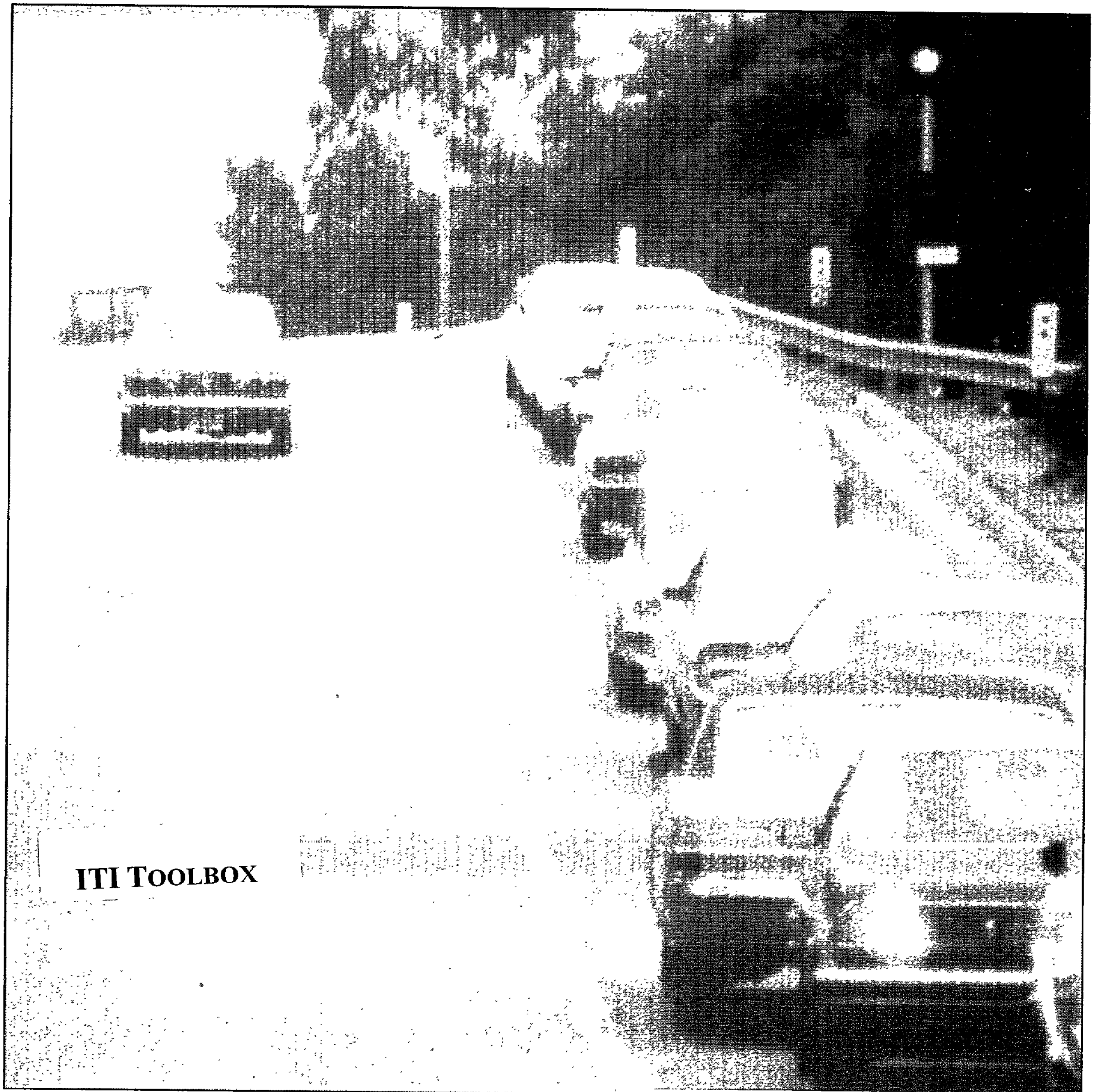
U.S. Department
of Transportation

Ramp Metering Status in North America

1995 Update

June 1995



Ramp Metering Status in North America
1995 Update

Final Report
June 1995

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RAMP METERING STATUS IN NORTH AMERICA - 1995 Update

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June 1995

FORWARD

This document represents an update to a previous report published by James Robinson and Mark Doctor in September of 1989 entitled "Ramp Metering Status in North America".[1] The previous report was a popular resource that provided useful information for agencies investigating the feasibility of ramp metering. It offered a straight-forward look at the operational and institutional issues inherent in ramp metering. In this update, the intent will be to maintain the body, scope, and "spirit'" from the previous report, while providing current information on the state of the practice in ramp metering. One final thought, acknowledgement and thanks needs to be given to the TRB Freeway Operations Committee for its support in completing this report. Additionally, thanks is given to everyone who responded to the survey (Appendix 1) that provided the prevailing information on ramp metering systems.

1.0 INTRODUCTION

Webster's New Collegiate Dictionary defines the verb "meter" as: "to supply in a measured or regulated amount". Ramp meters are traffic signals on freeway entrance ramps that supply traffic to the freeway in a measured or regulated amount. In the "measured" mode, meters can be operated to discharge traffic at a measured rate thus keeping demand below downstream capacity. As long as mainline demand plus ramp traffic flow does not exceed capacity, throughout is maximized, speeds remain more uniform and congestion related accidents are reduced. Ramp meters can also be operated to regulate ramp traffic to break up platoons of vehicles that occur naturally, or have been artificially created by release from nearby signalized intersections. The mainline, even when operating near capacity, can accommodate merging vehicles one or two at a time. On the other hand, when groups of vehicles attempt to force their way into traffic it creates turbulence that causes mainline flow to break-down. Reduced turbulence in the merge zones also leads to reduced sideswipe and rear-end type accidents that are associated with stop-and-go, erratic traffic flow.

With the advent of Intelligent Transportation Systems (ITS), ramp metering has become a key component of Advanced Traffic Management Systems (ATMS). However, ramp metering was a traffic management strategy long before ITS. The

RAMP METERING SYSTEMS

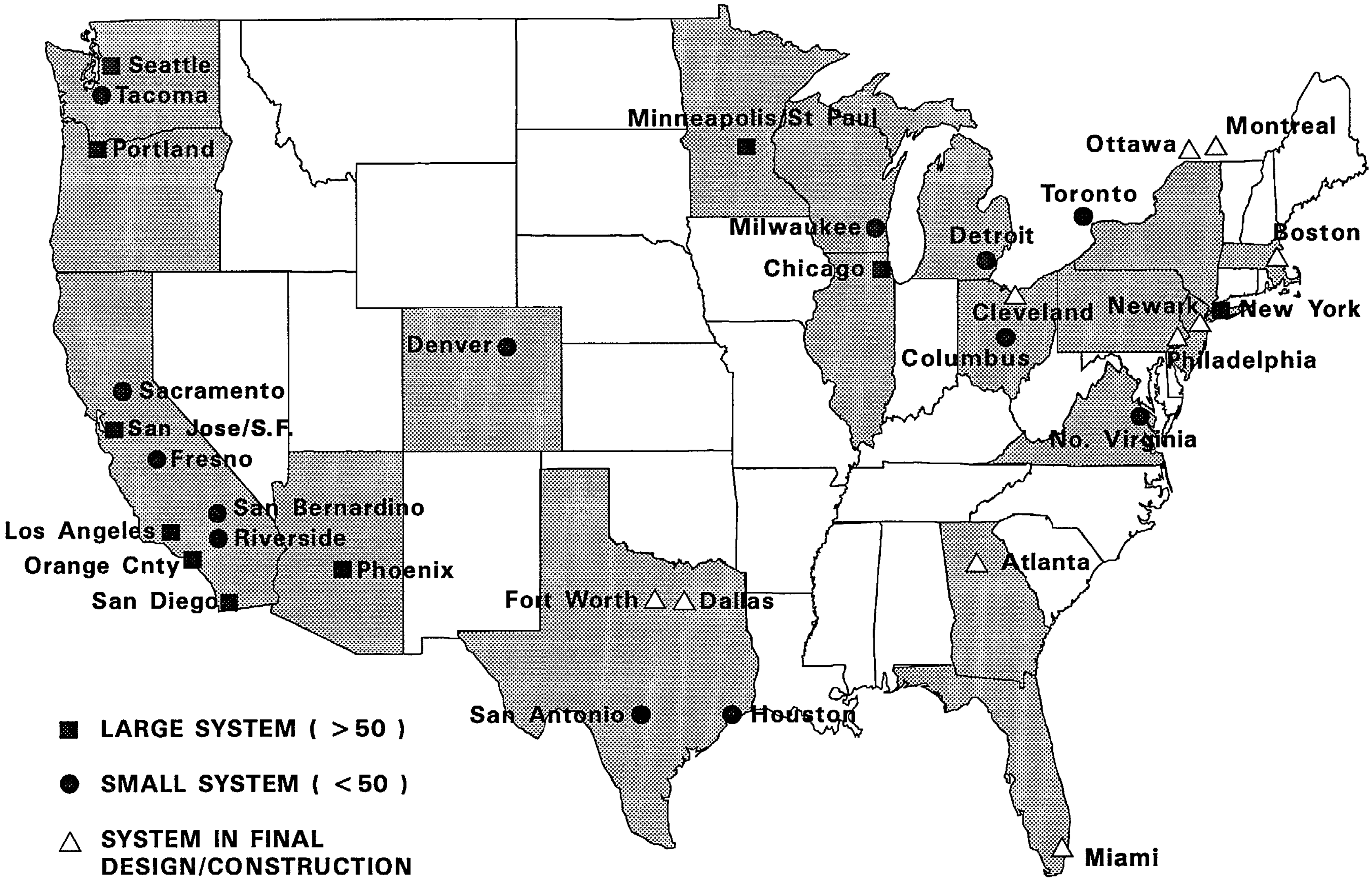

FIGURE 1

first metered ramp, as we know it today, was installed in Chicago on the Eisenhower Expressway in 1963. This first application, however, was preceded by successful tests of the effectiveness of metering traffic entering New York tunnels and ramp closure studies in Detroit. It is interesting to note that the initial Chicago study featured a police officer, stationed on the entrance ramp, who stopped traffic and released vehicles one at a time at a rate determined from a pilot detection program.[2] In Los Angeles ramp metering began in 1968. That system has been expanded continually until there are now over 800 meters in operation in L.A. County - the largest system in North America. Currently ramp meters are in operation in 23 metropolitan areas in North America (Figure 1). These metering systems vary from a fixed time operation at a single ramp to computerized control of every ramp along many kilometers of a freeway.

Many reports have been written that document the potential successes and benefits of ramp metering. However, the true measure is in the continued growth of ramp metering installations. Since 1989, the number of operating meters in North America has increased from near 1600 to over 2300; an increase of about 45 percent. Additionally, many existing systems are proposing expansions and/or upgrades. On the planning side, new ramp metering is being considered in numerous other cities as part of ITS early deployment plans or feasibility studies. By the year 2000, at least 33 cities in the United States and Canada will have functioning ramp meters. This will be 11 more systems than existed in 1989.

The objective of this paper is to provide an initial resource for those wishing to explore the feasibility of ramp metering in their areas. The paper is divided into six sections. The first three parts present a sample of various ramp metering applications in several cities and describes the benefits that have been reported. The fourth section addresses factors that should be considered and some of the capabilities and limitations of ramp metering. In the fifth, guidelines for the implementation of ramp metering are identified. The sixth part presents lessons learned from agencies currently operating ramp metering. An overview of the status of ramp metering in North America, a list of ramp metering contacts, and a bibliography are also included.

2.0 ENTRANCE RAMP METERING CASE STUDIES

The abbreviated case studies presented here are just a few examples of effective ramp metering operations. The benefit statistics presented are not consistent from city to city as there is no uniform evaluation criteria. Additionally, the measures of effectiveness (MOEs) vary depending on the objectives of the system. Complicating the matter, many ramp metering installations are implemented at the same time as other freeway improvements such as increased capacity, high occupancy vehicle (HOV) lanes, surveillance systems, traffic information systems, and incident management programs. In these cases, it is not always possible to evaluate the individual components of the larger projects. The conditions of the evaluations of these case studies are noted for each discussion.

2.1 Portland, Oregon

The first ramp meters in the Pacific Northwest were installed along a 10 kilometer section of I-5 in Portland in January 1981. The meters are operated by the Oregon Department of Transportation. I-5 is the major north/south link, and is an important commuter route through the metropolitan area. This initial system consisted of 16 metered ramps between downtown Portland and the Washington state line. Nine of the meters operated in the northbound direction during the PM peak and seven controlled southbound entrances during the AM peak. The meters operate in a fixed time mode. There are currently 58 ramp meters operating on five different freeways.

Prior to metering, it was common along this section of I-5 for platoons of vehicles to merge onto the freeway and aggravate the already congested traffic. The northbound PM peak hour average speed was 26 kph. Fourteen months after installation, the average speed for the same time period was 66 kph. Travel time was reduced from 23 minutes (but highly variable) to about 9 minutes. Pre-metered conditions in the southbound AM peak were much less severe and hence the improvements were smaller. Average speeds increased from 64 to 69 kph resulting in only slight reductions in southbound travel times.

