curb parking.

However, the study also discovered that "exceeding the limit" violations are substantially under-reported and under-enforced. While they involved 34.6% of the on-street meter violations, they accounted for only 3.3% of all citations. Eliminating this "hidden" violation could increase parking capacity by up to 25%.

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INTRODUCTION

On-street parking meters are nowadays an integral part of the American and western nations' urban landscape. It seems as if they have been there forever. However, in reality they have existed for only fifty years. Parking meters were first installed in Oklahoma City in July,1935 (Associate Retailers of Indiana). By 1947, they were adopted by 888 cities, mostly of small and medium size. At that time, only approximately one-third of the largest cities (about 0.5 million population) adopted parking meters, averaging 1,430 per city. By now it is hard to imagine a city, large or small, not having on-street parking meters. For comparison, in 1985 a large city (1.0 million or more) averaged 22,600 on-street metered spaces (Institutional and Municipal Parking Congress (IMPC), 1986). Parking meters seem to remain the domain of western nations. For example, Saudia Arabia, which exhibits high car ownership and faces strong congestion problems, has no parking meters. In order to provide employment to full-time parking attendants, some developing countries (e.g., St. Lucia) avoid parking meters.

The rationale for installing on-street parking meters in the U.S. has not changed much over the last fifty years, even if their number and intensity of use has grown. The goals of on-street parking meters are: to promote parking turnover; to act as a means of distributing a limited amount of on-street spaces (mainly in commercial areas) where demand exceeds supply; to provide short-term parking spaces for shopping or personal errands (this in contrast to long-term parking for commuters); to improve traffic circulation and economic viability of downtown commercial areas by maximizing the number of patron visits by car; and to generate revenue for the city. The main advantage of parking meters is that they are highly visible: they raise a red flag when their (short-term) legal use is expired. They are supposedly "self enforcing," in that they do not require a continuous man-power attendance to collect fees (meters are emptied only once or twice a week), or to supervise that they are being used only for short-term parking. The fact that the parker himself activates a mechanism which begins immediately to count time is supposed to make him aware of when his time expires, and eventually lead to better observance of parking regulations, compared to non-metered areas.

All of this is true so long as the drivers obey the law, park only for the legal time limit , and pay the required fee. However, it is common knowledge that parking regulations in general, and those concerning parking meters in particular, are often violated. Ross (1961) termed parking violations as "folk crime," which means that "the population that engages in illegal parking is virtually a replication of the entire adult community." A recent survey of the Institutional & Municipal Parking Congress (1986) validates this notion of "folk crime" in a different way: in

59.3% of U.S. municipalities, parking violation is defined as a civil offence, and only in 25.9% as a criminal offense (in 14.8% "other").

In spite of the built-in mechanism for self-activation, the explicit indication for remaining time, and the red flag, it is quite clear that parking meters are not "self-enforcing." Parking regulations and parking management are effective only as long as they are accompanied by, and associated with, strong enforcement by the police or other parking enforcement agencies. Notable experiment and detailed evidences for the effectiveness of strict parking enforcement can be found in a study in Washington, D.C. (Cima and Hildebrand, 1982). Other cities known for their successful strict enforcement policies are Boston, Denver, Colorado Springs, and Billings, Montana.

In spite of the widespread usage of parking meters as a means of controlling utilization and circulation of curb parking by motorists in central city commercial areas, there is a lack of systematic knowledge about parking behavior at parking meters: What is the average length of stay at a meter? What is the turnover and productivity of meters? Are meters effective in providing short term parking? What proportion of the parkers violate their usage? Which types of violations are more prevalent -- exceeding time limit, or under-payment? What proportion of the violators are ticketed? What is the elasticity of violations with respect to parking fees and parking penalties (tickets)? etc.

A comprehensive study which investigated these types of questions was conducted thirty years ago by the US Bureau of Public Works (1956). Later studies such as "A survey of Local Government Action" by the National League of cities (Heath, Hunnicutt, Neale, and Williams, 1976), and the recent "Public Parking 1986, Statistical Guide to parking in North America" by the Institutional and Municipal Parking Congress (1986), estimated the number of on-street parking meters, and their fee rates. However, they were not concerned with behavior and violations. DeBartolo, Preusser, and Blomberg (1978), who conducted an extensive review of the literature on on-street parking behavior and violations (covering 160 citations), indicated that "only two experiments directly involving parking behavior were identified and reviewed": Moore and Callahan (1940), and Chambliss (1966).

A gap seems to exist between the subjective perception of the average driver, who feels that the authorities are wasting public funds on enforcement of meter violations instead of fighting real crime, and the objective enforcement. The average parker feels that he is overly penalized (ticketed), that the police are on the "look-out" for him, and that he is being ticketed unjustly when his meter "just expires." At the same time, parking authorities tend to argue that their enforcement personnel are too few, and that as a result the city is loosing revenue from parking fees, and that

circulation is reduced due to lack of short-term parking. There is also a debate about the effectiveness of increasing fees, and/or penalties as a means for reducing violations. Some researchers (e.g., Shoup, 1984) argue that on-street parking fees are set too low relative to adjoining off-street commercial rates. This distortion in resource allocation leads to excessive cruising for on-street parking, which is wasteful in terms of energy, time, and air pollution. Only a drastic increase in meter fees, he argues, could eliminate this cruising. In contrast, downtown merchants argue that an increase in fees and/or penalties will discourage further shopping downtown.

This study employed empirical data about use of on-street parking meters in Ann Arbor to examine questions of parking behavior, violations, enforcement, and revenue discussed above. It utilizes two sources of data:

(1) Historical data about parking meter performance for a period of twenty years, 1965--1986, maintained by the Ann Arbor Department of Transportation.

(2) Survey of selected on-street parking meter sites in downtown Ann Arbor conducted during December, 1985, March, 1986, and June, 1986. The survey recorded parking meter usage, violations, and enforcement at twenty-minute intervals over the same block(s) area.

The study focused on on-street parking meters because they provide premium legal locations (in terms of minimizing walk time) downtown. They are major policy instruments for inplementation of short-term parking for a door-to-door service. They occupy public domain (i.e. streets) which belong to, and are paid by, the public at large, and as such should be open to all. Finally, "expired meter" is the most commonly cited parking violation-- a genuine "folk crime." For example, "expired meter" accounted for 58.5% of all citations issued in Ann Arbor in 1985. Being such a large group, those citations deserve attention and understanding.

The paper is organized in the following way: The next section is a review of the literature about parking in general, and parking meters in particular. It is followed by an analysis of on-street parking meter data in Ann Arbor over the last twenty two years. Data are first presented in graphical form, and later used to estimate models correlating meter revenue with fees, penalties, enforcement, etc. This is followed by a description and analysis of the 1985/86 on-street parking meter survey, and a conclusion.

PREVIOUS WORK

Violations of parking meter regulations are part of wider phenomen involving relationships among compliance with traffic and parking laws, enforcement of these laws, drivers' perception of risk, and the tradeoffs among time, cost, and expected penalty as an explanation to parking behavior. An extensive annotated review of the literature on these matters, covering the period until 1977, was conducted by DeBartolo, Preusser, and Blomberg (1978) as part of their study on enforcement of parking regulations in residential neighborhoods of New York City.

This study in New York City represents a new trend in parking experimentations and analyses, since the late 1970's, concerning parking management, including strict enforcement of parking regulations. For studies which summerize results of experiments throughout the country see: "Innovations in Parking Management" (US DOT,1982), and "Parking and Traffic Enforcement" (Urban Consortium, 1980). Enforcement as a major component of Transportation Systems Management (TSM), and of parking management, is discussed in Ellis (1982), Tanaka and Meyer (1981), and in Meyer and Sheldon-Dean (1981, 1981(a)). In general, studies on strict enforcement tend to indicate that stricter enforcement policies reduce quite substantially parking violations, free parking spaces, and "pay for themselves" in that revenue due to higher rate of citations and collections of fines exceeds the cost of extra personnel and equipment. In fact, stricter enforcement can be a revenue-generating instrument for municipalities.

