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National Conference on High-Occupancy Vehicle Systems

7th

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HOV SYSTEMS IN A NEW LIGHT

7th INTERNATIONAL CONFERENCE ON HIGH OCCUPANCY VEHICLE SYSTEMS

June 5-8, 1994

The Biltmore Hotel

Los Angeles, California

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HOV Systems in A New Light

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7th National Conference on High-Occupancy Vehicle Systems

HOV Systems in A New Light

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7th National Conference on High-Occupancy Vehicle Systems

HOV Systems in A New Light

TRB Committee on High-Occupancy Vehicle Systems

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A National and International Status Report

Jerry Baxter, California Department of Transportation-Presiding

Welcome and Opening Remarks

James van Loben Sels California Department of Transportation

Thank you and welcome to California. We do not have an earthquake scheduled for today, but sometimes they happen unannounced. We want to focus on HOV facilities over the next few days. Although we do not have all the solutions here in the Los Angeles area, we do have experience with different approaches and techniques. We certainly have major problems with traffic congestion that need to be addressed.

One of the things we have learned is that HOV facilities have to be approached as a system. Also, as we learned a number of years ago with the Santa Monica Diamond lane, there has to be public understanding and public support for the system. It appears that commuters now support HOV lanes. Part of this support relates to the realization that HOV facilities make it easier to live and work where people want to and to make other discretionary trips.

HOV facilities should include a total system of HOV lanes, park-and-ride lots, bus services, ridesharing programs, and other elements. A coordinated approach is needed to make these systems work. In the Los Angeles area, the California Department of Transportation (Caltrans) is working with the Los Angeles Metropolitan Transportation Authority (LAMTA) and other transit agencies, the county transportation agencies, and the California Highway Patrol to ensure that all these elements are present. The HOV lanes are also being coordinated with the development of the light rail transit (LRT), heavy rail, and commuter rail systems. Thus, we have found that one key to successful HOV development and operation is coordination among agencies and the supporting services.

Providing information to commuters on all these travel options is also critical. In the Los Angeles area, the 1-800-COMMUTE telephone number provides information on all modes. This system allows commuters to easily obtain information on alternatives to driving alone.

The partnership in the Los Angeles area is committed to developing and operating an extensive HOV system. You will have the opportunity to see many elements of this system on the tours over the next few days. In addition to the fixed facilities, extensive ridesharing programs, bus services, and marketing efforts are also being used. All of these elements are focused on providing quality services that commuters will find attractive enough to change from driving alone to using an HOV. The system must be safe, secure, and convenient.

An issue currently being examined in California and in other parts of the country is congestion pricing on HOV lanes. One idea is to allow single-occupant vehicles to use HOV lanes for a price. There are a number of issues associated with this concept, including potential degradation of travel times in the HOV lane and how to use the revenues generated from the pricing program. It is important to remember that raising revenues through congestion pricing and relieving congestion through the use of HOV facilities are two different concepts. Sometimes the lines between these two concepts get blurred, especially by public officials looking for ways to raise revenues. I hope you will discuss congestion pricing on HOV facilities at this conference.

You will also have the opportunity at the conference to hear about the experience with the recent earthquake in Los Angeles and the role HOV lanes, bus and rail services, and cat-pooling played in responding to the significant damage on many freeways. Temporary HOV lanes and detours were established, extra bus and rail service was added, and commuters were encouraged to carpool. Many commuters did change their travel modes during this time, and we hope they will continue to do so after the major repairs to the freeway system are complete.

I hope you will find the conference enjoyable and challenging. I would encourage you to ask questions and to share your experiences with others. I also hope you enjoy your stay in the Los Angeles area. Thank you.

Tour de HOV . . . An Overview of Recent HOV Milestones

Tim Lomax, Texas Transportation Institute

In preparing for this presentation, I have thought of myself as a tour guide. I will be discussing some of the events that have occurred in HOV facilities and issues since the last HOV conference-both aspects that have changed and those that have not. I will only highlight a number of projects and issues that will be discussed in more detail in other sessions during the conference.

I would like to start out by discussing what has not changed with HOV facilities. For example, when you come to Los Angeles, you think of Tommy Lasorda-he is just as obnoxious as ever.

The growth rate of HOV projects also has not changed. There continues to be a steady increase in the number of facilities and the miles of operating projects. Over the last ten years, the number of miles of HOV projects has increased from 120 miles to almost 550 miles. The types of projects have also increased, with more projects focusing on low-cost alternatives with shorter implementation times.

Cost effectiveness concerns continue to be discussed. HOV facilities are seen not just as a way to increase the efficiency of transit, but also to increase the efficiency of the whole corridor. The requirements of the ISTEA and other recent legislation has also increased interest in HOV facilities in many areas.

A number of HOV lanes around the country focus primarily on serving carpools, This is especially true of recent projects located on non-radial freeways in suburban areas. Support facilities and programs continue to be a major focus of HOV projects throughout the country. These include enforcement areas and enforcement techniques, park-and-ride lots, transit centers, integrated bus terminals, exclusive entrance and exit lanes, special incident response vehicles, and vanpool and carpool programs.

Although these trends are continuing in many areas, a number of changes have also occurred related to HOV facilities. For example, there now appears to be a clear relationship between HOV facilities and sport championships. Houston and the soon-to-be NBA champion Rockets, Dallas and the Super Bowl Champion Cowboys, Toronto and the World Series Champion Blue Jays, and New York and Stanley Cup Champion Rangers-all of these cities also have HOV lanes. It is no surprise that HOV lanes are being considered in Atlanta now that the Braves are not doing well.

Many existing HOV lanes around the country are being extended. These include the HOV facilities on I-84 in Hartford, the Gulf Freeway in Houston, I-5 and I-90 in Seattle, and a number of projects in California. The California facilities will be discussed in more detail in the next session this morning.

There are also a number of new HOV lanes throughout the world. The project on the A-l Freeway in Amsterdam represents the first facility in Europe open to carpools. A new HOV lane is also being developed in Madrid. The Century Freeway here in the Los Angeles area, along with Route 57 and Route 99 provide examples of new projects in California. HOV lanes have also been opened on I-495 in Long Island, I-80 in New Jersey, and I-65 in Nashville.

Many more HOV projects are in design or under construction. Examples of these facilities include I-270 in Maryland, I-287 in New Jersey, several freeways in the Toronto area, the Stemmons and the LBJ Freeways in the Dallas area, the Eastex Freeway in Houston, I-25 in Denver, and I-95 in Northern Virginia. A number of arterial street HOV lanes have also been opened or are in the planning and design stages. These include arterial street HOV lanes in Seattle and Toronto.

The use of HOV lanes to help respond to the recent earthquake in the Los Angeles area provides additional experience the HOV community can learn from. The ability to quickly implement these projects at relatively low costs provides good examples of the role HOV lanes can play in responding to incidents and accidents.

Advanced technologies are continuing to be explored to enhance the operation and management of HOV facilities. Automatic Vehicle Identification (AVI), which would be used with the HOV congestion pricing demonstrations being discussed, and the use of advanced technologies to monitor vehicle occupancy levels represent just two examples.

Supporting programs and facilities continue to be important parts of many HOV projects. Marketing materials, park-and-ride lots, transit stations, rideshare programs, and other activities are moving forward in many areas. An NCHRP Synthesis on HOV facilities, written by Chuck Fuhs, has been published by TRB. Additional information and guidelines are available from states, the ministries in Canada, and local transit agencies as well. If you are considering an HOV lane, much more information is currently available than was five years ago.

There are still a number of important issues related to HOV facilities that need to be addressed. The first is the air quality impacts of different types of HOV facilities and how HOV lanes can be used to meet the requirements of the Clean Air Act Amendments and other legislation. More areas are discussing the potential of lane conversions. This is related to air quality concerns, but also has cost and public acceptance implications. The vehicle occupancy requirements for HOV facilities are also being discussed in many areas. Capacity is being reached on some lanes which use a two person vehicle-occupancy requirement. Increasing the vehicle occupancy requirement to three persons is an option being seriously considered in many areas. This has the potential of reducing utilization levels, however, and may cause "empty lane syndrome" perception problems. The issue may be that we just do not have enough 2.5 person carpools. I will leave you with the challenge of determining how we generate 2.5 person carpools.

Thank you.

A National and International Status Report

Charles Fuhs, Parsons Brinckerhoff Quade & Douglas, Inc.

I appreciate the opportunity to be here this morning. Summarizing the recent experience with HOV facilities around the country and around the world is a difficult task. This year we thought we would take a little different approach to presenting an update on HOV activities. To accomplish this, a video has been developed with the assistance of individuals responsible for HOV projects throughout the world.

The following projects were highlighted in the video.

- Chicago, Illinois. The Illinois Department of Transportation (IDOT) is currently designing the first HOV lanes in the Chicago area. The selected design for the Stevenson Expressway is a concurrent flow facility with the HOV lanes located in the center median of the freeway. Implementation should occur in the next four years.

- Boston, Massachusetts. By the spring of 1995, two HOV projects will be in operation in the Boston area. These facilities, accounting for 14-lane miles, are located on I-93. In ten years, approximately 25 miles of HOV lanes should be in operation. These are part of a long-range HOV plan developed by a multi-agency planning group. The Massachusetts Highway Department is responsible for developing the I-93 HOV lane. Constraints for designing the contraflow HOV lane included limited rights-of-way and environmental issues.

- Long Island, New York. The HOV lanes on the Long Island Expressway are buffer-separated concurrent flow lanes. A 2+ occupancy requirement is used. Traffic is monitored by the Information for Motorists System (INFORM). Access and egress are by tapered acceleration and deceleration lanes. A 14-foot shoulder is provided on the left for enforcement and incident management. The Long Island Expressway HOV Task Force, which was formed in 1991, assisted in developing the operating guidelines for the facility. The Task Force is comprised of legislative representatives, the county executive, individuals from transportation, enforcement, and transit agencies, and representatives from the business community. The Task Force was instrumental in developing an outreach program to explain and promote use of the lane.

- New Jersey. The Diamond Express lanes on Route 80 in North New Jersey opened in March of 1994. These are IO-mile long concurrent flow HOV lanes. The facilities were developed in response to growing traffic congestion in suburban areas of the state. These lanes were originally intended to be general purpose lanes. Midway through construction, and even after a segment had been opened to general-purpose traffic, it was decided to make them HOV lanes. After six weeks of operations, the lanes appear to be well utilized, with volumes greater than originally estimated. In the morning peak-period, approximately 2,500 vehicles, carrying 6,300 people, are using the lanes. The travel time savings for HOVs using the lanes has been estimated at 10 to 15 minutes. The violation rate has been relatively low, averaging between five and ten percent. Public response has been mixed while the media has been supportive at times and neutral at other times. The HOV lane on Route 495 on the approach to the Lincoln is still averaging around 700 buses, carrying 34,000 people during the morning peak hour.

- Maryland. In September 1993, the first freeway HOV lane in Maryland opened. To date, the lanes have been well utilized and seem to be accepted by the public. The success can be attributed to the collaborative effort put forth by elected officials, the public, and the press. Informing the public on the purpose and goals of the HOV lane was of critical importance to the overall public acceptance. By 1997 it is expected that Maryland will have 18 miles of concurrent flow HOV lanes on I-270. In addition, a potential network of statewide HOV facilities is also being considered by the Maryland Department of Transportation.

- Nashville, Tennessee. In September of 1993, the first HOV lane in Tennessee opened on I-65 in Nashville. This is an eight mile concurrent flow HOV facility. The HOV lanes were added during the expansion of I-65 from four to eight lanes. The average daily traffic (ADT) on I-65 is about 68,000 vehicles. The HOV lanes operate Monday through Friday from 7:00 A.M. to 9:00 A.M. and from 4:00 P.M. to 6:00 P.M. Regional transportation agencies are working closely with the Tennessee Department of Transportation to promote the use of the HOV system.

- Charlotte, North Carolina. Currently, construction is under way on a barrier separated, reversible HOV lane in the median of U.S. 74 in Charlotte. This is a major six lane arterial, which carries approximately 97,000 vehicles per weekday. In the 1970s, a freeway was considered, but adequate right-of-way was not available due to the development in the area. A six lane expressway, with a reversible HOV lane in the median, was selected instead. The general purpose lanes have been designed for operating speeds of 45 miles per hour and will include access via auxiliary lanes. The HOV lane was designed for operating speeds of 55 miles per hour with access points at either end. The vehicle occupancy requirement for the HOV lane will be 3 + . The lane will be operated in one direction starting in 1996, and will be fully operational as a reversible facility in 1998.

- Florida. Florida's HOV effort began in November of 1991 when the Florida Department of Transportation (FDOT) issued a new Interstate Highway System Policy. This new policy established five key directives for the Interstate Highway System in the state. These were to maintain air quality consistent with the provisions of the Federal Clean Air Act Amendments; to support the development of viable urban communities by enhancing the viability of public transit; to support regional commerce and long distance trips by allowing high speed movements in dedicated lengths to promote energy conservation: to reduce congestion by designing facilities to promote the use of high occupancy vehicles; and to ensure that the ultimate system is affordable. The policy is also very specific in defining the limits of potential Interstate expansion. Interstate highways in urban areas cannot exceed ten lanes, while those in rural areas cannot exceed six lanes. Other elements identified to help meet the goals are allowing express bus services to use the HOV lanes, operating metropolitan rail service parallel to and within the I-4 right-of-way, frequent park-and-ride lots, expanded regional bus service, high speed intercity rail service operating within the I-4 corridor, and improvements on crossroads to ease bottlenecks at interchanges.

- Houston, Texas. Currently, 63.6 miles of HOV lanes are in operation on freeways in Houston, Texas. The total planned HOV lane system is 104 miles. All of the HOV facilities are barrier separated, reversible lanes located within freeway medians. Currently, HOV lanes are operating in five Houston corridors. The Metropolitan Transit Authority of Harris County (METRO) and the Texas Department of Transportation (TxDOT) have jointly developed the system and share operational responsibilities. The system also includes 22 park-and-ride lots and direct access ramps.

- Santa Clara County, California. The first HOV lane in Santa Clara County was opened on the San Tomas Expressway in 1982. Currently there are seven HOV lanes in operation and two more are under construction. By the end of 1994, there will be approximately 100 miles of HOV lanes in operation in the county. All of the facilities are concurrent flow lanes.

- Sacramento, California. Four miles of concurrent tlow HOV lanes are in operation on Route 99 in Sacramento. The HOV lanes represent lanes added to Route 99. The HOV lanes operate on a 24-hour basis. Plans are underway to extend the lanes, and other HOV projects are being considered.

- Seattle, Washington. The HOV lane system in the Seattle area continues to expand. The ultimate network is anticipated to comprise approximately 288 lane miles. Some 95 lane miles are currently in operation and an additional 60 miles are under construction. A variety of designs are used with the HOV lanes in the Seattle area. These include concurrent flow HOV lanes using both the insideand outside lanes, barrier-separated reversible lanes, and arterial street HOV lanes. The potential for converting existing general-purpose lanes to HOV lanes is also being considered.

- Amsterdam, Netherlands. An HOV lane was opened in October of 1993 on Highway A-l on the east side of Amsterdam. The lane is a reversible-flow facility and is eight kilometers long. Buses and carpools with three or more occupants can use the lane. The facility is open during the morning and afternoon peak-periods.

Report from the Federal Highway Administration

Jerry W. Emerson, Federal Highway Administration

Over the past 30 years, the vehicle miles of travel (VMT) in the United States has almost doubled from one to two million. The Interstate system was developed over this same period, and a great deal of new capacity was added to the roadway system. Even with this additional capacity, traffic congestion has increased significantly in most metropolitan areas.

The Interstate system is virtually complete now and little new capacity is likely to be added. The demand for travel, however, is expected to double again in the next 30 years. HOV facilities represent one approach to addressing this continued increase in travel demand.

There has been a significant increase in HOV facilities over the past 20 years. Prior to 1980, there: were less than 100 center-line miles of HOV lanes in operation around the country. Currently, there are around 550 miles. By the end of the decade, some 1,000 miles are anticipated to be in operation. Non-radial HOV facilities appear to represent a major portion of the new lanes. This appears to be a growing trend which responds to the movement of both residents and jobs to suburban areas.

There is every indication of continued interest in HOV facilities. The reasons for this include the ability of these facilities to move more people in fewer vehicles, while often staying within the existing freeway right-of-way. Implementation of HOV lanes can be accomplished relatively quickly compared to other alternatives, and joint funding is often available to support the planning, design, operation, and evaluation of HOV lanes. At the federal level, this includes funding from both the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA). At the state and local levels, funding may be available from highway, transit, and other agencies.

Many provisions of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 encourage the development of HOV facilities. Four sections address HOV lanes in detail. These are the Congestion Mitigation and Air Quality, the Interstate Maintenance, Metropolitan Planning, and the Statewide Planning sections. A number of subsequent regulations have been issued that implement many of these provisions.

The new joint FHWA/FTA planning regulations were issued in the fall of 1993. These require that the results of the six ISTEA-mandated management systems are included in the ongoing statewide and metropolitan planning processes. Consideration of demand reduction strategies, operation analyses, and other factors must be included in these plans. The six required management systems are pavement management, bridge management, safety management, congestion management, public transportation facilities management, and intermodal management. Each of these management plans has specific requirements and timelines for development and implementation. There are also penalties-such as the withholding of 10 percent of a state's highway funds-for non-compliance.

The congestion management system requires states and Metropolitan Planning Organizations (MPOs) to develop systematic programs to enhance the mobility of people and goods, not just vehicles. The congestion management system should be part of the ongoing planning process and should include consideration of all modes and alternatives. The goal is to reduce traffic congestion where it exists now and prevent it from occurring in places where it does not currently exist. Emphasis should be placed on the operation and performance of the existing system. HOV facilities will represent a significant focus of congestion management systems in many areas.

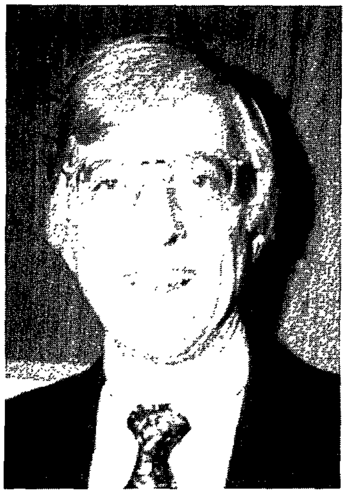
Congestion management plans should identify specific strategies for the efficient use of transportation facilities. Examples may include transportation demand management

(TDM) strategies, operational improvements, incident management techniques, and congestion pricing. In addition to the previously mentioned support for HOV facilities, the ISTEA provided for congestion pricing demonstration projects. Requests for proposals for congestion pricing pilot programs have been issued, and experiments with market pricing strategies and HOV buy-in or pricing could be considered.

Under the ISTEA, support for HOV facilities may be considered using National Highway System (NHS), the Surface Transportation Program (STP), and the Congestion Mitigation and Air Quality (CMAQ) program funds. Authorization of the proposed 159,000 mile NHS is currently being considered by Congress. In conclusion, the ISTEA and subsequent regulations are supportive of HOV facilities. As noted recently by U.S. Department of Transportation Secretary Pena, the goal is not to get more single-occupant vehicles on the system, but rather to encourage more use of all HOV modes.

Report from the Federal Transit Administration

Ronald Jensen-Fisher, Federal Transit Administration



It is a pleasure to have the opportunity to participate in this conference. I will cover three general topics in my comments this morning. First, I will discuss the new planning regulations, including the portion addressing major investment strategies. Second, I will summarize the Advanced Public Transportation Systems (APTS) program, which is FTA's IVHS component. Finally, I will highlight the transportation model improvement program, which applies to travel forecasting models.

As Jerry noted, the new Metropolitan Planning Regulations were issued in October of 1993. These regulations represent a significant change from past practices and will influence corridor and subarea planning. In the past, the approach to planning and the alternatives considered were often driven by available funding. If highway funds were available, highway alternatives were considered; if transit funding was available, transit alternatives were considered. The flexible funding provisions of the ISTEA really changes this approach.

The new planning regulations further support this change. The regulations require that a full range of reasonable options and alternatives be considered in subareas and corridors. Thus, the focus is no longer on a single mode. Rather it is on multiple modes and combinations of different modes. The regulations further require the involvement of multiple groups in the major investment studies. At the outset of a study, at least five groups must be involved in the initial discussions on the technical content of the study, the range of alternatives to be examined, and other issues. These groups are the state department of transportation, the MPO, the local transit agency, FTA, and FHWA. In addition, the regulations note that resource and environmental permitting agencies and private transit operators should be included early in the planning process.

Although rapid transit is often thought of as rail service, HOV lanes can provide a form of rapid transit. Providing express bus service, which can average 55 mph on an HOV lane, is certainly comparable to LRT or heavy rail service which may average between 22 and 30 mph. HOV facilities have rated very highly in the cost-effectiveness evaluations that have been conducted in many corridors. It is critical that buses, not just automobiles, be considered early in the design stage of HOV facilities. In the past, some HOV lanes have been designed without adequate consideration to buses. This has made the provision of bus service on some facilities difficult. The University of Washington is currently developing guidelines for transit considerations with HOV lanes. These should help enhance transit considerations in the planning, design, and operation of HOV facilities. In the future, FTA discretionary Section 3 funding will be strongly linked to designing HOV facilities with transit in mind.

The provision of information on bus routes and schedules, and ridesharing is critical to encouraging greater use of these modes. There are a number of opportunities today to use a wide range of advanced technologies to enhance the flow of information. FTA's APTS program includes a number of demonstrations focusing on the use of advanced technologies to improve the provision of transit information, as well as enhancing service delivery and management capabilities. Ron Fisher, who is the Director of the office heading this effort, is participating in this conference. There are two sessions focusing on APTS and HOV facilities, and I am sure Ron would be happy to discuss the program in more detail.

ISTEA and the Clean Air Act Amendments place additional demands on the travel forecasting process. In recognition of this, FTA, FHWA, and the Environmental Protection Agency (EPA) have initiated the travel model improvement program. This program, which is oriented toward improving travel demand forecasting models, has four components. The first element is being conducted by the Texas Transportation Institute. This is the outreach component which includes workshops, conferences, newsletters, reports, and other elements. The second component focuses on near term improvements to the traditional four step transportation modeling process.

The third element is developing a whole new generation of models. This is an enormous effort to completely restructure travel demand models. This includes a $27 million software development effort. Los Alamos National Laboratory is taking the lead in this portion of the project. This new approach involves examining travel at the micro or individual level, which is a completely different approach from the traditional models. The fourth element is considering new data needs and identify methods and techniques for collecting and analyzing data faster and easier. Part of this effort includes updating the existing FHWA manual on travel surveys.

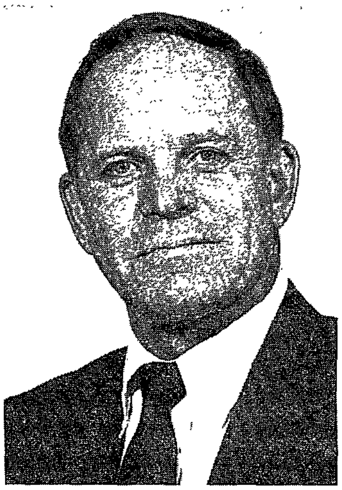
The activities in these three general areas provide a good indication of FTA's interest and involvement in HOV planning, design, and operation. I hope you will have a productive conference. Thank you.

HOV System Development in California

Arthur T. Leahy, Los Angeles County Metropolitan Transportation Authority-Presiding

Overview of Statewide HOV Programs and Issues

Jerry Baxter, California Department of Transportation



I would like to review the history of HOV development in California, highlight a few milestones, and share our experiences with you. The use of HOV facilities in California started in 1970 with HOV bypass lanes at the toll plazas on the Oakland Bay Bridge in the San Francisco area.

In 1973, the El Monte Busway opened. Jointly funded by FHWA, FTA, Caltrans, and the Regional Transit District (RTD), this facility was initially opened only to buses. It was later opened to carpools with three or more persons. Although this project continues to be successful, it is interesting to note that it has not been duplicated anywhere else in the state. The El Monte Busway shows that buses and carpools can operate on the same facility.

1976 was the next HOV milestone with the infamous diamond lane on the Santa Monica Freeway. This project, which I am sure you all know about, converted the number one general purpose lane in each direction into HOV lanes for carpools of three or more people (3 +). In hindsight, there are a number of things that probably should have been done differently on this project. For example, there was no marketing or public information program and the 3+ vehicle occupancy level may not have been appropriate. The project, which was implemented partially in response to the first regional air quality plan, may have set back HOV development in California ten years.

By 1983, there was only 35 miles of HOV lanes in California. Between 1985 and 1990 there was a resurgence of HOV development in the state. By 1990, there were some 220 miles of HOV lanes in California, and by the end of 1994, there will be 470 miles in operation. The Los Angeles region has embraced HOV facilities. The reaction is very similar to the experience with ramp metering. When meters were first introduced, there was some resistance, but now they are widely accepted. HOV lanes have also been institutionalized, as long as they are addition lanes.

In 1993, Caltrans adopted the Urban Freeway concept to treat the urban freeway system uniformly throughout the state. This approach was adopted based on the recognition that the state highway system should look and operate the same throughout the state. Characteristics of urban freeways include ramp metering, changeable message signs, television surveillance, service patrols, highway advisory radio, and HOV lanes. Thus, the HOV concept is imbedded in the urban freeway system in California.