Additional benefits that were evaluated for the PM peak period included fuel savings and a before and after accident study. It was estimated that fuel consumption, including the additional consumption caused by ramp delay, was reduced by 2040 liters of gasoline per weekday. There was also a reduction in rear-end and side swipe accidents. Overall, there was a 43% reduction in peak period traffic accidents.[3]

2.2 Minneapolis/St. Paul, Minnesota

The Twin Cities Metropolitan Area Freeway Management System is composed of several systems and sub-systems that have been implemented over a 25 year period by the Minnesota Department of Transportation. The first two fixed time meters were installed in 1970 on southbound I-35E north of downtown St. Paul. In November 1971, these were upgraded to operate on a local traffic responsive basis and 4 additional meters were activated. This eight kilometer section of I-35E has been evaluated periodically since the meters were installed. The most recent study shows, that after 14 years of operation, average peak hour speeds remain 16% higher, from 60 to 69 kph, than before metering. At the same time, peak period volumes increased 25% due to increased demand. The average number of peak period accidents decreased 24% and the peak period accident rate decreased 38%.

In 1974 a freeway management project was activated on a 27 kilometer section of

I-35W from downtown Minneapolis to the southern suburbs. In addition to 39 ramp meters, the system included 16 closed circuit television (CCTV) cameras, 5 variable message signs (VMS), a 2 kilometer zone of highway advisory radio (HAR), 380 vehicle detectors, and a computer control monitor located at the MnDOT Traffic Management Center in Minneapolis. This project also included extensive "freeway flyer" (express bus) service, and eleven ramp meter bypass ramps for HOV's. An evaluation of this project after 10 years of operation shows that average peak period freeway speeds increased from 55 to 74 kph or 35%. Over the same 10 year span, peak period volumes increased 32%, the average number of peak period accidents declined 27%, and the peak period accident rate declined 38%. Over one million dollars a year in road user benefits are attributed to reduced accidents and congestion. This system also has positive environmental impacts. Peak period air pollutant emissions, which include carbon monoxide, hydrocarbons, and nitrogen oxides, were reduced by just under 2 million kilograms per year.[4]

Over 300 additional ramp meters have been implemented from 1988 to 1995, and there are currently 368 meters in operation. Further projects are now in the design and construction phases. Over the next five years, the plans are to complete the ramp metering system which will cover the entire Twin Cities freeway network.[5] The success of the Twin Cities system has shown that the staged implementation of a comprehensive freeway management system on a segment-by-segment, freeway-by-freeway basis, over a long period of time, is an effective way of implementing an area wide program.

2.3 Seattle, Washington

In September 1981 the Washington State Department of Transportation (WSDOT) implemented metering on I-5 north of the Seattle Central Business District. Initially the system which is named FLOW (not an acronym), included 17 southbound ramps that were metered during the AM peak, and 5 northbound ramps that were metered during the PM peak. Currently, the ramp metering system includes 54 meters on I-5, I-90, and SR 520. These meters are all operated under centralized computer control. Future expansion plans include additional ramp meters on SR 520 east of Lake Washington, all of I-405, and I-5 south of Seattle.

One evaluation of the initial 22 meter system showed that between 1981 and 1987, mainline volumes during the peak traffic periods increased 86% northbound and 62% southbound. Before the installation of metering, the travel time on a specific 11 kilometer course was measured at 22 minutes. In 1987 the travel time for the same course was measured at 11.5 minutes. Over the same six year time period, the accident rate decreased by 39%.[6]

A somewhat unique application of metering was implemented in Seattle on SR-520 in 1986. While diversion caused by metering is often controversial, one of the objectives of metering SR-520 was to reduce commuter diversion through a residential neighborhood. The meters were installed on the two eastbound ramps on SR-520 between I-5 and Lake Washington. One of these ramps, the Lake Washington Blvd. on-ramp, is the last entry onto SR-520 before the Evergreen Point Floating Bridge. Because there were no bottlenecks downstream of this ramp, traffic would normally flow freely on the bridge and beyond. Motorists, especially commuters from downtown Seattle, were using residential streets to reach the Lake Washington Boulevard on-ramp to avoid congestion on SR-520. This on-ramp, however, was a major contributor to congestion on SR-520 because of the high entering volumes. By metering the ramp, it was anticipated that traffic diverting through the adjacent neighborhood from downtown would be discouraged by the delay caused by the meter. Motorists would instead use the Montlake Boulevard on-ramp which was also metered at the same time. A HOV bypass lane was also installed at the Montlake Boulevard on-ramp. Two other objectives of this project were to improve flow on SR-520 and to encourage increased transit use and carpooling.

An evaluation of this two ramp meter "system" after four months of operation showed there was a 6.5% increase in mainline peak period volume, a 43% decrease in the volume on the Lake Washington Boulevard on-ramp, an 18% increase the volume on the Montlake Boulevard on-ramp, and a 44% increase in HOV's using the Montlake Boulevard on-ramp.[7] Another indication of the effectiveness of the combination of the HOV bypass and the improved SR-520 flow is a decrease of 3 minutes in METRO (King County Department of Metropolitan Services) transit travel times for buses traveling from downtown to the east and a 4 minute decrease for buses traveling from University District to the east. The reliability of the bus travel times also improved and METRO adjusted the schedules for these routes accordingly.

In 1993, the WSDOT implemented weekend ramp metering for the first time. Three ramps north of Seattle on southbound I-5 have been metered several hours due to heavy weekend volumes. Because of this success, in March of 1995, weekend metering was expanded to include four additional southbound ramps.

In April of 1995, WSDOT began operating seven southbound I-5 meters during the evening commute. This is WSDOTs first implementation of metering both directions of a corridor during the same peak period. The motivation behind this operational change is that the traditional reverse commute direction has become increasingly congested. Prior to this, metering along this section had operated southbound (inbound toward Seattle) during the morning commute and northbound (outbound) during the evening commute.

2.4 Denver, Colorado

The Colorado Department of Transportation activated a pilot project to demonstrate the effectiveness of ramp metering on a section of northbound I-25 in March 1981.

The initial system consisted of five local traffic responsive metered ramps operated during the AM peak on a 4.7 kilometer section of I-25 south of the city. Periodic after evaluations revealed significant benefits. An 18-month after study showed that average peak period driving speed increased 57% and average travel times decreased 37%. In addition, incidence of rear-end and side-swipe accidents declined 5% due to the elimination of stop and go conditions.

The success of the pilot project led to expansion of the system. In 1984 a central computer was installed and a System Coordination Plan implemented which permits central monitoring and control of all meters. Since 1984, additional ramp meters have been added until reaching the current number of 28. In late 1988 and early 1989 a comprehensive evaluation of the original metered section was conducted. A number of changes occurred between 1981 and 1989, the most significant of which was the completion of a new freeway, C-470, which permitted more direct access to I-25 from the southwest area and generated higher demand for I-25. Volumes during the 2 hour AM peak period increased from 6200 vph in 1981 to 7350 vph in 1989 (on 3 lanes). Speeds measured in late 1988 decreased from the original evaluation, but remained higher than the speeds before metering was implemented; 69 kph before, 85 kph after in 1981, and 80 kph in late 1988. The frequency of accidents during the AM peak period did not increase between the original evaluation and 1989, as a result, the accident rate decreased significantly because of the increased volumes. Rear-end and side-swipe type accidents decreased by 50% during metered periods.

An interesting unplanned "evaluation" of the system occurred in the Spring of 1987. To accommodate daylight savings time, all of the individual ramp controllers were adjusted one hour ahead. Unfortunately, the central computer clock was overlooked. The central computer overrode the local controllers and metering began an hour late. Traffic was the worst it had been in years. This oversight did have a bright side for the Department of Transportation, since this incident, the media has been even more supportive of ramp metering.[8]

In 1988, the Colorado Department of Transportation conducted a study to evaluate different levels of ramp metering control. The study compared ramp meters operating in local traffic responsive mode versus meters operating under centralized computer control. The results showed that if local traffic responsive metering could maintain freeway speeds above 90 kph, centralized control had little or no additional benefit. However, if local traffic responsive metering was unable to maintain speeds near the posted speed limit of 90 kph, centralized control was very effective. Data showed speeds increased 35.5%, from 50 to 68 kph and vehicle hours of travel were reduced by 13.1%.[9] This evaluation shows the importance of implementing operating strategies that correspond to the needs of the freeway network.

2.5 Detroit, Michigan

Ramp metering is an important aspect of the Michigan Department of Transportation's (MDOT) Surveillance Control and Driver Information (SCANDI) System in Detroit. The SCANDI metering operation began in November 1982 with six ramps on the eastbound Ford Freeway (I-94). Nineteen more ramps were added on I-94 in January 1984 and three more in November 1985. An evaluation performed by Michigan State University for MDOT determined that ramp metering increased speeds on I-94 by about 8%. At the same time, the typical peak hour volume on the three eastbound lanes increased to 6400 vehicles per hour from an average of 5600 VPH before metering. In addition, the total number of accidents was reduced nearly 50% and injury accidents were down 71%. The evaluation done by Michigan State also showed that significant additional benefits could be achieved by metering the three freeway-to-freeway connectors on this section of I-94.[10]

2.6 Austin, Texas

In the late 1970's, in Austin, the Texas Department of Transportation implemented traffic responsive meters at 3 ramps along a 4.2 kilometer segment of northbound I-35 for operation during the AM peak period. This section of freeway had two bottleneck locations that were reducing the quality of travel. One was a reduction from 3 to 2 lanes and the other was a high volume entrance ramp just downstream of a lane drop. Metering resulted in an increased vehicle throughout of 7.9% and an increase in average peak period mainline speeds of 60% through the section. The meters were removed after the reconstruction of I-35 eliminated the lane drop in this section.[11] This situation shows the versatility of ramp metering in that it can also be used effectively as a temporary solution. Austin is currently in the preliminary design stages and is expected to begin ramp metering again in about 3 years.

2.7 Long Island, New York

At the other end of the spectrum from Austin is the INFORM (Information For Motorists) project on Long Island. The INFORM project covers a 64 kilometer long by 8 kilometer wide corridor at the center of which is the Long Island Expressway (LIE). Also included in the system is an east-west parkway, an east-west arterial and several crossing arterials and parkways, a total of 207 kilometers of roadways. System elements include 70 metered ramps on the LIE and the Northern State/Grand Central Parkway.

In 1989, an analysis of the initial metered segment was conducted after 2 months of operation. In the peak period, the study showed a 20% decrease in mainline travel time (from 26 to 21 minutes) and a 16% increase in average speed; from 47 to 56 kph. Motorists entering at metered ramps also experienced an overall travel time reduction of 13.1% and an increase in average speed from 37 to 45 kph. The MOE's for this project include vehicle emissions. For this initial segment, the analysis indicates there was a 6.7% reduction in fuel consumption, 17.4% reduction in carbon monoxide emissions, 13.1% reduction in hydrocarbons, and 2.4% increase in nitrous oxide emissions. The latter is associated with the higher speeds. Initial observations of the effect of metering the four lane parkway on the INFORM project, indicates the benefits may be even greater than those achieved on wider freeways. Intuitively this makes sense because the impact of an unrestricted merge on only two lanes (in one direction) can be severe.[12]

A more extensive evaluation of the INFORM project was completed in 1991. Data from this study showed much more conservative results. It is believed that this study is more representative of the true traffic conditions. The main reason for this is related to the "queuing off" (shut-down of the meter due to excessive queuing) of the ramp meters. The original study did not include areas where metering was usually shut off due to heavy ramp volumes, while this study accounted for all ramps. This evaluation showed while throughout had only increased about 2%, the average mainline speeds had increased from 64 to 71 kph, or about 9%. However, at two separate bottleneck locations, data showed increases of 53 to 84 and 53 to 89 kph, or gains of about 36 and 40% respectively. This evaluation also included calculation of a "congestion index". This index is the proportion of detector zones for which speeds were less than 48 kph (30 mph). While no benefit was shown in the evening peak period, the morning peak period showed an improvement of 25% in the congestion index. The accident frequency also showed encouraging improvement with a 15% reduction compared to the control section.[13]

2.8 San Diego, California

In San Diego, ramp metering was initiated in 1968. That system, installed and operated by the California Department of Transportation (Caltrans), now includes 134 metered ramps on 110 plus kilometers of freeway. No detailed evaluations of metering have been conducted on the San Diego system since the early installations, but sustained volumes of 2200 vph to 2400 vph, and occasionally even higher, are common on San Diego metered freeways. A noteworthy aspect of the program is the metering of eight freeway-to-freeway connector ramps. Metering freeway-to-freeway connectors requires careful attention to storage space, advanced warning, and sight distance. If conditions allow, freeway connector metering can be just as safe and effective as other ramp meters.[14] More discussion on freeway connector metering and mainline metering is provided later in this report.

2.9 Summary of Entrance Ramp Metering Benefits

Metering entrance ramps significantly improves mainline traffic flow. These case study evaluations, as well as others, show metering consistently increases travel speeds and improves travel time reliability, both of which are measures of reduced stop-and-go, erratic flow. It should be emphasized that these benefits occurred even though in most instances mainline volumes had significantly increased. Metering helps smooth out peak demands which would otherwise cause the mainline flow to break-down. A strong case can be made from the data reported that metering actually increases the throughout of a freeway. The data from Minneapolis, San Diego, Seattle, Detroit and Denver shows mainline volumes well in excess of 2,100 vph per lane on metered sections, and sustained volumes in the range of 5% to 6% greater than pre-metered conditions. Improved traffic flow, particularly the reduction in stop-and-go conditions, also reduces certain vehicle emissions. This has been shown in both the INFORM project and in the Twin Cities Freeway Management System.