Perhaps the most comprehensive parking enforcement program in the United States in recent years has been implemented in Washington, D.C. This Parking Enforcement Program (PEP) in Washington D.C. is also the most documented program in terms of its operations and effectiveness. The evaluation study of the program, supported by the U.S. DOT (Cima and Hildebrand, 1982), is one of the few published sources which provide information on violation rates and enforcement rates of on-street parking regulations in American cities. In spite of the growing interest in enforcement, the only national data on violation and enforcement ratios that we could identify were from the mid 50's (U.S. Bureau of Public Roads, 1956). Due to this lack of information, our study depends, for the most part, on data from Washington D.C. for comparison and verifications of results in Ann Arbor.

A similar enforcement and evaluation project, which provides measures of violations, enforcement, and utilization of on-street parking, was carried out recently in the central section of London, England. The program, with particular emphasis on clamping (booting), is discussed by Kimber (1984). Elliott and Wright (1982) developed a model which explains the the collapse of parking enforcement in large towns, using "catastrophe theory" (Zeeman, 1977) as a framework, and London as a case in point.

Most research, and we as well, consider parking violation a rational activity. The illegal parker weighs the expected cost of being caught and penalized against the benefits of parking illegally close to his final destination. Major benefits are savings of walk time, cruising (searching) time, and parking fee. When benefits exceed costs, illegal parking seems a rational choice. Gur and Reimborn (1984) specified and tested a disaggregate parking behavior model, where disutility of parking was defined as the weighted sum of these benefits and costs. The results confirm initial expectations that increased enforcement and penalties reduce illegal parking, while an increase in the value of walking and searching time will increase this activity.

The literature argues that parking violation, being a rational crime, is more likely to be influenced by punishment than are expressive-emotional crimes (e.g., assault , murder). Stricter enforcement experiments support this argument. On the other hand, social pressure (moral restrictions) tends to be ineffective, particularly with respect to parking-meter violations which, as desribed above (Ross, 1961), are "folk crimes"--crimes committed by a replication of virtually the entire adult population.

Parking Meter Violations and Probability of Being Caught

Parking illegally is essentially gambling against the odds of being caught and issued a citation, and of being forced to pay it. The expected value of a ticket from the violator's viewpoint is the value of the fine multiplied by the probability of being caught. So, for example, if the fine on "expired meter" is $3.00, and if only 10% of these violators are ticketed, the expected value of the fine is only 30 cents (300¢ x 0.1), which is about equal to the 1986 average hourly rate in cities of 100,000 population (IMPC, 1986). In turn, the probability of being caught is a function of the enforcement intervals by the policing agency's personnel. Derivation of this probability is shown below.

On-street parking meters have a designated time limit to encourage short-term parking (typically one hour in downtown). The two most common violations of parking meters are:
(1) "Insufficient payment." A driver parks for a legal duration which does not exceed the time limit, but pays only part of the fee for that duration, or none at all.
(2) "Exceeding time limit." A driver parks at the same metered-space for a duration longer than the legal time limit. He violates the meter regulations even if he pays for the extended stay. This is known in conmmon language as "meter feeding."
Other violations of on-street meters could involve usage by unqualified vehicle (e.g., private vs. commercial), during restricted hours (e.g. morning peak on an arterial), etc.

In case of "insufficient payment," the enforcement personnel (police or civilian) can easily

spot and determine when violation occurs. The probability of being caught (P) is given by equations (1):

(1) $P = PK(i) / INT(i,)$ when $0 <= PK(i) <= INT(i)$

$P = 1$ when $PK(i) > INT(i)$

Where:

P = probability of being caught for "insufficient payment,"

PK (i) = length of illegally parking, in i (minutes),

INT (i) = enforcement interval, of i (minutes).

Examples: if the illegal parking period equals or exceeds the enforcement interval, obviously there is 100% chance of being caught (P =1). If the illegal parking is equal to, say, 5 minutes, while the enforcement interval is 20 minutes, there is a 25% chance of being caught (P= 5/20 =.25) from equation (1), and so forth.

In the case of "exceeding time limit" (e.g., parking for two hours at a one-hour meter), the enforcement officer must first record the licence number of the parked car, or more commonly, chalk-mark the tire during his first surveillance of the metered space. Only during a second visit, when a car is found to exceed the time limit, can a ticket be issued. The probability (P) of being caught for this violation is given by equations (2) :

(2) $P = [PK(i) - LIMIT(i)] / INT(i)$ when $LIMIT <= PK <= LIMIT+INT$

$P = 1$ when $PK > LIMIT+INT$

where:

P = probability of being caught for "exceeding time limit,"

PK(i) = parking duration of i (minutes),

INT(i) = enforcement interval of i (minutes).

Examples: if one parks for 1.5 hours (90 minutes) at a 1.0 hour (60 minutes) meter, where enforcement occurs every 20 minutes, his parking time (90 min.) exceeds the sum of limit plus interval (80 min), and there is 100% chance of being caught. If at the same meter and interval, one parks for 70 minutes, his probability of being caught is derived from (2):

$P = (70 - 60) / 20 = 0.5$.

ANN ARBOR: BACKGROUND

Ann Arbor, Michigan, is a college town with a total population of approximately 105,000 and a student population of almost 35,000. The University of Michigan is the largest employer, and trip generator. It employs approximately 12,000 people. In combination with the adjacent City of Ypsilanti and other small towns, Ann Arbor is the focus of a metropolitan area (SMSA by the Bureau of the Census) of over 250,000 people. The main campus, located in close proximity to downtown, and the large student population residing nearby, make downtown Ann Arbor a strong and viable area for a city of its size, or even in comparison to larger cities. Given its size, Ann Arbor is a good representative of medium-size cities (100,000 - 250,000 people). Given the vitality of its downtown, Ann Arbor can represent on-street parking behavior in larger cities.

The University is not only the largest employer, it is also the largest provider of off-street parking. In 1986 it provided 17,365 spaces, 8,492 of which, or almost half, were reserved for staff parking (at a fixed annual fee of $125). For comparison, the city, which owns and operates all commercial parking, provides approximately 4,000 off-street spaces, mainly in the downtown area, plus approximately 1,300 on-street meters.

The policies of the University concerning eligibility for use of its off-street parking facilities further justify the selection of downtown Ann Arbor as a case study in parking meter behavior. In the downtown/central-campus area, off-street University parking facilities are reserved only for faculty and staff. Their use is "free" to employees who have purchased the annual parking permit. They are allowed to park at any parking structure/lot throughout the campus area, and their marginal cost of parking at any time in these facilities is zero. At the same time, for the purpose of discouraging students from driving to the University, there are, practically, no facilities for them. Their only parking alternatives are "on-street," or in a commercial lot. The provision of "free" off-street parking to the majority of the University employees is a phenomenon common throughout the country. Nationwide Personal Transportation Studies (NPTS) since 1969 (U.S. DOT, 1969, 1980, 1985) have consistently shown that approximately 93% of those who drive to work park free. The implications for this case study are that competition for parking in downtown is not affected , for the most part, by employees who tend to park free.

Ann Arbor does not have a strict enforcement policy. Its policy might be defined as "medium." It has a civilian dedicated parking enforcement force, it uses a computer to track repeated offenders, and it uses towing and booting as a means of penalizing unpaid ticket offenders and other serious violators. However, it is not as strict as, say, Washington D.C. In that respect, Ann Arbor represents parking enforcement policies of an "average" American city. The city is also quite typical in terms of its parking enforcement productivity, at least in comparison to other

medium size cities in Michigan, as shown in Table 1.