There was a further realization that the freeway system in the five county region around Los Angeles should look and operate the same. Thus, there was a need for the three Caltrans Districts in this area to work together and coordinate activities. Working with the counties and other agencies, an HOV master plan was developed for the region. Similar planning efforts are also underway in the San Francisco Bay area and the San Diego area. Current projections are that the ultimate California HOV lane system may reach 500 miles.

Thus, it appears that HOV lanes in California have become institutionalized. A major effort now is to ensure that the necessary support facilities and services are in place. These include park-and-ride lots, transit services, ridesharing programs, direct connectors, access ramps, enforcement, and other elements. These are all critical components to a successful HOV system. Part of this effort is to establish a closer working relationship with the Los Angeles County Metropolitan Transportation Authority (LACMTA) and other transit agencies. Houston, which you will hear more about during the luncheon speech today, provides an excellent example of a close working partnership between the state department of transportation and the local transit agency.

The HOV lanes in California and the Los Angeles area represent a mix of facilities. Although concurrent flow HOV lanes are the most common, buffer widths between the HOV lanes vary from 1- to 4-feet. The vehicle occupancy requirements on all facilities are two or more persons (2+), except the El Monte Busway, which is three or more (3+). Signing is relatively uniform throughout the state. The use of HOV bypass lanes at metered freeway entrance ramps is also being expanded.

A number of evaluation studies have been conducted on the HOV lanes in the state and monitoring efforts are ongoing. The El Monte Busway, which carries as many people during the peak-periods as the three adjacent freeway lanes, provides one of the best examples of the effectiveness of HOV lanes. There are still a number of issues that will need to be addressed. These include what to do when capacity is reached at the 2+ vehicle occupancy level, additional enforcement activities, and other concerns.

I hope you enjoy the conference this week and have a pleasant stay in Los Angeles. Thank you.

Los Angeles Experience with Bus/HOV Operations

Dana Woodbury, Los Angeles County Metropolitan Transportation Authority

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Thank you, Art. It is a pleasure to have the opportunity this morning to discuss the experience with bus and HOV operations in the Los Angeles area. As you know, we recently had the opportunity to test these systems during the Northridge earthquake. Buses and HOV lanes played vital roles in the emergency efforts, especially along the Santa Monica Freeway. This integral artery, which is the world's most heavily traveled freeway, immediately became the focus for traffic mitigation activities. While the freeway underwent extensive repairs, the left lane was converted into an HOV lane to help traffic flow more freely. This provided carpools with significant travel time savings over SOVs, which had to use local streets in some areas.

Buses were another critical element in the overall response to the earthquake. Within three days, 22 buses were added to routes on the west side and the San Fernando Valley. Within ten days, the MTA created, augmented, or rerouted 27 bus lines to assist earthquake affected commuters. Other transit operators-including the Los Angeles Department of Transportation, Santa Monica Municipal Transit, and Foothill Transit-joined this effort. The extra buses, along with the detour routes and the HOV lanes, made travel from the west side to downtown Los Angeles much easier.

The MTA and Caltrans are working hard to resolve the mobility problems in the Los Angeles area. The MTA's integrated transportation system includes 400 miles of light rail transit (LRT) and subways, which link up with Metrolink, the intercounty commuter rail network, and approximately 1,800 buses. A multimodal approach is needed, however, which encompasses both transit and freeway elements. HOV lanes are an especially important part of this mix in an automobile oriented society like Los Angeles. HOV lanes for buses, carpools, and vanpools are playing an ever increasing role in Los Angeles' freeway system.

Today, approximately 67 miles of freeway HOV lanes are in operation in Los Angeles County. These facilities carry an average of 1,250 vehicles an hour during the peak-periods. The average vehicle occupancy level on these facilities is 2.3 persons per vehicle. The facilities represent the joint efforts of Caltrans and the MTA, and have been funded through a combination of federal, state, and local sources. Earlier this year the MTA Board committed $3 15.9 million for construction of the next 88 miles of HOV lanes on nine freeway segments throughout the county. These lanes are expected to be open by 1998. Next month the MTA will release a request for proposal (RFP) for the development of an HOV Master Plan. The plan will help integrate HOV lanes with park-and-ride lots and transit centers. The different freeway corridors will be analyzed to determine where HOV lanes are needed and where cost-effective facilities can be developed. Freeway to freeway HOV connectors will also be examined.

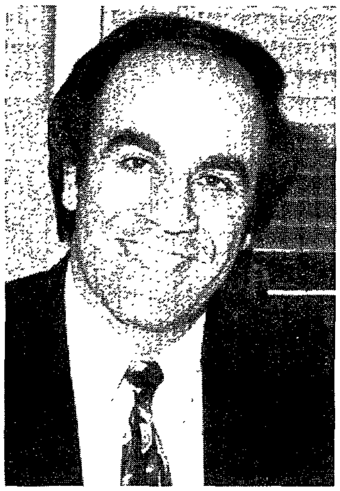
The newly opened Glen Anderson (Century or I-105) Freeway includes direct freeway-to-freeway HOV connections. These ramps appear to be a big bit with carpoolers. The HOV connectors represent another good example of Caltrans and the MTA working together. The MTA has almost completed the 20-mile LRT METRO Green Line, which is located in the center of the I-105 Freeway. The Green Line will intersect the METRO Blue Line, which runs 22 miles from Long Beach to downtown Los Angeles. When the Green Line opens next year, commuters from El Sagundo and Norwalk will have direct access to downtown by both HOV lanes and METRO. A further bonus will be added in 1995 when Caltrans completes the Harbor Freeway Transitway. This facility, which includes a 3-mile elevated structure, will provide a connection to the El Monte Busway at Union Station. Thus, HOVs will be able to travel from San Pedro to the San Gaberial Valley. Construction will also begin this summer on an HOV project on the Route 118-Sini Valley Freeway.

Jerry mentioned the El Monte Busway, which has been in operation for 20 years. For a long time, this single successful project was Los Angeles' only HOV project. It is still working today as some 18,000 daily passengers ride 12 bus routes using the HOV lane. Clearly, adding more HOV lanes will help address mobility problems in the area. By providing a regional HOV system, Caltrans and the MTA are building an integrated network that will help accommodate the mass transit and transportation demand management needs of the future. An HOV system provides commuters with the incentives of reduced travel times, improved trip reliability, and reduced costs. Further, it will encourage ridesharing.

The 14 million people living in the Los Angeles Basin own 6 million cars. Travel between counties in the area is so essential that transportation planning must consider the surrounding counties, which includes an area of approximately 12 thousand square miles. The total population of the region is expected to increase to between 21 and 23 million over the next 16 years. The number of daily vehicle trips will top 60 million, in 1990. HOV lanes and busways are two techniques that can be used to turn the Los Angeles mobility problem around. Everyone benefits from HOV lanes and busways through improved air quality, reduced congestion, and energy savings. In the long run this will help improve the quality of life in the region.

Developing, Implementing, and Operating an HOV Program for the Los Angeles Area

Raja Mitwasi, California Department of Transportation



Good morning and welcome to Los Angeles. There are over nine million people living in Los Angeles County. Approximately three million people commute to the central business district (CBD) on a daily basis. The freeway system in the county is over 500 miles, which represents only half of the system projected in the mid-1950s. The number of vehicles continue to increase in the region. As a result of these two factors, Los Angeles has some of the busiest freeways in the world.

The development of the HOV system in Los Angeles began in the early 1970s with the opening of the El Monte Busway. As Jerry mentioned, the Santa Monica Diamond Lane project, which converted an existing general purpose lane into an HOV lane, probably set HOV lane development in Los Angeles back ten years. If this project had not failed, the development of the HOV system would have occurred much sooner. The next HOV lane was opened about ten years later. Since then, research and engineering studies have guided the development of an HOV system in the region.

A video on the HOV system in Los Angeles was presented. The major highlights from this video included the following.

- The El Monte Busway opened in 1974. Initially opened to buses only, carpools of three or more passengers (3 +) were allowed to use the busway starting in 1976. The facility is 11 miles in length and cost $60 million to construct. The facility provides an HOV lane in each direction of travel. The HOV lanes are separated from the ad.jacent general purpose lanes by a 14-foot buffer.

- A circular bus station is located at the eastern end of the busway, providing direct access to the busway. A major park-and-ride lot is located around the station. A fly over access ramp is provided at Del Mar Avenue. The station at California State University, Los Angeles features a split roadway and a sky bridge.

- The extension of the busway into downtown Los Angeles, which was built 12 years later, cost $18 million. It provides access to the downtown street system without returning to the freeway.

- The Route 91 demonstration project re-striped the median to provide an HOV lane. The eastbound lane cost $250,000 for eight miles when it opened in 1985. The westbound lane opened in 1993 and cost $1.1 million.

- The Route 405 (San Diego Freeway) HOV lane opened in 1993. All lanes are 11-foot and the buffer is a l-foot double yellow line. This facility is being extended north through the interchange with I-105.

- The I-105 (Glen Anderson or Century Freeway), which is 17.3 miles long, will probably be the last new freeway to he constructed in Los Angeles. The facility cost $2.3 billion. It includes three general purpose lanes, one HOV lane, and a rail line in each direction. There are also six enforcement areas and six ingress/egress points in each direction. There are also direct connections to the future Harbor Freeway Transitway. These are referred to as the fifth level of a four level interchange.

- The HOV lanes on the Route 210 Foothill Freeway opened in January 1994. The 16 mile project cost $15.4

million. A rail line is located in the median of this facility through part of the project.

- The Harbor Freeway Transitway is currently under construction. This facility includes a 1.3 mile elevated "T" section that will carry two northbound and two southbound bus and carpool lanes. It also includes on-line transit stations. The Harbor Freeway Transitway is scheduled to open in July of 1995.

- The Los Angeles Route 14 HOV lane was initiated during the recent Northridge Earthquake. Carpools are allowed to use the outside shoulder of what was a truck connector in the northbound direction. In the southbound direction, the number one freeway lane was used as an HOV lane when the facility was reopened. HOV use on these lanes has exceeded 2,000 vehicles per hour.

There are approximately 65 miles of existing HOV lanes in the Los Angeles County, with an additional 40 miles under construction. Further, 115 miles of HOV lanes are in the design stage and 125 miles are in the planning process. Other measures are also being used to provide an integrated transportation system. Other elements include ramp metering, HOV bypass lanes, traffic system management and traffic operations systems, IVHS technologies, freeway service patrols, bus, rail, and carpools.

These efforts have been planned, funded, implemented, and are being operated through the joint efforts of Caltrans, MTA, counties, local governments, and other groups. This coordinated approach will continue to be needed to ensure that the system is developed and operated efficiently. Some of the challenges currently being faced in the area include obtaining media, political, and public support, right-of-way acquisition, maintaining traffic flow during construction, and nighttime construction. I am sure many other states are facing similar issues. I hope we will have the opportunity to discuss them during the conference this week and share ideas on ways to address them.

Orange County's HOV Program

Joseph Hecker, California Department of Transportation

On behalf of the Orange County portion of Caltrans, it is a pleasure to welcome you to this conference. I appreciate the opportunity to provide you with an overview of the HOV facilities in Orange County. Until 1988, Orange County was part of the 3-county Los Angeles Caltrans District. In 1988, Orange County became a separate district.

Orange County is located approximately 20 miles to the South of Los Angeles. Given the diverse home and work locations of commuters, and the numerous attractions in the area, traffic congestion is a major problem at all times. The rapid growth in population and the corresponding growth in vehicle registration has created a great demand for additional roadway capacity. For example, it has been estimated that the annual average daily traffic increased by 250 percent between 1966 and 1986.

Both Caltrans and the Orange County Transportation Authority (OCTA) recognized the need to explore long-term solutions to this rapid growth. HOV systems were viewed as important elements of this plan. The requirements of the Clean Air Act Amendments of 1990, as well as the financial cost of expanding existing facilities, provided additional challenges in this effort. Caltrans and OCTA responded with a county-wide interconnected HOV system. The focus of this system was to provide travel time savings and more reliable trip times to HOVs. Thus, freeway-to-freeway connectors and drop ramps were given equal priority with additional lanes. All of the freeways in the county will eventually have HOV lanes, and most will have freeway-to-freeway HOV direct connections.

Currently, 110 directional miles of HOV lanes are in operation on freeways in the county, along with 92 HOV bypass lanes at entrance ramp meters. One HOV drop ramp is in operation, two are under construction, and four more are in the planning stage. There are four freeway-to-freeway HOV connectors under construction and eight in planning. HOV lanes are in operation on I-405, I-5, Route 55, and Route 57. The HOV lanes in the I-405 corridor extend 48 directional miles, which makes it one of the longest full-time HOV lanes in the county. There are also 62 directional miles of HOV lanes under construction. These facilities should be operational by mid-1996. An additional 50 miles, which is currently in design, should be operational by 2000. With the addition of the HOV lanes being planned on three toll facilities, the county should have a total of 353 directional miles of HOV lanes in operation by 2001.

The requirements placed on air quality non-attainment areas, of which the greater Los Angeles metropolitan area is the only extreme classification, limit the types of freeway projects that can be constructed. The HOV lanes are being used to help address these issues. A combination of federal and state funding is being used, along with private funding for the toll road prqjects. The toll road projects include the use of congestion pricing techniques to encourage carpooling, vanpooling, and transit use.

To date, the HOV projects in the county have been developed and implemented through the joint efforts of Caltrans, the OCTA, the Transportation Corridor Agency (TCA), FHWA, FTA, and the private sector. This joint effort has been successful at developing a long-range approach to addressing the mobility needs in the area. This has helped Orange County become a transportation leader. A short video highlighting the HOV system from the perspective of a user was shown.

HOV System Operations and Plans for the Bay Area

H. David Seriani, California Department of Transportation

Thank you, Art. It is a pleasure to have the opportunity to discuss the HOV facilities in the San Francisco Bay area this morning. For those of you who are not familiar with the Bay area, it consists of nine counties. San Francisco-which is located just south of the famous Golden Gate Bridge-Marin, Napa, and Sonoma to the north; San Mateo, Santa Clara, and Santa Cruz to the south; and Alameda and Contra Costa to the east. Caltrans District 4 covers the nine county area. Approximately 155 lane-miles of the HOV lanes are in operation in the District, with another 65 lane-miles under construction. Some 12 lane-miles of the exiting HOV lanes are being modified. In addition, about 78 lane-miles are programmed within the next five years.

All of the HOV lanes in District 4 are contiguous part-time lanes with no buffers between the HOV lane and the mixed flow lanes. The lanes revert to general purpose use-open to all vehicles-during the non-peak hours. The minimum occupancy requirements for all of the HOV facilities-except the San Francisco/Oakland Bay Bridge-is two or more persons per vehicle (2+). Toll free passage for vehicles with three or more persons (3 +) is allowed on the Golden Gate Bridge from 5:00-9:00 A.M. and from 4:00-6:00 P.M. In addition, there are about 26 lane-miles of HOV lanes in operation on expressways. These are under the control of Santa Clara County. An additional 51 lane-miles are planned on the Santa Clara County Expressway by the year 2005. In addition, there are 11 HOV bypass lanes in the District, with another 56 HOV lanes programmed for the future.

The District 4 HOV program started in 1970 on the Bay Bridge. Originally opened as a bus-only lane, carpools were soon allowed to use the lane. Three major freeways-Routes 80, 580, and 880-serve the Bay Bridge, which is a double deck bridge with the westbound lanes on the upper deck and the eastbound lanes on the lower deck. There are five lanes in each direction of travel. Annual average daily traffic for the bridge is about 250,000. In 1982, metering lights were installed just downstream of the toll plaza to help control peak-period demand.

The Bridge has four HOV lanes in the westbound direction-two on the left side and two on the right side of the toll plaza. These lanes carry about 38 to 50 percent of ail the people over the Bay Bridge in the morning peak hours. The HOV lane users bypass the metering lights and congestion at the toll plaza, saving about 15 to 20 minutes. In addition, HOVs do not have to pay the toll charge. The left hand side lanes revert back to normal toll operation in the off-peak hours, and the right hand side lanes are bus-only lanes during the off-peak hours. The Metropolitan Transportation Commission (MTC) is considering increasing the toll on this bridge.

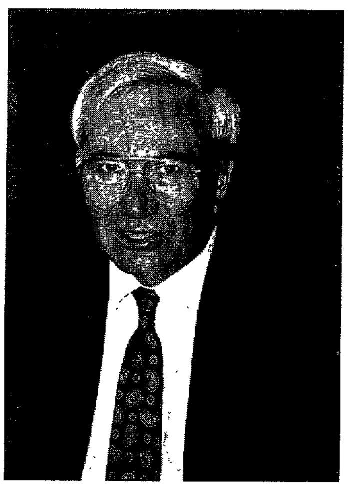
Forty-one park-and-ride lots are in operation in the Bay Area. A study is underway to examine the usage of existing lots and the need for future facilities. These facilities are served by a mix of rail and bus services.

The District 4 HOV program started in 1984 when 1/2c of the local sales tax of Measure A was approved by the voters. The HOV lane on Route 237 was also opened in 1984. The permissive shoulder HOV lane was allowed due to right-of-way constraints. Due to the left turn conflicts and to reduce confusion, the HOV lanes were located on the right hand side. Also, in addition to the regulatory signs mounted on the right shoulder, mast arms with real time changeable message signs were also installed. These signs give real time information to the motorists on the hours of operations for the permissive shoulders and the HOV lanes.

In 1986, the first few miles of the HOV lane on Route 101 was opened. Today, this facility is about 25 miles long in each direction. Utilization levels have increased dramatically with the completion of the last section of Route 101 HOV lanes. This indicates that HOV utilization will increase with the development of the HOV system. When all of the HOV lanes programmed in the District are completed, there will be more than 400 lane-miles of HOV lanes in the Bay Area.

San Diego's HOV Operations and Plans

Carl West, California Department of Transportation



I would like to discuss both the HOV planning activities currently underway in the San Diego area and describe the operating HOV facilities. HOV lanes in San Diego represent one approach being used to maintain the quality of life in the area. The HOV plan has been integrated into the growth management plan and is being monitored as part of the overall planning process.

The population of San Diego County is approximately 2.6 million. When added with Tijuana, Mexico, some five million people are expected to reside in the area within the next 20 years. The existing freeway system is approximately 300 miles. This will expand to 375 miles in the near future. About a third of the existing system experiences fairly severe levels of congestion. The geography of the area, which includes numerous canyons, results in many short trips using the freeway system. All four Interstate routes have ADTs of over 200,000. Congestion levels are expected to double, even with a planned 1.4 vehicle occupancy level during the peak hours.

A 140-mile HOV system plan is proposed for the San Diego region. In the development of the plan, both congestion levels and adequate median width were considered. Many of the older freeways in the central areas do not have enough space in the median for HOV lanes to be added. A measure of at least 1,000 vehicles per hour is used as the benchmark for consideration of an HOV lane.

The Regional Transportation Plan includes other policies addressing HOV facilities and supporting services. The policies call for special consideration for bus operations in the design of HOV facilities. The types of improvements include elements such as direct bus ramps, on-line stations, and other priority treatments. Also, any time adding to a four lane freeway or building a new freeway is being considered, HOV lanes must be examined. If HOV lanes cannot be justified at this time, sufficient right-of-way for future lanes should be acquired.

There is an extensive system of freeway entrance ramp meters in the county. HOV bypass lanes are being implemented at many of these ramps. The park-and-ride lot system is also being expanded and coordinated with the HOV facilities. Priorities have been established for different parts of the proposed HOV system.

The San Ysidro border crossing is the largest international border crossing in terms of vehicles and people in the world. Recently an HOV lane was opened at this facility. It is operated only during the week. The vehicle occupancy requirement is four or more persons (4+). There is also an HOV lane on the Coronado Toll Bridge. Carpools, which also do not pay a toll, represent 35 percent of the Bridge traffic. A bypass for buses leaving downtown San Diego is in operation in the Balboa Park area. This provides significant travel time savings for buses in the afternoon peak-period.

Located on I-l.5 is a two-lane, reversible, barrier separated HOV facility. It is eight miles in length. It is open for three hours in the morning-toward downtown San Diego-and for 3.5 hours in the afternoon in the outbound direction. It is closed during the rest of the day. There is no intermediate access, so the facility serves long trips in the corridor. It was constructed at a cost of $32 million in 1988 and could be converted to LRT in the future if necessary. The facility is managed by an off-site traffic management center. The signs and barriers are operated electronically, although a manual drive through is used to ensure that all vehicles have cleared the lane.

The I-15 HOV lanes have also been used for research and development activities associated with advanced technology projects. Tests have included IVHS technologies such as collision avoidance and high speed paint striping. These tests are conducted during the mid-day and on weekends. The lanes have also been used to manage traffic in the case of a severe accident in the general-purpose lanes. The criteria employed to determine if the HOV lanes should be used for traffic management purposes during an incident is that at least two general-purpose lanes must be anticipated to be blocked for at least one hour.

At the I-15 HOV entrance locations, electronic changeable message signs are used to communicate with motorists. Pop-up pylons and a barrier arm are used to close off entrance to the lanes. All of the devices are operated from the traffic management center.

A before and after study was conducted during the first few years of operation. Carpool volumes increased by some 53 percent during the tirst two years of operation. Vehicle volumes increased during the peak hour from approximately 900 vehicles to 1,900 vehicles. The public reaction to the facility has been generally positive.

The potential of congestion pricing or HOV “buy in” is being considered for the I-15 HOV facility with the excess revenue being used to support transit services in the corridor.

Experiences from the United States and Abroad

Morris J. Rothenberg, JHK & Associates-Presiding

Opening Europe's First High Speed HOV Facility on Route Al in Amsterdam

John P. Boender, Centre for Research and Contract Standardization in Civil and Traffic Engineering

Good morning ladies and gentlemen. It is a pleasure to be here to talk about Europe's first HOV lane on Highway Al near Amsterdam. I would like to start by explaining the operation and the design of the HOV lane and then Aad de Winter will discuss the incident management system and the initial experience with the HOV lane. The HOV lane was opened in October 1993. More details are provided in the paper we have prepared for this conference.

For those of you who are not familiar with the geography of Europe, the Netherlands is located in the northwest part of the continent. This area has a very high population density. The Netherlands is about 200 kilometers from north to south and 150 kilometers from the east to the west. About 15.5 million people live in the Netherlands. There are about 5.5 million cars and 15 million bicycles.

The Netherlands has a highway system of about 2000 kilometers. The region between Amsterdam, Utrecht, Rotterdam, and The Hague is called the Randstad. About six million people live and work in this area. This means that the population density in the Randstad is twice as high as in the rest of the Netherlands. This high population density is reflected in the number of cars using the highways in the Randstad and in the number of traffic jams which occur every day.

The HOV lane is located east of Amsterdam on Highway Al between Highway A9 south of Amsterdam and Highway A6 in the east. The HOV lane is located in the central reservation of Highway Al and in the morning peak-period it can be used by carpoolers from the residential areas in the center of the Netherlands to Amsterdam. In the evening, the lane can be used in the opposite direction by all traffic.

I would like to briefly explain the operational objectives of the facility. More and more emphasis is being given to the reduction of the negative effects of road traffic like air pollution, fuel consumption, and noise pollution in the Netherlands. One of the measures taken to address this is to promote carpooling and public transport. This can be achieved by giving them a time-advantage over other traffic. In the area where the HOV lane was built, design of a reversible lane had already started. In order to accommodate the desired time-advantage, the reversible lane was changed into an HOV lane in the morning peak-period. In the evening peak-period, it was not necessary to make it an HOV lane.

The HOV lane was designed as a reversible flow lane because of the difference in traffic volumes in the two directions. The lane is eight kilometers long. At the east end of the HOV lane where Highway Al joins with Highway A6, a special HOV flyover lane was designed. The HOV lane is open for HOV 3+ carpools, buses, and also motorbikes. The HOV 3+ designation was chosen due to the expected growth in the number of carpools if an HOV 2+ requirement was used. The HOV lane is open to carpoolers from 5:30 A.M. to 10:00 A.M. in the morning. In the evening, the lane is open to all traffic from 3:00 P.M. to 7:00 P.M.

I would briefly like to describe the design of the HOV lane. The HOV lane is located in the central reservation of Highway Al. Between the barriers, the available width is 5.85 meters. There is one 3 meter wide traffic lane with narrow shoulders of 1.3 meters on either side. Pullouts are designed for enforcement and for emergency parking at several locations along the HOV lane.

Ingress and egress is provided only at the ends of the HOV lane; there are no entrances and exits along the lane. The design of the entrances and exits required special attention to prevent drivers from entering the HOV lane when this is not allowed. Gates made with a breakaway provision are used to visually block the entrance.

Also, the entrances are protected with a moveable steel barrier on wheels. This steel barrier physically seals the entrance completely. When not in use, it is integrated in the concrete barrier.

One of the most expensive parts of the project was the flyover ramp. This flyover was built to allow carpoolers driving on Highway A6 to enter the HOV lane on Highway Al towards Amsterdam. The flyover has one lane and is open only in the morning peak-period.

It was too expensive to build a second flyover for the return trip, so carpoolers with a destination along Highway A6 have to use the normal lanes of Highway Al and use the normal interchange to Highway A6. In the evening, the reversible lane can only be used by cars with a destination along Highway Al through use of the ad-grade HOV slip ramps at the entrance and exit points. In order to reach the entrances, drivers have to make a clear filtering move from the left hand lane.

The exits of the HOV lane are designed as additional lanes to the highway. This lane becomes the fourth lane of the highway. After about one kilometer, the number of lanes again is reduced to three.

In the morning peak-period, carpoolers are able to use a three kilometer long extended ingress lane. This so-called approach lane was built to prevent carpoolers from joining a traffic jam before they could reach the entrance to the HOV lane on the east side of Highway Al. The approach lane is only separated from the main carriageway by rubber marker posts.