The other direct benefit, but one that has not been fully quantified, is the reduction in accidents attributed to metering. The case studies presented in this report consistently show a reduction in accident rates of 24 to 50 percent. However, the benefits derived from accident reduction goes well beyond the direct costs related to medical expenses and vehicle damage. To illustrate, assume an accident blocks one lane of three at the beginning of the peak period on a freeway with a 2 hour peak demand of 6000 vph. Studies show an accident blocking one of three lanes reduces capacity by 50%. A 20 minute blockage would cause 2100 vehicle-hours of delay, a queue over 3 kilometers long, and take 2 1/2 hours to return to normal assuming there were no secondary accidents or incidents. Clearly the safety aspects of metering are a major benefit.

3.0 CONNECTOR METERING CASE STUDIES

In recent years, a variation on the application of entrance ramp metering called connector metering, sometimes called freeway-to-freeway metering, has become more popular. This form of metering is being considered more often because, at times, entrance ramp metering alone is not enough to maintain desired mainline conditions. There are five cities operating connector metering, San Jose, Los Angeles, San Diego, Seattle, and Minneapolis. Combined, these cities operate 107 connector meters.

The same geometric issues that apply to entrance ramp metering, also apply to connector metering. However, because of the increased volumes and higher speeds, sight distances, queue storage, and advance warning signs are even more critical. The case studies below discuss issues related to connector metering.

3.1 SAN DIEGO, CALIFORNIA

One example of a connector metering installation occurs at southbound SR 67 to westbound I-8. This meter was installed to alleviate congestion on a heavily traveled section of I-8 downstream of this interchange. As a result of the metering, lane volumes have increased to 2500 vehicles per hour and the average speeds are near 97 kph.[15] During the peak hour, this three lane ramp meters about 2400 vehicles. Queues at this location average about 8 minutes during the peak hours. Although this delay seems excessive, vehicles seldom come to a complete stop. This slow rolling pace helps soften the impact of the long waits. The willingness of the motorist to wait can be shown by the high compliance rate and the minimal number of complaints. It is also deduced that motorists have accepted the situation because they see the benefits gained beyond the meter. Another example that reinforced the value of the meters occurred several years ago. An electrical malfunction caused the release of vehicles at a rate much higher than normal. The result was severe congestion that caused queues of several kilometers on I-8. Although this malfunction was clearly unintentional, it demonstrated how effective the meters had been.

3.2 LOS ANGELES, CALIFORNIA

Another example of connector metering occurs at southbound I-5 to southbound SR 110. Prior to the meter installation this connector was two lanes and merged to one lane before it joined SR 110 as an add lane. Connector volumes were extremely high most of the day while southbound SR 110 had a high volume of traffic only during the morning peak period from 6:30 to 9:30 a.m.. Delays were routinely encountered on the connector from early morning to late afternoon seven days a week. In order to reduce the time period of this delay, the connector was re-striped to join the southbound SR 110 as two lanes instead of transitioning to one lane. To avoid serious adverse impact on SR 110, during the morning peak, the connector is metered from 6:30 to 9:30 a.m. Monday through Friday to keep traffic volumes entering SR 110 approximately the same as before it was re-striped. Adverse impact on SR 110 is avoided and queuing on the connector has been eliminated from all periods except during metering operation when it is about what it was before re-striping and meter installation.[16, 17]

The newest connector metering in Los Angeles occurs on the new I-105 (Century) freeway. This east-west freeway, south of the city, is 29 kilometers in length and crosses four major north-south freeways. There were two primary reasons for implementing connector metering. First, because of court orders, the freeway was restricted to three lanes plus one HOV lane in each direction. Caltrans knew this road would be over-crowded almost as soon as it opened. Secondly, vehicles exiting the I-105 would be a problem. The other four intersecting freeways were already congested and would have a difficult time handling the additional vehicles from the I-l 05. To help alleviate these anticipated problems, Caltrans took a proactive approach by installing entrance ramp metering on every ramp, and connector metering on most connectors. To handle the high volume connectors, platoons of two or even three vehicles per lane are released. When three vehicles are released from one lane, the minimum cycle length is 8.2 seconds (2 seconds of green, 1.5 of amber, and 4.7 of red). At first, motorists had trouble with the three car platoons. They now appear comfortable with the operation, which has helped reduce some of the long queues. Even with the long queues experienced at some connectors, compliance has been good. Caltrans also noted that accidents on the connector meters have been minimal, no more than a typical entrance ramp meter. Overall, Caltrans has been pleased with the connector metering.[16]

3.3 MINNEAPOLIS/ST. PAUL, MINNESOTA

The Twin Cities first installed connector metering at two locations back in 1971. The Minnesota DOT now operates 74 connector meters, the largest number in North America. From experience with their system, the following hypothesis was developed by the MnDOT to in part justify the need for connector metering. In most cases, less than 40 percent of mainline volumes, entering a given freeway segment, come from arterials. MnDOT estimates that at least 40 percent of the traffic entering a freeway segment must be metered in order for entrance ramp metering to be effective. Therefore, MnDOT feels in many instances connector metering is needed along with entrance ramp metering to produce an effective ramp metering "system".[17]

One example of connector metering occurs from eastbound I-94 to southbound SR 65. Delays on this ramp can reach 8 minutes with queues extending to one-half kilometer. Even under these circumstances, compliance has been good while complaints have remained low. This positive reaction can be attributed to the improved level of service experienced once motorists reach the mainline. One study related to the metering operation showed that while mainline volumes had increased 17 percent, the peak hours speeds had increased by 29 percent. The same study also determined that accidents were reduced by 21 percent during the peak hour.[15]

All four connector ramps from I-494 are metered to north and southbound I-35W. One of these ramps initially experienced back-ups that extended back onto the mainline of I-494. This caused problems because motorists would by-pass the queue and forcefully merge in at the last minute. This problem was rectified by widening the ramp from one lane to two lanes. Except for this problem, these connector meters have been very effective. One analysis concluded that metering was partially accountable for speeds increasing 38 percent on both north and southbound I-35W.[15] In addition, these freeways experienced a reduction in the number of accidents.

3.4 SUMMARY OF CONNECTOR METERING BENEFITS

Connector metering offers an additional opportunity for agencies to manage the flow of traffic on a freeway system. It also improves equity amongst motorists along the corridor by metering vehicles that may have entered the freeway on a un-metered entrance ramp. San Diego operates most of its connector meters during the morning peak, metering vehicles that predominately come from outlying areas.

In many instances meters are installed to improve mainline operations and better manage queuing and delay that occurs at freeway-to-freeway interchanges. However, as shown in Los Angeles, connector metering has other uses. The success stories described above all occurred while in many instances long queues and delays occurred on the connectors. However, motorists have become tolerant because they experience mainline freeways that operate at high levels of performance.

4.0 MAINLINE METERING CASE STUDIES

Mainline metering is a another variation of entrance ramp metering. To date, mainline metering has only been used upstream of severe bottlenecks caused by geometric constraints, such as bridges and tunnels. In many instances, the capacity of tunnels and bridges has often lagged behind the capacities of approaching freeways. This often occurs because many times it is not feasible, due to cost and other environmental controls, to widen these structures.

Discussed below are the only three documented cases of mainline metering in North America. Although Oakland, California is the only location currently operating mainline metering, it is being considered by several other agencies. As part of the Central Artery Project in Boston, the Massachusetts Highway Department plans to install three mainline meters, all at entrances to tunnels. The Washington State DOT is also considering installations on the freeways approaching the Tacoma Narrows Bridge.

4.1 Oakland, California

The mainline meter in Oakland is located just west of a 22 booth toll plaza on the westbound approach to the San Francisco-Oakland Bay bridge. The purpose of the meters is to reduce the severe congestion that was occurring on the bridge. Although with meters queues of 30 minutes can exist, this is better than pre-metered conditions.[15] Travel benefits occur for three reasons. First, the orderly progression forced by metering helps smooth the flow at the merging area. The second reason relates to truck operations. Congestion often occurred on the uphill portion of the bridge, making it difficult for trucks to accelerate. This would add to the already poor conditions. Lastly, while the metering has reduced the number of incidents on the bridge, occasionally they still occur. When an incident does take place, it is much easier for the tow trucks, or other emergency vehicles, to reach the incident location. This reduced response time is crucial. With the enormous volumes, it is imperative that the time period of a capacity reduction is minimized. This case study shows a good example of how metering can be used to control queue locations. Many times queuing is inevitable, but by choosing the optimal location for the queue, otherwise constrained conditions can be maximized. This application of traffic management can produce significant benefits.

4.2 Hampton Roads Tunnel

This tunnel, located in southeastern Virginia, provides the only connection between Hampton and Norfolk. Before mainline metering began in August of 1983, delays of up to two hours were not uncommon. The congestion in the tunnel caused cars to overheat and carbon monoxide (CO) levels to increase. The metering operation was commenced whenever traffic speeds in the tunnel dropped below 25 kph. As a result of metering, CO levels were reduced requiring less ventilation, and fewer vehicles overheated keeping lanes open and moving.[18] The metering was an operational success. However, due to motorist complaints and a lack of political support, these meters have been removed.

4.3 Baltimore Harbor Tunnel

The Baltimore Harbor Tunnel was a test site used in the mid 1970's to study restricted flow on traffic facilities. The project involved implementing mainline metering 1200 feet upstream of the tunnel portal. Metering was activated when flows became congested, this usually occurred at speeds between 32 and 40 kph. Results of the analysis showed increased speeds in the tunnel and capacity increases of about 10 percent per lane.[19] Again, similar to the Hampton Roads situation, mainline metering was discontinued as a result of political pressure.

4.4 Summary of Mainline Metering

Often new and different traffic engineering techniques, like mainline metering, take time to catch-on. This relates to taking the "let somebody else make the mistake first" position. However, to study the effects of mainline metering, agencies can look at unregulated conditions that currently exist. Two examples of unregulated mainline metering include toll booths and incidents.[15,18] Mainline toll booths act similar to meters in that there is a reduction in capacity because every vehicle must come to a stop. As seen in Chicago, after exiting the toll booths the freeway returns to free-flow conditions. Lane blocking incidents are also artificial reductions in capacity. Again, after passing the scene of the incident, traffic usually returns to free-flow conditions. It should be noted that even though the end results are similar to mainline metering, unregulated metering creates larger and unnecessary queuing. This is because these situations are not being managed in an organized manner, as would be the case with metering.

Freeway bottlenecks can occur for a number of reasons. Commonly, they occur at geometrically constrained locations where tunnels and bridges exist. At these situations, mainline metering is a viable traffic management tool that has been proven to increase throughout and improve flow conditions. However, mainline metering is the most restrictive form of ramp metering. For this reason it suffers from a lack of political and public support, making mainline metering difficult to implement.

Nevertheless, if the institutional barriers can be overcome, significant benefits are waiting to be gained.

5.0 RAMP METERING CONSIDERATIONS

To this point, this report has shown ramp metering in a pro-implementation approach. However, it is not the intent of this paper to "sell" metering. Ramp metering is not a cure-all for freeway traffic congestion, but properly designed and well managed ramp metering has proven to be an extremely cost effective strategy in reducing congestion. Metering is not appropriate for every location, there are issues of design and operation that must be considered before implementing any ramp metering program.

5.1 Applications for Ramp Metering

Freeways and arterials are fundamentally different systems. On arterials, traffic engineers encourage platoons to improve the quality of flow. On freeways, platoons entering a congested, or nearly congested, mainline create unstable conditions which can lead to the "break-down" of traffic flow. Freeway entrance ramps are the links between these two "different" systems. Ramp meters act as transitioning elements to split-up platoons and prepare vehicles to merge with freeway flow conditions.

Recurring congestion is the predictable occurrence of slow downs in traffic flow. Typically it occurs during peak hours in the same location on a daily basis. Ramp metering is the primary traffic management tool to reduce the impacts of recurring congestion. Metering is also used during non-recurring congestion (incidents, debris, etc.) to help manage flow in the vicinity of, and upstream of, a temporary bottleneck. However, metering is primarily used as a proactive tool to delay the onset of, and reduce the time period of, recurring congestion.

5.2 Types of Ramp Metering Systems

The sophistication and extent of a ramp metering system should be based on the amount of improvement desired, existing traffic conditions, installation costs, and the continuing resource requirements that are necessary to operate and maintain the system effectively. The simplest form of control is a fixed time operation. It performs the basic functions of breaking up platoons into single-vehicle entries and setting an upper limit on the flow rates that enter the freeway. Presence and passage detectors may be installed on the ramp to actuate and terminate the metering cycles, but the metering rate is based on average traffic conditions at a particular ramp at a particular time. This type of operation provides the benefits associated with accident reductions, but is not as effective in regulating freeway volumes because there is no input about mainline traffic. Pre-timed control can be implemented on any number of

ramps, and is often implemented as an initial operating strategy until individual ramps can be incorporated into a traffic responsive system.