Table 1

Parking Citation in Medium Size Michigan Cities, 1985

City	Population (1000)	Enforcement Personnel	Spaces Enforced	Citations/ Employee/ Day*	Citations/ Enforced Space
Ann Arbor	104	**12	***18,285	66	0.043
Grand Rapids	183	5	8,229	64	0.039
Lansing	128	6	7,200	63	0.052
Kalamazoo	80	7	5,100	61	0.083

* Based on 300 operating days
** 2 of these people primarily enforce parking City-wide (sidewalks, blocked driveways, etc.)
*** Including 5,000-7,000 unattended University spaces (campus housing, athletic campus, etc.), enforced mainly by University personnel; city collects all fines. Excluding restricted spaces (fire lane, handicapped spaces, etc., in all shoppping centers) and attended U. of Michigan structures.

Source: internal memo, City of Ann Arbor, February, 1986. Based on telehpone survey by the Department of Transportation.

The number of citations issued per employee per day is quite consistent in all four cities, slightly more than 60 (for comparison, in Washington, D.C. 1980, it was 109). The number of citations per enforced space is a more ambiguous measure. Because some spaces are enforced by both the City and another entity (e.g., The University of Michigan, in Ann Arbor), it is hard to assign an exclusive ratio to the City's enforcement personnel. Joint enforcement is common in many cities where large institutions (universities, hospitals, etc.) provide and control many parking spaces.

HISTORICAL TRENDS OF PARKING METER USAGE IN ANN ARBOR

Based on historical records by the City Department of Transportation over the last 21 years, 1965-1985 (plus estimates for 1986), it was possible to study the historical trends of on-street parking meter usage and enforcement, as reflected by the annual revenues from, and citations of, these metered spaces. The historical data show how revenues (gross, or per meter) relate, over time, to fees, fines, enforcement, and provision of alternative off-street parking. The data are unique in that they cover a relatively long period of time, and as such could allow one to estimate the elasticity of parking meter revenue (or demand) to levels of fees and fines, and to study the relationship among these variables. Parking meters have been in existence for 50 years, since 1935. These data cover the last 22 -- the years in which the automobile has established its dominance. The data are presented in two ways:

(1) Charts showing trend lines for the period 1965-1986, and

(2) Linear regression model correlating revenues with fees, fines, citations, and alternative parking arrangements (off-street spaces, etc.).

Chart 1 shows the annual gross revenue from parking meters, in nominal and in constant (1000's) dollars, and the total number (in 1000's) of parking violation tickets issued during the period 1965-1986. The chart also shows (on the bottom) the total number of parking meters in each year, and (in the middle) dates of changes in fees or fines.

Parking violation citations concerned all type of violations (not only meters). However, data from 1985 indicate that 58% of all tickets were for "expired meter." It seems reasonable to assume a similar rate in other years. For comparison, in Washington, D.C., 1982, 46% of all tickets were for "expired meter,"

Nominal Versus Constant-Dollar Revenues

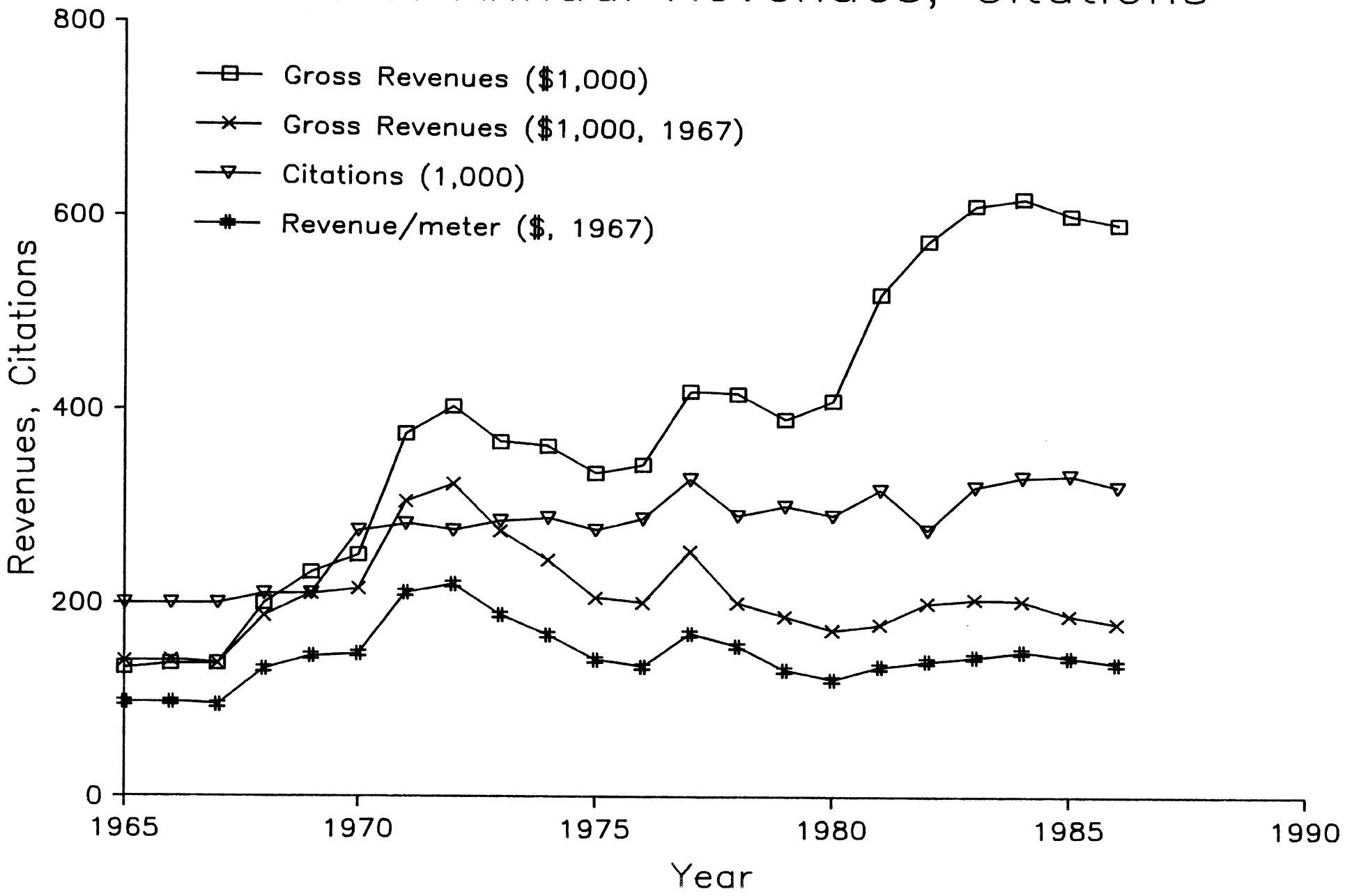
"Revenues" are from direct meter revenues, not including fines. They are shown in two ways:

(1) Nominal dollars not adjusted for inflation, and

(2) Constant dollars, 1967 = 100.0.

It is quite obvious that constant dollars provide a very different picture than the one given by nominal revenues. Until 1978 the constant dollar followed, at a somewhat lower level, the nominal path. However, from 1978 the relations are very different. The sharp increase in nominal dollars shows no significant change, or even a mild decline when translated into constant dollars.

Chart 1. Annual Revenues, Citations



During the 22-year period there were three increases in fees and two increases in fines. (This excludes the July, 1986, increase, which is too recent to assess.) Table 2 shows those changes, by period, in current (nominal) and constant (1967) dollars.

Table 2
Changes in Fees and Fines, by Year of Change
in Current and Constant (1967) Dollars

	Fees		Fines	
Year	Nominal $	Constant $	Nominal $	Constant $
1965	.05	.052	1.0	1.06
1967	.10	.100	--	--
1970	.20	.172	--	--
1975	--	--	2.0	1.35
1977	.25	.146	--	--
1978	--	--	3.0	1.53
1986	.30	.087	5.0	1.48

Table 2 shows that in spite of continuous increases, the effective fee in 1986 ($.085) was lower than the fee in 1967 ($.100). Fines in nominal dollars increased five fold (400%) over the last 22 years, from $1.0 to $5.0. However, in constant dollars they increased only by slightly more than 50%. Also, inspite of a recent (1986) increase, the effective fine was only reversed to its 1978 level of about $1.5 (in 1967 dollars). The deterioration in fees and fines due to inflation is similar to the phenomenon cited in Elliott and Wright (1982) in London, England, as one of the causes for "the collapse of parking enforcement."