As a support medium for the HOV lane, park-and-ride facilities were built at interchanges on Highways Al and A6 prior to the start of the HOV lane. A total of eight carpool-parking areas were built. On the highway and the feeder roads, drivers are guided to these areas by traffic signs. The carpool parking areas have parking spaces for about twenty-five cars. In addition, the lots contain bus stops, bicycle parking facilities, and a public telephone.

Additional information is being distributed within the region to promote carpooling. Brochures are used to inform drivers not only about the benefits of carpooling but also about ways to organize a carpool.

Finally, I would like to talk about the signing and pavement markings used in the Netherlands as compared to the situation in the United States and Canada. We do not use road markings like the diamond sign used in the United States and Canada on HOV lanes. To inform drivers about what HOV -stands for, information sign postings were positioned prior to the approach lanes. In the Highway Code in the Netherlands, there is no carpool sign available.

To insure the legal validity of the HOV lane, we were forced to use a somewhat complex solution for the time being. The lane had to be closed for all traffic with the exception of carpool 3 + and buses. When the HOV lane is open for traffic, the signpost shows "Carpool 3 + " and the destination Amsterdam. When the lane is not open, the signpost for the HOV lane is changed into neutral gray, and drivers are not given any information about the HOV lane outside the operating hours.

And de Winter, Netherlands Ministry of Transport, Public Works and Water Management

I would like to talk about incident management, time and cost benefits, and the initial use of the HOV lane. As with other road infrastructure, it is unavoidable that traffic incidents, such as breakdowns and accidents, will occur on the HOV lane. Reports of incident occurrence may be received by automatic or visual detection. An adequate procedure is needed to help with this effort.

A stationary vehicle on the lane will be detected by the S. O.S., which stands for Speed Observation System. The S.O.S. is linked to a closed circuit video camera network. The camera closest to the incident is activated automatically upon detection. Visual detection can be done by police, road-service patrols, road users, and by video in the Traffic Control Centre. The video system for visual monitoring consists of twenty-three cameras and is linked to the S.O.S. All these systems are remotely controlled and monitored from the Control Center. Every report which is received is passed on to the Control Centre as the central point of dispatch.

In the case of a breakdown or accident on the HOV lane, the occupants should remain in their vehicles; walking across the HOV lane or main carriageway is not allowed, out of concern for road safety. A sign on the barrier tells drivers to stay in their car in a breakdown, because the vehicle will be detected automatically. In case of breakdown or accident, the entrance to the HOV lane is immediately sealed off. This is to prevent the lane from filling and risking the chance of other accidents occurring. This measure also enables emergency services to work more safely on the lane.

Two emergency vehicles (tow trucks) are constantly on call while the HOV lane is open. One emergency vehicle is intended for towing vehicles away from the lane when minor accidents occur. The other emergency vehicle is equipped with a crane with a long reach and can be deployed to lift vehicles over the barrier and out of the lane when more serious accidents occur. In this case, the traffic lane furthest to the left of one of the main carriageways is cleared of traftic.

Construction started on the HOV lane in September 1991. The HOV lane was opened to traffic on October 27, 1993. The total cost of the project was approximately $30 million, of which $6 million was directly attributable to the HOV lane. The other $24 million would have been spent regardless of construction of the reversible lane. The extra $6 million included the modification of the reversible lane into an HOV lane, the construction of the flyover, and the approach facilities for carpoolers.

In general, it can be contended that the HOV lane has lived up to the expectations formulated prior to construction. In November, the first whole month after the opening, about 1,000 vehicles per morning period used the HOV lane. In the following months, the volume increased, to an average of 1,200 vehicles in April. Eighty-three percent of the vehicles using the HOV lane during the morning period are passenger cars; thirteen percent are motor bikes, and five percent are buses.

The total number of people making use of the HOV lane during the peak morning rush hour (except for motorcyclists) is at approximately 1,700. The performance of a normal traffic lane in Holland is approximately 2,400 people per hour. If the observed growth increases, within two years, the HOV lane performance will be considerably higher than that of a normal traffic lane.

The journey time for drivers on the main carriageway during the morning period is about thirty to fifty minutes. This is ten to thirty minutes more than for carpoolers in the HOV lane. In November 1992, eleven months prior to the opening of the HOV lane, the Al was number one on the National Jam-chart. In November 1993, the Al dropped to fourth place. The total length of the traffic jam rose in December on the Al. The total duration, however, was reduced by twenty percent, and in the Jam-chart it dropped one place.

In the first four months after opening, six accidents occurred. In all cases, the damage was limited to superficial damage. In three of the cases, a barrier was hit. The other collisions were bumper-to-bumper collisions caused by slippery road surfaces or the lack of clarity about the route.

The majority of drivers on the main carriageway have indicated that the HOV lane has no negative influence on road safety. During the first four months of operation, the lane was closely monitored by the police. The number of violations in this period remained relatively low, much less than one percent. Later, the level of police monitoring was slowly scaled down, which led to a slight rise in the number of violations to about one percent on the days the monitoring took place.

A few months prior to the opening of the HOV lane, there was a certain amount of attention from the media. This attention was primarily of a slightly negative nature. In the months after the opening, there were further negative reports in the media. They focused on the following points:

- Traffic jams would occur due to a short weaving section near the exit in the west.
- Traffic jams would be longer than before.
- The lane would not be used-the so-called empty lane syndrome.

The most important lesson to be gained from this is that communication on this type of project can be a crucial factor. It appears to be almost impossible to refute negative publicity, even if it is based on patent untruths. The government has little or no opportunity to present its standpoint when negative publicity has already started. I have gathered some headlines of Dutch newspapers. I think maybe a few of them will be difficult for you to read, but you must believe me when I say that they are not all that positive.

After opening, an apparently empty HOV lane led to a discussion in the media and even in the Parliament about opting for a two-plus occupancy rate. This call was so strong that the Minister found it necessary to initiate an extra study into a possible change to two-plus occupancy.

The first results of this study show that the HOV lane has lived up to expectations. The design and layout are sufficiently obvious and recognizable to the road users and there has been no negative influence on road safety. I have noted the transit performance, which already approaches that of a normal traftic lane. In addition, there is a clear increase in the utilization of the lane in the busiest morning rush hours.

The HOV lane has led to a lessening of traffic jam problems in the morning rush hours, as well as the evening rush hours. Despite the empty lane syndrome, decreasing the occupancy to two plus can only offer solace over the very short term.

It was a pleasure and honour for us to present the first results of the Highway Al HOV lane to you. Thank you for your attention.

HOV Planning and Policy Development in Ontario

Thomas J. AppaRao, Ontario Ministry of Transportation

Thank you for the opportunity to discuss HOV planning and policy development in Ontario. This paper focuses mainly on our activities in the Greater Toronto Area. I will describe the activities of the Provincial government, while Tom Mulligan will discuss the efforts of the Municipality of Metropolitan Toronto.

The Greater Toronto Area (GTA) is the largest urban region in Ontario and indeed the whole of Canada. The GTA accounts for 40 percent of the population and 50 percent of the economic base of the Province. Obviously, an effective and efficient transportation system is necessary to serve the social and economic needs of this region. The Greater Toronto Area contains five regional municipalities-Halton, Peel, York, Durham and Metropolitan Toronto-and thirty local municipalities. The GTA extends about 100 miles east-west and 80 miles north-south. The population is approximately four million, and this is forecast to grow to over six million in the next 30 years. Currently one-half of the population lives in Metropolitan Toronto.

The transportation system in the Toronto area includes roads, highways, rapid transit, commuter rail, and an extensive bus system. The Province is responsible for building and operating the highway system; GO Transit, a provincial agency operates the commuter rail system; and the Province and the municipalities share the capital and operating costs of municipal roads and transit. The total provincial/municipalcapital funding for transportation in the GTA is approximately $1 billion/ year.

There are many current and future trends that led the province to examine the High Occupancy Vehicle (HOV) option. First, there is an increasing congestion on the road system. Secondly, an increasing share of the growth is occurring in suburban areas, which in turn leads to a large growth in interregional travel as well as intra-regional travel in the regions surrounding Metro Toronto. These trends are expected to continue and to become more significant problems in the next 30 years. The increased travel demand cannot be accommodated by road expansion alone due to limited rights-of-way as well as social and environmental considerations, while transit cannot address all of the suburban travel growth because of the dispersed nature of the demand and cost considerations.

These were some of the factors that led to Ontario's HOV policy, which was announced two years ago. Prior to this, the Province had been actively involved in promoting ride sharing and assisting municipal HOV lane development. With the announcement of the policy, the Province has initiated actions that would lead to HOV facilities on provincial highways. The Province is also taking a much more comprehensive, deliberate, and pro-active approach towards the development of an integrated provincial/municipal HOV system in the GTA.

The Ontario HOV policy formally recognizes the importance of HOV facilities in addressing future transportation, environmental, social, and economic needs. The policy emphasizes collaboration with other levels of government, transit operators, and the private sector in developing these systems. The critical importance of support programs are also recognized. The objective of the Ontario HOV system is to complement and enhance the transit systems, not to compete with them. The HOV systems can also play a strong role in forming a transit habit among commuters and can serve as a precursor to future rapid transit facilities.

Ontario is taking a combined opportunity-based and traditional planning approach to the development of the HOV lane systems. To date, four major freeway corridors have been studied to determine the need and feasibility of providing HOV lanes. Preliminary or detail design is under way on three of these corridors. A few additional issues are being examined in the fourth corridor. All four corridors were identified to be viable from an HOV demand standpoint. Studies will soon be initiated on three additional corridors. An HOV network study, which will cover the entire GTA region, will also be initiated soon. A provincial/municipal committee has been established to provide leadership, coordination, and communication on HOV programs and issues. A funding strategy for HOV facilities has been established and a strategy to address the support programs is being developed.

The long-term vision for the HOV system in the Toronto area includes HOV lanes on all major highways. The HOV lanes on highways and on arterial streets would be well integrated. The physical facilities would be supported by appropriate programs and policies to ensure their effective use. The HOV and transit networks would be well coordinated to complement each other provide better service to the user. The HOV network would enable buses to run faster and operate more efficiently, making bus transit more attractive to users.

Tom Mulligan, Municipality of Metro Toronto

It is a pleasure to have the opportunity to discuss HOV planning and development activities from the perspective of the Municipality of Metropolitan Toronto. The philosophy of the municipality differs slightly from that of the Province. We are concerned with the arterial street network rather than the Provincial Highway system. The roadway network in our area is maturing, resulting in a limited ability to respond to the growing travel demands. One approach being pursued by the Municipality is trying to change commuter travel behavior from driving alone to using HOVs--including transit, carpools, vanpools-and bicycles and walking.

Most major urban areas in Ontario have experienced significant growth over the past 25 years. Much of this growth has been in low density suburban areas. This has resulted in severe congestion in many areas. This trend is expected to continue unless major changes occur. Arterial street HOV lanes can help address suburban traffic congestion by focusing on person movement rather than vehicular movement. HOV lanes can also provide priority to buses, thereby improving reliability and operating speeds.

The emphasis of the approach being taken in Toronto is to make the arterial system more efficient by giving HOVs priority over single-occupancy vehicles. The HOV lane system plan has been developed by examining potential opportunities for enhancement and by maximizing resources. The result is a proposed grid network HOV lane on our major arterial roads.

To maximize the person carrying capacity of the roadway network, transit operations should be a major consideration in any HOV project. Most of the arterial street HOV lanes in Toronto utilize the curb lane to provide easy bus access. The eligibility of other HOVs and the vehicle occupancy requirements depend on how many buses are anticipated to use the lane. For example, with the high bus volumes on many HOV lanes in Toronto, only 3 + carpools and vanpools will be allowed to use the lanes. In areas with less bus service, a 2+ vehicle occupancy requirement may be used.

The HOV system developed by the Municipality of Metropolitan Toronto follows the arterial street grid network. The proposed network of HOV lanes will penetrate most suburban areas and will connect major employment and residential areas. The HOV lanes will be integrated with the existing rapid transit lines in the region and in some cases may act as precursors for rapid rail facilities. It is anticipated that the development of the HOV system will take about 25 years.

It was recognized early in the development of the HOV program that in addition to the HOV lanes, a number of support programs and facilities needed to be provided to help promote use. Ridesharing programs are being implemented in a number of areas. One approach includes a ride matching pilot study in a suburban office park. Other programs provide preferential parking for HOVs at subway station park-and-ride lots, travel information centers at shopping malls and office buildings, and assisting employers establish their own ridesharing systems.

To ensure that the public understands and supports the arterial street HOV lanes, special attention is being paid to public awareness and marketing programs. An effective enforcement program is also critical to insure that the public perceives the lanes are being properly used. High violation rates will work against future HOV programs.

In conclusion, the Province and the municipalities are very supportive of HOV facilities and programs. All groups are working together to plan, design, operate, and enforce a system of HOV facilities that will address the growing issues of traffic congestion and will enhance the quality of life in the region.

An Evaluation of Houston's HOV Facilities

Dennis L. Christiansen, Texas Transportation Institute

It is a pleasure to have the opportunity to discuss the ongoing evaluation of the Houston HOV lane system. Bob MacLennan provided an excellent overview of the Houston transit and transportation system in his luncheon speech yesterday. I would like to focus my remarks today on the ongoing assessment of the lanes that have been conducted by the Texas Transportation Institute (TTI) with the support of the Metropolitan Transit Authority of Harris County (METRO) and the Texas Department of Transportation (TxDOT).

Traffic congestion became a major problem in Houston during the 1970s. HOV lanes were one of the alternatives examined to address these growing concerns. A contraflow HOV lane on the I-45 North Freeway was implemented in 1979. The lane was opened to buses and authorized vanpools during the morning and afternoon peak-periods. Although many people did not think the lane would work, it was a big success. Premium park-and-ride bus service was introduced and ridership levels increased significantly.

The success of this initial project led to the development of an extensive system of HOV lanes in Houston. Currently, 64 miles of a planned 105 mile HOV lane system are in operation in five radial freeway corridors. The facilities have been planned, designed, constructed, and are being operated through the cooperative efforts of METRO and TxDOT. The HOV lanes represent the largest component of METRO's long-range transit plan.

Although there are a few sections of two-lane, two-direction facilities, most of the HOV lanes in Houston are one-way, reversible lanes located in the median. They are usually 20 feet wide, and are separated from the mainlanes by concrete median barriers. Some of the lanes were implemented by narrowing the general-purpose traffic lanes and/or the inside shoulder. Ingress and egress is provided in a variety of different ways. Slip ramps are provided in some areas. This is the cheapest and easiest form of access to the HOV lanes, but conflicts may arise with merging vehicles. Grade separated access ramps are also used on the Houston HOV lanes. These ramps cost $3 to $6 million on average and provide direct connections from major park-and-ride lots and transit stations.

The cost of the HOV lane system has averaged approximately $6 million a mile. Annual operating costs average $250,000 per lane. Some 80,000 people use the lanes on a daily basis, with carpools and vanpools accounting for 60 percent of this and bus riders 40 percent. The costs for carpool and vanpool use is very low.

One of the keys to an effective HOV facility is attracting new bus riders and carpoolers. In Houston, the HOV lanes have influenced commuters to change from driving alone to using HOV modes. The HOV lanes have attracted young, educated, white-collar Texans to use transit. The survey results indicate that the time savings, trip time reliability and the ability to avoid traffic congestion are the main reasons people use the lanes. A comparison of a freeway corridor with an HOV lane and one without indicates that bus ridership is twice as high in the corridor with the HOV lane. HOV lanes have produced more reliable travel times, which in turn has increased the efficiency of bus service and improved schedule adherence. Cat-pool volumes have also increased. In addition, carpools using the HOV lanes tend to last longer.

The HOV lanes have support from the general public in Houston. In addition to support from HOV users, survey results from motorists in the general purpose lanes indicate that the lanes are considered good improvements to the transportation system. Support for the motorist system among users and non-users continues to grow.

The experience in Houston indicates that, while HOV lanes are not the total solution to traffic congestion and environmental problems, they can play important roles in helping to address these concerns. They represent one set of tools to help improve mobility. Other areas considering HOV lanes may want to examine the experience in Houston in more detail.

Implementation of HOV Lanes on I-270: Lessons Learned

Heidi F. Van Luven, Maryland State Highway Administration

Good morning. It is a pleasure to have the opportunity to talk about the first freeway high-occupancy vehicle (HOV) lanes in Maryland, which was opened last September. We approached planning for the HOV lanes like a pilot project. We knew for practical, legal, and economic reasons, however, that HOV lanes were going to be part of the mix for all future highway planning in Maryland. Therefore, the project had to work. To date, the project has been working well.

I would like to start by providing a background to transportation planning in Maryland and the first HOV project. Interstate 270 serves a heavily traveled corridor, which includes residential communities and high technology business campuses. I-270 is a radial freeway that connects the rapidly growing corridor of northwest Washington, D.C., with the Capital Beltway. Between 1970 and 1990, the average daily traffic volumes have more than doubled along this corridor. The increasing traffic volumes show the effect of this continued growth and the reasons for much of the traffic congestion experienced today.

In 1991, approximately ten miles of I-270 were widened to accommodate eight mainline freeway lanes and four continuous collector-distributor lanes. This widening utilized the available right-of-way, leaving no room for additional expansion. Forecasts, however, indicate that the capacity of even this expanded 12 lane roadway will be exceeded by the year 2000. This would result in gridlock on one of Maryland's most important transportation corridors. Obviously, something had to be done to prevent this.

One of the first things that was done, after the 12 lane widening was completed in 1991, was to put up signs over the new median lane that read "Future HOV Lane." Although the traffic volumes at that time did not justify opening the new lane as an HOV lane, it was felt that the public needed to be prepared for such a possibility.

Historically, the solution for gridlock has been to add more lanes but since there is no more right-of-way available in the I-270 corridor, long-range planning had to include HOV lanes as a major consideration along with other transportation options. The Maryland State Highway Administration (MSHA) believed that HOV lanes were a viable means of slowing down the rapid increase in the rate of traffic growth. At the very least, HOV lanes would guarantee free flow conditions for those who chose to carpool or ride the bus during peak-periods. The requirements of the 1990 Clean Air Act Amendments were also a consideration. The I-270 corridor does not meet federal air quality standards and is considered a non-attainment area. With the passage of the ISTEA, federal matching ratios for interstate projects in non-attainment areas dropped from 90 percent to 80 percent except for HOV projects.

SHA had planned to widen portions of I-270 to the north and south of the 12 lane expansion section. These projects were part of the capital program. Although interstate funding was to be used for these projects, securing additional funds for the ten percent increase in the state match was a significant concern.

From a transportation planner's perspective, the concept of HOV lanes appears to be a good one. However, elected officials and the public-at-large do not always agree, but most news reporters think 'that this difference of opinion is wonderful because it creates controversy-and controversy makes for good stories.

As a result, when the State of Maryland began to consider using HOV lanes as a possible solution to gridlock, you can understand why we approached the idea with great reservation. We decided to give the concept of HOV lanes a try, however, and hoped to benefit from the lessons of HOV history-rather than having to repeat them. Pioneers have always paved the way for those who follow, and Maryland is grateful to those of you who are veterans of the great HOV wars.

We knew from your experience what we were up against in terms of public and private resistance. We also realized, from recent local experience, that the public generally balked at the idea of HOV lanes. You see, a recent attempt to implement HOV lanes on the Dulles Toll Road in nearby Virginia failed, generating considerable public skepticism about HOV lanes, especially among motorists along the I-270 corridor.

Therefore, in March of 1993, when we launched our HOV lane study, a strategy was developed that not only recognized the potential resistance and skepticism on the part of motorists and policy makers, but also incorporated the need to deal with this into every step of the planning process. We began by reviewing the experiences other states had with HOV lanes. Based on this assessment, we came to the following conclusions.

- Before any decision is made to implement HOV lanes, options should first be developed and presented to and discussed with the public. This discussion should include whether to open or maintain the lanes as general-use lanes.

- Develop a high profile information campaign that will make clear to the public and to the press just how HOV lanes work and the benefits of HOV facilities.

- Time the implementation of the HOV lanes so that it will be obvious to the public that their use will help to relieve congestion in the general-use traffic lanes. It is counterproductive if the public sees empty HOV lanes when the general-use lanes are overcrowded.

- Make HOV lanes part of an overall strategy that includes employer-based carpool programs, park-and-ride facilities, and other services.

At the beginning of the I-270 HOV study, we decided that it was as important to collaborate on the development and evaluation of alternatives, as it was to collaborate on making a final decision. To accomplish this, a technical team which included representatives from the county in which I-270 is located and from the Federal Highway Administration (FHWA) was established. Sub-teams were also formed to address operational issues and public relations. Further, as the study progressed, the metropolitan planning organization, local and state elected officials, and interest groups throughout the corridor were informed about the status and findings from the study. The key to the collaborative approach was two-way communication that made our constituents also our stake holders. We told them what we were doing; they told us what they thought. The result was that we were able to make reasonable modifications to the HOV options as we went along.

The public was kept informed throughout the process. Although people continued to strongly resist the concept of HOV lanes, many began a gradual shift from resisting the idea to giving HOV lanes a chance if we could prove that they would work. Overcoming people's resistance to the HOV concept by giving them facts and figures was key to our public information campaign. For example, during the planning process, a broadcast-quality video tape was produced that explained what HOV lanes were, how they worked and why they were being considered. This video was shown to citizen interest groups, elected officials, and at a formal public hearing.

The public hearing on the I-270 HOV lane proposal was highly publicized. A press release, which included a toll free HOV "hotline," was widely disseminated to all print and electronic news outlets. As a result, the press asked for and received advance interviews. Television stations appreciated having professionally produced tape footage to illustrate the story, and repeatedly aired the HOV "package" as well as a pre-recorded question-and-answer session before the hearing. The turnout at the public hearing and the tremendous number of phone calls and letters that followed were evidence that the public information campaign had been effective.

In the summer of 1993, the decision was made to move forward with HOV lanes on I-270. A letter stating that the decision had been made was mailed to citizens groups, civic associations, business leaders, and elected officials within the I-270 corridor. An announcement to the general public was also made at a press conference. Special one-on-one meetings were held with radio and TV traffic reporters, transportation writers, and editorial boards of local newspapers. Employer information packets were distributed to major employers and ridesharing coordinators along the I-270 corridor to help them answer the most commonly asked questions about HOV facilities. Employers were urged to encourage employees to share a ride.

One of the most important tactics at this point in the public information strategy was advance signing. For example, months before opening the first HOV lane, a permanent HOV sign was put up and a small banner which read "future" was placed over it. Then, one month before opening the HOV lane, another banner was placed over the permanent HOV signs. That banner read "Opening September 27th." Once the HOV lane opened, variable message signs were used to advise drivers that they were approaching the HOV lane.

A solid base of technical information was also developed as part of the HOV study. Vehicle occupancy counts verified that there were enough existing high occupancy vehicles to ensure that the HOV lanes would be used by existing carpoolers even if the estimated diversion did not occur. Volume and capacity projections established the need for a two person (2+) minimum occupancy requirement per vehicle. These projections also helped in the comparison of the people moving capability of the HOV lanes versus the general-use lanes. Data on vehicle occupancy and peak hour traffic volumes were used to determine the best hours for HOV operation. Data on travel times before and after implementation of the HOV lanes were calculated and compared to show the travel time savings resulting from the HOV Ianes.

Opening day on September 27, 1993, exceeded our expectations. The vehicle volumes in the HOV lane were good, the press reports were favorable, and one public opinion poll indicated that the majority of the people thought HOV lanes were a good idea. We did have one interesting event during the opening, however. As officials and the press were watching from a bridge, an incident involving a violator in the HOV lane, a motorist in the adjacent lane, and a police car pursuing the violator occurred. No one was hurt, but guess what story led the news that night?

Ongoing monitoring has been conducted since the opening of the HOV lane. During this time, the HOV lane volumes have ranged from approximately 400 to 600 vehicles per hour during the evening peak-period. Average travel times for all motorists on' I-270 have improved. Before the HOV lane was opened, the average travel time for the two mile segment was five minutes. Since the HOV lane opened, the average travel times are down to four minutes in the general-use lanes, and two minutes and 17 seconds in the HOV lane.

Violation rates have been fairly high, averaging approximately 23 percent. A range of enforcement methods continue to be tested to find the best way to reduce violations without slowing traffic or increasing accidents. The courts have upheld the violation citations to date.

We credit the success we have had to four key factors. First was the collaboration with the public, the press, elected officials, and local interest groups from planning through implementation. Second was the ongoing communication through open debate and discussion. This not only informed the public but also provided useful feedback that often led to modifications which either improved the plan or avoided impasses. Third, close attention was given to all operational details, from signing and paint striping to enforcement. This helped ensure everything went as smoothly as possible at start up. Finally, we avoided startup confusion by anticipating potential problems. The public was informed that HOV lanes were coming, when they were coming, and what to expect on opening day. Providing the public with helpful information was instrumental' in getting the public to cooperate that first day.

The I-270 pilot project just described is the first of four phases planned in the I-270 corridor. With Phase I, a new HOV lane was constructed on the northbound side of the 2% mile East Spur segment of I-270 with evening peak-period restrictions only. Phase II will open by July of this year. This will include a new southbound HOV lane, to Phase I's northbound HOV lane, operating in the morning peak-period from 6:00 A.M. to 9:00 A.M. Phase III will open in the summer of 1996. Newly constructed lanes will help to relieve bottlenecks just north of the widened 12-lane section. On the same day that the new lanes are opened, the existing median general-use lane in the original 12-lane widened section will be converted to an HOV lane. The intent of this simultaneous implementation is to reduce the sense among single occupant vehicle drivers that they have lost something. Phase IV will open in the summer of 1997. These newly constructed lanes will help to relieve bottlenecks at the southern end of the widened 12-lane section, known as the I-270 West Spur.