The next level of control, traffic responsive, establishes metering rates based on actual freeway conditions. The local traffic responsive approach utilizes detectors and a micro-processor to determine the mainline flow in the immediate vicinity of the ramp and the ramp demand to select an appropriate metering rate. Traffic responsive control also permits ramp metering to be used to help manage demand when incidents occur on the freeway, i.e. reduce the metering rate at ramps upstream of the incident and increase the rate at ramps downstream.

System-wide control is a form of traffic responsive control but operates on the basis of total freeway conditions. Centralized computer controlled systems can handle numerous ramps in a traffic responsive scheme and feature multiple control programs and overrides. Control strategies can also be distributed among individual ramps. A significant feature of system control is interconnection that permits the metering rate at any ramp to be influenced by conditions at other locations. Denver showed that this type of control has significant benefits when properly applied.' References 20, 21, and 22 contain detailed descriptions of various ramp metering controls.

Ramp meters operating in local traffic responsive mode or under centralized computer control are governed by software codes called algorithms. These algorithms emulate operational strategies and policies developed by the ramp metering agency. For example: when metering begins, when it ends, how and when changes in metering rates occur, overrides for long queues, etcetera. A discussion of ramp metering algorithms is beyond the scope of this report, however, good examples of existing ramp metering strategies, from Seattle and Minneapolis, can be found in References 23 and 24.

System control need not be limited to the freeway and its ramps. The concept of integrated traffic control combines or coordinates freeway and arterial street control systems to operate on the basis of corridor wide traffic conditions. The potential advantages of integrated control include reduced installation and operating costs, corridor wide surveillance, better motorist information, and quicker and coordinated use of all of the control elements (meters, signals, signs, etc.) in response to real time traffic conditions. Simulation results from one study showed that, during an incident, coordination of arterial traffic signals and ramp meters can improve the traffic performance of a corridor.[25] The only existing integrated system in the U.S. is the INFORM project, but the concept is attracting considerable interest. Two cities, Seattle and Irvine, California, are in the process of implementing systems. Numerous other agencies are actively considering the integration of freeway and signal control systems. The initial efforts are primarily aimed at non-recurring situations where the signal timing can be modified in response to freeway incidents. Work is also underway, however, on corridor wide surveillance and adaptive control strategies.

5.3 Metering Rates

Metering rates have definite upper and lower limits which do affect the feasibility of metering. The maximum discharge rate of a single metered lane is about 900 vehicles per hour (vph). This is based on a minimum reasonable cycle length of 4 seconds (2.5 seconds of red, or red plus yellow, and 1.5 of green). The discharge rate can be increased by permitting two vehicles per green, but then the minimum cycle length should be increased to about 6 or 6.5 seconds. The maximum discharge rate then increases to 1100 or 1200 vph. Another technique employed at high volume ramps is to widen the ramp to 2 or more lanes at the meter and permit one or two vehicles per lane per green. These ramps are then transitioned back to one lane before merging with the freeway. Maximum discharge rates for this type of operation, with one vehicle released per lane, is about 1800 vph. Metering high volume ramps presents a number of problems and requires extensive analysis.

It has also been found that there is a practical minimum discharge rate as drivers simply will not wait more than about 15 seconds. At that point violations increase significantly. The most restrictive rate then is about 240 vph. After metering begins it may take several weeks or even months to calibrate the system parameters. For this reason, it is important to observe the operation closely.

5.4 Ramp Geometrics

Numerous states have design guidelines for metered entrance ramps. Common amongst the designs are certain characteristics that make ramps suitable for metering. The three primary considerations are the availability of storage space, adequate acceleration distance and merge area beyond the meter, and sight distance. Storage requirements can be estimated from the projected metering rate and the ramp traffic demand. An adjustment can also be made for shifts in demand that may occur as a result of metering. A number of techniques are employed to assure that non-freeway bound traffic on local streets is not adversely impacted by ramp meter queues.

The most common technique used to enlarge storage space is to increase the number of lanes on the ramp before the meter. In Minneapolis it has become standard procedure to meter ramps only if two or more storage lanes can be provided. On new freeways, even where metering is not contemplated until some future date, provisions for adequate storage should be a design consideration. On existing freeways, re-striping or re-constructing ramps to allow for two or more lanes is common. Other than agencies individual preferences, no consensus has been reached on the most appropriate way to release vehicles from two-lane ramps. Simultaneous, intentionally staggered, and independently (randomly) released vehicles are all being used. In Minneapolis, one loop ramp was widened to four lanes approaching the meters. The meters release vehicles from two lanes at a time, alternating between the right pair and the left pair. Downstream of the meter the vehicles merge into one lane before reaching the freeway.

Estimating shifts in demand requires judgement and should be based on site and traffic conditions. To estimate the storage requirements for new installations in Minneapolis, the staff uses a rule-of-thumb of 10% of the pre-metered peak hour volume. In other words, if the peak hour ramp demand is 500 vehicles, storage for 50 vehicles should be adequate. If there is storage for 5% of the pre-metered volume, it may be adequate but additional analysis is necessary and mitigating measures may be required. If the storage length is not adequate for 5% of the pre-metered volume, mitigating measures are required or metering is not considered feasible. In San Diego, it has been observed that a 10% to 15% reduction in pre-metering peak hour ramp volumes is usually achievable without significant adverse impact. It is also common in California to estimate storage requirements using an arrival-discharge chart.[26] Once the number of vehicles is determined, the number is multiplied by 29 feet/vehicle to obtain the total minimum required storage length. Another common queue estimation method is through computer simulation programs such as FREQ, FRESIM, and FRED.

In San Diego, storage is not limited to the ramp proper in most locations. There, a portion of the surface street approach is used to store vehicles, in one location as far as 2000 feet from the freeway. This arrangement may require modification of signal timing at nearby intersections and channelization to reduce the impact the ramp queue might have on non-freeway bound traffic.[14] This technique has proven quite successful in San Diego, and no doubt has application in other locations.

Some ramps are physically constrained and unable to provide adequate storage. Even properly designed ramps will occasionally experience volumes that exceed storage capabilities. For this reason, most metering systems include queue detection loops, near the entrance to the ramp, which send an “alarm” when long queues form. Most agencies’ policy is to keep queued vehicles from impacting local streets. Therefore, when an alarm is sounded, metering rates are adjusted to allow more vehicles through. If the queue persists, some agencies turn the metering off to clear the vehicles. Seattle uses an additional “advance queue loop” which is used to help predict the onset of excessive queuing. Seattle also uses CCTV to visually monitor ramp queues. If required, the operators can manually override the central computer and increase the metering rates. Reference 27 has a detailed discussion of queuing detection components in Denver, Chicago, Toronto, Los Angeles, and Seattle.

The distance downstream of the meter must be adequate to permit vehicles to accelerate to freeway speeds from a stopped condition. The acceleration characteristics of heavy trucks and small economy cars, and the grade of the ramp are factors that must be considered. Many agencies have lengthened acceleration lanes to provide for safe merging.

The third consideration is sight distance. Because of the curvature on many ramps, it is difficult to obtain minimum stopping sight distance requirements. Additionally, unless the public is well informed, drivers generally are not expecting to stop on an entrance ramp. Therefore advance warning signs are usually needed to make drivers aware of the forthcoming stop. Blank-out signs or static signs enhanced with flashing lights are the most common forms used. In addition to advance signing, at high accident ramps, INFORM also uses strobe lights in the red lens to help emphasize the stop indication. Many states have standardized advance warning signs and other ramp metering considerations. One good resource is a document developed by Caltrans entitled "Ramp Meter Design Guidelines".[26]

5.5 HOV By-Pass Lanes

By itself, a single traffic management strategy will not solve urban congestion. In fact, the basis of traffic management is the application of combinations of strategies that complement each other. Another strategy that is frequently used in combination with ramp metering is a HOV by-pass lane. This is a parallel ramp or ramp lane that is reserved for HOV's to by-pass the meter and thus provide a travel time incentive for carpools, vanpools, and buses. Currently there are over 640 metered ramps with HOV by-passes in North America. In Phoenix and Denver the metered mixed flow lanes receive an extended red indication to allow the safe merge of an HOV vehicle. In areas where the number of HOV's becomes too large, the occupancy rule can be modified or the HOV lane can also be metered. This latter strategy is used in San Diego where the HOV by-pass lanes are metered but, because HOV volumes are lower, there is still a time advantage on the by-pass lanes. Informative articles on HOV metered ramp designs are included in References 28 and 29.

5.6 Ramp Meter Signal Heads

In section 4E-22 of the Manual on Uniform Traffic Control Devices (MUTCD), broad guidelines are given for ramp meter signal heads.[30] This is one reason why most signalized ramps have similar designs; however, there are no national standards, only recommended practices. This is for two reasons. First, two and three section signal heads have both been used successfully. Secondly, to require a change in hardware and software, without substantial cause, would be considered wasteful spending.[31]

As mentioned, both two and three section heads are commonly used. California requires the three section head whenever more than one vehicle is released from a lane. Some agencies, like Denver, have three section heads, but only use the amber during start-up. After, they go back to phases with only green and red indications. The agency should choose the head and type of operation based on local driver expectancy and local design regulations. However, whichever type is chosen, each operating agency should develop a standard and maintain consistency throughout its ramp metering system.

5.7 Enforcement

The effectiveness of ramp metering, like any other traffic regulation, is largely dependent on voluntary driver compliance. As part of the public information effort, it should be made clear that ramp meters are traffic control devices that must be obeyed. The laws and penalties should be clearly explained. In cities where the advance publicity was positive and plentiful, violation rates are lower. Again, like any other regulation, enforcement is needed. Cooperation with police agencies is essential. Effective enforcement requires good enforcement access, a safe area to cite violators, adequate staff, support by the courts, and good signs and signals that are enforceable. Enforcement needs must be considered and accommodated early during the project development and design stages. Enforcement personnel should also be included early on in the planning and design of ramp metering projects. Compliance is critical to the success of a ramp metering system. Compliance rates, have generally been good in most areas across the country. However, violations are contagious and can multiply quickly. The result can lead to an extremely ineffective ramp metering system.

5.8 Diversion

A major issue that is raised in connection with metering is the potential diversion of freeway trips to adjacent surface streets to avoid queues at the meters. Extensive evaluations of existing metering systems show that adjustments in traffic patterns, after metering is implemented, take many forms. However, it is possible to predict the likely impacts of metering before it is installed. Factors that enter into the analysis include trip length, queue length, entry delay, and especially the availability of alternate routes. The impact of attractive and efficient alternate routes can be a key factor in the effectiveness of a ramp metering system.[32] The probable new traffic patterns, including diversion, can then either be accommodated in the design and operation of the system, or become part of a decision that metering is not feasible.

Metering may in fact divert some short trips from the freeway. In concept, freeways are not intended to serve very short trips, and diverting some trips may even be desirable if there are alternate routes that are under-utilized. Diverting traffic from high volume, substandard, or other problem ramps to more desirable entry points should be an objective of metering where it is feasible. Such an action does require a thorough analysis of the alternate routes and the impacts of diversion on those routes, and improvements on the alternate routes when and where they are needed.

In Portland, city officials were very concerned about entrance metering creating problems on parallel streets. Before the meters on I-5 were installed, the city and state agreed that if volumes on adjacent streets increased by more than 25% during the first year of operation, the state would either abandon the project or adjust the meters to reduce the diversion below the 25% level. Following meter installation, the increase in local street volume was not substantial. Evaluations of the impact of metering on adjacent streets have been conducted in Los Angeles, Denver, Seattle, Detroit and other cities. Significant diversion from the freeway to surface streets did not occur in any of these locations. Formal and informal agreements are common between state and local jurisdictions in connection with metering projects and close advance coordination between jurisdictions is highly recommended.

In some cases, there may not be feasible alternates routes due to barriers such as rivers, railroads or other major highways. Metering still can and does operate effectively where diversion is not an objective of the system. The systems in Denver, Northern Virginia and Chicago, for example, operate under a so called non-diversionary strategy. In these systems, metering is sometimes terminated at least until the queue dissipates. Significant benefits in freeway flow and accident reduction still result from non-diversionary metering. The onset of mainline congestion consistently begins later in the peak period and ends earlier. Many days the mainline does not break down at all. Accidents and accident rates are also reduced. For example, in Denver it was observed that many drivers entered the freeway earlier in the morning. Peaks or spikes in volumes were thus leveled out over a longer period of time resulting in better utilization of freeway capacity.[8]

In each of the case studies, as well as on other systems, there was an increase in peak hour or peak period freeway volumes after metering was installed. In a number of cases metered freeway sections experienced volumes that exceeded 2,000 vehicles per lane. These are not random occurrences and can be attributed to flow rates higher than those that occur under level of service “F”, or “break-down” conditions. In some instances the improved mainline flow resulted in higher volumes on the metered ramps as well. In San Jose, an increase in some peak period ramp volumes has been observed after metering began. Before metering, when the mainline flow broke down, the ramps would back up causing reduced ramp volumes. After metering, the freeway seldom broke down and some ramp volumes over the peak period actually increased. Also, even with the ramp delays, some drivers that were using other routes found (or perceived) the freeway offered a faster trip and were attracted to the freeway. A well designed and operated ramp metering system improves operations and does not cause excessive diversion to adjacent streets. The latter is caused by excess demand and/or inadequate capacity.