On-Street and Off-Street Spaces

The number of on-street meters remained almost constant, at approximately 1,400, with a maximum of 1,495 in 1976, and a minimum of 1,300 in 1985. This is because most of downtown is built, and almost all available on-street space has been exhausted since the mid 1960's. Between 1965 and 1980, while on-street meters remained almost constant, the City, which owns and operates all commercial parking, was increasing the supply of off-street parking (surface lots and garages) in the downtown area. Off-street parking increased from about 950 in 1965 to approximately 1,500 in 1966, and to 2,200 in 1967. It further increased to more than 3,000 in 1969, and to more than 4,000 in 1980. There were no major changes since 1980 (a new commercial garage will open soon; however, its impact is not reflected in these data).

Changes in Number of Citations, Fees, and Fines

The number of parking tickets issued is almost a direct function of the enforcement personnel, where each officer issues about 60 tickets/day. The number of tickets increased substantially from 210,000 to 275,000 between 1968-69 and 1970. Between 1970 and 1975 it remained fairly constant at 270,000 to 290,000 per year. From 1975 on, it remained at a level of approximately 300,000 per year, with more fluctuations than in the early 1970's. The reason for the early growth is unclear and untraceable now. However, it is known that since 1970 the number of enforcement officers remained constant (about 12 full-time employees). This is reflected in the almost constant number of tickets issued since 1970. The fluctuations over the last ten years seem to be attributed to the civilian or police nature of the enforcement. In 1975 responsibility for parking enforcement was transferred from the police to a civilian unit (even before, most of the personnel was civilian). Since then the number of citations increased, but also the fluctuations in their number. A large increase occurred during the first two years of the civilian administration (1976-77) from 275,000 to 330,000. However, eventually it fell back to 290,000. The data seem to indicate that a dedicated civilian force of similar size could increase enforcement productivity by about 10% or more. However, its civilian nature also leads to more fluctuation.

During the 20-year period, there were three increases in fees and two increases in fines, as shown in Table 2. Chart 1 demonstrates, as expected, delayed reaction between a change in pricing and a corresponding increase in nominal revenue (given that the size of the enforcement force remained unchanged, and assuming high demand for on-street parking). However, the reactions are quite different. Both fee increases of 100% (1967 and 1970) took about 1.5 to 2.5 years to reach peak revenue. In contrast, the 25% increase in 1976 seems to have peaked immediately in 0.5 year, and then dropped back to the previous level in another year. A more careful analysis indicates that this change should be attributed to increased enforcement, rather than an increase in fee. Notice that the line indicating an increase in revenues in 1977 is almost parallel to the one showing an increase in ticketing. In 1976 enforcement moved from the police to a civilian authority. During the first year of the new management, productivity increased. However, it fell back to its "normal" level, with a corresponding reduction in revenues.

The response to increase in fine is less apparent. After the first increase (100% in 1975), revenues fell. The revenues seem to have followed a reduction in enforcement. (Note the parallel "valley" in 1975.) In contrast, ever since the 50% increase in June, 1978, revenues have been consistently increasing, even during a reduction in ticketing in 1982 , and when the number of meters decreased (since 1984). The regresssion analysis, shown below, indicates that revenues actually fall as a response to increase in fines.

In summary, Chart 1 indicates that large increases in fees lead to corresponding increases in revenues, but the response might take up to two years. People seem to avoid this kind of "price shock" by not paying the meters. However, eventually they get used to the new prices and return to their "normal" violation rate. This avoidance is a rational decision when expected fines remain constant and the fee increases. Small increases in fees did not have this effect. The policy impact of increasing fines as a deterrent is less clear. However, a regression analysis, below, indicates that the impact is negative.

REGRESSION ANALYSIS OF HISTORICAL DATA

Table 3 and Table 4 list 15 regression equation models estimated with the 22 years of data for Ann Arbor. The models estimate revenues from on-street parking as a function of on-street meters, hourly fees, tickets isssued, and fines (for expired meter), and availability of alternative off-street parking. Table 3 shows revenues in current (nominal) dollars, while Table 4 shows revenues in constant dollars (1967=100.0). A constant dollar is designated by an asterisk (*). In each model, the upper value is the coefficients, and the lower (in parenthesis) is the corresponding "student-t."

Model 1 and model 10 are the "full" models, including all five dependent variables. All other models exclude at least the explicit measure of on-street parking meters. This is because the number of on-street meters remained almost constant throughout the last 22 years, resulting in low t-values (below 2.10, at 95 % confidence interval) when included in the equation. We do not argue that the number of meters has no effect on revenues, but rather that for this particular data set, the number of on-street meters is insignificant as an explanatory variable. However, we suspect similar results in other cities, because the number of on-street metered spaces was already exhausted by the mid 1960's. Other models (not shown here) differentiated also between spaces in surface and parking garages. They were excluded because of similarity in results to all "off-street" commercial spaces. (The demand for parking was also excluded from the models. Proxies for the demand, measured in terms of traffic counts, and of built floor-space in downtown Ann Arbor over the last 20 years, showed that it remained virtually unchanged).

The R Square values for all of the models are high (0.7988 to 0.9065). However, examination of the t-values indicate that in all but two cases--models 14 and 15--some of the variables in the equations were not significant at the 0.05% level (t-value below 2.10), or even at the 10% level (t 0.10, 19=1.73); i.e., one can not reject the hypothesis that the coefficient=0.

Table 3

Regression Models: Revenues in Current (Nominal) Dollars

Coefficients

(t-values)

Model No.	Dep. Var.	Const.	X2	X3	X4	X5	X6	R Sq.
1	X1	531.8714	-0.5012 (-1.4043)	0.9007 (1.3627)	5.0862 (1.0195)	0.0677 (0.2314)	0.0644 (2.18561)	0.9065
2	X1	-280.8676	--	1.26437 (2.0220)	2.5953 (0.5413)	0.3501 (1.6004)	0.0624 (2.0633)	0.8950
3	X1	-256.3398	--	1.5937 (2.4256)	6.5226 (1.3600)	0.3839 (1.6192)	--	0.8687
4	X1	-271.7968	--	1.1950 (1.8377)	6.2044 (1.4067)	--	0.0315 (2.1000)	0.8792
5	X1	24.8048	--	--	15.5005 (4.5662)	0.3540 (1.3335)	--	0.8258
6	X1/X2	254.6460	--	1.2299 (2.2624)	-0.0407 (-0.0106)	0.3873 (2.2166)	0.0446 (1.8473)	0.8866
7	X1/X2	-244.6113	--	1.0533 (1.9159)	3.9519 (1.0599)	--	0.0486 (1.8297)	0.8539
8	X1/X2	-73.7711	--	--	5.0323 (1.4624)	0.3599 (1.8627)	0.0586 (2.2640)	0.8525
9	X1/X2	3.8735	--	--	10.4602	0.3858	--	0.8106

X1= Revenues , in 1000's dollars per year
X2= No. of on-street meters
X3= No. of tickets, in 1000's, for on-street parking meter violations
X4= Fee/hour, in cents
X5= Fine, in cents, for insufficient payment
X6= No. of spaces in off-street locations (garages+lots)

Table 4

Regression Models: Revenues in Constant (1967) Dollars *

Coefficients

(t-values)