The statewide plan for HOV implementation will be an outgrowth of this pilot project. A statewide network of potential HOV facilities is being identified as part of this process.

In conclusion, one of the most important lessons learned from this project is that for HOV lanes to succeed, they have to be used, and in the final analysis, it will not be the Maryland State Highway Administration that determines whether HOV lanes will be used, but the drivers themselves. All that we in MSHA can do is hope that if we build it, they will come-or to be more precise, if we build it, they will carpool. So we will continue to plan, to collaborate with all constituencies, and to learn as we go. But we also plan to step up our campaign to convince Maryland motorists that an HOV highway may be as inevitable as an information highway.

Experiences from the Northridge Earthquake: Applying HOV Treatments in an Emergency

Donald G. Capelle, Parsons Brinckerhoff Quade & Douglas, Inc.-Presiding

The Caltrans Response

Charles J. O'Connell, California Department of Transportation

I would like to provide an overview of the Caltrans response to the Northridge earthquake. Although it was a major earthquake, the impact on the freeway system would not have been all that bad except for the fact that I-5, the major interstate route between Canada and Mexico, was severed at the interchange with State Route 14. This is a location where, because of the topography, there is no parallel arterial or freeway. Interstate 5 also is a major north/south truck and car corridor in this region. The severing of this route caused trucks to be rerouted throughout the Southern California area and resulted in major problems for commuters living in the area north of Los Angeles. At that location, I-5 carries approximately 130,000 vehicles a day. Trucks account for some 15 to 20 percent of this traffic. Other facilities that were affected include State Route 14 and State Route 118 which carry approximately 180,000 vehicles a day, respectively. Both of these routes are primarily commuter freeways. On the other hand, the Santa Monica Freeway (I-10) carries some 340,000 to 370,000 vehicles a day depending upon the location. It is located in the heart of the west side of downtown Los Angeles, and there is a substantial grid network of alternate routes in the Santa Monica Freeway Corridor primarily high standard arterials and some parallel freeways which are not present in the I-5 Corridor.

The I-5 Freeway was also severed at Gavin Canyon just north of SR 14. Major sections of State Route 118 immediately east of I-405 were also severely damaged. Also the eastbound roadway suffered major damage and collapsed on a viaduct section; the westbound roadway was temporarily shored, resurfaced and reopened in a relatively short time to carry both east and west traffic.

One of the innovations on I-10 was the utilization of an eastbound off-ramp which was quickly repaired and opened in the opposite direction for utilization by westbound HOVs. Two alternate routes were provided where I-10 was severed at La Brea Avenue.

The utilization of truck route/bypass lanes at the I-5 and State Route 14 interchange area provided two lanes in each direction almost immediately for traffic detoured by way of State Route 14. With a little creativity, the northbound direction was expanded to include an HOV lane and two general purpose lanes. Southbound State Route 14 was restriped to provide one HOV lane (and two SOV lanes) which provided a quick bypass so that traffic could more efficiently utilize the southbound truck lanes which remained opened. In addition, a superseded parallel state highway known as Sierra Highway, which was essentially a four lane facility, remained open to traffic. Traffic flow was modified to provide initially three lanes in the peak direction and one lane in the opposite direction. However, as soon as the truck bypass lanes were opened, Sierra Highway was permanently converted to three southbound lanes and one northbound lane thus balancing total capacity. The key here was the ability to convert to HOV operations an HOV lane in each direction on the truck bypass. In the northbound direction, a three mile HOV lane was created, and in the southbound direction, a IO-mile HOV lane was created. These lanes were extremely effective, providing about a 15 to 20 minute savings in travel time to HOVs. All of these changes were accomplished through the coordinated efforts of Caltrans, City and County of Los Angeles and the city of Santa Clarita.

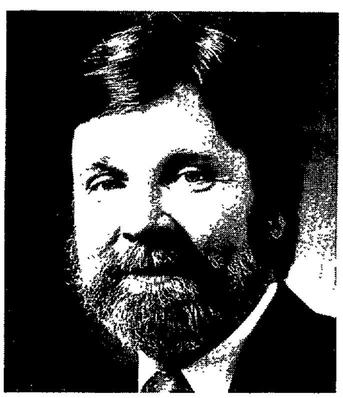
On I-5, a two-lane detour was created which utilized the superseded state highway arterial (known as the Old Road) which provided for two lanes of traffic in each direction as compared to the eight lane I-5 freeway. No HOV lanes were in use on this bypass.

HOV lanes were used on State Route 118 because restoration of original capacity was able to be provided in less than a month and a parallel arterial system existed. This section of State Route 118 was essentially a six-lane facility. By restriping and reshoring the westbound viaduct, six lanes of traffic (three lanes in each direction) were provided, essentially restoring the original capacity, while the eastbound viaduct was being rebuilt, Two detours were established on the Santa Monica Freeway between Washington Boulevard and La Brea Avenue. An HOV detour utilized the Santa Monica Freeway right up to the location of the structure collapse. Westbound HOVs utilized a converted eastbound offramp/ connector and were essentially taken off the freeway at one offramp and immediately back on the converted eastbound offramp. Eastbound HOVs were taken off at La Brea Avenue and returned at Washington Boulevard. A more circuitous detour was necessary for SOVs that were diverted off the freeway at La Brea Avenue approximately one mile upstream of the HOV lane determination. Eastbound HOVs were also exited at Robertson where they traversed local arterials leading to the freeway at Washington Boulevard. Overall, there was a savings of approximately 15 to 20 minutes for HOVs during the peak commute period.

The public adapted well to the installation of HOV lanes, both on I-10 and I-5/SR 14 truck lanes. On the SR 14 truck lanes, peak HOV volume frequently ranged from 2,000 to 2,200 vehicles per hour per lane during peak periods. On I-10, HOV usage ranged from 700 vehicles per hour to 1,400 vehicles per hour during peak periods. Mixed flow lanes on the State Route 14 truck bypass frequently ranged as high as 2,400 vehicles per hour per lane. The overall savings to the public utilizing HOV lanes averaged approximately 20 minutes.

The Los Angeles County Metropolitan Transportation Authority Response

Arthur T. Leahy, Los Angeles County Metropolitan Transportation Authority



The earthquake occurred at 4:31 A.M. on January 31, 1994. That was a holiday Monday morning. By 5:30 A.M., an emergency command center had been established at the LACMTA. Staff from all departments-including operations, equipment maintenance, facility maintenance, engineering, safety, communications, and the news bureau-gathered at the center to share information and to start identifying response strategies. The group examined the extent of damage to facilities and equipment, available communications, and alternatives.

A number of immediate actions were initiated. First, all bus and rail operators were mobilized. **This** effort followed the previously developed emergency plan, so LACMTA personnel knew what to do. An assessment of all facilities was initiated to determine the extent of damage and necessary repairs were identified. These efforts were coordinated with those of other agencies through the command center in the basement of City Hall.

Although the first day was very difficult with reoccurring aftershocks, 96 percent of the normal bus service was operated. Ridership was about 20 percent below normal, but it was important for transit dependent groups. Responses from riders indicated that the service was critical for traveling to and from work. This provided a reassurance to the public that the city was still functioning.

The Metro Blue Line was also in operation that day. The system was inspected after each aftershock to ensure that all the structures were still sound. The Red Line subway was not in operation, however, due to the inspections needed after each aftershock. A bus bridge was established replicating the route of the Red Line. On Tuesday, the day after the earthquake, all bus and rail service was in operation. Ongoing communications were maintained with Caltrans and local jurisdictions. This was critical since many of the bus route were impacted by detours and conditions on the freeways and local streets. Approximately 75 detours were in place within 24 hours of the earthquake.

During the weeks after the earthquake, the MTA actively participated in an interagency planning committee. This committee was chaired by a representative from the governor's office. A great deal of support was provided by the governor's office, as well as federal officials. Other representatives on the committee were from Caltrans, the City of Los Angeles, law enforcement agencies, and the other transit agencies in the area. The purpose of the committee was to plan and coordinate street and highway detours, bus service changes and new services, and coordinating public information. Daily updates and press releases were used to help communicate with residents and travelers.

In closing, the experience of the LACMTA indicates the importance of having an emergency plan that all employees are familiar with. It is also critical to update these plans after they are used in an emergency. The plan worked well and all employees knew what they should do. The single largest key to success was probably the close coordination and communication among the different agencies. This enhanced the efforts of each agency and provided a coordinated approach to addressing problems and to communicating with the public.

The Metrolink Response

Richard Stanger, Metrolink

I would like to take this opportunity to provide an overview of the Metrolink system and to describe how we responded after the earthquake. Metrolink started operations just 15 months before the earthquake in October of 1992. Metrolink is part of the Southern California Regional Rail Authority, which was established through a joint-powers agreement among five counties. The sole purpose of the authority is to plan, build, and operate commuter rail service.

The system has expanded very rapidly. The initial system included 112 miles when it was opened in 1992. By June of 1993, 196 miles were in operation. Currently, the system includes 346 miles. By 1995, the Metrolink system will encompass 500 miles on seven lines.

A number of factors have contributed to this growth. First, the bond measures passed in 1989 and 1990 earmarked adequate funds to build the system. The bond measures were largely a response to the significant increases in congestion experienced in the Los Angeles area. Between 1980 and 1990, vehicle miles of travel increased by approximately 60 percent, with only a 2 percent increase in road miles. Second, for the first time, freight railroads were willing to sell major portions of urban track. Between 1990 and 1993, public agencies purchased 700 miles of railroad rights-of-way and track, along with 700 acres of stations, yards, and other facilities. Slightly less than half of this is anticipated to be used for commuter rail. Third, county governments realized they would have to work together to implement a commuter rail system. Finally, improvements to existing railroad rights-of-way are categorically exempt under California environmental law. This allowed immediate movement toward construction.

The Metrolink system uses existing railroad rights-of-way and freeway median rights-of-way. Where possible, existing stations have been renovated. The cost of the initial four lines was approximately $600 million. This included almost 200 miles of track and the central maintenance facility. This averages out to approximately $3 million a mile. The subsidy per trip **is** approximately $0.28 per mile or $8.70 for an average trip. The subsidy levels have been declining.

After the earthquake, key segments of the freeway system were broken and traffic, especially in the north, was disrupted. The rail lines fared much better. The Red Line bounced one foot vertically and one foot laterally, but remained relatively undamaged. Surface railroad tracks, especially in curves, moved as much as a foot laterally, but maintained gauge.

It was evident immediately after the earthquake that there was a need to expand Metrolink service to help maintain mobility. Service was not operated the day of the earthquake because of the need to inspect the system after each aftershock. The reassignment of vehicles into the area started immediately, however. Three trains were available due to the delay in the opening of the Orange County Line. Also, the MTA had purchased the Saugus Line to Palmdale a year earlier, so that the track was already owned.

Ridership levels were below normal on Tuesday, but on Wednesday, an additional 4,000 people rode the system. This continued through the next week. It was also evident that service would have to be extended to intercept commuters coming from the Antelope Valley where 300,000 people live. By Thursday, agreements had been reached with the cities of Lancaster and Palmdale that by the following Monday the system would be extended to Lancaster and two new stations would be open. The new stations were developed quickly, with at least six contractors working simultaneously. Also the Corps of Engineers and the SeaBees helped construct some stations, along with city and county public works departments. The response was truly a group effort.

Before the earthquake, daily system ridership was slightly under 1,000. Ridership peaked in the two weeks immediately after the earthquake and then leveled out. Caltrans was able to open part of the I-S/Route 14 interchange by the end of January. We knew that ridership would decline, partly because we had only 14,000 seats available for some 21,000 riders. Riders who purchased a February monthly pass could ride through March for free and free emergency trips were provided for firefighters, police, and other individuals.

Current ridership is about 3,000 after the reopening of the I-5 bridge and the Route 14 ramps. This is still four times greater than before the earthquake.

A number of capital improvements are being made on the line. The 78 mile trip took approximately 2 hours and 25 minutes. The extremely slow curves required trains to operate at about 28 miles an hour. This is unacceptable for long term service. Metrolink is working with the Federal Emergency Management Agency to improve the line. Initially, it was thought that reconstruction of the I-5 interchange would take about a year. Although I would like to compliment Caltrans for doing an extremely fine job of rebuilding the freeways, part of me wishes it had taken a little longer.

Based on a preliminary analysis, four improvements were identified to reduce the travel time from 2 hours and 25 minutes to 1 hour and 35 minutes. First, ten miles of new track had to be built in the Antelope Valley to get off the Southern Pacific mainline. Second, curves needed to be straightened in the 33-mile Soledad Canyon area. These two steps saved 40 minutes in travel time. Third, one tunnel needed to be repaired. Although it did not sustain much damage, standing water in the tunnel became a problem. Fourth, ongoing work approaching Union Station in downtown Los Angeles is being completed.

A number of activities have been undertaken to accomplish this. On an average day since the earthquake, 6,400 cubic feet of earth has been moved, 900 tons of ballast has been spread, 1,500 feet of rail has been laid, and 300 ties have been set or replaced. All of this is being done under freight and Metrolink traffic. These repairs and improvements have cost approximately $50 million, or $1 million a mile. Most of the funding has come from the Federal Emergency Management Agency and the Los Angeles County Metropolitan Transit Authority (LACMTA).

In many ways, the earthquake put Metrolink on the map. Before the earthquake, probably only about 10 percent of the residents in Los Angeles knew what Metrolink was. Now, this number is probably 80 or 90 percent. The response by Metrolink showed that the system could be counted on and that it is an important part of the overall transportation system in the Los Angeles area.

Emerging Issues, Research, and Vision for HOV Systems-Panel Discussion

Donald G. Capelle, Parsons Brinckerhoff Quade & Douglas, Inc.-Presiding

Panelists:
Katherine F. Tumbull, Texas Transportation Institute
Morris J. Rothenberg, JHK & Associates
Leslie N. Jacobson, Washington State Department of Transportation
Keith Gilbert, Automobile Club of Southern California
Arthur T. Leahy, Los Angeles Metropolitan Transportation Authority

Dr. Capelle opened the session by noting that the Conference participants had completed forms on the first day identifying key issues, research needs, and future visions related to HOV facilities. The responses to the survey were compiled into nine categories. Panel members were asked to respond briefly to some of those issues. A summary of the responses from the panelists is provided.

There have not been any recent developments in HOV enforcement techniques. What enforcement approaches will be used in the future?

Jacobson: One of the most important things we can do is to involve representatives from the enforcement agencies very early in the HOV planning and design process. Enforcement officials should also be involved in developing the operating plans for HOV facilities. Ensuring that enforcement areas are designed and located properly is important, as is providing a system that makes sense to the public. This can make enforcement easier.

Tumbull: A number of areas around the county are examining the potential application of a variety of advanced technologies to assist with HOV enforcement. Although there is not a currently available technology that can be used to help determine the number of vehicle occupants, this possibility is being examined. A number of research studies and demonstration projects are focusing on this issue. Within the next few years, there should be a much better idea of what these technologies are and how they can be applied. This represents just one of a number of combinations of IVHS technologies and HOV systems. The luncheon comments by Bob MacLennan also raise an important issue that enforcement for the worst case scenario needs to be considered. This should include how to guard against motorists doing strange things and misusing the facilities.

Rothenberg: Enforcement needs to be considered early in the design phase, and we need to do our best at building compliance into the design and operating plans for HOV facilities. It is also important to remember that HOV facilities are new in many areas and motorists may not be familiar with the requirements. This points to the need to improve public information and marketing programs. If we do a better job at informing people on the proper use of the lanes, we may be able to reduce violations.

Gilbert: One of the best enforcement devices is a low technology approach; the $271 maximum fines given to violators in California. This seems to work from a consumer standpoint.

Although bus service is an important part of many HOV facilities, some transit agencies around the country consider HOVs to be competitive with bus or rail services. Are HOV facilities competitive or complementary to other transit services?

Leahy: At the MTA, HOV lanes and busways have been viewed as compatible with rail sections. The El Monte Busway provides a good example of buses, carpools, and vanpools all using the same facility. The addition of carpools may have resulted in some degradation of bus speeds, but overall it has worked well. The impact of a busway or HOV lane on bus ridership is very positive. Before the El Monte Busway was opened, there were approximately 1,000 daily riders in the corridor. Now, approximately 19,000 to 22,000 daily passengers ride buses in the corridor. Service has been increased significantly since the busway was open, with peak hour headways averaging between one to three minutes.

Tumbull: There are two important points to make about bus services and HOV facilities. First, as noted in some of the other presentations, there has been a significant growth in non-radial HOV lanes. Bus services have historically been provided in a radial direction; providing service from suburban areas to the downtown. Correspondingly, there has been little suburb-to-suburb bus service. With the growth of non-radial HOV lanes, we need to look at the role bus service should play in serving this travel market.

It is also important to note that many transit systems continue to have problems ensuring adequate operating assistance. Houston, Dallas, and the other Metropolitan Transit Agencies in Texas are lucky in that they have a dedicated sales tax revenue that provides a stable funding base. Other transit agencies around the country do not have this. These are two important challenges currently facing many transit systems. We need to be aware of these concerns and work with transit agencies to try to enhance bus services on HOV facilities.

Jacobson: One of the responsibilities we have at the state department of transportation is to work with transit agencies to make sure the HOV facilities will support the transit service in the area. Thus, like enforcement, representatives from transit agencies need to be involved early in the planning and design stages to ensure that transit operations are adequately considered. Also, in an area like Seattle, which does not have a rail transit system, the HOV lanes have helped increase bus services and ridership levels. Representatives from Community Transit would probably agree that the Seattle HOV lanes have been very supportive of their system and partly responsible for the increase in ridership experienced over the last decade.

Rothenberg: The key is really to get people out of their single-occupant vehicles. Carpools represent an important step away from the habit of driving alone. It may lead to greater use of other forms of transit also. It is also important to remember that HOV facilities are just one of the transportation tools available. There are a number of different markets that need to be served and the transportation system should be responsive to these different market segments.

A number of proposals are currently being considered to use congestion pricing on HOV lanes by selling excess capacity to single-occupant vehicles. What do you think of those proposals and the possible use of congestion pricing on HOV lanes?

Gilbert: We discussed this issue at a session earlier today and there did not seem to be a great deal of opposition to the concept. Rather than calling it congestion pricing, I would consider it similar to the idea discussed in the Los Angeles area a number of years ago of providing a premium service for a premium price. At first, this was discussed in terms of separate roadways. Now the idea of using excess capacity in HOV lanes to provide this premium service **is** being considered. There may not be all that many areas where this concept would be feasible because it would require an exclusive HOV lane with limited access points. In addition, I am not sure that there is much excess capacity on many HOV lanes. I am not sure I agree with the idea of allowing 3+ carpools to use an HOV lane free, but charging 2+ carpools. It seems that we should be encouraging all forms of ridesharing.

Environment issues, especially air quality, continue to be important concerns in many areas. Are we getting any closer to understanding the environmental impacts of HOV facilities?

Rothenberg: This issue represents the highest priority research project identified by the TRB HOV Systems Committee's Subcommittee on Research. A problem statement on this topic was developed and submitted to the National Cooperative Highway Research Program (NCHRP) for funding. It was not accepted this year for funding, but it may be considered next year. A number of NCHRP projects do focus on air quality issues, however. One of these is focusing on quantifying air quality benefits and costs from transportation control measures and other techniques to reduce automobile usage. HOV facilities should be considered within this project.

Jacobson: One of the issues discussed at the air quality session was the fact that existing transportation and air quality models are probably not sophisticated enough to adequately examine the impacts of HOV facilities. In addition, a number of other issues must be considered in this analysis. These include the type of HOV facility being considered, the estimated mode shift, characteristics of the travel corridor, and local conditions.

PART 2-KEYNOTE LUNCHEON SPEECHES

HOV as a System-Wide Solution

Robert G. MacLennan, General Manager, The Metropolitan Transit Authority of Harris County

It is a pleasure to participate in the Seventh National HOV Conference here in Los Angeles. I bring greetings from the home of the next NBA Champions-the Houston Rockets. The community pride in the Houston area has been very evident during the basketball playoffs. Although Metropolitan Transit Authority of Harris County (METRO) does not allow any advertising on our buses, a METRO bus has been painted with "Go Rockets." Free rides are currently being provided on this bus.

Los Angeles is a great location for the conference. There are a number of similarities between the HOV facilities in Houston and Los Angeles. Both represent coordinated and cooperative efforts between numerous groups. The HOV lanes in Houston have been developed-and continue to be operated-through the-joint efforts of METRO and the Texas Department of Transportation (TxDOT).

The HOV lanes in Houston represent a basic element of the mass transit system and are a major part of the overall transportation system. How Houston got to this point was not necessarily a well planned route, however. Rather, it brings to mind an anecdote about Bishop Fulton J. Sheen.

Some of you may remember that back in the 1950s and 1960s, Bishop Fulton J. Sheen was a great moral force in the United States. He had a program on television that was broadcast nationwide, and he traveled all over the world presenting inspirational talks.

One evening in Philadelphia, Bishop Sheen decided to walk from his hotel to the Philadelphia Town Hall even though he was unfamiliar with the city, Sure enough, he became lost and was forced to ask some boys to direct him to his destination.

One of them asked Sheen, "What are you going to do at Town Hall?" Sheen replied, "I'm going to give a lecture." "What about?" the boy asked. "On how to get to heaven. Would you care to come along?" "Are you kidding?" said the boy, "You don't even know how to get to Town Hall!"

It would be terrific for me to be able to tell you that Houston public transportation planers knew from the start how high occupancy vehicle lanes would be used to provide a system-wide solution to our transportation problems. However, like Bishop Sheen, although we knew our ultimate destination, we did not know the route we were going to take to get there.

A brochure produced in 1978 illustrated the route METRO planned to take when it was created as a brand new transit authority in Houston, Texas. The brochure shows an artist's conception of four steps in Houston's public transportation future.

The first picture is of a congested freeway; which was certainly the state of Houston traffic in 1978. The next frame shows a dedicated busway down the middle of that freeway. The third picture shows construction taking place on the busway, and the fourth picture shows a rail line in place of the busway.

Well, we have not gotten to the rail line yet because a funny thing happened on the way to the train. Our busways turned into an HOV lane network, and we realized we had a successful transportation system on our hands.

Once we realized that, we made managing the assets of the HOV lanes a major part of the system-wide solution for Houston's traffic problems. We have had quite a bit of success doing that. According to the Texas Transportation Institute, Houston is the only major city in the country which has had continuously declining congestion levels since 1984.

Here's the route we took to our version of "transportation heaven"-our 64 mile, and soon to be 104 mile-barrier separated HOV lane network.

What we only recently decided to call "High Occupancy Vehicle" lanes were at first simply "contra-flow" lanes. They then became barrier separated "Authorized Vehicle Lanes," or "Transitways." These lanes were mainly seen as effective mass transit techniques-but not "the system-wide solution" to traffic management.

Houstonians like their cars and pickups, and many think they have a right to their single occupant vehicles. These independent folks were somewhat hostile to the first contraflow lane because it took an existing lane of freeway, in the off-peak direction of travel, and restricted its use to buses and vanpools.

The citizens trapped in traffic alongside the HOV lanes did not interpret the intermittent buses or large vans flying past them as 47-less-cars-blocking-their-way. They thought they saw under utilization of these transit lanes. And they complained so loudly that we began to allow carpools to enter these previously transit-only lanes.

At first, we had all kinds of restrictions. Drivers had to go through a training course, display an authorized user tag, and ferry at least three passengers in addition to the driver. Needless to say, Houstonians remained hostile. They knew how to drive, and they cherish their privacy. Until we lowered the occupancy minimum to two persons, few carpools used the HOV lanes. When we finally dropped the training requirement and let any two persons brave enough to figure out how to get on the lane try the “transitways,” the HOV lanes very quickly became as popular as sliced bread.

Thus, we backed into using our transitways as true HOV lanes because of public opinion. Meanwhile, the cost of building a train system, and the political problems attendant with both the cost and possible locations took a toll on public opinion. Not-in-my-backyard attitudes toward train building had a lot to do with the utilization of a freeway-based HOV lane system.

Since we were a new agency, and we were seeking federal funds, Houston METRO held two areawide referenda that solicited citizen input on the locally preferred transit system technology. In a 1993 election, heavy rail got soundly trounced.

We conducted a lot of surveys and public opinion polls in the mid-1980s, and in 1988, we ran the issue up the flagpole again. This time the vote indicated strong support for dedicating 25 percent of our sales tax to street construction and maintenance of traffic management in general. This is when METRO really became a different type of transit authority and really became a serious transportation agency. It also looked like there was support for rail technology in the form of a loop connector fed by a bus system that added to the HOV system, rather than replacing it.

We were, at this time, beginning to get federal appropriations for our system as well. The following sequence of events took place over the next tive years:

- the board changed, and rail was dropped;

- the board changed again, and a new rail plan was developed and adopted;

- the mayor and the board changed, and rail was dropped again.

The current Board of Directors took a good look at Houston’s transportation assets, including the HOV lanes, and, realizing the treasure we had in them, decided that Houston should stick with and expand on our state-of-the-art bus system and run it on HOV lanes wherever and for as long as that makes sense. We were successful in getting approval to keep and continue the federal funding program on the basis that our HOV lanes were still fixed guideways. We named our system-wide solution “The Regional Bus Plan. ”

Of course what I have just told you is a very simplified version of a very complex fifteen years of existence. Even today, there are some who say that HOV lanes are not legitimately fixed-guideway transit systems. I would argue that it is exactly the sort of intermodal system that ISTEA was formulated to encourage.