5.9 Public Acceptance

A very important aspect of ramp metering is the need to gain public and political support. In New York, the public relations campaigns referred to ramp meters as “merge lights”. It was believed that the new term conveyed a more positive message.[13] To the public, ramp meters are often seen as a constraint on a roadway normally associated with a high degree of freedom. Although definite benefits may be achieved by metering and have been demonstrated statistically, the benefits may not be recognized by individual motorists. A three minute wait at an entrance ramp, however, is easily recognized. A proactive public relations program should be an integral part of every metering project.

Unfortunately, the fear of a negative public reaction is often used as an excuse and is, in reality, the true reason operating agencies reject ramp metering projects. Often cited are examples of "failures" due to public opposition. An implementing agency should expect and be willing to accept some criticism for applying an unpopular control device. Criticism is nothing new to most highway agencies, but ramp metering is. As a result, the agencies are not comfortable with fully supporting a strategy that they have no experience with. Most of the failures of metering projects attributed to public rejection can be directly linked to a "business as usual" approach by the implementing agency.

Successful public relations campaigns will explain the difficulties of mitigating freeway congestion problems and the cost effectiveness of management techniques such as ramp metering. The campaigns should also provide realistic expectations of the system's benefits, and show how taxpayers will experience improved freeway conditions. The most common method of disseminating ramp metering information is through brochures or media advertisements on television and radio. Some examples of public relations brochures are shown in Appendix 2. In Minneapolis and Los Angeles, the "public" has actually requested additional metered ramps. This public input has become one of the factors in evaluating and selecting new metered locations.

In Seattle the Washington State DOT (WSDOT) has developed a methodical approach to implementing ramp metering.[33] Their process describes what needs to be accomplished starting five years prior to ramp metering all the way up to one week before, and continuing to six months after start-up. The procedure includes public input, the design process, and the public relations focus. In Tacoma, Washington, the WSDOT went beyond the typical public relations campaign of brochures and media advertisements. WSDOT has incorporated a ramp metering lesson into both public and private driver education school curricula. The lesson, which lasts about 30 minutes, helps students to understand what ramp meters are and what they mean to the driver. The information packet for this lesson includes a lesson plan, information sheets, brochures, key chains, and a well developed 12 minute video entitled "Ramp Meters: Signals for Safety". A promotional videotape from the FHWA entitled "Ramp Metering: Signal for Success" is another example of how the merits of ramp metering can be presented to the public. This 17 minute videotape, which is intended for citizens and public officials, explains the principles and benefits of ramp metering. It addresses key issues such as safety, efficiency, equity, and public relations. Copies are available through the FHWA or the Institute of Transportation Engineers (ITE).

5. 10 Equity

The complaint that ramp metering favors longer trips at the expense of shorter trips can be a controversial issue. Close-in residents argue they are deprived of immediate access to the freeway, while suburban commuters can enter beyond the metered zone and receive all the benefits without the ramp delays.

Again there are strategies that have been employed to mitigate the equity issue. In Detroit, the initial metering was operated only in the outbound direction to minimize the city-suburb equity problem. Once the effectiveness of the metering was established, the system was expanded with less objection. This strategy will also be used in Atlanta where northbound I-75, leaving the city during the evening peak, will be the first section metered.[34] In Seattle, the system was designed to allow more restrictive metering rates farther away from downtown. With the long trip length, motorists originating from the suburbs have the most to gain from improved freeway conditions. The minor additional delay experienced at the meters is more than offset by the reduced mainline travel times. In Milwaukee where the question of equity has been a limiting factor in the expansion of metering, it is now proposed to expand the system by metering each ramp that contributes traffic to congested freeway segments. Metering rates will be designed to be comparable for all ramps. For example, if it is determined a 10% reduction in demand is needed on the freeway segment, metering rates will be established to reduce all ramp volumes by 10%. In addition, each ramp metering rate will be adjusted to the extent possible in order to assure average motorist delays are about the same for the outlying ramps as they are for closer in ramps.[35]

Even if only a few drivers experience increased travel times, there may still be objections simply because some have to wait at the ramps and other drivers do not. A reasonable analogy can be made between a metered freeway and a signalized arterial. Vehicles entering an arterial from a minor street must generally wait at a traffic signal while traffic already on the arterial is given priority. In both cases, the freeway and the arterial, the entering vehicles experience some delay in order to serve the higher volume facility.

6.0 GUIDELINES FOR RAMP METERING

There have been a number of attempts to develop “warrants” for ramp metering, but it is difficult to establish a single set of conditions because of the many factors involved. There are few, if any, freeways that experience congestion that can not be improved by metering. The operation of the freeway, however, is only one of several factors that must be considered in evaluating the appropriateness of metering. Ideally, metering should be but one element of an overall freeway management program.

However, ramp metering has proven to be successful on its own without the assistance of other traffic management tools.

The Manual on Uniform Traffic Control Devices (MUTCD) provides some general guidelines for freeway entrance ramp controls in Section 4E-23.[30] The Manual states that the installation of ramp meters should be preceded by an engineering analysis. It also describes the factors that should be examined in the study, most of which have been covered in this paper in greater detail. The Manual then gives a very broad description of when the installation of ramp meters may be justified. It simply states that entrance ramp signals may be justified when the total expected delay to traffic in the freeway corridor, including freeway ramps and local streets, is expected to be reduced. Minimum volume warrants were considered, but not used because freeway capacity does vary according to geometric, traffic and driver characteristics. Freeway operating conditions provide the most guidance. Candidate freeways for ramp metering are usually plagued with poor peak period conditions such as speeds of 48 kph or less, and volumes of only 1200 to 1500 vehicles per lane per hour. Other candidates for metering include new and reconstructed facilities that may become overloaded shortly after they are completed. There is agreement among operating agencies that it is best to implement metering before conditions get severe. More restrictive metering rates can then be applied gradually as demand increases over time to help spread the peaks and thus maintain operational efficiency.

In Minneapolis/St. Paul, high accident locations and freeway operating conditions were the two most frequent factors used to identify candidate ramps for metering. Metering some ramps may also be required to complete a system, to prevent undesirable shifts in travel patterns, to address the equity issue, and/or to improve the quality of a merge operation.

7.0 LESSONS LEARNED

As stated at the beginning of this report, the intent of this document is to provide an initial resource for agencies exploring the feasibility of ramp metering. To continue this theme, it was surmised that great benefit could be gained from agencies that are operating ramp meters. Their past experiences and mistakes could help identify potential trouble areas up front, allowing necessary precautions to be taken. Another resource to help identify potential issues is the guidance provided by an Implementation Plan which is required by the FHWA for all new, or expanded, traffic control systems.[36,37]

In communicating with agencies (Appendix I), the following question was posed, "If you could go back and start your ramp metering program over, what would you do different?" There were two primary answers to this question, provide adequate vehicle storage and improve public relations. Many agencies stated that adequate space to store queues is a critical element to the success of ramp metering. Queues that reach local streets cause overrides in the metering system requiring vehicles to be released quicker (sometimes shutting the meter off). This contradicts the intent and reduces the usefulness of meters. Several agencies mentioned that it is was best to provide ample storage from the beginning, to help minimize complaints. Public relations was also considered a key to effective ramp metering. Several states said more emphasis on a public relations campaign would have developed genuine public and political support, softening the initial impact of metering. Agencies, like the Colorado DOT, say the good rapport with the media is a great ally. Several states also acknowledged that periodically reminding the public of the benefits of ramp metering is also helpful.

There were several other notable replies. Some states thought benefit analysis studies should have been conducted. They felt using statistics from their own system would be better accepted when talking to the public and politicians. When questioned about the effectiveness of the metering system, an agency would be able to validate their own subjective opinions, and national statistics, with locally generated benefits. Another common reply involved police support. It was agreed that law enforcement is an important part of insuring compliance. Several states felt that the early involvement of law enforcement would have created better teamwork and cooperation (as mentioned earlier in this report). Another valid lesson is to make sure money is spent during implementation to obtain accurate software code documentation, as well as trouble shooting manuals that are user-friendly. This is extremely helpful during expansion and employee turn-over. Although only mentioned by a few agencies, the continued funding for adequate maintenance and operations support is also an important consideration. Keeping ramp metering hardware and software in peak condition accomplishes two points. First, the number of local (bulbs, electrical) and system failures are reduced. These types of malfunctions can cause the motorist to lose trust with the metering. Second, a well managed system is needed to reap maximum benefits. The last significant lesson learned was unusual because while some agencies felt a more aggressive implementation approach was necessary, the Minnesota DOT felt just the opposite. The Minnesota DOT activated so many signals, so quickly, that it was difficult to optimize the signals.

8.0 CONCLUSION

Currently, over 70 percent of the miles traveled during peak hours are under congested conditions.[38] Much of this is the result of inefficient freeway operation. Ramp metering has proven to be one of the most cost-effective techniques for improving and maintaining the efficient operation of urban freeways during peak traffic periods. The benefits derived from ramp metering have been well documented in this report. They include:

- Accident rate reductions of 24 to 50%
- Increased throughout of 17 to 25%
- Increased mainline speeds of 16 to 62%

The results of the above benefits include consistent commute times, less congestion, and reduced driver frustration. Metering is not a cure-all for urban freeway congestion, but if conditions are proper, the effectiveness of a well planned and operated ramp metering system is undeniable.

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RAMP METERING STATUS IN NORTH AMERICA - 1995

ARIZONA

PHOENIX: 65 ramp meters, 28 on I-10, 28 on I-17, and 9 on US 60. 28 meters will be under centralized computer control by mid 1995. 9 ramps have HOV by-pass lanes. First installation occurred during the 1970's, which consisted of 10 meters on I-17. Future expansions include a freeway management system that will cover 320 kilometers. Ramp metering will be an integral part of this system.

CALIFORNIA

FRESNO: 15 local traffic responsive ramp meters. 8 of the ramps have HOV by-pass lanes. The first 6 ramp meters were installed in 1993.

LOS ANGELES/VENTURA COUNTY: 808 ramp meters operate on most freeways in the Los Angeles area. Most operate local traffic responsive. 313 ramps have HOV by-pass lanes. 32 meters operate all day. This system also includes 19 freeway-to-freeway connector meters. The first ramp meter installation was in 1968, which included 8 meters on I-110. There are near-term plans to upgrade the system to centralized computer control.

ORANGE COUNTY: 278 ramp meters operate on most freeways in Orange County. Most operate local traffic responsive. 105 ramps have HOV by-pass lanes. The system is currently being upgraded to centralized computer control.

RIVERSIDE: 43 local traffic responsive ramp meters are operating, 38 on SR 91 and 5 on I-15. There are 12 ramps with HOV by-pass lanes. There are plans to upgrade the system to centralized computer control.

SACRAMENTO: 19 local traffic responsive ramp meters are operating, 2 on I-5 and 17 on US 50. 8 of the ramps have HOV by-pass lanes. First installation occurred in 1983.

SAN BERNARDINO: 35 local traffic responsive ramp meters are operating, 19 on I-10 and 16 on SR 60. There are 12 ramps with HOV by-pass lanes. There are also plans to upgrade the system to centralized computer control.

SAN DIEGO: 134 centralized computer controlled ramp meters operate on most freeways in the San Diego area. 57 ramps have HOV by-pass lanes. This system also has 8 freeway-to-freeway connector meters. The first installation occurred in 1968. 50 additional meters will be turned on in late 1995.

SAN JOSE/SAN FRANCISCO AREA: 98 local traffic responsive meters operate in the San Francisco Bay area predominately near San Jose. The freeways include SR 17, SR 85, SR 87, US 1010, I-280, and I-880. 23 ramps have HOV by-pass lanes. There are 4 freeway-to-freeway connector meter currently operating. Five others have been constructed and should be operational during late 1995. There is also mainline metering after the San Francisco-Oakland Bay Bridge toll plaza and includes HOV by-pass lanes. Expansion plans include ramp metering throughout the San Francisco Bay Area as part of an area-wide traffic management system.

CANADA

MONTREAL, QUEBEC: 9 fixed time ramp meters are under design, 1 on A-40 and 8 on A-l 5. Installation is planned for 1996. Future plans include upgrading the ramp meters to local traffic adaptive, and possibly area-wide control.

OTTAWA, ONTARIO: Up to 8 ramp meters are being considered for installation on Highway 417.

TORONTO, ONTARIO: 10 centralized computer controlled ramp meters are located on Queen Elizabeth Way (QEW). The first installation occurred in 1975. Feasibility plans are currently underway for the expansion of existing ramp metering on QEW; up to 42 ramps. Feasibility studies for Highway 401 should be started shortly. Up to 54 ramp meters could be installed.

COLORADO

DENVER: 28 centralized computer controlled ramp meters are operating on I-25, I-225, I-70, I-270, and US 6. 5 ramps have HOV by-pass lanes. First installation occurred in 1981 when 5 meters were installed as part of demonstration project. Future expansion includes a recently advertised project to upgrade central computer hardware and software.

FLORIDA

MIAMI: 22 centralized computer controlled ramp meters will be installed on I-95. Meters will be activated in October of 1997 as part of the I-95 Intelligent Corridor System. The first 17 mile phase is being built in Dade County. The project will include variable message signs, CCTV, and vehicle detection.