Model No.	Dep. Var.	Const.	X2	X3	X4	X5	X6	R Sq.
10	X1*	243.8605	-0.0618 (-0.5366)	0.1548 (0.8270)	11.7581 (7.3223)	-0.9519 (-4.5389)	-6.3265 (-.05275)	0.8956
11	X1*	143.6123	--	0.1921 (1.1296)	11.2570 (8.8045)	-0.9171 (-4.6980)	-4.6001 (-0.4680)	0.8937
12	X1*	147.5387	--	0.1335 (1.5157)	11.3738 (9.3484)	-0.9081 (-4.7944)	--	0.8927
13	X1/X2*	79.6677	--	0.2316 (1.9368)	6.8851 (7.2130)	-0.5832 (-3.8898)	-0.0025 (-0.4023)	0.8629
14	X1/X2*	119.5044	--	--	7.8402 (7.6682)	-0.5157 (-3.0657)	--	0.7988
15	X1/X2*	81.5457	--	0.1923 (2.8575)	6.9101 (7.4297)	-0.5743 (-3.9663)	--	0.8616

X1= Revenues , in 1000's dollars per year
X2= No. of on-street meters
X3= No. of tickets, in 1000's, for on-street parking meter violations
X4= Fee/hour, in cents
X5= Fine, in cents, for insufficient payment
X6= No. of spaces in off-street locations (garages+lots)
X1/X2= Revenues per meter in dollars

* indicates constant (1967) dollars

one sided t-value$_{.025,\ 16}$ =2.120; t$_{.025,\ 19}$=2.093

Revenues are expressed in terms of "gross revenues," or "revenues per meter," in "current" or "constant" (*) dollars. In general, "revenues per meter" show better results than "gross revenue," and "constant" dollars better than "current" dollars: they show more significant variables in the equation. For example, both model 1 and model 6 include all five dependent variables (X2 to X6). However, where only X6 (off-street spaces) is significant in model 1, once revenue is expressed as a fraction (X1/X2) in model 6, also X3 (tickets) and X5 (fine) become significant. Models 10 and 13 are the equivalents of 1 and 6 (respectively) expressed in constant dollars. Again, when using revenue/meter X3 (tickets) becomes significant, and the insignificant X2 (meters) is eliminated.

Interestingly, X6 (alternative off-street parking), which is significant in all models using current dollars (at a significance level> .10%), becomes insignificant in all models using constant dollars. This seems to indicate that the demand for on-street parking is unique, and cannot be easily substituted by alternative arrangements, when real (constant dollar) cost of parking is taken into consideration. Put differently, the demand for parking might be segmented to on-street and off-street, which are almost mutually exclusive. Hence, the increase in supply of off-street spaces would not necessarily satisfy the demand for on-street. Perhaps this explains the common phenomenon of cruising for parking, even when the parking fees are similar in "on" and "off-street" spaces, and the difference in walking distance is negligible (as is the case in Ann Arbor).

As indicated earlier, better results were obtained when revenues, fees, and fine were expressed in constant dollars, those listed in Table 4. Model 15 is the best model because it includes all of the significant variables which can best reflect the relationship among revenues, fees, enforcement, and fines. Not very suprisingly, it indicates that revenues per meter (X1/X2) were positively related to fee (X4) and to enforcement (X3), measured in terms of tickets issued. However, it does come as a surprise to find that the revenues were negatively correlated to the fine (X5). Note, the negative sign (-) of the coefficient of X5 persists in all of the models in Table 4; also, all of these coefficients are significant. This result is not unique to model 15; it is more general.

The interpretation of the negative coefficient seem to be that as the real (constant) cost of the fine rises, potential on-street parkers shy away from doing so, because they foresee themselves unavoidably violating the meter, being caught, and paying a high price. The violation is unavoidable because sometimes, somehow, we'll exceed the time limit even if we are very conscientious. Most people probably assign a much higher subjective probability for being caught,

than the objective reality. Survey data in Ann Arbor, shown in detail later, indicate that the average rate of citations to violations is less than 10% (8.3%). At 300¢ fine (until June 30, 1986), the expected fine, based on objective reality, was only 25¢ (.083x300), which is about equal to the hourly fee prevailing at that time. When the fine drastically rises, in real terms, they look for other alternatives where "insufficient payments" violations are more avoidable, for example, an attendant garage, or a four-hour meter, even when needing less than an hour parking. A different example which supports this explanation is the low violation rate at "handicapped parking," which is associated with a high fine ($50 in Ann Arbor). Admittedly, there are moral considerations in not violating the latter; however, the stiff fine seems to help.

In summary, the regression analysis indicates that on-street parking meter revenue is better explained by real cost, rather than nominal cost, and by revenue per meter rather than gross revenue. In terms of policy implications it reenforces the evidence that enforcement pays--unsurprisingly, revenues rise with stricter enforcement. More importantly, it suggests that rising fees rather than rising fines is a more effective means of increasing (real) revenues from on-street meters. More than that, increasing fees might be counterproductive to raising revenues. A drastic increase in fines may alter parking behavior and discourage drivers from using on-street parking, and eventually from using the downtown enterprises which try to lure them away from the free-parking shopping centers.

A case in point is the recent (July 1986) decision of the City of Ann Arbor to increase its revenues from on-street meter operation in downtown. The Chamber of Commerce opposed a fee increase, fearing that it will discourage patrons. Eventually a compromise was reached where hourly fee was increased from 25¢ to 30¢ (20%), while the fine was increased from $3.0 to $5.0 (66%). This action is expected according to the model (no. 15), to result in a loss of $126.98 per meter due to the fine increase, and only a $43.78 increase due to the raise in fee. A fee increase of 15¢ (about the same magnitude of 66%), and no increase in fine is estimated to increase meter revenue by $131.34.

SURVEY OF PARKING BEHAVIOR

Methodology

The research team selected three sites of on-street parking meters in Ann Arbor, and continuously monitored their usage during six mid-week days. Three surveys were conducted in late 1985, and another three in mid-1986. All sites are located in active commercial, financial, and entertainment areas, which are major traffic generators, and exhibit high usage of parking meters. The first two sites, surveyed in late 1985, are two city blocks in a commercial district adjacent to the University campus (State Street), typical of a "college town" shopping area. The third one is the major shopping area in downtown Ann Arbor, appropriately named Main Street. Together they represent major and secondary shopping areas in downtown.

In each site, the surveyers continuously monitored the same meters. They systematically circled a block or a group of blocks, visiting the same meter every twenty minutes on their route. At each meter they recorded the license-plate of the parked vehicle (if parked), whether it committed a violation, and if so, whether it was cited. The continuous monitoring, over a relatively short duration (20 minutes) provided a dynamic picture of usage, violations, and enforcement.

The first three surveys monitored the campus (State street) area over a two-hour period-- 12:30 to 2:30 p.m. (peak), and 8:30 to 10:30 a.m. (off-peak). The latter surveys on Main street covered a seven hour period each-- 9:00 am to 4:00 pm. Overall, the six survey-days monitored parking usage over 27 hours. They observed 69 meters in the campus area and 27 meters on Main Street. At three observations per meter per hour, all surveys combined included 2,004 observations. Each 20-minute period covered 4 block-faces in the campus area, and 6 block-faces on Main Street. In total, the survey covered 810 block-faces. For comparison, the study in Washington D.C. surveyed 301 block-faces before the Parking Enforcement Program (PEP), and 228 block-faces afterwards. The methodology here was different. Whereas in Washington, D.C. the surveyers followed a designated route, which covered every space only once, the survey in Ann Arbor covered the same area(s) over an extended period. For example, each meter on Main Street was observed 21 times in a day, or 63 times during the three days.

The surveys of short durations (two hours) versus full days (seven hours) were done purposely in order to examine whether the results are significantly different. If not, as the surveys showed, they indicate that short surveys can provide the same useful information at lower cost and efforts. For similar reasons we conducted one off-peak short survey.

Unintentionally, the three surveys on Main Street provided some additional insight. During the first day (December 85) the meters were mechanical. By the time the later surveys were conducted (June 1986), the meters were replaced by electronic mechanisms. The surveys seem to

indicate better compliance with the electronic meters. Also, during the third day, more than half of the metered spaces were declared illegal (in the morning), or free spaces (in the afternoon). This is a common practice during special events in many cities. This unintentional change provided an opportunity to examine behavior under changing conditions.