Let us look at the bus aspect of the system first. Buses make great sense in cities like Houston for two major reasons: we have a very large service area, 1,279 square miles, and comparatively low densities. In fact, every corridor in Houston that could justify rail has an HOV lane either in operation or under design. Houston has no natural barriers like oceans or mountains to contain its growth, so it just spreads across on the coastal plain like cattle looking for fresh grass.

Also, for better or worse, Houston is the last large American city without zoning. We thought last year that we might get zoning, but our citizens voted it down still one more time. So planning and channeling development is very hard to do in a city like ours. This makes a flexible transportation system essential if we are to respond to the needs of our growing city.

More and more, Houston is becoming-as Joel Garreau says-a collection of ***Edge Cities.*** Our central business district, while still the major employment center, is being challenged by numerous other employment nodes such as the Texas Medical Center and The Galleria/Uptown area. These are just two of about twelve areas that are attracting employees away from the central core. Three of these major activity centers alone are in the nation’s top twenty employment districts today.

Thus, Houston is like most other large cities in the world. The central business district is no longer the only employment center. This suburbanization of work locations creates problems for transportation geared to hub-and-spoke systems which are typified by the rail systems of older cities.

Our large interconnecting freeway system has already laced these employment centers together, so using the freeway HOV lanes for buses makes, good sense for Houston. Our park-and-ride system brings the workers directly to the large major activity centers, or drops them off at transit centers to make transfers to other suburban locations. Bus riders who make the trip all the way to a major activity center on one bus are dropped off close to their buildings.

One of the many issues associated with a possible rail system in Houston is how it compares with the effectiveness of the park-and-ride bus system as far as collecting and distributing riders. This, of course, is on top of the fact that the average park-and-ride bus speed is twice that of the average rail line, plus park-and-ride service is already very cost efficient.

All of the rail systems evaluated in Houston have presented problems when factoring in distribution of passengers from the central train station onto buses for delivery to the downtown office buildings. Riders' trips become longer if they have to change modes. This challenge may not be formidable in cities with long-established intermodal transit systems, but Houstonians have never been substantial users of public transit, so we are constantly competing with the automobile for their business.

Distribution problems become much smaller when the transportation system is comprised of buses and carpools because they are much more flexible. Flexibility is the key word when dealing with low density areas. HOV lanes amplify the flexibility needed.

There are, of course, planning challenges to the effective use of HOV lanes. Finding the right mix of vehicles, hours of operation, number of passengers, and safety has not been easy. I have already told you that we started out requiring four persons with a trained driver and an authorization card, then we dropped to two persons. Once the word got out about what a good deal this was, ridership in carpools increased so rapidly on the I-10 West transitway that we had to raise the occupancy requirements during the peak hours. To keep the HOV lane from clogging up, we require three persons in each car during the morning and afternoon peak hours.

In order to retain our bus passengers, we have to keep the traffic moving swiftly on the HOV lane. Thus, good management and monitoring of the traffic flow is essential. Currently, we are very close to raising the occupancy levels during the morning peak hour on two other freeway HOV lanes to keep them flowing smoothly.

We have also changed the operating hours for the HOV lanes. Originally, they were only open during the peak hours. Complaints about under-utilization of the lanes led to vastly expanded hours, however. Late in 1993 and early in 1994, three wrong-way incidents occurred on the lanes that lead us to restrict operating hours. The incidents appear to be caused by driver errors. One case might have been the result of two teenagers deliberately going the wrong way with no lights at night playing chicken. Another involved a driver with a blood alcohol content of 0.27 whose entry onto the HOV lane defies any logic and some laws of physics.

We took a number of steps to prevent these types of incidents from occurring again. The entries and exits to the lanes have become more controlled and extra enforcement personnel have been deployed. We also cut back the operating hours initially. Recently we have upgraded our signage and extended the hours again, but not quite as broadly as before.

Over time, we have continued to add to the HOV lane system. Almost 65 miles are currently in operation. An additional 40 miles are under construction or in design. Every time a new lane opens, we see ridership rise dramatically.

Right now, combined with our bus system, our HOV-network carries more passengers than the bus and rail systems of San Diego or Miami or Atlanta. The system operates at a cost-per-passenger mile of about $0.05 per mile.

With this bus-based, HOV-based system, it has become very difficult to justify investing in a rail system. We would invest in rail if and when the HOV system, carefully managed to achieve maximum use of its assets, did not meet Houston's needs any longer.

For example, the HOV lane on which we have already increased the occupancy requirements during peak hours is on one of the most heavily traveled freeways in the Houston region-the one heading from Houston to Austin and San Antonio. There may be a time when we will have to increase the occupancy requirements on this HOV lane to four persons, then go to vans, then go back to buses-only. By that time, demand for capacity will have risen so high that ridership on a rail system parallel to the HOV lane might be economically feasible. If and when that occurs, we will fulfill the promise of our original brochure and install the beginning of a rail system. At the moment and in the foreseeable future, not only is the ridership not there for a rail system, but the HOV lanes also provide other benefits.

Houston's HOV lanes help us comply with ISTEA requirements that high occupancy vehicle facilities must be considered before general purpose freeway lanes are added, even though our HOV lane network was already under construction before that ISTEA ruling came abut.

In Houston, we've found that middle class, inner city neighborhoods and environmental groups would rather have HOV lanes added than double deck or significantly widen our freeways, even though land is available for widening.

The HOV lane alternative also appears to be preferred over a commuter rail line or toll roads down existing freight rail rights-of-way through a major Houston park and alongside inner-city neighborhoods. So, recent experience indicates that many residents are more open to HOVs than other modes of transportation. Further, while the lower cost of HOV lanes compared to rail makes HOV seem an excellent investment, the fact that HOV rights-of-way can also be utilized as rail lines in the future-if passenger ridership warrants that expense-helps us respond to rail-oriented Houstonians.

Now, I would like to shift gears and address the topic of HOV lanes as a system-wide solution. I would like you to consider your city's total transportation system as a bundle of major assets and talk about asset management for a moment. In "Driving Forces that have Shaped Transportation Demand Management," Tad Widby says, "If most businesses in the United States . . . [wanted] to increase their output . . . they may add a second shift, have one of 'their lesser-used plants produce more product, or take some other action. Few would . . . build a second manufacturing plant. Most, would try to get more productivity from their existing assets. In the transportation field . . . the response to the need to handle more trips has often been to build more capacity rather than to wring more capacity or productivity out of what we already have. ISTEA clearly sets asset management as a fundamental priority. "

In this context, if a total transportation system is looked at as a manufacturing process "one would consider the inputs, the outputs . . . and other aspects to gain greater productivity. Before adding capacity, it is likely that one would consider adding a second shift (spreading the peak), finding more efficient product delivery means (increasing vehicle occupancy), using just-in-time inventory control (demand response and incident management are close approximations), and applying pricing schemes designed to move the product more cost effectively (deep discounts for transit riders and perhaps congestion pricing for carpoolers and vanpoolers). "

It would be great to tell you that when Houston looked at its transportation assets, our leaders decided to make better use of our assets by putting HOV lanes down the center of all freeways. As I have already told you, however, we worked our way into our current system.

After we looked at rail costs, and evaluated which heaven we wanted to enter, we realized we had already created a system that was bigger than most, more effective than many, and had gained popularity with Houstonians. Only then did we really begin to treasure the system.

Not only had we utilized the unused Houston freeway medians as an asset, and improved them, but we now began to see other ways to organize and manage our system so that our assets are even more productive.

I have mentioned that we increased vehicle occupancy by upping the number of passengers needed for peak hour travel on the HOV lane; we plan to do more of that. I have also touched on how management of occupancy levels is crucial to keeping the HOV lanes flowing rapidly so that we maintain our transit riders.

METRO has also taken a significant role in Houston's cooperative freeway incident management program, a major element of which is the Motorist Assistance Program or MAP. This is a particularly good example of the coordination of various public agencies and the private sector to manage our total assets for the good of the region. In this cooperative effort, METRO laid out the program and pays the salary of sheriff's deputies to drive the MAP vans. The Houston Car Dealers Association provides many of the vans that patrol the freeways. Houston Cellular provides free telephone air time for motorists to call in freeway incidents that are blocking travel. METRO police-with interagency agreements with state, county and various other cities-are also specially trained to control the clearance of incidents and accident investigation on the major freeways in the Houstonregion.

One of the most important ways that we are going to maximize our HOV lane assets is by employing intelligent vehicle highway systems (IVHS) management tactics. A number of projects are underway in the area.

Loop detectors and cameras-installed in the mid-1980s-are being updated to provide instant information about transitway and freeway traffic conditions. METRO and TxDOT are now installing similar systems on all the major transitways and freeways of Houston. These electronic aides will be run from a new central control facility.

The central control facility is another cooperative project of METRO, the TxDOT, the City of Houston, and Harris County. Personnel in the facility will monitor traffic on freeways and many major thoroughfares. A temporary traffic control center is currently in operation.

From the new center, we will oversee and adjust traffic on a real-time basis so police will be able to respond more quickly to incidents that slow traffic. This coordinated system is informally called the "Houston Intelligent Transportation System" or HITS.

At the same time, TxDOT is building a fiber optic network to link the freeway electronics to the central control facility. Included in this computerized transportation management system are loop detectors, closed circuit television, ramp metering signals, electronic message signs, and radio information to provide immediate information to drivers about traffic conditions ahead and possible alternative routes if problems develop.

We also have begun the preliminary stage of the federally-sponsored ***Smart Commuter*** IVHS operational test. METRO and TxDOT have divided that project into two components. In one component, we will provide access to immediate traffic and transit information for a test group of drivers who commute from north Houston on Interstate 45 to downtown.

The second part of the ***Smart Commuter*** test will allow a selected group access to real-time ride matching information. Our plan is to provide computer linked information for west side commuters-headed for the Galleria, a huge "Edge City." Commuters will enter departure and destination information, then that information will be matched with someone who wants a ride to the same area. A meeting place will be arranged-say a park-and-ride lot-and "instant car-pools" will result.

Not necessarily related to the maximization of the HOV system, but an integral part of our total transportation asset management program, is our program to install smart intersections. METRO has begun a $120 million program to have our intersections "talk" to traffic lights, and have traffic lights talk to each other, and automatically adjust movements in traffic corridors and cross-corridors.

These new smart intersections will also relay that information to the computerized central control facility. We will have almost 600 intersections modified and functioning in the next two-and-one-half years. Some are already linked and operating together. TxDOT has a program similar to METRO's for the roadway traffic signals under its control. Together, the two agencies have some $500 million committed to these programs.

If we go back to Tad Widby's comparison of managing transportation assets like we would manage the assets of a manufacturing plant, you will remember that we have talked about using IVHS to make our product more efficient. We have talked about increasing vehicle occupancy requirements to both assure efficiency and to add the equivalent of a second shift by spreading the peak traffic. We have talked about a just-in-time inventory control equivalent, in the use of demand response transit as well as our cooperative incident clearing, our Motorist Assistance Patrols, and the coordination of all traffic from our new central control facility.

I will briefly mention that a pricing scheme designed to move the product cost-effectively comes in the form of the current free use of the HOV lane. Park-and-ride patrons, as well as carpool and vanpool patrons, receive the bonus of time, and faster movement when they use the HOV system. During the peak hours, traffic flows in the HOV lane at a much faster pace than in the freeway main lanes. For instance, on the 13 mile Katy HOV lane, METRO buses and carpoolers usually save 18 to 22 minutes per trip over the main lane drivers.

Another asset management technique we are examining is congestion pricing. We would like to test this concept first on an HOV lane that is under design right now. In this instance, we hope to sell unutilized capacity as long as that capacity is available without impeding the flow of overall traffic.

The other bonus for consumers with the decrease of single occupant vehicles is in the form of cleaner air. Automobiles are polluters and the Clean Air Act has fairly strong support among our citizens. The 1991 Clean Air Act Amendments openly call for increased vehicle occupancies. Houston, which is a Severe Non-Attainment area for ozone, is going to have to increase vehicle occupancies for workers by about 25 percent. That means cutting one-in-four single occupant vehicles each day of the work week.

Clearly these governmental mandates are powerful organizing principles. HOV lanes are perfectly situated to provide alternative ways to respond to these mandates. Also, the law passed by Congress last summer allowing up to $60 per month of discounted transit passes to be non-taxable, will clearly benefit HOV lanes in increased bus occupancy.

California's recently passed cash-out law requires employers of more than 50 employees who subsidize their employees' parking in leased space to offer the workers cash in lieu of parking. This is another governmental mandate that will indirectly increase the use of the HOV lane by carpools, vanpools, and buses.

As my final point, I would like to say that looking at the transportation infrastructure as a whole, rather than from the point of view of competing governmental agencies, is the key to this asset management program. Your city's transportation assets may be different from Houston's. HOV lanes may or may not be the most efficient use of the transportation rights-of-way in your city.

Examining your city's total transportation assets with clear eyes, devoid of territorial protection and with strong interagency cooperation, may yield new insights. That may be the most important system-wide solution of all.

The cooperative efforts of the various transportation agencies have been essential to evaluating the best use of the total transportation assets of Houston and Harris County, and have pointed Houston in the direction of HOV lanes as our organizing principle. In fact, cooperation is the basic ground on which we have constructed our little piece of HOV heaven.

Responding to Mobility Challenges Following the Northridge Earthquake

Dean R. Dunphy, Secretary of Business, Transportation and Housing Agency, State of California

The Emergency Transportation task force was created to respond to the Northridge earthquake. Mr. Dunphy played a videotape which documented the earthquake damage and the reconstruction effort. The videotape included the following points.

- At 4:30 A.M., on January 17, 1994, a major earthquake hit Southern California. An emergency transportation task force was established later that day for the sole purpose of getting the Los Angeles freeway system back in operation.

- Segments of major freeways in the Los Angeles area suffered major damage. Damaged facilities included the section of the I-10 on Santa Monica Freeway just west of downtown, the raised interchange of I-5 and Route 14 in the San Fernando Valley, a section of I-14 just north of the Route 5 and Route 14 interchange, and Route 118 in the San Fernando Valley.

- Sixty people died in the earthquake, and thousands more were injured. Damage to buildings, roads, and other facilities was estimated in the billions of dollars. Further, it was expected that the city would not be back to normal for two years.

- Minutes after the earthquake, Caltrans went to work setting up detours and getting the demolition crews out to the sites. By 11:00 A.M., demolition contractors were already working. Crews worked 24 hours a day, seven days a week, to help get the freeways back to normal conditions.

- After 84 days and $30 million, the Santa Monica Freeway was restored to normal working conditions. Although standards were maintained, the quick response can be attributed to cutting red tape and to incentives for early completion. It took four months to get I-5 back in operation. Repairs to all the freeways should be completed by the end of 1994.

- Immediately after the earthquake, traffic congestion in major travel corridors was terrible. The media and other sources provided strong encouragement to the public to take public transit or carpool to help alleviative congestion. Commuters responded in a positive manner. For example, ridership increased by some 95 to 100 percent on one bus route. New Metrorail stations were developed to help meet the demand on rail service. Special HOV detours were developed. These provided significant travel savings of 15 to 20 minutes and encouraged HOV use.

- Other actions were also taken. For example, some two-way streets were converted into one way facilities, trucking companies were asked to stagger their delivery hours, and temporary roadways were built where freeway sections had collapsed.

- In summary, I think the video provides an excellent overview of the quick response by Caltrans and other agencies to the Northridge earthquake. The quick, coordinated reaction to this disaster is just another example of the good working relationship that exists among transportation agencies in the Los Angeles area. Thank you.

PART 3-WORKSHOP REPORTS

Planning, Implementation, and Policy Development: Recent Experiences-Part 1

Paula Hammond, Washington State Department of Transportation-Presiding

Developing HOV Options in New York City: The Long Island Expressway (I-495)

Peter 0. Sucher, HNTB Corporation

Mr. Sucher discussed efforts to identify new and expanded low cost HOV options which could improve transportation service and efficiency on the Long Island Expressway (LIE) corridor for westbound morning traffic; these efforts were also discussed in a paper written by Mr. Sucher. Mr. Sucher included the following points in his presentation.

- Recently, attitudes toward HOV facilities have changed in New York City. Selected lanes on the upper deck of the 59th Street bridge were converted for HOV use during the morning peak-period to determine how HOV lanes would work in the New York City environment.

- The purpose of this study was to develop improvements to the existing LIE corridor. The LIE corridor extends from the Queens Midtown Tunnel (QMT) on the west to the Queens/Nassau County Line on the east, a distance of approximately 14 miles. The LIE is the only east-west, mixed traffic, limited access route serving Manhattan and Long Island. Currently, there is a two mile contraflow lane on the LIE, from just east of Greenpoint Avenue to the QMT. This contraflow facility is separated from opposing traffic by pylons.

- A major constraint in the corridor is the bridge carrying the Long Island Railroad over the LIE, which represents a significant physical constraint. Reconstruction would be very expensive and would significantly impact the surrounding residential area.

- The westbound traffic volumes in the LIE corridor steadily decline as traffic approaches the QMT. The highest traffic volumes on the mainlanes and the service road occur where the LIE crosses the Grand Central Parkway. The volume here is approximately 7,700 vehicles. The average auto occupancy level is about 1.3 persons per vehicle, with 25 percent of the mainlane autos having two or more passengers.

- The contraflow lane is open to buses, occupied taxis, and authorized vehicles. No carpools are allowed on the LIE contraflow lane. Currently 127 express buses use the contratlow lane in the peak hour, resulting in an express bus demand in excess of 5,100 passengers.

- The objective of the project was to come up with a low cost alternative to improve the efficiency of the LIE corridor. One alternative considered was to expand the westbound bus lane eastward. Other alternatives were to allow vanpools and carpools to enter the lane.

- A total of six alternatives were developed for preliminary consideration. Alternatives 1 and 2 were extensions of the existing contraflow HOV lane currently operating. Alternatives 3 and 4 allowed carpools and vanpools to use the entire HOV lane; both alternatives utilized a fly-over structure, and a moveable barrier, extending the HOV lane approximately two miles and continuing in a concurrent flow lane to the QMT. Alternatives 5 and 6 extended the HOV lane east of the Long Island Railroad overpass, using the left lane as a dedicated HOV lane.

- These alternatives were evaluated by **a steering** committee that consisted of the New York State Department of Transportation (NYSDOT), New York City Department of Transportation (NYCDOT), Federal Transit Administration (FTA), Federal Highway Administration (FHWA), and local community boards. The committee narrowed down the alternatives to two basic options. These were examined in more detail in the next phase of study. The options combined elements of Alternatives l-4 and included a moveable barrier and a contraflow lane.

- The contraflow option would extend the contraflow lane eastward to the Grand Central Parkway area. This alternative would require buses and taxis to weave through mixed flow traffic to access the contraflow lane or would require construction of a fly-over structure.

- The moveable barrier alternative would allow carpools and vanpools to use the lane. Based on the projected demand, it was recommended that buses, occupied taxis, and 3 + carpools be allowed to use the HOV lane created by the moveable barrier. The demand estimates for the initial use of the lane is approximately 700 vehicles carrying over 7,600 passengers. Time savings are estimated at as much as 10 minutes. The cost for the improvements are expected to range from $14 million to $30 million. Overall, the benefit cost ratio is expected to be 2.5:l.

- While both the contraflow and moveable barrier alternatives met the objectives of the study, the moveable barrier alternative offers the opportunity to increase carpool use and help promote the objectives of the Clean Air Act Amendments and the Employer Trip Reduction by encouraging carpool, vanpool, and bus use. It also offers the potential to serve HOVs in two directions, rather than just one.

- It was recommended that the moveable barrier alternative be carried into more detailed engineering studies as part of a larger corridor study. The NYSDOT is in the process of developing this study effort.

Policy Guidelines for HOV Facilities
Donald Sarndahl, JHK & Associates

Mr. Samdahl described the development of HOV policy guidelines for use by state, regional, and local agencies in the Phoenix, Arizona area. This topic was also addressed in a paper written by Mr. Samdahl and Peter M. Lima. Mr. Samdahl conveyed the following points in his presentation.

- The policy guidelines were developed in a study conducted by JHK and Lima & Associates in the Phoenix area. Phoenix currently has 26 miles of HOV lanes on two freeways, and additional facilities are being planned.

- Phoenix undertook an aggressive freeway construction program in the late eighties, and developed a freeway management system, improved transit service and HOV lanes. However, an integrated HOV system plan was not developed, nor were policies to guide the development of HOV lanes and HOV support facilities. In 1990, initial work was done on the development of an HOV policy, but this policy was not formally adopted.

- The development of the policy guidelines was part of a partnership to examine HOV facilities as a means to meet travel demand and as an air quality conformity measure.

- Several types of facilities are addressed by the policy guidelines. In addition to HOV lanes, freeway to freeway ramps, freeway to arterial street or park-and-ride ramps, ramp metering, ramp metering bypass lanes, park-and-ride lots, and bus stations are addressed in the policies.

- The process to develop the policies included identification of the opinions of stakeholders, the applicable federal requirements, existing HOV policies in the region, HOV policies in other states and regions, and a redefinition of the goals, objectives, and roles and responsibilities of all agencies.

- Reaching a consensus on a commitment statement was a key to getting the agencies to move ahead. The process started with identification of a mission statement, and then the commitment statement was framed and adopted by the participating agencies. The commitment statement indicates that HOV lanes should be an integral component of the freeway system, and that a full range of support facilities and programs should be considered as part of the overall policy statement,

- HOV policies were framed in a number of categories. A needs determination was identified to set threshold criteria for the application of HOV treatments. One of these criteria relates to the level of congestion in the corridor. More specific criteria were identified for other types of HOV facilities. For example, freeway to freeway HOV connections should only be used at the intersection of two high volume HOV corridors. Basic policies were also identified for design, hours of operation, enforcement, maintenance, monitoring, and evaluation. Funding sources, marketing strategies, and support programs are also addressed by the policy. The HOV and related policies were adopted by the agencies in December of 1993.

- Once the HOV policy was adopted, the HOV system plan could be developed. The plan identified 111 miles of HOV lane, 5 pairs of freeway to freeway HOV ramp connections, 11 exclusive HOV freeway to arterial ramps, 99 HOV bypass ramps, 30 park and ride lots, and 2 bus stations, proposed for implementation over the next fifteen years. The plan was adopted.

- The policy also mandates reserving right-of-way for future HOV facilities. The policy does not definitively answer every issue, however. The policy is flexible regarding issues such as the inclusion of buffers adjacent to HOV lanes, and the use of direct ramp connections, which increase the cost but enhance system continuity. The policy stresses integration of HOV facilities, and recognizes agency roles, responsibilities, and commitments. In general, the policy should have specific intent, but be flexible as to how it can be applied.

Developing and Testing HOV Lane Alternatives-
I-290 Eisenhower Expressway in Chicago, Illinois
John C. Tone, Parsons Brinckerhoff

Mr. Tone described the development and testing of HOV lane alternatives for the I-290 Eisenhower Expressway in Chicago, Illinois. These alternatives were also discussed in a paper written by Mr. Tone. Mr. Tone made the following points in his presentation.

- Chicago currently has rail transit operating in the, median of some freeways, but does not currently have any HOV lanes. Despite good transit, highway travel and vehicle miles traveled have been increasing, and are contributing to Chicago's status as a severe non-attainment area. As a result, the city and surrounding six counties are faced with mandates to increase average vehicle occupancy by 25 percent.

- The goals of this program are to demonstrate the effectiveness of an HOV facility on I-290, and at the same time minimize diversion from the parallel transit lines. The development of the scope for this project was a joint effort with the Illinois Department of Transportation (IDOT). The program is also being coordinated with the Chicago Metropolitan Planning Organization (MPO), which is responsible for determining the traffic demand forecast. Sketch plan volume estimates of the HOV demand have been used in the preliminary analysis, however. A key to this project is to gain an understanding of existing congestion and delay levels, and to see how an HOV facility would function in a complex multimodal network.

- A two stage study is being undertaken. This includes an overall feasibility assessment and a macro-level assessment of the design features of potential alternatives. Alternatives being considered include an interim low cost lane by re-striping the current facility, and buffer or fully separated HOV lanes.

- The study area is six miles long, and I-290 currently carries over 200,000 vehicles per day. It is a major bottleneck in the regional network. On the east end, I-290 has an eight lane cross section, which becomes a six lane cross section at the second interchange. On the west end there are 16 lanes feeding into six lanes, demonstrating significant lane imbalance. The facility has traffic congestion for 14-16 hours per day, six days a week, and even on Sunday the conditions are not favorable. In the eastbound direction, eight directional lanes feed into three, and a six lane toll road funnels into a single lane onto I-290. This location typically backs up for five miles.

- The ramp metering system and IDOT's Surveillance Project provided an abundance of data for the study. Considering the hourly volumes in westbound direction, early morning traffic starts between 5:00 A.M. and 6:00 A.M., with peak traffic already over 5,000 vph. High volumes continue until after 8:00 P.M.

- In the morning peak, the directional distribution is about 50/50 in the middle of the segment. At the west end, there is more traffic going west toward the O'Hare area than there is going east toward downtown. Similarly, the inbound volumes are very high in the evening peak. Eastbound traffic approximates westbound traffic in the evening and the peak hour is between 3:00 and 4:00 P.M.