GEORGIA

ATLANTA: 5 centralized computer controlled ramp meters will be installed on I-75. The meters are being implemented as part of the area-wide ATMS. The meters will be installed prior to the 1996 Summer Olympics. Expansion plans, numerous other corridors have been studied and prioritized.

ILLINOIS

CHICAGO: 113 centralized computer controlled meters are located on I-90, I-94, I-90/94, I-290, I-57, and Congress Parkway. 103 meters operate local traffic adaptive and 10 operate on area wide control. First installation occurred in 1963 on I-90 (now I-290).

MASSACHUSETTS

BOSTON: As part of the Central Artery project, 3 locations will have mainline metering. All three locations are at portals to control flow through tunnels. Ramp metering is also being considered at 12 locations. Further studies will be done to insure the feasibility of the meters. Earliest activation would be near the year 2000.

MICHIGAN

DETROIT: 49 ramp meters with centralized computer control, 28 on I-94 and 21 on I-10. First installations occurred in 1981 as part of the SCANDI project. 10 additional ramp meters on I-75 are proposed to be installed within two years.

MINNESOTA

MINNEAPOLIS/ST.PAUL: 368 ramp meters on I-35W, I-35E, I-94, I-394, I-494, I-694, SR 169, SR 62, SR 100, SR 36,and SR 77. 347 operate under centralized computer control and 21 operate fixed time. 46 of the ramps have HOV by-pass lanes. The system includes 74 freeway-to-freeway connector meters. The first ramp meter installation was in 1970 and included six meters. Most of the installations occurred between 1988 and 1995. Over the next five years, 84 more meters will be installed. This will complete the metropolitan area system.

NEW JERSEY

NEWARK: 1 meter is being installed on I-80 as part of the MAGIC system. Activation will not occur until late 1996. This ramp met all geometric criteria, and upon implementation, will be studied to determine the feasibility of adding more ramp meters.

NEW YORK

NEW YORK: 70 ramp meters are operating, 50 on I-495 and 20 on the Northern State Parkway. All meters operate local traffic adaptive and some are under centralized control. 55 ramp meters were first installed in 1989 as part of INFORM project. There are also 9 ramp meters on I-678 in Queens. Currently these meters are not operating, but will be re-activated after completion of the re-modeling being done to the control center.

OHIO

CLEVELAND: 3 ramp meters are being constructed on I-71 in a suburb southwest of Cleveland. The impetus for the meters is a new shopping mall requiring widening of an arterial which feeds the ramps to I-71. The ramp meters will be fixed time and operate only in the peak direction during peak hours.

COLUMBUS: 6 fixed time ramp meters operate in time of day mode, 3 on I-71, 1 on I-70, and 2 on SR 315. The first installation occurred in 1973, which consisted of 3 meters. As part of a freeway management system under design, six more meters will be added. The new system will have capacity for up to 66 ramp meters. Future upgrades include traffic responsive meters and centralized computer control.

OREGON

PORTLAND: 58 fixed time meters operate along I-5 ,I-84, I-205, SR 217, and US 26. 6 ramps have HOV by-pass lanes. Expansions plans include a new system on I-205 and upgrading the meters to centralized control. The first 16 ramps were installed in 1981.

PENNSYLVANIA

PHILADELPHIA: 16 centralized computer controlled ramp meters are under construction on I-476. Meters operate under fixed time, local adaptive, and area-wide control depending on the traffic volumes. Meters are activated by time of day; however, local traffic adaptive control may occur 24 hours/day in response to incidents. A future expansion includes 17 ramp meters on I-95. Construction is scheduled for 1997-2005.

TEXAS

DALLAS: Currently, there are no operating ramp meters. Due to highway reconstruction, 35 ramp meters on US 75 were removed in the early 1990's. As part of the construction, on US 75, the ramp metering infrastructure is being installed. Several others freeways are under also under construction, which will allow for ramp meters to be installed in the future. First installation occurred in 1971.

FORT WORTH: Currently, there are no operating ramp meters. All existing meters on I-30 were removed in 1989 due to freeway reconstruction. Expansion of the freeway traffic management system will include 10 ramp meters on SH 360 (mid 1996) and 10 meters on I-35W (mid 1997).

HOUSTON: Due to construction, currently, only a few ramp meters are still operating. By early 1996, as part of a new Intermodal Transportation Management System, 106 centralized computer controlled ramp meters will be operating on I-10, I-45N, I-45S, US 290, and US 59. The first installation occurred in 1975.

SAN ANTONIO: 1 local traffic adaptive ramp meter operates on US 281. 9 ramp meters were originally installed in 1977. After mainline capacity was increased due to widening, 8 of the meters were removed. Future plans include possible installation of ramp meters as part of the TransGuide ATMS.

VIRGINIA

NORTHERN VIRGINIA (D.C. Suburbs): 26 centralized computer controlled ramp meters, 16 on I-395 and 7 on I-66. There are 2 ramps with HOV by-pass lanes. The first installation was in 1985, this included all 26 ramp meters. No future expansions are planned. However, during a major re-construction project on I-95, the foundations and conduits of the ramp metering infrastructure are being installed.

WASHINGTON

SEATTLE: 54 centralized computer controlled ramp meters that adjust metering rates based on current system-wide traffic conditions. 12 ramps are located on I-90, 37 on I-5, and 5 on SR 520. 37 of the ramps have HOV by-pass lanes. The system also has 5 freeway-to-freeway ramp meters. First installation occurred in 1981. Since 1993, 3 ramps, located on SB I-5, have been operating for several hours on weekends. Weekend metering was expanded to include 4 additional ramps in March of 1995. For the first time, in 1995, WSDOT began metering in both directions during the same period. This is due to the ever increasing reverse commute congestion on I-5. Over the next five years, 50 new ramp meters will be installed on I-5, SR 405, and SR 167.

TACOMA: 1 meter operates time of day on I-5. Expansion plans, over the next five years, include 26 additional ramp meters along I-5.

WISCONSIN

MILWAUKEE: 43 local traffic adaptive ramp meters operate on I-94, I-43, I-894, I-794, and US 45. Some of ramps are under centralized control. 7 ramps have HOV by-pass lanes. The first installation was in 1969, which consisted of 3 meters. 17 additional ramp meters were installed in 1994 and 17 more will be implemented in 1995. By the end of 1995, all meters will be operating under centralized computer control.

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APPENDIX 1

RAMP METERING SURVEY

SURVEY OF RAMP METERING

This survey is one source of data being used to update the report entitled "Ramp Metering Status in North America", September 1989. The update is being done at the request of the Traffic Management and Technologies subcommittee of the Freeway Operations committee of TRB. The goal of the update is to provide current information about ramp metering. The update will provide useful information to both agencies that are currently involved in ramp metering, and agencies that wish to pursue the feasibility of ramp metering. Your help in answering these questions is greatly appreciated.

- **When answering the questions, please circle or check all answers that apply.**

- **Please use backside if more room is necessary.**

---

1. YOUR NAME:

2. CONTACT NAME (if different):

AGENCY:

ADDRESS:

PHONE:

3. FREEWAY NAME(S):
(i.e., I-94,SR-14)________________________________
 # OF METERED
ON-RAMPS **0 0 0 0 0 0**
(if more space is needed, please use back)

4. DO YOU HAVE FWY-TO-FWY CONNECTOR METERING? **YES NO**

IF YES, HOW MANY DO YOU HAVE? ______

5. DO YOU HAVE MAINLINE METERING? **YES NO**

6. SIGNAL HEADS (Check all types that apply):

2-LENS:	( ) Arterials ( ) Connectors
3-LENS:	( ) Arterials ( ) Connectors
2 & 3 LENS ON SAME RAMP	( ) Arterials ( ) Connectors

7. DO YOU HAVE HOV BY-PASS LANES? YES NO

IF YES, HOW MANY? _______

IF YES, ARE THEY METERED? ALL SOME NONE

IF YES, WHAT CAN USE HOV BY-PASS?

IF YES, DOES THE NUMBER OF ENTERING HOV VEHICLES AFFECT THE METERING RATE? YES NO

ARE THERE ANY SPECIAL/UNIQUE RAMPS? IF YES, PLEASE DESCRIBE.

8. IS THERE CENTRALIZED CONTROL OF THE METERS? ALL SOME NONE

9. CONTROL TYPE:

NUMBER THAT OPERATE:

FIXED TIME	( )
LOCAL TRAFFIC ADAPTIVE	( )
AREA-WIDE CONTROL	( )

NUMBER THAT OPERATE:

TIME OF DAY	( )
24 HOUR	( )
TRAFFIC RESPONSIVE	( )

IO. WHEN WERE METERS FIRST INSTALLED? HOW MANY?

11. **HAVE THERE BEEN ANY MAJOR EXPANSIONS? WHEN? HOW MANY?**

12. **ARE ANY FUTURE EXPANSIONS (OR ENTIRELY NEW SYSTEMS) / FEASIBILITY STUDIES PLANNED? IF YES, PLEASE BRIEFLY DESCRIBE.**

13. **HAVE ANY METERS BEEN REMOVED? HOW MANY? WHERE? WHEN? WHY?**

14. **IF YOU HAVE MULTIPLE LANE RAMPS, HOW ARE VEHICLES RELEASED (INTENTIONALLY STAGGERED, SIMULTANEOUSLY, RANDOMLY)?**

15. **DO YOU RELEASE PLATOONS OF VEHICLES? WHY? WHERE? HOW MANY PER GREEN? WHAT ARE THE CORRESPONDING MINIMUM CYCLES?**

16. **WHAT IS THE POLICY WHEN EXCESSIVE QUEUE OCCURS ON THE RAMPS?**

17. **IS THERE A METHOD FOR ESTIMATING QUEUE LENGTHS BEFORE INSTALLING A RAMP METER (If yes, please quickly describe)?**

18. HAVE THERE BEEN ANY BENEFIT ANALYSIS STUDIES DONE SINCE 1989? IF YES, PLEASE LIST TITLES, OR IF POSSIBLE SEND IN WITH SURVEY FORM.

19. WHAT IS THE POLICY FOR TURNING ON RAMP METERS (i.e., THRESHOLDS BASED FREEWAY OCCUPANCY, VOLUMES, SPEEDS OR TOD)? ARE THE METERS ACTUALLY TURNED ON BY A COMPUTER, BY AN OPERATOR, OR BY AN OPERATOR WITH A SUGGESTION FROM THE COMPUTER?

20. ARE THERE ENFORCEMENT AREAS FOR RAMP METERS?

ALL SOME NONE

21. WHAT IN THE WAY OF PUBLIC RELATIONS HAS BEEN DONE TO EDUCATE THE PUBLIC PRIOR TO THE INSTALLATION OF RAMP METERS? IS THE PUBLIC EDUCATION A CONTINUOUS EFFORT EVEN AFTER METERING HAS BEGUN? IF YOU HAVE ANY BROCHURES, PLEASE SEND THEM IN WITH THIS SURVEY.

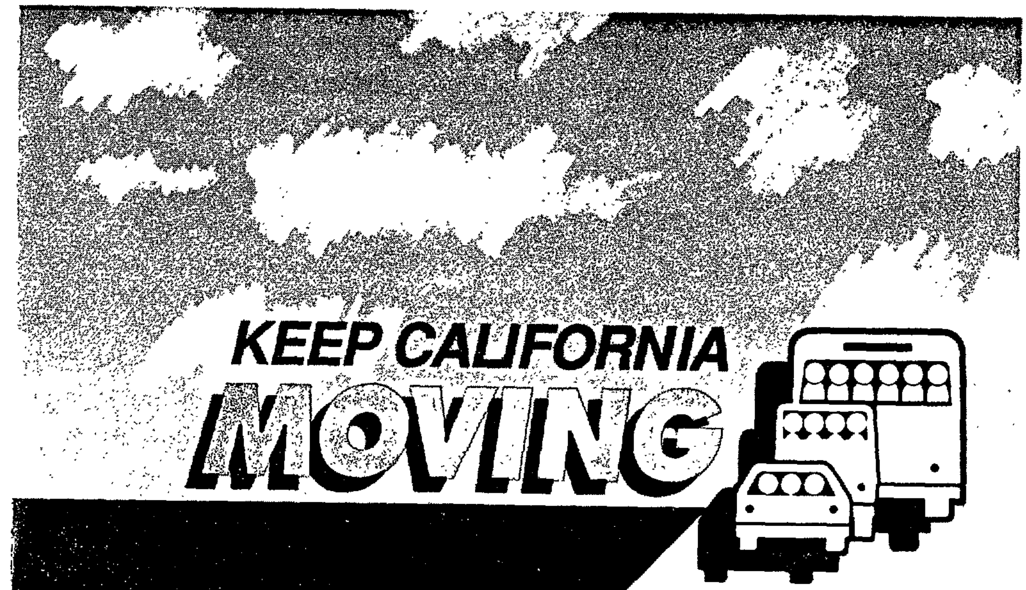
22. IF YOU COULD GO BACK AND START YOUR RAMP METERING PROGRAM OVER, WHAT WOULD YOU DO DIFFERENT (i.e., WHAT LESSONS DID YOU LEARN)?