In the campus area one site (A) was enforced only by the City, while the other (B), by both City and University. Again, it provided an opportunity to study (in a limited case) two types of enforcement. Finally, all surveys were conducted during the mid-week to avoid a weekend bias. Also, the weather in all surveyed days was "normal." Results of the surveys are shown in Table 5 and Table 6.

Demand

The demand for on-street parking meters was extremely high. Almost all of the available spaces were used most of the time. Occupancy ratio, defined as occupied space-hour/available space-hour, averaged 93.0% on Main Street throughout the day, and 99.5 % around campus during the peak. Even off-peak averaged almost 80%. For all practical purposes, the on-street meters are used all of the time. It seems that demand exceeds supply. The surveyers observed (but not recorded) many vehicles which kept on cruising for on-street parking spaces. This result is not surprising, nevertheless it reenforces the notion that this type of parking arrangement is in high demand. In contrast, during the same period, one could observe excess supply in upper floors of adjacent parking garages, which provide parking at similar rates.

Violations

The violation rate can be measured in several ways. Also, the same vehicle can violate more than one meter regulation while parking at the same space. For example, it can have an "insufficient payment" during the first hour, and "exceeding time" violation if parked for more than the legal time limit (i.e., one hour in downtown Ann arbor).

The Violation/vehicle ratio is the sum of all observed violations, of all types, divided by the total number of vehicles parked during the survey period (including those sharing illegally meter space). This ratio was high. It averaged 48.6% on Main Street, and above 50% on the campus sites. In other words, one-third of cars parking at the on-street meters violated the legal usage and 60% of them violated both legal time limit and required parking fee. This is exactly what Ross (1961) defined as "folk crime." This measure could not be compared against other studies (i.e., Washington D.C., or New York), because they did not apply continuous observation.

Table 5

Survey of Parking Meter Usage, Main Street, Downtown Ann Arbor

Survey No.		(1)	(2)	(3a)	(3b)	(1)+(2)	(1)+(2)+(3a)
Survey Date		03/12	06/25	06/26	06/26*		
Meters surveyed		27	25	9	16	52	61
Duration (hrs)		7	7	7	4	21	21
Vehicles parked (at meters)	200	223	53	77	423	476	
Total Violations		109	92	43	--	201	244
Exceed time limit		43	30	16	--	73	89
Insufficient payment		48	41	19	--	89	108
Sharing meter space		18	21	8	--	39	47
Tickets issued		6	6	3	--	12	15
Turnover (per space-hr)		1.06	1.27	0.97	1.20	1.16	1.11
Average stay (minutes)		42.60	39.60	44.68	39.20	41.02	41.40
Standard dev. (min)		27.70	25.60	31.54	22.40	26.64	27.17
Occupancy ratio		93.0%	94.0%	99.0%	87.0%	93.5%	93.5%
Unpaid meter space-hr		24.9%	17.6%	39.0%	--	21.3%	27.2%
Violation/vehicle **		50.0%	37.7%	70.5%	--	43.5%	46.7%
Ticket/violation		5.5%	7.5%	7.0%	--	5.7%	5.9%

*parking meter spaces in this survey day were signed as "no parking" before 12 noon, and "free parking" from noon on.

**including vehicles sharing meters' space

Table 6

Survey of Parking Meter Usage, Campus Area, Downtown Ann Arbor

Period and site*	Off-Peak, A	Peak, A	Peak, B	Total Peak
Survey Date	11/11	12/04	12/12	
Meters surveyed	33	34	35	69
Duration (hrs)	2	2	2	6
Vehicles parked (at meters)	84	94	94	188
Total Violations	50	54	48	102
Exceed time limit	14	17	17	34
Insufficient payment	33	33	28	61
Sharing meter space	3	4	3	7
Tickets issued	0	3	15	18
Turnover (per space-hr)	1.27	1.38	1.34	1.36
Average stay (minutes)	39.07	42.98	44.57	43.76
Standard dev. (min)	25.09	28.43	29.96	27.74
Occupancy ratio	79.0%	99.0%	100.0%	99.5%
Unpaid meter space-hr	26.0%	24.5%	19.0%	21.8%
Violations/vehicle **	59.5%	57.4%	51.1%	54.3%
Ticket/violation	0.0%	5.6%	31.3%	17.6%

Site A policed only by city, site B policed by both city and university.

Peak= 12:30-2:30 pm.

Off-peak= 8:30-10:30 am

** including vehicles sharing meters' space

However, some comparison is feasible. The Washington D.C. survey recorded in the CBD "before" a rate of 1.47 to 2.18 "overtime meter violations" per block. Using the same measure, one finds a ratio of 0.7 during the first two days on Main Street (178 violations/252 block-faces). However, the comparison is not very meaningful, given the different length of City blocks. Assuming a double size block-face in the D.C, the ratio in Ann Arbor would be quite similar, a 1.40.

The unpaid metered space ratio is the ratio of used but not paid-for space-hour divided by the occupied space-hour. This represents the loss to the City's coffer due to "free" illegal use of the on-street meters. In general, about one quarter of the the spaces are used without pay. The average three-days on Main Street was 27.2%; and in the campus area 21.8% during the peak, and 26.0% during the off-peak.

The fact that about 25% of the space is used free implies that the City could realize 4/3 (133%) of currrent revenues per meter if all users paid the fee. In 1985 average revenue per meter was $465, and total revenues from on-street meters $600,000. Had every user been paying the full fee for his parking duration, revenues would increase by $153, and $198,000 respectively. However, this would have been offset by a reduction of about $560,000 in lost revenue from tickets for "insufficient payment" (187,072 tickets x $3.00). Obviously, from the City fiscal viewpoint, the existing situation is preferable, even after taking into consideration the cost of enforcement. In addition, without enforcement, the violation rate could increase even further.

In general, there are slightly more violations during the off-peak. This is due to a common knowledge about light or no enforcement during the early and late hours. For this reason, the all day survey, which includes off-peak hours, shows a somewhat higher violation rate, measured either in terms of "unpaid space-hour" or "violation/vehicle hour."

Also, it might be interesting to note some change in violation rate during some unexpected changes. The unpaid meter ratio and the violation/vehicle ratio declined to 17.6% and 37.7%, respectively (survey (2) on Main street) when electronic meters replaced the mechanical ones. These limited data suggest that people might have perceived electronic meters to be better "watch dogs," and hence violated less. In contrast, when many meters became free (survey (3a) on Main Street), people avoided paying even when they had to do so. The unpaid meter ratio and violation ratio increased to 39.0% and 70.5%, versus the average of about 25.0% and 50.0%, respectively. Admittedly, these data are limited, but they might indicate consistant variations in behavior. If electronic meters truly enforce better payments, they could represent an efficient investment.

The "exceeding time limit" - using the meter beyond the legal time limit (e.g., one hour) represent about 35% of all meter violations: 36.4% (89/244) on Main Street, and 33.3% (34/102)

near campus in peak. This seems to be a most under-reported type of violation. It is hard to detect, compared to "insuficient payment"- parking within the legal time limit but not paying enough for it. The latter is self-evident when the red flag is raised. In contrast, the former requires that a space will be visited twice, and chalk-marked during the first visit. Further, data from Main Street indicated that about one third of violators committed both "exceeding time limit" and "insufficient payment" violations at the same time. These violators were also responsible for about 85% of the unpaid space-hours. The under-reporting of exceeding time limit is shown below in Table 7.

Table 7
Violations Versus Tickets for Parking Meter Violations (%)

Violation Type	Violation Occurred (survey)	Tickets Issued*
insufficient payment	54.7%	58.6%
exceeding time limit	34.6%	3.3%

*source: Ann Arbor Department of Transportation, report on total parking citation issued, by category, during 1985. Total citations = 319,522.