- Vehicle occupancy counts indicate 2 + occupancy rates as high as 27 percent, and 32 percent on some ramps. Three plus occupancy rates are as high as 12 percent on some ramps. There is also heavy truck traffic on the facility, with over 12 percent of the vehicle mix comprised of heavy trucks.

- Lane drops restrict the traffic flow on west end. In the eastbound direction, many vehicles use parallel arterials and then enter the expressway after the bottleneck section. On the ramp from Austin Boulevard, over 1,500 vehicles enter on the left entrance where a lane is added.

- Level of service (LOS) analysis indicated LOS E and LOS F conditions at both the west and east end of the facility. At beginning of the study, the client and the toll road authority viewed the bottleneck situation as being an eastbound problem. But analysis of the speeds, delays, capacities and volumes indicated that queuing is worse in westbound direction with the drop from four lanes to three lanes.

- Analysis of speed and delay characteristics indicate that from 6:00 to 8:00 A.M., eastbound speeds are down to 10 mph in lane drop areas. Speeds in these areas do not return to a reasonable speed (40 mph) until after 9:30 in the morning. Similarly, the westbound queue starts forming at 1:00 P.M., and by 3:00 P.M. it extends almost the full six miles back to the loop.

- Once a congestion problem was clearly identified, the issue became whether it could be addressed by an HOV facility. Working with the Chicago Area Transportation Study (CATS), a number of traffic assignment networks were developed for use in the model. Alternatives considered included: a re-striping option with full accessibility and buffer separated lanes between interchanges; more access restricted options, including an access restricted option serving express trips from the west end into the Oak Park area; and an option that provided buses access to the Chicago Transit Authority (CTA) rail terminal at Des Plains.

- A number of scenarios were considered with respect to occupancy requirements. Analysis indicated that the facility would be congested under a 2+ occupancy mandate, with approximately 1,600 vph in the evening peak-period. However, the facility may suffer from the empty lane syndrome if a 3+ occupancy requirement is implemented, with volumes as low as 290 vph in the eastbound morning peak-period. Two options being considered for implementation include limiting access points and using a 2+ occupancy requirement, and implementing tolls to provide additional access, tolls would also provide additional funding for the project.

- The HOV analysis is complicated by the activities of the Illinois State Toll Highway Authority (ISTHA). The I-88 tollway, one of the major routes feeding into I-290, is in the process of installing Automated Vehicle Identification systems (AVI). The ISTHA has expressed concern regarding the implementation of tolls on I-290, and has recognized the need for AVI users on I-88 to be eligible to use the HOV lane on I-290.

- In summary, while work is still in progress, I-290 meets all primary and secondary requirements for an HOV facility. Alternative lane configurations that are being developed at a concept plan level have ruled out some of the more cost intensive alternatives. Options that are being evaluated include the use of a flyover ramp at the major merge area at the west end to eliminate weaving, and modification of the right of way in the parallel railroad and transit envelopes to provide space for a separate HOV roadway. Construction of the HOV facility as a separate roadway would be preferable from the standpoint of minimizing impacts on the existing expressway lanes.

HOV System Planning in the Puget Sound Region

Robert E. Fellows, Washington State Department of Transportation

Mr. Fellows described HOV system planning in the Puget Sound region. Mr. Fellows made the following points in his presentation.

- Seattle currently has 94 miles of HOV lanes. Existing lanes are located on I-5, I-405, I-90, and 520. Additionally, there are 60 miles of HOV lanes currently under construction. When the entire HOV plan is realized, there will be 288 miles of HOV lane in the area.

- Seattle's typical HOV facility is a left side concurrent flow lane, with an 8 inch gore stripe. There are also some right side concurrent flow HOV lanes, and there are barrier separated reversible lanes on I-90. Seattle's HOV lanes operate 24 hours a day, with a 2+ vehicle occupancy requirement on all but one facility.

- HOV system planning is important for a number of reasons. Unlike the general purpose lane system, which is intact, and to which incremental improvements can be made without regard to connectivity, HOV facilities are unique, and phasing is important. When a new HOV facility segment is opened, it must connect to both existing segments, and future segments, and it must open in an orderly way.

- Because the state now pays for a large percentage of cost for the construction of an HOV facility, the Washington State Legislature has become more interested in HOV planning and operations.

- HOV planning is needed for a number of reasons. In Seattle, coordination between HOV lanes located on the inside and outside of a freeway is important, especially with respect to transitions between the two types of facilities. Another reason HOV planning is important is because many HOV projects are implemented in stages, which implies that the phases of construction must be coordinated. HOV planning must also address funding issues, because funding must be available to complete the entire HOV facility to avoid "islands" of HOV lane being constructed. HOV planning also must consider the special needs of transit. Finally, HOV planning should include coordination among the different agencies involved.

- Although HOV planning has come a long way in the Puget Sound area, there is still a need to identify additional access needs to address other issues. Improvements to the existing and planned HOV facilities include accommodating the needs of transit and enforcement, and enhancing safety. Seattle has a strong express bus system linking Tacoma, Seattle, and other locations. Currently, buses have difficulty merging across traffic to enter some HOV lanes. This obviously is not desirable from either a traffic flow or safety perspective.

- A major effort is under way to examine some of these issues. The program consists of eleven studies, which are being conducted by a consortium of consultants.

- Two of the studies are general analyses of future traffic and the HOV travel markets. These studies are examining future travel demands and the role of HOV facilities.

- There is also a study examining HOV lane conversion options. This study includes public opinion research, and opportunities to bring together groups on all sides of the lane conversion issue.

- The study on safety and enforcement issues is examining how improvements can be made, and is determining where safety problems currently exist. There are four studies looking at transit access needs in specific corridors. One of these studies is evaluating inside and outside HOV lanes, and the access needs that are required if the entire lane is moved to the inside lane. Other access studies include an arterial HOV study, which will determine how to improve HOV travel in downtown Seattle, and a study focusing on freeway to freeway HOV connections.

- The environment in which HOV planning is taking place is also important. HOV planning in the Puget Sound area was originally a two part process, with Washington State Department of Transportation (WSDOT) responsible for the specific facility work, and the Metropolitan Planning Organization (MPO) responsible for the HOV plan. However, it is hard for the MPO to do comprehensive work when there are so many other responsibilities that must be met.

- There are other factors that may eventually affect the HOV system in the region. Discussions continue on the role of a rail rapid transit system in the region. The implementation of a rail transit system would obviously affect the HOV system in the region. This kind of uncertainty affects the planning process, and as a result, HOV planning takes place in a fluid environment.

- Areas where additional work is needed include examining arterial street HOV facilities and park-and-ride lots. WSDOT will play a coordinating role in these studies, working with different groups.

Planning, Implementation, and Policy Development: Recent Experiences-Part 2
Christine Johnson, Parsons Brinckerhoff Quade & Douglas, Inc.-Presiding

Implementing Florida's Interstate Policy: The Interstate Four Multi-Modal Master Plan
Victor P. Poteat, Post Buckley Schuh & Jernigan, Inc.

Mr. Poteat commented on the recent transportation developments and future goals of the state of Florida. He also discussed the I-4 corridor in detail. These topics were also discussed in a paper written by Mr. Poteat and Alice Gilmartin. Mr. Poteat included the following elements in his presentation.

- In 1991, the Florida DOT adopted a policy that limited roadway expansion. This policy placed a strong emphasis on future mobility and included two goals: to direct local trips on the interstate system to transit and other high occupancy vehicles (HOV) in dedicated lanes, and to provide for long distance and interstate travel and the transport of goods.

- In urban areas, the policy limits freeways to no more than six general use lanes, and four barrier separated lanes serving through trips and HOV vehicles. In rural areas, freeways are limited to no more than six lanes, three in each direction, for all traffic modes.

- The limit on freeway lanes is intended to maintain air quality, develop a liveable urban community, limit expansion of right-of-way, support regional commerce, allow through truck movements, encourage energy savings, and facilitate affordable projects.

- The focus of this policy is on multi-modal solutions to urban and intra-regional trips. The exclusive use lanes were designed to promote HOV use.

- A light rail system is currently being planned in the 75 mile I-4 corridor in the Orlando area. Over the next 20 years, a 1.5 to 20 percent increase in volume is expected in the I-4 corridor. There is already considerable congestion in this area.

- During the first level of analysis, 14 design and operations alternatives were developed. The first set of alternatives focused on the design components. These alternatives suggested that the highway would be improved by implementing six general use lanes, and four special lanes. In the area of transit, an express bus system and a light rail system were tested, as was a combination of both. The interstate policy indicated that provisions for high speed rail within the interstate right-of-way should be made wherever possible. Operational components, such as the frequency of access to HOV lanes and the number of large trucks were also considered.

- The next level of analysis considered five alternatives, which included varying levels of transit and highway improvements. In each case, analysis considered the impacts of implementing transit in conjunction with highway improvements in the I-4 corridor.

- The main concept emphasized is that an HOV lane must be managed over time. Ongoing studies must be conducted to determine the demand, optimal occupancy, and best way to manage the HOV facility.

Planning Criteria Used in HOV Studies in the Greater Toronto Area
Michael J. Delsey, IBI Group-Toronto, Ontario

Mr. Delsey discussed the planning criteria used in the Greater Toronto Area (GTA), and a case study of Highway 404. This topic was also addressed in a paper written by Mr. Delsey. The following elements were included in Mr. Delsey's presentation.

- Presently, Ontario does not have any HOV lanes. There is, however, an HOV system in Ottawa. Although the benefits of HOV lanes are very attractive, they are still considered a risky endeavor. The process for implementing an HOV lane includes monitoring corridors for opportunities for HOV lane implementation, assessing the physical feasibility, performing corridor overview studies, and making an executive decision for or against implementation.

- The Ministry of Transportation of Ontario (MTO) recently undertook four studies concerning HOV facilities in the Toronto area. The MTO's corridor overview study focuses on the analysis of the need and the justification for the system, the development of a variety of concept alternatives, the evaluation of alternatives, and the selection of the best solution. IBI was assigned to study the Highway 404 corridor.

- Highway 404 is 14 kilometers long, with six lanes at the south end, four lanes at the north end, and a number of arterial and freeway interchanges. There are plans **to** widen this freeway to ten lanes in the next five years, the possibility of including HOV lanes in this expansion is being considered prior to the initiation of construction. At the north end, the facility has a wide rural median, demands in this region is expected to increase significantly over the next ten years. Further south, there is a six lane cross section, the median begins to narrow, and the freeway looks more urban in nature. The right-of-way becomes more constrained, and the land is developed immediately adjacent to the highway.

- In 1991, Highway 404 had an average annual daily traffic volume of 60,000 vehicles per day at the north end, and 200,000 vehicles per day at the south end. Much of this traffic comes from Highway 401. The southern end of Highway 404 terminates at the intersection of Highway 401, a 12 lane express facility. Highway 401 was built in the 1960s, and for a number of years has served over 300,000 vehicles per day.

- In the evaluation of the need and justification for HOV lanes, traffic forecasts and analysis, operational characteristics, and any other factors that might support HOV in the Highway 404 corridor were explored.

- In 1993, 2 + demand ranged from a low of 500 vehicles per hour to approximately 1,300 vehicles per hour, depending on the time of day and direction of travel. There is HOV demand throughout the day, which supports a 24-hour operating policy, which is supported by the Ministry.

- Three components of travel demand are normally calculated and considered in HOV analysis: primary diversion, secondary diversion from parallel corridors, and latent demand from new carpools that form to take advantage of benefits of the HOV facilities.

- One factor that affects demand is access. Access could initially be served by at-grade weave zones, or by direct access ramps. There are also a number of proposed support facilities, including arterial HOVs, a connecting freeway HOV, and opportunities for park-and-pool lots.

- The study focused on the GTA Travel Forecast Model, developed by IBI, which operates within the Multi-Modal Transportation Planning Model (ME2). The multi-class assignment algorithm of ME2 allows HOVs to access the entire road network, while SOVs are prohibited from accessing the HOV lanes. When the model runs, HOV and SOV trips are simultaneously assigned between origins and destinations; the combined travel demand influences overall congestion and link travel times until an equilibrium is reached in the network. Model results include both primary and secondary effects of HOV demand.

- In the forecast years 2001 and 2011, HOV volumes ranged from 600 to 1,500 vehicles per hour southbound in the morning peak hour. Similar demand is expected in the northbound direction, due to the balanced traffic pattern.

- Some of the inherent deficiencies of the model include the fact that no penalties are assigned for access into or out of the HOV lane, and minimal time penalties are assigned for at-grade weave zones. Adjustments were made in the benefit-cost analysis to account for the deficiencies.

- Latent demand was the third component of the HOV forecast volumes. Typically, latent demand is calculated by multiplying the primary diversion component by as much as 120 to 160 percent. However, when the volumes predicted by the modelling effort were multiplied by 1.2 or 1.6, the resulting demand was unreasonably high. As an alternative, the arc elasticity method was used, as suggested by Tim Lomax of the Texas Transportation Institute. The arc elasticity method compares HOV demand before and after implementation of an HOV lane with expected travel times and speeds. Application of the arc elasticity method yielded latent demand values of 10 to 25 percent.

- The recommended HOV lane was a two-way, median oriented, concurrent flow, buffer separated facility operating 24 hours a day. To lower the cost, the initial facility had at-grade weave access rather than direct ramp treatments.

- The benefit-cost analysis was a comparison of the cost of an HOV lane and four basic widening plans. The first plan was widening ten of the 14 kilometers without any connections to Highway 401 or the Dawn Valley Parkway. This was a low cost alternative, but it actually resulted in negative benefits as compared to the base case, which was the addition of mixed flow lanes. Under the other alternatives considered, the addition of direct connections at the south end in alternative two, the addition of direct access ramps in alternative three, and the addition of arterial connections in alternative four, both the costs and the benefits increased. However, when considering alternatives three and four, the costs continued to increase with the implementation of arterial connections, and the benefits actually decreased marginally. This may have been due to the fact that the

HOV travel time benefits are overestimated when the mixed flow lanes become very congested and it is difficult for the HOVs to enter and exit the freeway.

- Even though the MTO has not implemented an HOV system, it has been under consideration for a number of years. A plan will probably be implemented when funds are available, and when the MTO is confident that the project will succeed.

Successful Planning of HOV Facilities Under Severe Environmental and Physical Constraints: The Southeast Expressway Contraflow HOV Lane

William T. Steffens, Massachusetts Highway Department

Mr. Steffens discussed the implementation of an HOV lane in the Massachusetts area, including factors such as the public, physical constraints, and environmental constraints. A more detailed presentation of this material was provided in a paper written by Mr. Steffens and Luisa Paiewonsky. Mr. Steffens included the following points in his discussion.

- In 1972, a contratlow lane was implemented on I-93, the Southeast Expressway. The facility was separated from the main lanes by large plastic cones that were set up manually. The project continued until one of the workers putting the cones out was killed. In 1976, a concurrent, take-a-lane project was initiated. This lane immediately suffered from the empty lane syndrome, and a lack of enforcement, which prompted the project to be terminated in less than two weeks.

- The driving force behind the most recent HOV initiative, which examined an 8.3 mile section of I-93, was environmental constraints.

- The facility travels through densely populated areas with the right-of-way varying between 110 and 100 feet, and crosses 15 bridges. Due to the resulting constraints, as well as the past failures, a feasibility study was conducted to demonstrate that an effective HOV lane could be built. The only feasible alternative was to retrofit, because the entire right-of-way was consumed by travel lanes or utilities.

- The average daily traffic volume on this segment of I-93 is approximately 190,000 vehicles, making this facility one of the most heavily used roadways in the state.

- A long range plan was developed for this corridor so that immediate decisions could be made in accordance with future goals. An oversight committee was developed, it included representatives of all **the** major funding agencies, as well as the conservation law foundation, EPA regulators, and private organizations that supported the HOV study. The committee assisted in the development of criteria for the HOV project.

- A one year deadline for the HOV feasibility study kept the Massachusetts Highway Department focused. The study criteria included five to ten minutes of travel time savings, and long term HOV lane effectiveness, the analysis was initially based on a 2+ occupancy requirement.

- A fatal flaw analysis committee was also established, the sole purpose of this committee was **to** eliminate any proposals that violated basic objectives, such as those that resulted in negative air quality impacts.

- The oversight committee concluded that in the short term, a reversible contraflow lane should be developed using moveable barrier technology. This contraflow lane was widely accepted by the public and the media.

Criteria Used in HOV Planning and Feasibility Studies in the Greater Montreal Region

Ortevio Gallela, TRAFIX Consultants, Inc., Montreal, Quebec

Mr. Gallela reported on the steps that the Ministry of Transportation in Montreal is taking to include HOV facilities in the development of the future transportation plan. He discussed many different corridors in Montreal, as well as studies that were conducted to determine the feasibility of HOV in these corridors. This topic is also discussed in a paper written by Mr. Gallela and Robert Olivier. Mr. Gallela included the following points in his discussion.

- HOV planning in Montreal is unique due to the fact that Montreal is an island. The population is approximately three million, and is expected to expand to four million in the next twenty years. Half a million people live on the north and south shores, the island is very densely populated.

- Because the island was developed in the fifties and sixties, there are very few highways. Highway 40 has been in operation since the sixties and has an average daily traffic volume of 140,000 vehicles and an average daily traffic volume of 60,000 vehicles on the service road. There are 11 bridges from the north shore to the south shore, there is significant congestion on these bridges. One of the goals is to improve the efficiency of the bridges.

- In the early eighties, Montreal experimented with a contraflow lane. It was extremely successful, and it is still in operation. It serves approximately 100 buses per hour and 7,000 passengers per hour. Although congestion is only a problem during the peak hours, the number of peak hours is increasing.

- The Ministry of Transportation of Quebec has decided to implement two of the recommendations developed by TRAFIX Consultants. One of the recommendations is the addition of an HOV lane on Highway 15. The current average daily traffic volume on this facility is 100,000 vehicles, 6,600 vehicles during the peak hour. In the Highway 13 corridor, the moveable barrier technique is already in operation.

- Park Avenue, an arterial corridor that links two subway lines, is located in a dense neighborhood and leads into the downtown area. This facility had two lanes in each direction until a fifth lane was added in the middle. This lane was reserved for the peak direction travel, and was implemented mainly to gain a curbside lane for bus operation. The inside lanes are general purpose lanes. The curbside bus lane currently serves 25 to 30 buses per hour.

- Twenty to 25 percent of the planned HOV lanes are currently in operation. Three of the HOV studies used in the planning process will be explained here. The regional accessibility study attempted to identify possible HOV facilities for carpools and buses. Nine bridges with highway sections leading to them were selected for evaluation. The Ministry of Transportation developed a set of criteria that must be met before an HOV lane can be built. The criteria dealt with both the number of vehicles that cross the bridge and the travel time savings. The average delay at the bridge approach is approximately 20 minutes. A ten minute minimum travel time savings was identified.

- The second study examined eight facilities, both freeways and arterial, to select candidate corridors for transit improvements. For freeways, the major criteria were minimum travel time savings of 0.6 minutes per kilometer for buses, and a minimum volume of 300 carpools and 30 buses. For arterials, the travel time savings should be approximately 10 % of the normal travel time, and the number of persons in the priority lane should exceed the number of people in the non-priority lanes. This study was performed in 1992. Since then, Highway 13 and 15 have been under construction for HOV lanes and almost 60 miles of bus and taxi lanes have been implemented.

- The third study examined the accessibility of buses and taxis in the downtown area. In this study, various reserved lane scenarios on the three major arterial leading into downtown were evaluated. Both operational and facility factors were evaluated. The operational criteria included transit, traffic, parking, and infrastructure factors. The facility criteria considered the type of facility, contraflow, curbside, reversible, etc. The practicality of each system was broken down into two components, the accessibility of the system to malls and other highly used areas, and the comfort of the system for both operators and users of the system. In each of the three corridors, the authorities decided that there was enough public support to convert a lane to a bus and taxi lane.

- These projects have been quite successful. All of the projects have been take-a-lane and the public has been supportive. The only problem has been the need for a more objective evaluation of the advantages and disadvantages of these systems.

Advanced Transit and HOV Roadway Systems

John West, California Department of Transportation-Presiding

Twin Cities Travlink Project

James L. Wright, Minnesota Department of Transportation

Mr. Wright provided an overview of Travlink, one of the IVHS Operational Tests currently being undertaken by the Minnesota Department of Transportation (MnDOT). The Travlink project, which is being implemented in the I-394 corridor, is being funded by federal, local, and private sources. Mr. Wright covered the following points in his presentation.

- The objectives of the Travlink project are to:

  - Improve service quality and increase transit ridership.

  - Check the performance of advanced public transportation technology in a real world environment, from both a passenger and operator perspective.

  - Evaluate the impact of automatic vehicle location (AVL) on service efficiency and quality, including schedule adherence and safety.

  - Determine customer responses to information technologies.

- The project includes a number of components. An AVL system is being installed with 80 buses in the I-394 corridor using a Global Positioning System (GPS). One thousand advance traveler information systems are being located in homes and at work sites. Display monitors are being installed at selected transit stations, and electronic signs are being implemented at four park-and-ride lots. Finally, an automatic vehicle identification (AVI) system, using buses as probes for the Advanced Travel Information System (ATIS) database, is being implemented.

- The project focuses on the I-394 corridor, which serves approximately 180,000 vehicles per day. The corridor includes a freeway and an HOV lane system. Three transit centers and seven park-and-ride lots, with 1,000 parking spaces, are also included in the project. Access to I-394 is completely ramp metered, with ramp bypass for HOVs.

- The project is enhanced by the availability of 6,000 parking spaces in downtown parking garages that have HOV discounts, and closed circuit television (CCTV) for incident management. Further, 38 autoscope cameras, which provide speed, volume, density, and vehicle mix information as well as visual imagery are located in the corridor, along with changeable message signs.

- The system will provide information via videotext terminals and kiosks. Information that will be provided includes how to get to a location, transit schedules and maps, current bus status, bus fares, park-and-ride lot locations, special events and service changes, specialized transportation services, and customer services.

- There are a number of participating agencies, both in the public and private sector. The five participating public sector agencies include MnDOT, FHWA, FTA, the Regional Transit Board (RTB), and the Metropolitan Transit Commission (MTC). Private sector groups participating include Westinghouse, US West, 3M, and Motorola.

- The evaluation goals for the Travlink project include examining user acceptance, assessing the effects of institutional issues, and analyzing the technical performance of the system. The evaluation plan has been completed by Cambridge Systematics.

- Market research was conducted in the initial stages using focus groups. Results indicated that the project should serve peak-period commuters on I-394, and provide congestion information, accident information, work zone information, and information about mode alternatives. Results also indicated that the perception of the project was negative. This feedback has resulted in project modifications, and two additional focus groups will be held later this year.

- The AVL will be installed in 12 buses, initially, and testing should begin by the end of June. The advanced traveler system final design is also proceeding. This system will provide real-time schedules, probe information on speeds, construction and incident information, and MTC schedules via the kiosks and videotext terminals.

- The Operational Test, with 80 vehicles and 1,000 videotext terminals, is scheduled to begin in October, 1994. It is hoped that the evaluation of the first phase will be completed by June, 1995.

Bellevue Smart Traveler Program

Eldon L. Jacobson., Washington Department of Transportation

Mr. Jacobson provided an overview of the Bellevue Smart Traveler program, which focuses on encouraging people to use an HOV mode to get to work. Mr. Jacobson covered the following points in his presentation.

- The first phase of the Bellevue Smart Traveler program was a six month test, funded by the Washington State Department of Transportation (WSDOT) and US Department of Transportation (USDOT). Other partners in the program include the University of Washington, the Bellevue Transportation Management Association, Pactel Paging, METRO, and Seiko.

- Every day, approximately 22,000 commuters travel to downtown Bellevue, a suburb on the east side of Seattle. Currently 80 percent of the cars entering downtown Bellevue are SOVs.

- The Bellevue Smart Traveler program provides dynamic carpool matches, based on the preferred travel route and departure time of potential carpoolers. The program also provides traffic and transit information. Volunteers access information through the use of pagers which are being provided free during the test.

- The program is based on a dynamic ridesharing concept, which is a day-to-day arrangement for carpooling. Survey results indicated that a carpool or vanpool to or from work on an occasional day-to-day basis is the most popular type of rideshare.

- The goal of the program is to encourage alternatives to SOV commuting by providing traveler information and by emphasizing the benefits of carpooling to the individual commuter. An expected benefit of the program is decreased traffic congestion. It is estimated that traffic delays will be reduced by 50 percent if one in ten SOV commuters will shift to a carpool. It is also expected that, if the program is successful, it may serve as a model for other cities.

- Participants were recruited through employers, who had to register to participate. Encouraging employees to participate was a major challenge of the project. After registration, the volunteers were divided into three rideshare groups, depending on their employment center.

- To use the system, participants call the traveler information center (TIC) using a touchtone telephone and enter their ID and password. To offer a ride or search for a ride, participants must specify whether the ride is to work or home, the day, and the time. The system lists the available rides, and provides the driver's first name. If a particular ride is chosen, the phone number of the driver is provided so that contact can be made. Participants can also access traffic and transit information, as well as assistance, using the touchtone telephone.

- The same information can be accessed using the pager. The pager can also be used to access news, sports, weather, business and traffic information. Further, it can be used for traditional paging.

- Technical problems that have been encountered include limited display room on the pager, availability of traffic reports, and the use of pagers is not recorded. Preliminary results indicate that more rides were offered than sought, and the viability of rideshare groups is unclear. Questions that must still be answered include what constitutes a viable rideshare group, and how to encourage people to get out of their cars and accept a ride.