23. IS THERE ANYTHING ELSE THAT MIGHT BE HELPFUL?

APPENDIX 2

PUBLIC RELATIONS BROCHURES

CALIFORNIA DOT (CALTRANS)
RAMP METER BROCHURE



RAMP METERS

Solutions for Your Community's Traffic Problem

Caltrans

Ramp meters reduce accidents and increase speeds for everyone

When it comes to reducing gridlock on the freeways, ramp meters play a major role in Caltrans plan to keep California moving

At many meters, a computer controls the signal cycle

Ramp meters: An effective tool for smoother traffic

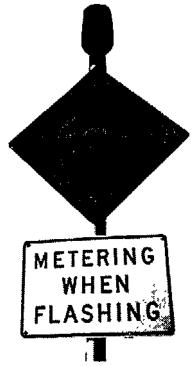
Ever since the fist ramp meters were installed in the Chicago and Detroit areas in the early 1960s, they have been one of the most cost-effective, efficient ways of managing traffic flow. When it comes to reducing gridlock on the freeways, ramp meters play a major role in Caltrans plan to keep California moving.

The concept behind ramp metering is simple: By using a signal at congested onramps, Caltrans can control the rate at which vehicles enter the freeway Vehicles entering at short intervals-usually between four and 15 seconds per cycle-are less likely to slow down existing traffic and can merge onto the freeway with less potential for accidents.

Traffic then enters the freeway with: out the traditional bottlenecks associated with some onramps.

Smoother traffic, fewer accidents

But more than just easing gridlock, ramp meters help Caltrans move more people with fewer accidents on California's freeways. In areas where ramp meters have been installed, average speeds have increased by as much as 50 percent, the volume of vehicles has increased from 50 percent to 80 percent and accident rates have dropped between 20 percent and 50 percent.



Different meters for different needs

There are three basic types of ramp meters: fixed-interval, locally controlled and centrally controlled.

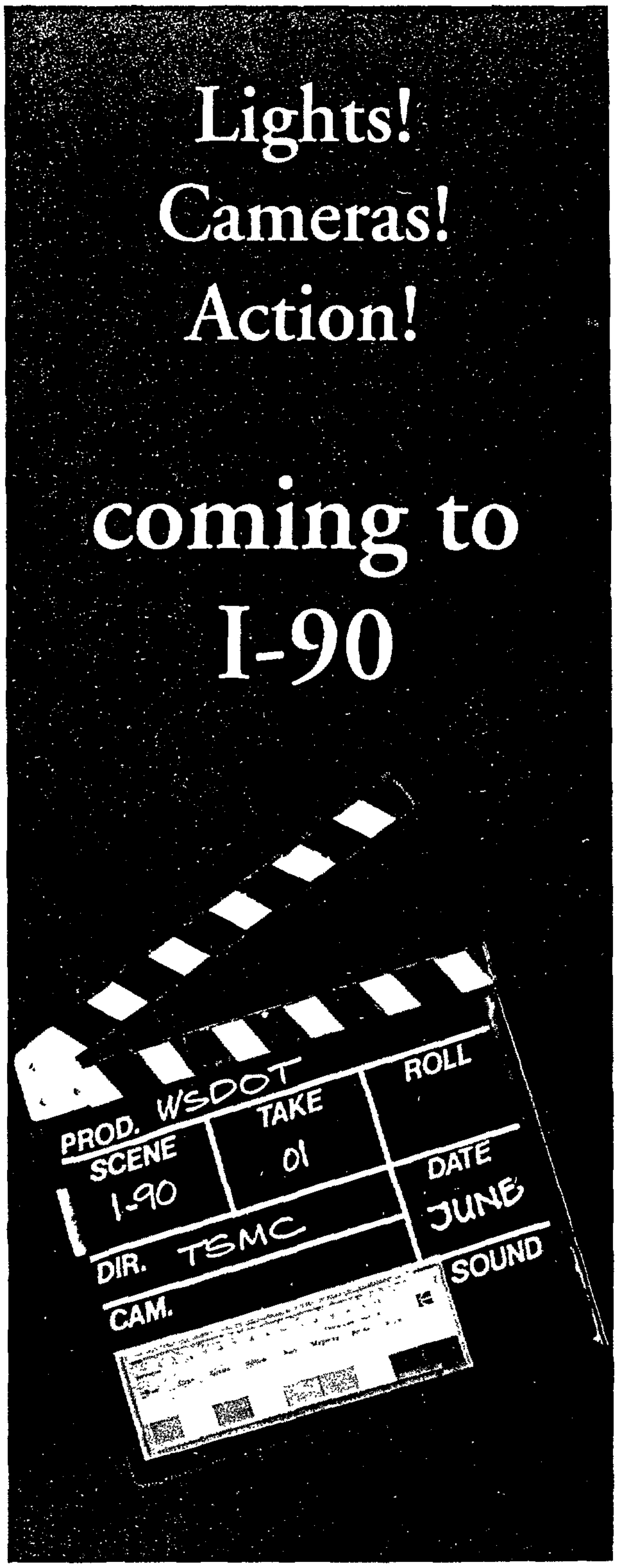
Fired-interval meters feature a cycle rate based on average traffic conditions at a specific ramp. Although not responsive to changing traffic conditions, they are as effective at reducing accidents as other meters and may be used at a temporary location.

Locally controlled ramp meters, sometimes called ***traffic-responsive meters,*** adjust the timing of their cycles to the actual traffic flow in the vicinity of the ramp.

Centrally controlled meters are the most advanced meters available. Metered ramps are controlled by a central computer, so the metering rate at any ramp may be influenced by traffic conditions at the other locations on the freeway

In addition to the three basic meter types, other variables can include carpool bypass lanes at metered ramps and meters that operate only during certain hours. Carpool bypass lanes allow vehicles with a specified minimum number of occupants to enter the freeway without waiting at a ramp meter.

WASHINGTON STATE DOT
2 RAMP METER BROCHURES

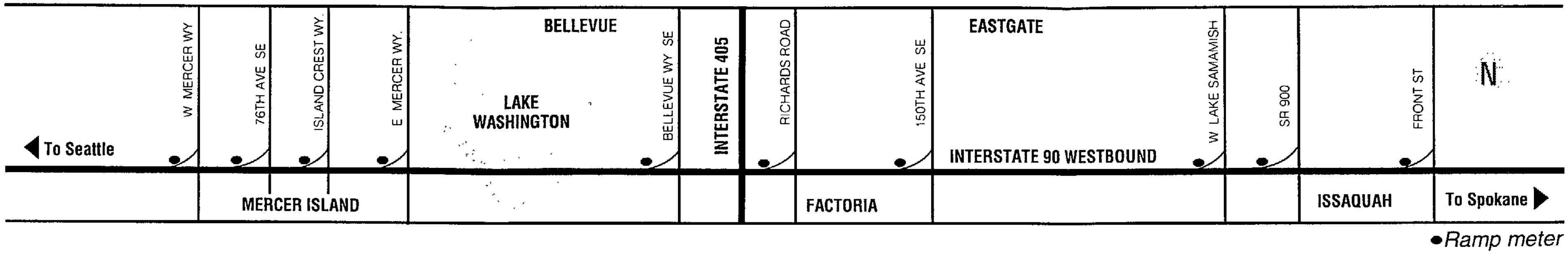


IT's A **ROAD SHOW**

by the
Washington State
Department of Transportation
(WSDOT)

Beginning in June the hooded ramp meters along Interstate 90 will disrobe and come to life.

The ramp meters are part of a creative mix of state-of-the-art electronic equipment that helps reduce traffic congestion and improve mobility on our freeways.



Beginning in June, ten ramp meters on westbound I-90 will be turned on during the morning commute period.

Setting the Stage

WSDOT's Traffic Systems Management Center (TSMC) is working backstage to help alleviate congestion with a crew of technical experts and their high-tech gadgets and gismos. Traffic lights and closed-circuit TV cameras are part of the show; other tools are electronic roadway signs, the Highway Advisory Radio (HAR) system, incident response teams, motorist assistance patrols, and a traffic data collection and display system. This particular show features our cast of ramp meters on I-90.

What is a Ramp Meter?

A ramp meter consists of two components: a traffic signal and a "loop detector" or traffic sensor. The loop detector has a magnetic field that senses when a vehicle passes over it, and it collects traffic information for TSMC. The loop detector controls the ramp meter and detects any problems with the equipment.

Crowd control

While ramps meters aren't a cure-all for the crowds of vehicles jamming up the roadways, they have proven to be a cost-effective strategy for reducing congestion. Ramp meters are used when they are most needed.

In general, the metered ramps are located on I-5 and State Route 520, and beginning in June they will be activated on westbound I-90.

Typically, ramps are metered from 6:00 to 9:00 a.m., and from 2:30 to 7:00 p.m. On I-90 they will be metered in the mornings only. A few selected ramps on I-5 are metered on weekends. Keep in mind that traffic engineers monitor the system and adjust the starting and ending times for metering each day in order to meet specific traffic conditions. WSDOT also works closely with the city and county traffic engineers to maintain a smooth flow of traffic on the arterials that access the freeway.

Things to know about Ramp Meters

- Delays at ramp meters during peak hours average less than two minutes. (No, you won't be able to read Tolstoy's War and Peace while waiting to merge onto the free way!)
- Ramp meters are a proven method of relieving traffic congestion, so they benefit all drivers. By actually increasing the efficiency of the freeway during a time of increased demand, ramp meters save tax payers the costs associated with building new lanes or roads.
- Ramp meters are programmed to respond to actual freeway conditions.
- Accident rates decreased by 39 percent between downtown Seattle and Lynnwood after ramp metering was implemented in the corridor.
- Travel time has decreased with the implementation of ramp metering in Seattle, despite a significant increase in traffic volumes. (Before metering was implemented, a specific 6.9 mile section of I-5 from south Snohomish County to Northgate took 22 minutes to drive. In 1984, after metering, despite increased volumes, the same section took 11.5 minutes.)

HOVS can bypass Ramp Meters

Some freeway ramps have special lanes on them with diamonds painted on the pavement. These HOV bypass lanes allow carpools, vanpools and buses to bypass the ramp meter and the traffic queue waiting to enter the freeway. It's another way that using the HOV system can help those who share the ride save time.

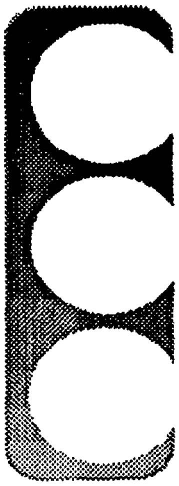
For more information call WSDOT at: 440-4484. or 440-4700

Persons with disabilities may request this information be prepared and supplied in alternate forms by calling collect (206) 664-9009 or 1-800-486-8392 (TTY or V).

COMING TO A RAMP NEAR YOU!

RAMP METERS

Ramp meters have proven to be one of the most cost-effective and efficient tools for easing traffic congestion.



Washington State Department of Transportation

WHAT IS A RAMP METER?

Ramp meters are stop-and-go signals located on entrance ramps to the freeway. They control the frequency with which vehicles enter the flow of traffic on. the freeway.

By pacing the entry of vehicles onto the freeway — usually at intervals of between 4 and 8 seconds, depending on existing congestion levels — the merging vehicles are less likely to slow down traffic already on the freeway.

The result is fewer interruptions to the smooth flow of traffic on the freeway; the risk of accidents from merging traffic is greatly reduced, and traffic speed on the freeway actually increases.

RAMP METERS PROVEN TO BE EFFECTIVE

TRAVEL TIMES IMPROVE

- Delays at ramp meters during peak hours average less than two minutes. (No, you won't be able to read Tolstoy's War and Peace while waiting to merge onto the freeway!)

- In Seattle, overall travel times improved with the implementation of ramp metering, despite a significant increase in traffic volumes. (Before metering was implemented, a specific 6.9 mile section of I-5 from south Snohomish County to Northgate took 22 minutes to drive. After metering in 1984, despite increased volumes, the same section took 11.5 minutes.)

- In California, average freeway speeds increased by approximately 50% after ramp metering was implemented.

TAX MONEY IS SAVED

- By actually increasing the efficiency of the freeway during a time of increased demand, ramp meters save taxpayers the costs associated with building new lanes or roads.

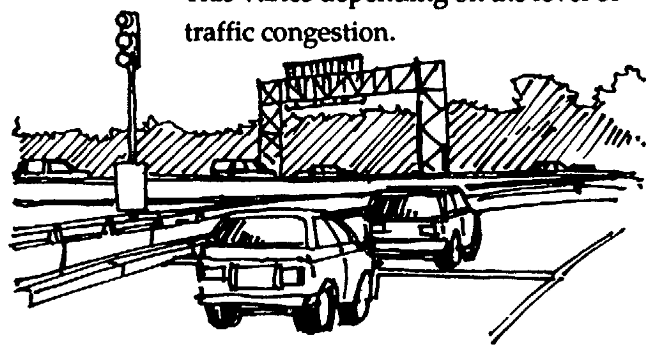
ACCIDENTS DECREASE

- Accident rates decreased by 39 % between downtown Seattle and Lynnwood after ramp metering was implemented in the corridor.

- In California, accident rates have dropped by 20 % to 50 % where ramp meters have been installed — despite increases of 50% to 80% in traffic volumes.

Crowd control

While ramp meters aren't a cure-all for the crowds of vehicles jamming up the roadways, they have proven to be a cost-effective strategy for reducing congestion. In general, ramp meters are located on our busiest freeways: Interstate 5, State Route 520, Interstate 90, and they are planned for Interstate 405. Typically ramps are metered from 6 to 9 a.m. and from 3 to 7 p.m. This varies depending on the level of traffic congestion.