While the proportion was approximately 55% for both violation and tickets for "insufficient payment," only one-tenth "exceeding time limit" were ticketed. Other empirical studies on parking enforcement (i.e., Washington, D.C.) did not account at all for this prevailing violation. Unenforced meter feeding at this large magnitude is a very serious problem, because the violators reduce drastically the supply of limited premium on-street spaces.

Enforcement

The empirical data indicate a low level of enforcement, measured in terms of citations issued versus violations that took place. Overall, the survey recorded 396 violations; only 33 of them (8.1%) were ticketed. During the off-peak the ticket/violation ratio was 0.0%. The highest ratio was recorded in the campus area B, during the peak (31.3%). This is a unique area. It does not lie in the University's jurisdiction per-se. However, due to its proximity to the campus, it is enforced by both City and University personnel (fines are paid to the City). The latter enforce more strictly, resulting in a much higher rate. This suggests that allowing institutions (public, or even private corporations) to issue tickets (so long as the latter does not benefit directly from ticket revenue) is a feasible public-private cooperative solution to improved enforcement.

The enforcement ratio in areas controlled exclusively by the city was only 5.2% (18 tickets/348 violations). However, by either measure the objective enforcement measure was low. Unfortunately, these data could not be compared against results of studies in other locations (other studies did not have comparable data),. However, results from an earlier study in Ann Arbor, conducted by the Department of Transportation in June 6, and June 15, 1978, 8:00 am to 3:00 pm, indicated that the ratio then was even lower. Only 4 tickets were issued for 639 violations--a ratio of less than 1.0%.

The low enforcement level does not seem to be unique to Ann Arbor. The productivity of enforcement personnel was similar in several Michigan cities (see Table 1). There is no reason to suspect that Ann Arbor has a higher violation rate. The combination of the two lead to the conclusion that this low enforcement rate probably prevails throughout the United States. Nevertheless, a rate which seems, at first, to be quite low is sufficient to deter many violations. Recall, only 25% of the available space was used free.

The expected value of the 300¢ fine, at the objective enforcement level of 5.2%, is only 15.6¢ (300 x .052). It is lower than the hourly fee of 25¢. At 8.1% it is 24.3¢, about equal to the fee. Rational analysis suggests that a probability sufficient to equate fee with expected fine is 8.3%. (300 x .083 = 25). The objective enforcement level is close in magnitude to equating probability of 8.3%. This explains, in part, why what seems at first a very low enforcement level is sufficient to discourage violations, resulting in a 75% payment ratio for the available space.

Utilization and Turnover

One of the major goals of on-street parking meters is to provide short-term parking at a short walking distance close to the final trip destination (i.e., for shopping, personal errand, etc.). As the length of stay becomes shorter, more drivers can utilize this premium limited space, which is so vital to bringing patrons to downtown.

Tables 5 and 6 indicate that the average stay was of 41.5 minutes (standard diviation = 27.5). Also, the median of 40.0 minutes was close in magnitude to the mean. Based on this measure, one has to conclude that the meters seem to do what they were designed for, to provide curb, short-term parking. However, the high proportion of almost unticketed "exceeding time limit" violations (Table 7) indicates that a relatively high proportion of the available space is abused by medium and long term parking. Table 8 provides more insight to this problem. It shows the length of stay at parking meters on Main Street, in twenty-minute intervals, over a seven-hour period (data for the campus area was excluded due to the short length of the surveys), and the percent of used and abused space by parkers in these intervals. Chart 2 shows it in graphic form.

Table 8

Length of Stay (20 Minutes Interval)

Time (min)	Vehicles		% 0f Available	Abused as % of
	No.	%	Space-Hour	Available Space-Hr.
20	225	47.2	17.4	0.0
40	95	20.0	14.7	0.0
60	66	13.9	15.5	0.0
80	34	7.1	10.6	2.6
100	25	5.2	9.7	3.9
120	12	2.5	5.6	2.8
140	2	0.4	1.1	0.6
160	6	1.3	3.7	2.3
180 or more	11	2.3	14.1	11.8
Total	476	99.9%	92.4%	24.3%

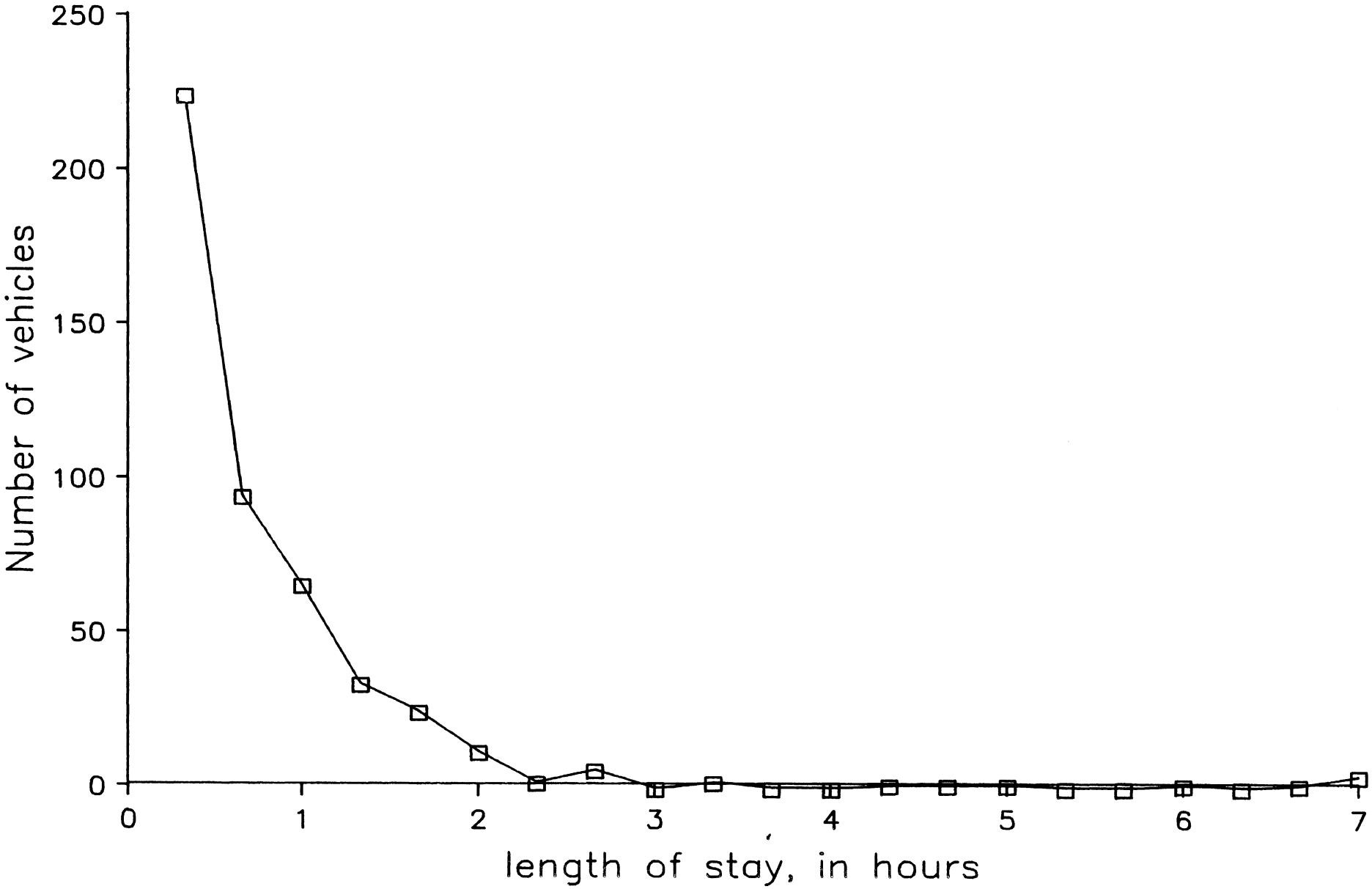
*total available space-hour= 427.0

total occupied space-hour=397.3

Almost half of the vehicles (47.2%) used the spaces for short-term parking of 20 minutes or less. Further, 81.8% parked for 60 minutes or less, and they occupied only 47.6% of the available space-hour. In contrast, about the same amount of space (44.8%) was used by 18.8% of the vehicles which exceeded the time limit (by 20 minutes or more). The abused space was about a quarter (24.3%) of the available space. The problem lies for the most part with long-term parkers, and not with those who stayed an extra 20 minutes (or less). For example, 11 vehicles representing only 2.3% of all users parked for 3 hours or more, and abused 11.8% of the available space-hour, about one half of the abused space. In contrast, 7.1% parked up to an extra 20 minutes and misused only 2.6% of the available space.