- The six month demonstration phase was completed on April 15, 1994. Major statistics as of April 15, considering 53 users in 3 ride groups, include:

  - 447 phone calls were received.

  - 509 rides were offered.

  - 148 rides were sought via telephone; when considering this statistic, it is important to note that most rides were sought via pagers, and have not yet been quantified.

  - Traffic information was accessed 110 times.

  - Transit information was accessed 40 times.

- An expansion of the project has been approved. This expansion will be funded through the federal IVHS Operational Test Program and will include additional employers and a test of two way pager technology.

Market Research on Single Trip Ridesharing

William C. Jeffrey, Virginia Department of Transportation

Mr. Jeffrey discussed the development of a methodology to evaluate people's response to casual carpooling, and the effects of delays and fares on their willingness to participate in a casual carpool. Mr. Jeffrey made the following points in his presentation.

- Casual carpooling, unlike traditional carpooling, allows commuters to share a one-way, one time ride with no further obligation. Casual carpooling utilizes empty seats in private vehicles as a form of public transportation.

- One thousand surveys were distributed during the morning rush hour to commuters working in Tysons Comer, Virginia, a high density employment center. Two hundred surveys were returned. The resulting sample was relatively homogeneous. It included commuters who drive their own car to work in Tysons Comer during daytime hours.

- The goal of the project was to produce a methodology for quantifying the value of time to commuters, rather than to state conclusively how all commuters will be affected by casual carpooling, travel time savings, delays and fares.

- Survey questions focused on how many extra minutes commuters would spend to pick up a co-worker for a fare of $1, $2, $3, and $4, and how much they would be willing to pay for a ride that was 0, 5, 10, and 15 minutes from their home.

- Linear regression analysis of the data indicated that, with respect to drivers:

  - Delays between 0 and 15 minutes were much more important than fares between $1 and $4 when determining the number of commuters who would be willing to give rides in a casual carpool situation.

  - More drivers were willing to accept casual carpool riders if no delay were incurred.

  - Few drivers were willing to accept casual carpool riders if 20 minutes of delay were incurred.

- Linear regression analysis of the data indicated that, with respect to riders:

  - Delay was more important than fares when estimating the number of potential casual carpool riders, but by a smaller margin than for drivers.

  - The number of respondents willing to be casual carpool riders decreased as delays increased, and as fares increased.

  - When the fare was unrestricted (no maximum), the fare was the dominant factor; when the maximum fare was $4, the dominant factor was delay, although the fare was still important.

  - Although riders with an 80 minute commute are willing to pay more than riders with a 20 minute commute time, a distance based price should not be assumed to be the best alternative until additional research has been conducted.

- Linear regression analysis of the data indicated that, with respect to both drivers and riders:

  - The fare factor is minimal compared to the delay factor.

  - The length of the commute was not found to have an influence on the willingness of a commuter to give or take a ride. Drivers with a commute time of 80 minutes are no more willing than drivers with a commute time of 20 minutes to spend extra time picking up riders.

- The results indicate that delay is much more important than any fare up to $4 on a person's willingness to be a carpooler, even for riders, although fares do have an effect on commuters' willingness to carpool. The length of commute is insignificant when considering a person's willingness to be a carpool driver, and has a small effect on a person's willingness to be a rider.

Houston *Smart Commuter* IVHS Operational Test
Sarah M. Hubbard, Texas Transportation Institute

Ms. Hubbard provided an overview of Houston ***Smart Commuter*** IVHS Operational Test. This topic was also discussed in a paper written by Katherine Turnbull and Sarah Hubbard, Texas Transportation Institute (TTI), Gloria Stoppenhagen, Metropolitan Transit Authority of Harris County (METRO), and Charles Dankosik, Castle Rock Consultants, Inc. Ms. Hubbard made the following points in her presentation.

- ***The Smart Commuter*** project is being co-funded by METRO, the Texas Department of Transportation (TxDOT), FHWA, and FTA. Project assistance is being provided by TTI. A national evaluation of the ***Smart Commuter*** Operational Test is being coordinated through the Volpe Center. Castle Rock Consultants and SAIC are conducting this national evaluation.

- The intent of the Houston program is to use advanced technologies to inform commuters about traffic conditions and high occupancy vehicle alternatives, and consequently, to increase use of the HOV lanes.

- A market assessment was conducted in the early stages of the development of the Operational Test. This assessment included focus groups and surveys of users and non-users of the Houston HOV lanes. The non-user survey results indicated that commuters do listen to traffic reports, and do change their travel behavior based on this information. The survey results also showed that while most non-users know the location of the nearest park and ride lot, many do not know enough about the bus system to feel comfortable enough to begin using it.

- The results of focus groups indicated that commuters wanted a number of options for their daily commute. The results further indicated that the traffic information provided must be accurate and timely. The focus group participants suggested that the information and system must be simple and easy to use, and should provide solutions, not just information. All of the findings of the market assessment were considered in the development of the Operational Test.

- The Operational Test capitalizes on the existing transportation infrastructure in Houston, which includes an extensive HOV system. There are approximately 64 miles of HOV lanes in operation in five corridors. The ***Smart Commuter*** program focuses on increasing the efficiency of this system by encouraging its use. The program includes components in the I-45 North Freeway corridor, and in the I-10 West or Katy Freeway corridor.

- The component in the I-45 North Freeway corridor will provide real-time traffic and transit information to commuters in their home and at work. This information may influence some of these commuters to utilize an HOV mode rather than taking a single occupancy vehicle. ***S*** The participants will live in the Kuykendahl area, and work downtown. This traditional suburb to downtown commute is well served by frequent transit service from the Kuykendahl park-and-ride lot.

- The real-time traffic data that will be provided includes a graphic depiction of travel times for both the freeway and HOV lanes. The real-time traffic data is already being collected through the AVI program in Houston. Information about the park-and-ride lot and transit services will also be provided. Typical information that will be provided includes the bus schedules, bus fares, and where the bus will stop once it gets downtown.

- A major component of the ***Smart Commuter*** program is the evaluation program. The local and national evaluations are being closely coordinated. The evaluation will examine the impacts of the provision of real-time traffic and transit information at home and at work. Impacts may include changes in commuter time of travel, travel route, and mode of travel, and any consequent changes in the utilization of the HOV facilities. The local evaluation, which will quantify these impacts, has been developed by TTI, and some of the before data collection activities have begun.

- ***smart Commuter*** participants in the Katy Freeway component will live in the Addicks area and work in the Post Oak/Galleria area. The commute targeted in this component of the ***Smart Commuter*** program is a suburban commute, a travel pattern that is not well served by traditional transit services. The basic concept for the Katy freeway component is the provision of a real-time carpool match for both drivers and passengers.

- Because the Katy Freeway HOV lane has a three person minimum occupancy requirement during some hours, the ***Smart Commuter*** program will not only encourage the formation of 2+ carpools, but will also encourage a shift from 2 person carpools to 3 + carpools. The ***Smart Commuter*** program will encourage the use of carpools through both the current incentives of a reduced and more reliable travel time, and the convenience of a real-time carpool matching service.

HOV Systems and Air Quality Impacts

Jim Ortner, Orange County Transportation Authority-Presiding

Results of the Sacramento Models

Robert A. Johnston, University of California, Davis

Mr. Johnston discussed the development of a model which was designed to project vehicle emissions levels for the Sacramento area. He outlined the background of the study and this model. A paper, authored by Mr. Johnston and a former student of his, Mr. Ceerla, was available. Mr. Johnston made the following points in his presentation.

• A review of current models used in the Sacramento area, indicated that they were most inadequate for current purposes. While modelling efforts are rapidly improving, most still do not meet the accuracy requirements specified by the 1990 Clean Air Act Amendments.

- Most HOV studies focus on capacity improvements, although capacity improvements are important, many agencies are interested in the impact HOV lanes have in vehicle control emission rules. Empirical studies have shown that the addition of HOV lanes results in increases in speed, but not necessarily reductions in vehicle volumes.

• The United States Department of Transportation (USDOT), FHWA, and the California Air Resources Board have all issued reports analyzing HOV lanes, mostly these focus on travel time and vehicle emission levels on the freeway before the HOV lane was developed. In many cases the models in use focus on a five to ten year planning horizon, although some models look at long range impacts.

• The objectives of this study were to test HOV alternatives, land use alternatives, and travel pricing policies in the Sacramento region. All of the alternatives focused on reducing vehicle miles travelled, emissions, and energy use. The alternatives were evaluated based on a 20-year planning horizon. Alternatives evaluated include:

- A no build scenario.

- Concurrent flow HOV freeway lanes.

- Concurrent flow HOV freeway lanes with parking, gas, and mileage pricing.

- Take-a-lane HOV freeway lanes.

- Take-a-lane HOV freeway lanes with parking, gas, and mileage pricing.

- Light rail transit.

- Light rail transit, with parking gas and mileage pricing.

- Transit oriented development, land use intensification, and light rail transit.

- Transit oriented development, land use intensification, light rail transit, and parking, gas, and mileage pricing.

• The analysis indicated that the lowest vehicle miles travelled (VMT) resulted from the implementation of the transit oriented development, land use intensification, and pricing strategies. Transit oriented development and land use intensification without pricing resulted in the second lowest VMT. The light rail transit alternative resulted in lower VMT than the HOV alternatives.

• The alternative with the lowest vehicle hours of delay was the light rail transit and pricing option. The HOV and pricing alternative was second lowest in terms of delay. The transit oriented development and pricing alternative had the lowest total vehicle hours, while the transit oriented development without pricing was second.

• The best alternative with respect to minimizing emissions was the transit oriented development and pricing. The transit oriented development without pricing option was second. The light rail transit and pricing alternative rated third, and significantly better than the HOV alternatives. The transit oriented development and pricing option also conserved the most fuel.

• The study also included an analysis of the costs associated with different alternatives. The HOV alternatives resulted in a higher cost than the light rail transit alternatives.

• The results of the analysis indicate that transit land use policies and pricing policies are worth further study from an air quality standpoint since these alternatives had the lowest VMT, emission, and fuel use. The take-a-lane HOV and pricing alternative rated as good as the new

HOV lane alternative in terms of delay, better in VMT and costs, but worse with respect to emissions. The **no-**build HOV scenario was nearly as good as new lane HOV scenario with respect to emissions other than hydrocarbons. The land use and pricing scenario is potentially the most equitable, in terms of increasing accessibility to low-income housing.

The Effect of HOV Lanes in Reducing VMT and Emissions

Victor Martinez, HNTB Corporation

Mr. Martinez presented a paper, prepared by Mr. Bieberitz, HNTB, on the effects of HOV lanes in reducing VMT and vehicle emission levels. Mr. Martinez included the following elements in his presentation.

- The Clean Air Act Amendments of 1990 require a significant reduction in emissions for many urban areas in the United States. How this will be accomplished when traffic is increasing in these areas will be a significant challenge. Reducing VMT through the use of HOV lanes is an approach being considered in many areas. HOV connectors can also be used to enhance the operational effectiveness of HOV lanes. Increase in the use of transit, carpooling, and vanpooling will also be important.

- Urban freeways make up less than three percent of the total urban highway mileage, but carry approximately 30 percent of the total traffic. In Milwaukee, freeways make up eight percent of the arterial street mileage, but carry approximately 40 percent of the total traffic.

- ❄□ examine the effectiveness of HOV lanes, four different cities were studied. HOV lanes in Seattle, Minneapolis, Orange County, and San Diego were included in the analysis. The results of this analysis indicated that:

  - A poll in the Seattle area found that 85 percent of the people had used the HOV lane and 14 percent use them three to five days a week.

  - In Minneapolis, the I-394 HOV lane has resulted in an increase from a 1.23 average vehicle occupancy (AVO) before the HOV lane, to 1.3 A'VO during the initial operations. A 1.6 AVO is projected by the year 2000.

  - In Orange County, Route 55 had a 1.21 AVO before the HOV lane was opened and a 1.34 AVO after. In San Diego, the AVO in the I-15 corridor increased from 1.22 to 1.28 after the implementation of the HOV lane.

- Freeway HOV lanes are currently being considered in Milwaukee. The current AVO in the Milwaukee area is 1.17. With a freeway HOV lane system the AVO is projected to increase to 1.21. If the Milwaukee area grows at an annual rate of one percent, VMT could be expected to increase by 12 percent, even with HOV lanes. The Clean Air Act Amendments require a 45 percent reduction in vehicle emissions. Given this analysis, the expected reduction in VMT is too small to meet this requirement. Therefore, it appears that drastic changes in transportation will be required by 2005 to meet the requirements of the Clean Air Act Amendments.

The State of Modelling for Emissions and HOV Lanes

All three speakers discussed the status of current modelling effects related to estimating the air quality impacts of HOV lanes. The speakers also responded to questions from the audience. Major points covered in the discussion included the following.

- Lower emission levels may occur in the future due to a number of factors. Cleaner fuels, electric vehicles, and greater use of HOVs may all contribute to reducing emissions. Also, any strategy that allows vehicles to operate in a steady state process will lower emissions. Studies show if you can eliminate hard accelerations and decelerations on freeways, emissions can be decreased by a factor of 40 or 50. There is a lot of uncertainty in the models, however, and some models predict that in certain situations emissions may actually increase.

- Improvements are needed in current models to adequately estimate the emission impacts of HOV lanes and HOV facilities. Most existing models provide rough estimates. The current models are good for estimates of total emissions but are not sufficient for comparing strategies related to different types of lanes, alternatives within certain corridors, and other factors. There is a need for a closer connection between what the vehicles are doing on the road, traffic dynamics, and emission levels.

- The design of an HOV facility may impact emission levels. The HOV facility must provide maximum benefits to be attractive enough for motorists to change from driving alone to an HOV mode. Also, emission levels are lower when a steady speed of 55 mph can be maintained. If the speed varies for even a short period of time, the carbon dioxide emissions will increase by a factor close to 20. Thus, HOV lanes should be designed to maximize a steady speed and eliminate starting and stopping.

- Progress is being made in the development of low emission and clean fuel vehicles. Estimating what the impact is of allowing these vehicles to use HOV lanes is difficult, however, the real question is how to get people to buy these cars. Access to HOV lanes or preferential parking benefits would help provide an incentive for people to choose these cars.

- The emission profiles for buses, car-pools, and vanpools should be examined in terms of emissions per person. For example, a full bus may have a lower per person emission level than a clean fuelled car. A four person carpool is tough to beat in terms of emissions, however.

Funding HOV Systems

Linda Bohlinger, Los Angeles County Metropolitan Transportation Authority-Presiding

Methodology for Determining the Investment Worthiness of High-Occupancy Vehicle Projects

Richard S. Marshment, University of Oklahoma

Dr. Marshment briefly discussed the different funding sources that are available for HOV lane construction. He also summarized current research activities being conducted for the FHWA. Dr. Marshment addressed the following elements in his presentation, which were also covered in a paper prepared for the conference.

- There are a lot of options for funding HOV lanes. At the federal level funds from both FTA and FHWA can be used for highway projects. The ISTEA should make it easier to finance HOV lanes, due to the flexible funding provisions of many sections. Although greater flexibility is provided in the ISTEA, multimodal and intermodal projects are still more difficult to fund because of their complexity.

- The research being conducted for FHWA examines HOV lane evaluation techniques and funding sources. The research is assessing existing evaluation methods for HOV lanes. This includes examining possible biases with current techniques, analyzing new approaches, testing these new evaluation methods on actual projects, and evaluating how various methods influence project ranking.

- The first step in the study was to inventory existing evaluation methods. A number of different techniques were examined including a user-benefit analysis, the FTA new rider index, the American Association of Highway and Transportation Officials (AASHTO) user-benefit index, and other methods.

- The new rider index, which is also referred to as the incremental cost per new rider, adds the capital and operating costs of an alternative, subtracts the existing user benefits, and divides this value by the number of new riders attracted. One criticism of this method is that it has a modal bias. With an HOV project, the benefits to carpoolers and the reduction in congestion are not included in the calculation.

- The AASHTO user-benefit index calculates the difference between the incremental benefit of a project and the capital costs plus the salvage costs. A positive index indicates that the project would be beneficial. The higher the index, the greater the estimated benefits of the project. Limitations with this model include the requirement for at least two forecast periods in the future, with interpolation in the intermediate years, and a possible modal bias.

- Another alternative examined represented a combination of other methodologies. This approach focuses on a single year assessment with locally established parameters, user and non-user impacts, and modal impacts. The benefit-cost items that are used include travel time savings, transfer costs, capital construction costs, and subsidies.

- Evaluation procedures usually must address two questions. The first is whether to build an HOV facility or not. The second is to compare different alternatives. Three criteria were identified for consideration in the evaluation procedure. These are economic efficiency, financial efficiency, and user efficiency. The four perspectives that must be considered during the evaluation process are the federal, state, local, and user perspective. The five types of financing that can be used are discretionary grants, formula grants, user fees, bonds, and general revenues. A viable project should meet one or more investment criteria and one or more perspectives.

- An example of how a revised evaluation methodology might work was examined for an HOV lane in Oklahoma. The parameters included air quality improvement, accident reduction, noise reduction, and auto parking. The work trip value of time reflected the local wage rate, and the non-work trip value of time was twenty-five percent of the local wage rate.

- One of the preliminary recommendations from the research study is to expand the horizon past 15 years. A longer time span, such as a 20 or 30 year forecast, would help determine the full benefits of the different alternatives. Consideration should also be given to the relationship between transportation and land use. Transportation investments have a significant impact on land use. In most modelling efforts, land use is held constant.

Funding HOV Lanes from the Federal Perspective

Jeffrey Lindley, Federal Highway Administration

Mr. Lindley discussed the perspective of FHWA on financing options, HOV buy-in projects, temporary reductions in standards, and lane de-conversion. Financing options were discussed in light of recent legislation and new federal programs. Mr. Lindley addressed the following topics in his presentation.

- The ISTEA addresses HOV facilities in a number of sections and provides increased flexibility in the use of federal funds. For example, HOV projects could potentially be funded through the National Highway System (NHS) program, the Congestion Mitigation and Air Quality (CMAQ) program, the Surface Transportation Program (STP), FTA, and Interstate Maintenance. While HOV alternatives are generally an appropriate use of funds within each of these programs, the HOV facility must be seen as the best expenditure of the transportation funds. In addition, a wide range of state and local funding can be used to support HOV projects.

- FHWA does not oppose HOV buy-in prqjects, but concerns have been raised with these types of projects. Proposals for pricing in HOV lanes are usually trying to address the empty lane syndrome, and maximize efficiency of an HOV lane. It is critical that HOV buy-in prqjects maintain acceptable speeds, tolls and enforcement monitoring do not impede traffic, and that operational problems at access points be avoided.

- Design standards need to be examined carefully on a case by case basis. Reduction in standards may be appropriate in some cases on a temporary basis. Some examples of the temporarily reduced standards are 11 foot lane widths and shoulders on only one side of a facility. These allowances should have little impact on operations or safety, and are usually implemented only for short sections of a facility.

- There have been a few recent instances of lane de-conversion, such as the Dulles Toll Road. In this case an HOV lane was designed, implemented, and opened, only to be converted to use by general purpose traffic. In the post-ISTEA period, this type of situation may end up in a legal battle if federal funds were used to construct the HOV lane.

State Perspective of HOV Lane Funding

Pete Hathaway, California Transportation Commission

Mr. Hathaway summarized Caltran's perspective on HOV funding, and discussed the prioritization of prqjects and programs. Mr. Hathaway highlighted the following elements in his discussion.

- The main job of the California Transportation Commission (CTC) is to establish priorities for capital projects. The regions send their priority list of projects to the CTC. These lists are used to develop the state program. This, and the regional ranking form the basis for the state's priorities.

- Caltrans has had a policy for many years that all new freeway construction in urban areas must include carpool lanes. The ISTEA further supports this approach.

- Due to the recession, the long-term rail program has been limited. Current projects include both rail and freight components, however. One example is the Almeda freight corridor, which would provide access from the port through the city. This is proposed to be a consolidated rail line without any cross traffic conflicts. There are also a number of freeway projects. Examples include completing a gap on Route 710 and widening a section of Route 5. Given limited funding, not all of these prqjects can be financed immediately. Currently the carpool lane program is a top priority and is receiving $3 15 million.

- Five years ago legislation was passed establishing an $18.5 billion, ten year program called the Transportation Blueprint. Under this program, improvements are programmed using a seven year planning horizon, however. The CTC was unable to program anything for the year 2001 due to funding limitations.

- A number of factors have contributed to the current funding problems. One of these factors is Proposition 156, a $1 billion rail bond that was on the ballot in 1992. The voters passed the first of three rail bonds in 1990, but turned down the second one, and as a result, the program lost a billion dollars. Another factor is the recession, which has decreased revenues by approximately $400 million in the last few years. Furthermore, Congress has held back $200 million in funding that is due to California. Thus, lack of funding for critical transportation projects is a major concern in the state.

Innovative Ways to Fund HOV Lanes

Geoffrey S. Yarema, Nossaman, Guthner, Knox and Elliott

Mr. Yarema discussed different funding methods for HOV lanes. He summarized the financing used for the HOV and toll lane projects on the Harbor Freeway in Los Angeles. Mr. Yarema highlighted the following parts of a paper prepared on this topic for the conference.

- The standards being used by FHWA on HOV buy-in projects attempt to maximize the use of HOV lanes, ensure a high level of service for all HOVs, mandate minimal traffic impedance due to enforcement, and avoid problems at access points. Although not all HOV lanes will be able to meet these standards, it appears the new Harbor Freeway transit lane will.

- The Harbor Freeway transit lane is 13 miles in length and has two lanes in each direction, with relatively few access points. A number of factors support the use of a toll lane program on the Harbor Freeway HOV lanes. Factors include the construction of the transitway, which represents a large capital investment in an important transportation corridor, the fact that the facility is expected to be under utilized if dedicated solely for HOV use, and the fact that the transitway design is well suited for adaptation to the high occupancy toll (HOT) lane concept.

- The HOT lanes concept would permit toll-paying SOVs only to an extent that their use would not compromise free-flow on the facility. SOV use would be regulated by electronic toll collection devices that would also be used for enforcement. The revenues generated from the SOV tolls could be applied to meet local transportation needs. Benefits of this approach included maintaining quality of service for HOVs, providing greater mobility for SOVs, improving traffic flow on parallel freeways and arterials, and increasing revenues.

- The driving feature of this approach appears to be the additional revenues that will be generated. Conservative estimates indicate that anywhere from $5 to $15 million would be generated from the SOV tolls.

- The project is similar to the Route 91 program in Orange County, which is currently under construction. A number of other congestion pricing applications are being considered and implemented in California. These include the Foothill Corridor, the San Waukeen Hills Corridor, the Eastern Corridor, Route 125, extending Route 57, I-15 in San Diego, and the Oakland Bay Bridge.

- A number of steps must be followed to implement these types of projects in California. First, state legislation authorization must be obtained. Second, both Caltrans and FHWA should be involved early in the process as their support and approval is critical. Third, it is also important to involve the local MPO and air quality management district. Finally, the vendor procurement process for the installation and operation of the toll equipment must be initiated.

Developing Integrated Systems: Park-and-Ride, Transit Stations, and Supporting Programs

James J. Snyder, New Jersey Department of Transportation-Presiding

Parking Demand Analysis for HOV Facilities

Gerald R. Cichy, Wilbur Smith Associates

Mr. Cichy discussed the parking demand analysis for HOV facilities conducted in the Dulles corridor in the Washington, D.C. area. This analysis included the phased consideration of parking demand for ridesharing, express bus, and rail. Mr. Cichy highlighted the following elements of a paper prepared for the conference with Patricia G. Drake, Wilbur Smith Associates, and William W. Mann, Virginia Department of Transportation.

- The project was initiated in 1990 when the Commonwealth Transportation Board of Virginia passed a resolution calling for the development of a comprehensive phased multimodal program of improvements in the Dulles corridor. The project corridor includes the Dulles airport and the surrounding ‘area. Roadway facilities in the corridor include the Dulles Toll Road and the airport access roads.

- A total of six sites were examined for possible development of parking facilities at the western end of the corridor. Two of the sites were on airport property and the other four were on private property. The corridor was divided into four origin zones related to the Council of Government traffic assignment zones. The destination zones were downtown Washington, D.C., a ten-mile zone around the downtown, Tysons Comer, and Dulles Airport.

- The number of trips from the different origin-destination pairs were then examined. A number of elements were examined to estimate carpooling in the area and potential use of the facilities. First, decline in the percentage of carpooling between the 1980 and 1990 census was considered. Second, the 1990 census data was utilized and the propensity for carpooling in the I-95 corridor-which has an HOV lane-and the Dulles corridor were compared for each of the destination zones. Different carpool occupancy levels were also analyzed. From past experience, a 75 percent capture rate was estimated for the parking facilities.

- The results from the analysis were used to evaluate the potential use of each facility. Three sites were identified as the most feasible for the development of park-and-ride lots in the corridor. Two of these facilities are currently being implemented.

- There was excellent cooperation on the study from all agencies and jurisdictions, the airport authority, and private developers. This represents a critical element in helping to ensure the successful development of HOV and park-and-ride facilities.

Freeway Service Patrol Program-Proposed FHWA Implementation Guidelines

Diane Perrine, Los Angeles County Metropolitan Transportation Authority

Ms. Perrine discussed the coordination between the Los Angeles County Metropolitan Transportation Authority (MTA), the California Department of Transportation (Caltrans), and the California Highway Patrol (CHIP) to implement a large scale freeway service patrol. She also described the role of freeway service patrols in traffic mitigation. Ms. Perrine highlighted the following elements in her presentation from a paper prepared for the conference with Shaker Sawires of the MTA.