High-tech freeways

Ramp meters are part of a large computer-operated network that is centralized in WSDOT's Traffic Systems Management Center (TSMC). Throughout the Puget Sound area, "loops" are embedded in the pavement that provide TSMC with information about traffic flow, such as the volume and speed of vehicles on freeways and ramps. This traffic data is continually fed to the ramp meters, affecting the timing of the lights.

Cameras

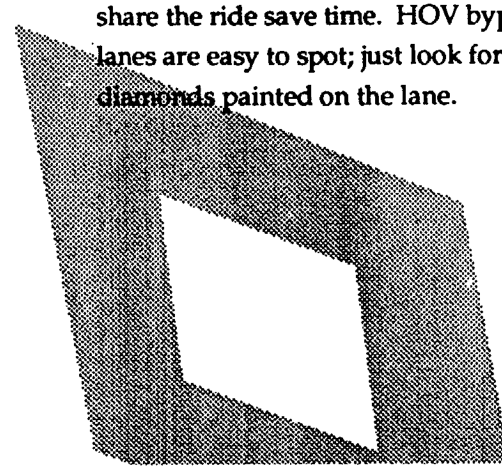
In addition to ramp meters, WSDOT is installing closed-circuit-television cameras that allow traffic engineers to monitor the ramps visually. This allows the technicians to make adjustments to each meter if it is necessary.

You trigger the meter

Ultimately, however, you trigger the meter to turn green when you drive your vehicle up to the white line at the meter. The timing is set by TSMC, but vehicles trigger the light.

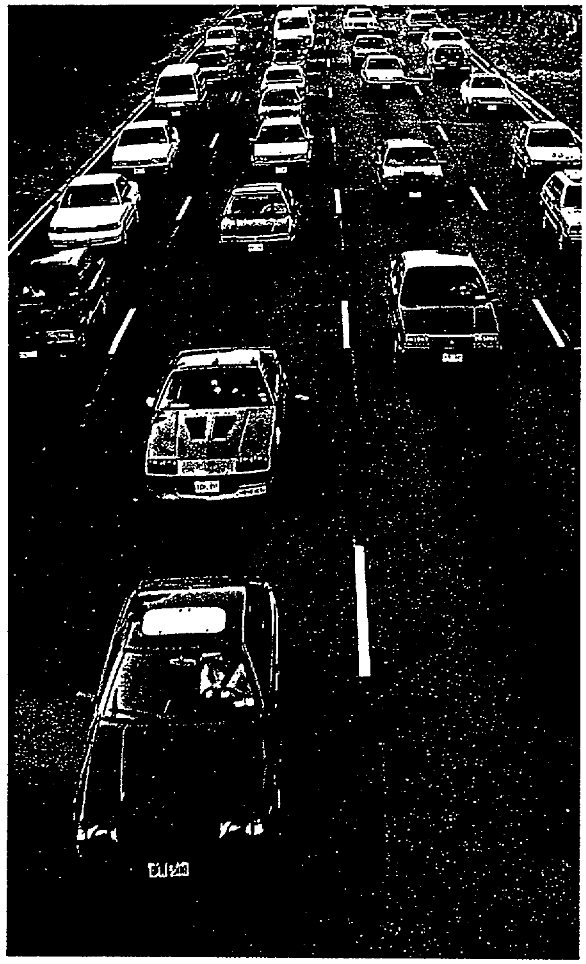
HOVs can bypass ramp meters

Some freeway ramps have HOV bypass lanes on them. HOV bypass lanes allow carpools, vanpools and buses to bypass the ramp meters and the traffic queues waiting to enter the freeway. It's another way that using the HOV system can help those who share the ride save time. HOV bypass lanes are easy to spot; just look for the diamonds painted on the lane.



NEW YORK STATE DOT

RAMP METER EXCERPT FROM THE INFORM BROCHURE



INFORM

The Traffic Information System For Long Island Drivers!

'Information **For** Motorists

Observe Merge Lights

Wait for the Green

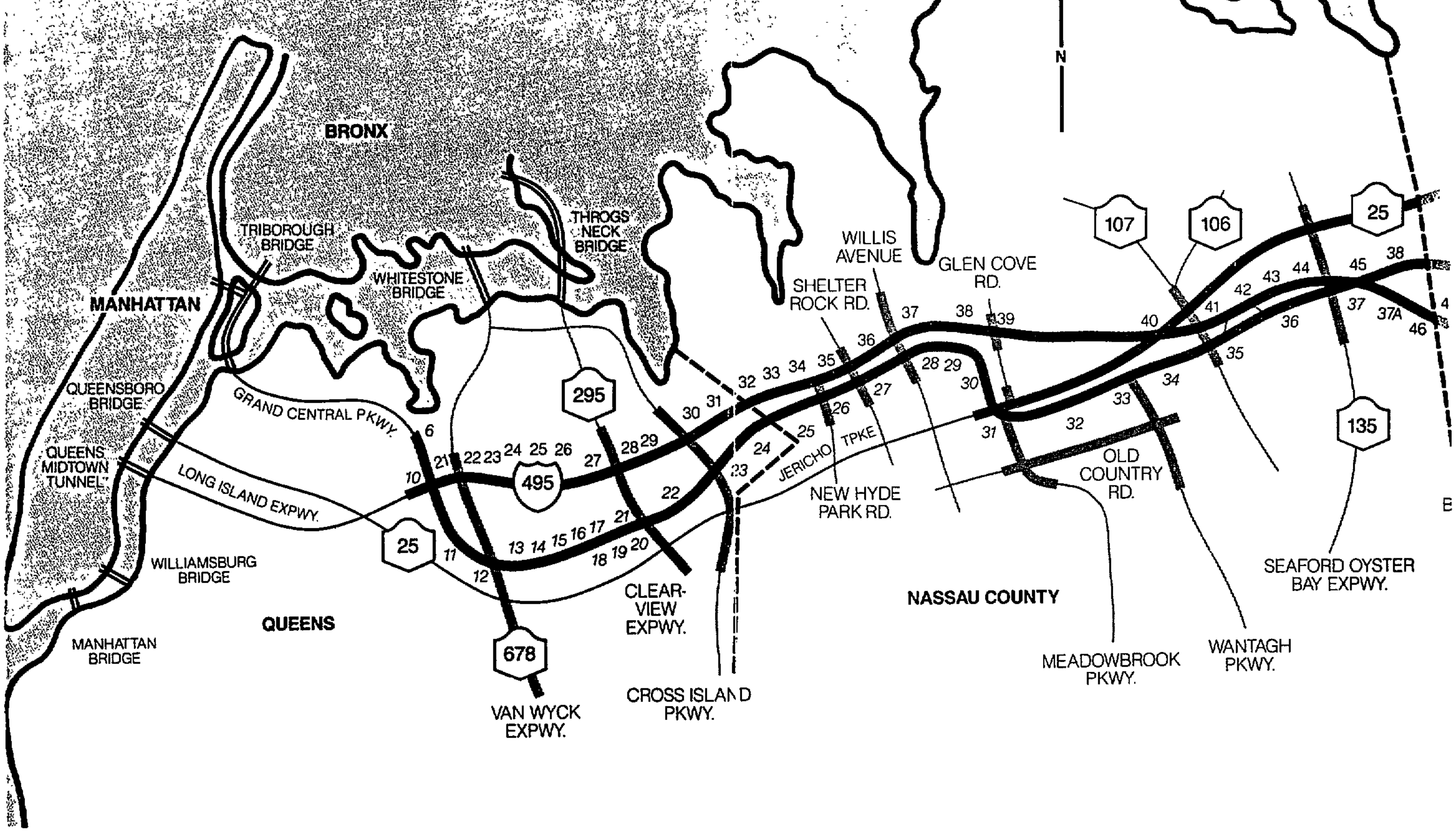
Merge lights are designed to let vehicles enter the highway *one at a time*. A red signal requires you to stop on the ramp. At most, the light will be red for just 12 seconds. When it turns green, proceed to merge onto the highway—cautiously—entering the flow of traffic.

Your brief wait on the ramp will help to smooth traffic flow on the main highway, shortening overall travel times by enabling all vehicles to maintain steadier highway speeds. Steadier speeds also mean safer travel.

Merge lights operate only when their use can improve driving conditions. When a merge light is not operating, merge cautiously into the highway traffic flow.

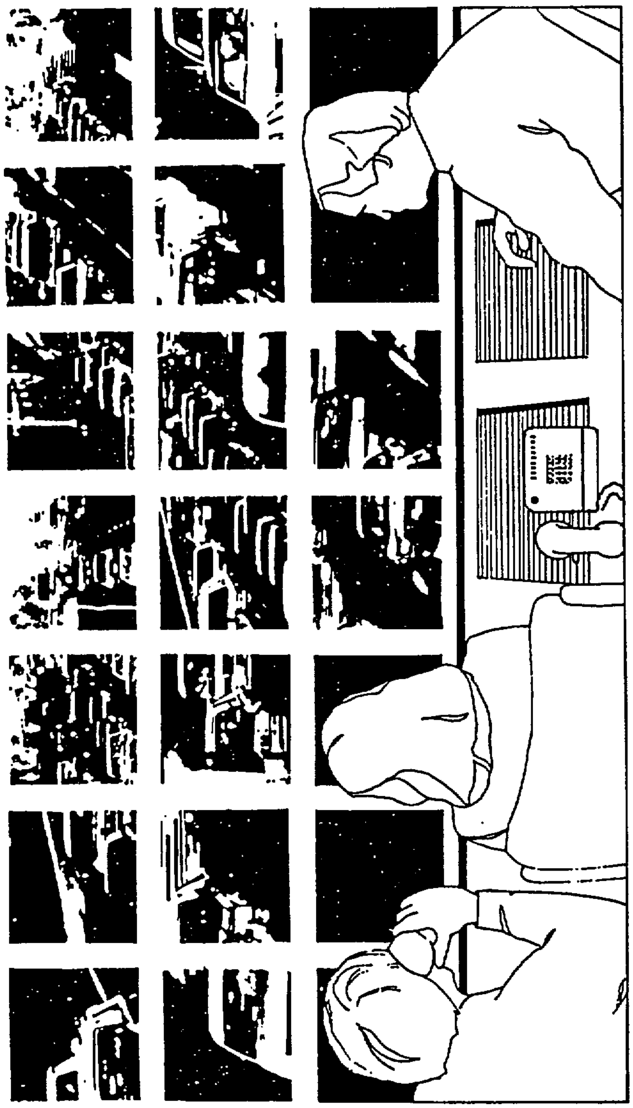
Remember, merge lights are legal traffic signals. Failing to stop for a red merge light is a moving violation, subject to penalties under New York State Vehicle and Traffic Law.

Computer-timed merge lights let vehicles enter one at a time to keep traffic moving more smoothly.



VIRGINIA DOT

RAMP METER EXCERPT FROM THE
NORTHERN VIRGINIA
TRAFFIC MANAGEMENT SYSTEM BROCHURE



I-395/I-66's
TRAFFIC
MANAGEMENT
SYSTEM

VIRGINIA
DEPARTMENT OF HIGHWAYS
AND TRANSPORTATION

...MOVING TRAFFIC FASTER
& SAFER

Ramp Metering

Ramp meters are one way to control congestion and reduce bottlenecks.

Ramps are metered with traffic signals. When given a green light, vehicles enter the interstate one at a time facilitating an even flow of traffic on the interstate's main line.

Although the signals look like ordinary traffic lights, they actually are controlled by VDH&T's finely-tuned computer system. Each signal can be individually adjusted by the computer to instantly respond to traffic conditions, but all work together as a system.

QUESTIONS AND ANSWERS

Q: Will traffic lights on the ramps cause long delays for motorists waiting to get on the interstate?

A: Motorists concerned about delays on the ramps should know that the longest red light available to the system is 12 seconds. This means with a line of cars in front of you, you won't wait more than about two minutes on the ramp.

Q: But won't the traffic lights cause traffic to back up on local streets if the interstate is severly congested?

A: No, the traffic lights won't cause that problem because the system has a failsafe mechanism. Sensors at the end of all metered ramps are triggered if vehicles begin to back up past the ramp entrance. At that point, the meter automatically shifts into its faster cycle time to clear the ramp. Or the traffic manager may turn the ramp meter off until congestion is reduced. If traffic backs up on local streets, it's not because of the ramp metering system, but it is because the interstate has exceeded its ability to handle traffic efficiently.

Q: Because I live closer to the District than other commuters, won't the ramp metering system favor those who live further out and cause me excessive delay?

A: No, because once you are on the interstate, you will reduce the time it normally takes you to get to work. Short interstate trips show proportionally larger time savings. For example a six-mile drive in what used to be stop and go traffic could be as much as 15 minutes quicker. It is true, though, that you may have to wait a little longer to enter the interstate system but you still will save time once you get on the interstate.

Q: What happens if a motorist runs the red light on the ramp?

A: The meters are intended to help and the system will only work with the cooperation of drivers. Running a ramp light is the same violation as disobeying any traffic signal in Virginia.

NOTICE

DOT-T-95-17

DOT-T-95-17

Technology Sharing

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