The "exceeding time limit" violations deserve special attention. This under-enforced, "hidden" violation drastically affects utilization of parking meters as a mechanism for allocation of short-term curb parking. For example, if all exceeding use during the Main Street survey was eliminated, the public could enjoy an extra 103.7 space hours. At the average stay of 41.5 minutes

Chart 2. Parking length



recorded in this survey, it could accommodate another 149 vehicles, or increase capcity by 31.3% (149/476). At a more coservative estimate of 20 minutes per stay (the mode in this survey), it could have increased capacity by 65%.

This study clearly indicates that monitoring more closely these violations could have a high pay-off in terms of increase in capacity. We do not discount the difficulty of enforcing them (e.g., two visits to the same meter). However, given the already exhausted supply of metered curb space in most downtowns, the high demand, and the importance of these spaces to the vitality of the CBD, the extra effort seems justifiable. The fact that most of the abused space-hour is violated by a small number of long-term parkers (3 hours or more), suggests that they could be caught, even if the second visit occurs after several hours.

CONCLUSIONS

On-street meters are a common means of providing short-term parking for shoppers and other users of downtown. They are essential for the vitality of the CBD, and their demand exceeds the supply. Violation of parking meter regulations is also the most common illegal act, committed virtually by the entire driving population. About one half of all parking violations are those of parking meters. In spite of this, there is little systematic knowledge about parking meter behavior. This study provided some insight into this phenomenon.

The study is based on experience of one city, Ann Arbor, Michigan. However, we believe that the data are representative of most medium and even large cities in the U.S. Moreover, wherever the results of this study were comparable with limited studies in other cities, they showed a consistency. The study is unique in that it combined analysis of historical data, which provides perspective on behavior over a long-term, with an in-depth survey of current behavior.

The historical data on parking meter revenues and enforcement over the last 21 years indicated that in spite of a series of increases in fees and in fines, the real cost (in constant dollars) remained at the level which prevailed in the mid-1960's, if not less. For example, a 25¢/hour fee in 1985 was in real (1967) dollars only 7.7¢, which is less than the 10¢ fee required in 1967. Similarly, a $3.0 fine in 1985, or $.65 in constant dollars, cost less than the $1.0 fine in 1967. We suspect that similar results will be found in other cities. This is not unique to the U.S. Studies in London, England, also showed a deterioration of the fee-fine level. So, in spite of a increase in parking meter revenues, the cost to the consumer actually fell, which could have increased length of stay and reduced turnover.

The regression analysis indicated that real cost provides a better measure for studying the relations among revenues, fees, and enforcement than current dollars, probably because the former

relates them to the actual cost confronted by the consumer. This analysis reconfirmed the common knowledge that enforcement works: more citations led to higher revenues. Also, unsurprisingly, revenues related positively to fees. A more surprising result was that fines correlated negatively to revenues: an increase in fines would lead to a decline in revenues. This result could probably be explained by the fact that they replace on-street meters by other alternatives which are less prone to (eventual) violation as fine increases. Also, the regression analysis seemed to indicate that the demand for on-street parking is unique and independent of alternative off-street parking. The increase in supply of off-street facilities (at similar cost and walking distance) did not affect meter revenues. This might explain the familiar phenomenon of cruising for parking. In this particular case, neither higher fees nor a longer walk could explain the cruising. In terms of policy implications, the historical data implied that raising fees rather than raising fines is a more effective method of increasing revenues. This is in contrast to prevailing practice by the Chamber of Commerce to protect the deflated fees at the expense of higher fines.

The survey of parking meter usage indicated, as expected, a very high level of demand. Occupancy ratio was close to 100%. On-street parking meter spaces are highly desirable. The independence of curb parking from other alternatives was further reenforced by the fact that supply of off-street parking, in upper levels of parking structures, exceeded demand during the same period.

The more interesting results concerned violation and enforcement. In contrast to the common attitude of the consuming public, the enforcement level, measured in terms of issued citations, was very low. At the same time, the violation level of parking meters alone (not counting other types of parking violations) was very high. On the average, the violation ratio (violations/parked vehicle) exceeded 50%. In contrast, the citation ratio (tickets/violations) in areas controlled exclusively by the city was only 5.2%. In other words, while on the average every third vehicle violated meter regulations, only one in twenty vehicles was issued a citation. These results were consistent with a previous study in Ann Arbor in 1978, and with findings in Washington, D.C., prior to the strict enforcement program.

The higher level of enforcement in an area controlled jointly by the University and the City (31.3%) suggests that public-private cooperation in this area could benefit the legal short-term parkers, at no extra cost to the cities. This would obviously benefit the private institutions located adjacent to the meters by increasing capacity for their patrons.

However, the expected value of the fine--cost multiplied by the objective (empirical) probability of being caught--was about equal to the hourly fee. At that level, consumers are expected to be indifferent between paying the fee or taking the chance of being caught and paying the fine. As such, the 50% violation ratio is consistent with the equality of the fee to the expected

fine. Being indifferent, half pay the fee, while another half avoid it. In an unscientific survey of people throughout the City, most respondents stated a much higher citation level. Nevertheless, it seems that the consumers have an accurate sense of the enforcement level, even when stating a higher one.

An important finding of this study was the exposure of a high level of "hidden," underenforced violations of "expired time limit." While the study found that 36.9% of meter violations were of this nature, tickets for this violation accounted for only 3.3% of the total. The problem lies not so much in the low enforcement level itself as in the fact that these violations reduce substantially the short supply of short-term parking. The study found that "exceeding time" used illegally approximately 25% of available space-hours. It estimated that eliminating these violations could increase capacity by 31 to 65 percent (at an average stay of 41.5 minutes, and 20 minutes, respectively). This violation is harder to enforce, because it required two visits. However, the pay-off to the public would justify the extra efforts. Because a small number of violators who park for long periods (three hours or more) account for most of the abuse of the limited supply of space-hours, catching them is feasible.

Finally, the study indicates that short-term parking meters do work, even at low to medium enforcement levels. Even though many users, about one in three, either park for free, exceed the time limit, or both, most parkers use them in accordance with their major goal: for short-term curb parking. Almost half of the users (47.2%) park for 20 minutes or less, and four in five (81.1%) for one hour or less. The relative short parking duration versus the feasible enforcement interval might explain the high rate of "free" parking. It is simply hard to catch people who park free for a short time. From the City's coffer viewpoint, unpaid use might be considered a loss (though revenues from citations exceed losss from meters). However, as a means of allocating a limited supply of premium parking space for the public, meters perform efficiently. In an auto-oriented society, on-street parking meters in downtown are a vital resource which should be administered with care. Revenues from meters should be viewed only as a by-product of the meters, where the major benefits are indirect, derived from the efficient allocation of space to maximum users. To improve this already quite successful task, a stricter enforcement of "exceeding time limit" deserves higher priority. If enforced more strictly, it could substantially increase the capacity at relatively low cost. Unquestionably, it is cheaper than constructing more parking structures (Also, the maintenance of these spaces: sweeping,snowplowing, surface maintenance, lighting, etc., is charged to the street system. Consequently they are also cheaper to operate). As the study indicated, parking structures are not a genuine substitute for on-street parking.

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