- According to Caltrans statistics, approximately half of all congestion is caused by incidents. This is especially true with limited access HOV lanes. Many incidents do not warrant the response of a full incident response team, however. In many cases, tow trucks are more cost effective than police at responding to minor accidents and incidents.

- The Los Angeles freeway service patrol program has been in operation for three years. The results of this program show it has been successful at reducing congestion for motorists stuck behind the stalled vehicles. Accident rates have been reduced by 3 percent. Incident response time has been reduced by approximately 15 minutes, or about half. The service patrol program has also reduced air pollution caused by stalled vehicles.

- The most important benefit, however, may be the positive public response to the program. Public acceptance of the freeway service patrol is very high. All three agencies receive numerous letters from motorists and residents on the program. Caltrans has estimated the benefit/cost ratio of the program at 11:l.

- Approximately 16 percent of the incidents responded to involve two vehicles in the left lane or the left shoulder. These motorists are unable to walk across the freeway to a call box or other help. Thus, the program helps some 200 individuals every day during the peak hours who would otherwise be stranded on the freeway.

- Similar programs have been implemented in at least 38 metropolitan areas around the country. It appears that the use of freeway service patrols especially important with HOV lanes. The presentation on the patrols used in Houston today provides one example of this.

- Freeway service patrols also provide the opportunity to report accidents early. Since vehicles are constantly moving throughout the freeway system, incidents are often observed and response time is greatly reduced.

- Freeway service patrols are most effective on HOV facilities and freeways with high traffic volumes and speeds under 30 mph. Also, areas with high accident rates and deficient shoulders are prime candidates for patrols. All of these factors help identify areas that may be prime candidates for recurring accidents.

- The Northridge earthquake in January provided a test of the use of freeway service patrols to monitor areas of reduced capacity due to emergencies. Extra funding from FHWA and Caltrans was used for additional patrols. Over 3,000 assists were made with these funds.

- A call box system could be used as an interim step toward a service patrol. Call boxes may also be appropriate for lower volume areas. Call boxes are a less expensive alternative, they function on a 24-hour basis, and they can be used throughout an area. In Los Angeles, both solar paneled and cellular technologies are used with the call box system.

- Contracting for freeway service patrols should be considered. Tow companies have a great deal of expertise in clearing accidents. Three year contracts provide adequate time for companies to amortize their equipment, but also require that funding be available for that period. In Los Angeles, CHIP supervises the service through field inspections and the use of automatic vehicle location (AVL) systems. CHIP also monitors services by posing as stranded motorists. Extensive initial three-day driver training programs are required of all operators, along with monthly and annual refresher training.

Application of a Siting and Demand Estimation Model to Coordinate Park-and-Ride/HOV Facility Planning

William E. Hurrell, Wilbur Smith Associates

Mr. Hurrell summarized a paper on the statewide park-and-ride siting project conducted for Caltrans. Alice Sgourakis, Wilbur Smith Associates, and Steven B. Colman, Dowling Associates, co-authored the paper. Mr. Hurrell covered the following points in his presentation.

- Caltrans currently oversees a network of over 400 park-and-ride lots, with over 29,000 parking spaces. This is almost 4,000 acres of land devoted to park-and-ride facilities. The purpose of this study was to examine the way decisions were being made on locating, sizing, and designing park-and-ride lots. The project was intended **to** examine a number of basic factors including the factors influencing use, and the location and design features that contribute to a successful park-and-ride facility. Although many of the lots are well utilized, some are not well used.

- In addition, Caltrans wanted to obtain a better understanding of the characteristics of park-and-ride lot users and to explore the potential for public/private joint development opportunities. Further, the study examined the relationships between park-and-ride use and HOV use, including transit use.

- The project has been divided into three phases. The first phase, which is complete, examined park-and-ride facilities throughout the country and included site specific data collection at lots in California. The second phase involves the development of a park-and-ride facility siting methodology. The third phase will involve training Caltrans staff in the use of the methodology, which will include a demand forecasting process.

- One of the major activities in the first phase was a detailed examination of park-and-ride facilities in Southern California. Approximately 170 lots, with 17,500 parking spaces, are located in Southern California. These range in size from lots with only 12 spaces to as many as 2,100 spaces. A survey of 89 facilities was conducted for this study. The survey included both interviews of users at larger lots and mail back surveys at smaller facilities. A 29 percent response rate was obtained on the mail surveys.

- The survey results helped identify the general characteristics of park-and-ride lot users. Ninety-eight percent of the respondents drove to the lot and the average vehicle occupancy of automobiles entering the facilities was estimated at 1.13. Transit, with 43 percent, was the most common departure mode. Vanpooling was second with 31 percent and car-pooling was third with 18 percent. 5.5 percent reported that they used an HOV lane for at least part of their trip. Work was the most commonly reported trip purpose at 98 percent. The average destination parking cost was $6.18 a day. Thus, one reason people may use park-and-ride lots is to avoid parking costs at their destination.

- Information was also obtained on the demographic and socio-economic characteristics of park-and-ride users. The respondents were fairly evenly split between females, 51 percent, and males, 49 percent. The most commonly reported occupations were secretarial/ clerical, 19 percent, technical/administrative, 38 percent, and professional 15 percent. Over 50 percent of the respondents reported household incomes of over $40,000. Further, 91 percent were between 25 and 60 years of age, with the majority of these between 36 and 45. This indicates that many users represent the middle income, middle age group.

- Information was also obtained on trip characteristics. 30 percent of the respondents reported living within three miles of the facility. The average time to the lot was 7.5 minutes, and the median distance was 5.4 miles. This is similar to past research, which has identified park-and-ride market areas of approximately five miles. On the other hand, the average distance from the park-and-ride facility to the final destination was 27 miles.

- Security and lighting were identified by respondents as the two most important factors influencing use of park-and-ride facilities. Other features identified as important were the quality of the transit service, the availability of pay telephones, sheltered waiting areas, and other amenities. Utilization levels were also higher at lots associated with HOV lanes. This relationship is being examined in more detail.

- The general approach for examining park-and-ride lots starts with an overall evaluation of the need for such facilities in a region. Corridor specific information is then examined. This includes the demand estimation process for alternative sites, the identification of the most appropriate sites, analysis of land availability and costs, and a ranking or rating of facilities. A seven-step process is being developed in this study. A park-and-ride demand estimation tool is a key component of this process. This model will be integrated into the regional model. It is sensitive to the factors that influence park-and-ride demand and is easy to use. The model will be tested in Southern California as part of the study.

Phase Three of the Evaluation of the I-394 Transportation System
Allan Pint, Minnesota Department of Transportation

Mr. Pint presented the results from the third phase of the ongoing evaluation of the I-394 HOV lane and related transportation system. This covers the first full year of operation of the completed facility. The I-394 transportation system includes 11 miles of freeway and HOV lanes, transit centers, metered freeway access points, and parking garages in downtown Minneapolis. Mr. Pint summarized the following highlights from a paper co-authored by Joseph J. Kern and Charleen Zimmer, Strgar-Roscoe-Fausch, Inc.

- The HOV lanes include three miles of two-lane, reversible barrier separated lanes and eight miles of concurrent flow HOV lanes. All the freeway entrance ramps are metered, with HOV bypass lanes at about half the ramps. The facility is a completely automated system that includes closed-circuit television, loop detectors, ramp metering, changeable message signs, and HOV entrance and exit gates. All of these elements are monitored and controlled by MnDOT's Traffic Management Center. Other elements include three transit centers in the corridor, park-and-ride lots, and three parking garages on the edge of downtown Minneapolis which provide direct access to and from the HOV lane and charge reduced parking rates for rideshare vehicles.

- The first evaluation phase, which was completed in 1989, examined the introduction of the interim HOV lane, The second phase evaluated the use of the interim lane during construction of the final facility. The third phase evaluates the first year of operation and will establish the ongoing monitoring process.

- Overall, the average daily traffic (ADT) on the total facility increased from 86,000 vehicles in 1984 to 137,000 in 1993. Most of this increase occurred in the last year, with the completion of the total system. The current ADT is 146,000. Morning peak hour inbound vehicles increased from approximately 4,000 vehicles to 6,000 vehicles. Some 1,600 vehicles, carrying 4,600 people, use the HOV lane during the morning peak hour.

- One of the primary objectives of the project was to increase auto occupancy levels in the corridor. This has been accomplished. In 1984, the morning peak hour auto occupancy level was 1.15. This increased to 1.31 by 1993. Transit ridership has also increased in the corridor. Since 1984, service has been increased in the corridor and transit ridership has grown by some 63 percent.

- A 2+ vehicle occupancy level is used on the HOV lane. Violation rates on the barrier separated segment are very low, averaging below 4 percent. Violation rates are slightly higher in the concurrent flow sections, but for the most part, motorists appear to obey the occupancy requirements.

- Travel time savings have averaged around five percent. The park-and-ride lots are well utilized and expansions to some are being planned to accommodate additional vehicles. The three parking garages include approximately 6,000 parking spaces. Rideshare vehicles from I-394 pay only $20 a month to park in the garages. Currently, approximately 3,160 contract spaces have been sold in the garages. Two-thirds of these are I-394 carpoolers. A guaranteed ride home program has recently been introduced to further encourage ridesharing in the corridor.

Carpooling with Co-Workers in Los Angeles: Employer Involvement Does Make a Difference
Roy Young, Commuter Transportation Services

Mr. Young summarized the results of an analysis comparing co-worker carpools with those formed with friends and family members. Using data from the 1993 State of the Commute, which is an annual study of commuter behavior and attitudes in the Greater Los Angeles area, this analysis examined the commute behavior, employment characteristics, attitudes toward commuting, and demographic characteristics of these two groups of carpoolers. Mr. Young covered the following elements in his presentation.

- Los Angeles has a relatively high carpooling level when compared to other major metropolitan areas of the country. The State of the Commute study indicates that carpool rates have been relatively flat since 1991, however. Although the share of carpooling has remained relatively constant since 1991, changes have occurred in the composition of carpools during this period. Carpools formed with co-workers increased from 34 percent total of carpoolers in 1991 to 42 percent in 1993.

- The average trip distance for co-worker carpools tends to be higher than the travel distance for carpools formed with family members or friends. The average distance for co-worker carpools is 20 miles, compared to 11.6 miles for other carpools. Co-worker carpools are also four times as likely to use park-and-ride lots for carpool formation. Both of these factors have important implications for forecasting the demand for both park-and-ride lots and HOV facilities.

- The survey results indicate that employer incentives have had a positive influence on carpooling with co-workers. Incentives reported include customized ride matching services, preferential parking, and financial subsidies. It also appears that both large and small work sites are producing improved carpool use.

- The two groups also appear to have different motivations for carpooling. Co-worker carpoolers noted costs, comfort, and stress reduction most frequently than other carpools. Co-worker carpools further seem to include more males, more middle age, and more middle-to-higher income levels than those with friends and family members.

Enforcement Issues

John W. Billheimer, Systan Inc.-Presiding

The California Perspective

Lt. Shawn 0. Watts, California Highway Patrol

Lt. Watts discussed the difficulties California Highway Patrol (CHP) officers encounter enforcing the requirements for proper use of HOV lanes. He described his experience with HOV lane enforcement in the Los Angeles area. Lt. Watts included the following elements in his discussion.

- The officers issuing tickets for violators need adequate space to pull vehicles over and to write the citations. CHP has proposed to Caltrans that the HOV lane system be restriped so that the buffer zone is on the left-side instead of on the right. This would allow officers to stop vehicles against the median wall, and would consequently limit their exposure.

- An ideal enforcement area would be a minimum of 1,300 feet long with tapers on both ends for a total length of approximately 2,000 feet. This would provide enough room for the officer and driver to safely pull into the pocket, stop, and safely pull out again. The width should be at least 14 feet.

- Large enforcement areas tend to collect debris, which causes a safety problem. Enforcement areas should be cleaned regularly.

- The frequency of enforcement areas along HOV lanes is also a concern to the CHP. The enforcement areas should be placed so that an officer can station his vehicle in one enforcement area, observe a violation, and pull the violator over in the next enforcement area.

- Most of the existing enforcement areas are too short to pull into and out of safely. If an enforcement area is not provided, the officer may try to pull the motorist over to the right, across the general purpose lanes. The general purpose lanes are usually congested, which makes this method of enforcement more difficult and dangerous. As a result, fewer violators receive citations, and the number of violations increases.

- Motorists need to be educated regarding what they should do when they are pulled over in an HOV lane. When driving in the HOV lane, motorists should pull over to the left side if at all possible. This will help reduce the danger to both the officer and driver.

- The variety of lane separation treatments for various HOV facilities may cause confusion for some drivers. Each type of separation causes its own unique set of problems concerning enforcement. For example, one type of separation used is a painted double yellow line. Although it is illegal for motorists to cross these lines, it is very difficult to enforce.

- Buffer areas that are between 8 feet and 12 feet wide encourage both HOV and SOV motorists to use the buffer area for vehicle refuge. These buffer areas are **not** satisfactory as enforcement areas because of the high speed traffic on both sides. Sometimes pylons are placed in the wide buffer between the HOV and mixed flow lanes. These pylons prevent the area from being used as an enforcement area, and are usually knocked down by motorists.

- Some forms of separation allow very infrequent access to, and egress from, the HOV facility. As a result, an officer may have difficulty entering the lane, or may remain in the lane, for extended lengths,

- Some HOV lanes only operate during peak hours, and others operate 24 hours a day. Motorists who are familiar with one set of operating hours may not realize that other HOV lanes operate during different hours. HOV lanes that operate only during the peak-hours tend to have high violation rates at the beginning and the end of the operating periods. Another related issue is the need for consistent signing.

- Electronic enforcement of HOV facilities would be more cost effective and safer. It would remove officers from situations with high speed traffic on both sides and would enhance the ability to monitor all parts of the lanes.

The Federal Perspective

Jim Robinson, Federal Highway Administration

Mr. Robinson showed a video on the design of HOV enforcement areas. The video was prepared by Ron Klusza from Caltrans. Following the video, Mr. Robinson discussed HOV enforcement issues. He covered the following points in his discussion.

- The tirst enforcement area built on SR 91 was 800 feet long and 10 feet wide. This size proved to be both too short to safely stop a vehicle and pull back into traffic, and too narrow for safety.

- An ideal enforcement area, developed in coordination with the CHP, would be a minimum of 1,300 feet long and 14 feet wide. The appropriate spacing of enforcement areas depends on many factors including the availability of space, and access to the HOV lane. As a minimum, there should be at least one enforcement area every three miles.

The Washington State Perspective
Leslie N. Jacobson, Washington Department of Transportation

Mr. Jacobson discussed HOV enforcement in Washington State. The following points were covered in his presentation.

- Law enforcement officials in the Seattle area estimate that one in ten of the vehicles in the HOV lanes are single occupancy vehicles. Approximately 300 tickets are given for HOV violations per month. Because these tickets are moving violations, they appear on the violator's driving record. In Washington, the fine for an HOV violation is $47; the fine in California is $217.

- It appears that the levels of HOV enforcement varies between different areas and different states. It is estimated that violations are highest in areas with little enforcement. When violation levels are high, even otherwise law-abiding drivers may begin to use the HOV lane.

. The HERO telephone line receives about 1,000 calls per month. When a first violation is reported to the HERO program, an informational flier is mailed to the violator. When a second violation is reported, a letter is mailed to the driver, telling them that they have been spotted illegally using the HOV lane. If a fourth violation is reported, a trooper may make a personal call to the driver's house. Although the HERO program does not have the authority to issue tickets, many drivers use the line to vent their frustrations.

- A survey was conducted to determine the public's perception of the HERO program. The results of this survey indicated that:

  - 75 percent of the respondents felt HOV violations were a problem, 50 percent felt violations were only a minor problem.

  - 81 percent of the respondents knew about the HERO program.

  - 71 percent of those indicating knowledge of the system, thought HERO was a good idea while 50 percent of this 81 percent thought HERO reduced violations.

  - Six percent thought violations were reduced a great deal as a result of the HERO program, 3 1 percent thought violations were not reduced very much as a result of the HERO program.

  - 64 percent of the general population favored the HERO telephone line, 24 percent had no opinion about the program, and 12 percent disliked the program.

- Ninety percent of the calls received on the HERO line are for first time violators, 7 to 9 percent are second time violators, and only 1 to 3 percent are for drivers with three or more violations. There have been only a couple of cases in which a trooper has actually visited someone's home.

Experience from the Shirley Highway HOV Lanes
David L. Tollett, Federal Highway Administration

Mr. Tollett discussed the evolution of HOV lane enforcement in Virginia. Methods of enforcement previously used were summarized and possible improvements were highlighted. The following points were covered in Mr. Tollett's presentation.

- The first HOV lane opened on the Shirley Highway in Virginia in 1978. The manner in which the HOV lanes have been enforced has changed throughout the years. When the HOV lanes were first opened, violators were charged with failure to obey highway signs. This is a moving violation, and resulted in a $35 fine and three points on the violator's license. This type of enforcement resulted in over 10,000 citations per year in Northern Virginia.

- A HERO program was implemented to reduce the number of violations. This program was in effect for approximately one year. It was not well received because the public did not like the idea of being informants.

- A proposal to record license plate numbers visually, and mail citations to violators was initiated based on legislation passed by the General Assembly. This legislation held the registered owner responsible for the operation of a vehicle. State law enforcement officials decided that drivers of rental cars and out-of-state vehicles, who may not know what an HOV lane was, would not receive citations. The citation could be rebutted in court if the owner wished to testify that they were not driving at the time of the violation.

- Although it is relatively quick and easy for enforcement officers to note the license plate numbers of violators, the paperwork to process each citation was lengthy. To decrease the amount of officers' time involved in this process, the troopers now turn the plate numbers over to a clerk, who looks them up. The summons are then filled out electronically and mailed. With this system in effect, the fine increased to $50 plus court costs of $24, for a total cost of $74. Points do not accrue on drivers' licenses because the driver is not specifically identified, but rather the owner of the vehicle is.

- The new electronic procedure is now in use and seems to work well. A lack of support from the courts diminishes the effectiveness of the system, however. HOV violations have the lowest conviction rate of any violation in the state, varying from 30 to 50 percent, depending on the jurisdiction. Support from the legislature and courts is needed to strengthen the laws for HOV enforcement. One way to garner this support may be to include them in the planning and marketing processes. Electronic enforcement would also be enhanced by a device that would be able to "see" into vehicles and determine if they are in violation of the HOV restrictions.

- For HOV lanes to be effective, there must be an expectation that if you violate, you will be caught, and the court will follow-up on the citation.

Experience from Recent Enforcement Studies

John W. Billheimer, Systan Inc.

Mr. Billheimer discussed a number of HOV enforcement studies that have been conducted for Caltrans and the CHP. The following points were covered in his presentation.

- A recent study was conducted in which HOV violation rates were measured before, during, and after periods of special enforcement. The enforcement patrols were sent out in different configurations and at different times of the day.

- It was determined that one officer policing the HOV lane had a similar effect on the violation rate as two officers policing the lane half as often. The one officer was less disruptive to traffic, however.

- Heavy enforcement over a three month period was not significantly more effective than the same level of enforcement over a one month period. The same percentage of violations occurred with one officer located on a ramp one day a week for one month as with one officer on the ramp one day a week for three months.

- One method of enforcement presently in use in California is the ramp enforcement program. This entails monitoring violation rates on the ramps and sending out enforcement depending on the violation rates. Ramps with higher violation rates get more enforcement than those with lower violation rates. The same approach is now being tried on HOV lanes.

- On HOV lanes that are available for use only during limited operating hours, the violations increase at the beginning and end of the operating period. In the morning peak-period, the violations are higher at the beginning of the peak-period, while it is still dark, than at the end of the period.

- Studies found that there is no correlation between the speed differential of the HOV lane and main lanes and the HOV violation rate. A fast moving queue had fewer violations than a slow moving queue, but there was very little correlation with the actual amount of time saved. This may be due to the tendency to overestimate the amount of time that is saved by travelling in the HOV lane.

- The original enforcement areas on many HOV lanes were too small to use for pulling a vehicle over, but having an officer sit in the area anyway was helpful for deterring violations. If a driver is pulled over on the right shoulder, across all the lanes of traffic, other drivers do not know that the driver is receiving a citation for an HOV violation; therefore, they do not know that the HOV lane is being enforced.

- Less special enforcement is needed for longer HOV lanes than for shorter ones. There is a greater probability of violators in the longer HOV lanes being pulled over by regular enforcement because they are in the lane for a longer period of time.

- Automated enforcement would be a great help. A study was conducted examining the use of video enforcement. Different configurations of cameras were examined to record vehicle occupancy rates. The cameras were able to record the occupancy with 95 percent accuracy, but 20 percent to 40 percent of the vehicles identified as violators were not. An officer was placed down the road from the cameras to verify that the vehicles identified as violators actually were. The errors occurred due to things such as a child or an adult asleep on the seat.

- It is very important to contact enforcement agencies at the beginning of the HOV lane planning stage. Enforcement personnel can then be included throughout the planning, design, and operations process.

Enforcement Issues in the Boston Area
Robert W. Brindley, Parsons Brinckerhoff Quade & Douglas, Inc.

Mr. Brindley discussed the problems related to enforcement of the HOV facilities in the Boston area. The following points were covered in his presentation.

- When building a new facility, it is very important to involve representatives from law enforcement agencies early in the planning stages. Once the facility is operating, a continuous exchange of information with law enforcement personnel is also necessary. Information such as what data needs to be collected before accidents can be removed from the lanes, and what consists of a violation must be determined.

- It is important that all of the rules and restrictions for use of the HOV lane be made available to commuters, law enforcement personnel, and judges. This should include the kind of vehicles allowed, the vehicle occupancy requirements, and hours of operation.

- There is currently an effort in Boston to use photo enforcement to issue citations for individuals running red lights. It would be beneficial to extend this enforcement to HOV lanes. Photo enforcement has been attempted previously, but with little success. The registry did not keep good records, so quite a few of the cases were dismissed because the car was stolen or not registered properly. Currently, the registry is converting their files from 3 X 5 inch cards to computer files, so that system will become more reliable. Once this is accomplished, HOV photo enforcement may be feasible.

- Another issue concerns judges and the courts. Often, if a judge does not agree with the use of HOV lanes, the violation cases will he dismissed.

HOV System Pricing and Toll Collection

Keith Gilbert, Automobile Club of Southern California-Presiding

Selling Surplus HOV Capacity: The Arizona Tollroad Company Case

Henry Wall, *Kimley-Horn & Associates*

Mr. Wall discussed the concept of using IVHS technologies in conjunction with road pricing to create a smart HOV lane. He used an example from Arizona to describe how this concept might be applied in practice. Mr. Wall covered the following points in his presentation.

- There are three major purposes of smart HOV lanes. First, it creates a congestion management tool through HOV lane pricing. Second, it promotes more efficient use of under-utilized HOV lanes. Third, it creates a revenue stream to fund other services.

- There are a number of different HOV/road pricing concepts. One approach is to convert an under-utilized HOV lane into a priced HOV lane. IVHS technologies such as AVI and toll tags, electronic signs, and ATMS could be used in this conversion. The general concept in this approach is to let 3+ HOVs travel for free, charge 2+ HOVs a reduced fee, and charge SOVs a higher price for use of the HOV lane. This could be done in real-time to ensure that the traffic flow does not get too heavy.

- HOV pricing at freeway ramp meters is another concept, as is HOV pricing on busways. A new lane could also be added as a toll lane. Finally, an existing lane could be taken for a smart HOV lane.

- Under the ISTEA, it is illegal to impose tolls on existing federal interstate freeways except as it may be permitted under the Congestion Pricing Pilot Program. Tolls on added lanes to the Interstate system are allowed, however. In Arizona, the initial concept was to utilize an existing HOV lane, which was built with Interstate funds, as a toll facility. The resulting revenues would be used to build other HOV lanes and supporting facilities. The current legislation does not allow this approach, however.

- Potential benefits from these approaches include value pricing, raising users' awareness of the cost of congestion, creating additional capacity, enhancing the efficiency of the HOV lane and the full facility, improving public perception, generating additional revenues, and justifying HOV lanes in additional areas. Air quality levels may also improve and other environment benefits may be realized.

- Taking an existing freeway lane may be more feasible if HOV pricing is utilized, rather than just converting it into an HOV lane. The impact of SOVs is lessened and public acceptance is improved.

- There are a number of perceived drawbacks to HOV pricing strategies. Some people think the HOV lanes and air quality will be degraded. These concerns could be addressed through the use of advanced technologies to manage the facility, however. Other issues relate to equity and the potential lowering of vehicle occupancy levels.

- The speed and operating conditions in the HOV lane can be managed by regulating the toll charge. This can be accomplished through the use of IVHS technologies. Advanced technologies can also be used to monitor and enforce a smart HOV lane.

- The revenues generated from HOV pricing could be used for many purposes. Possible projects include building additional HOV lanes, and marketing carpooling, express bus services, park-and-ride facilities, IVHS projects, and many other transportation and non-transportation projects. The real issues to advancing these concepts are not technological, but institutional and organizational.

Bay Bridge Pricing Demonstration

Karen Frick, Metropolitan Transportation Commission

Ms. Frick discussed the congestion pricing demonstration project which is being implemented on the Bay Bridge in the San Francisco Bay area. She presented the background to the project, the general concept, and the current status. Ms. Frick covered the following points in her presentation.

- A number of groups came together a few years ago to look at market-based pricing strategies in the Bay area. These included the MTC-the MPO for the area-Caltrans, and other governmental, business, environmental, and public interest groups. FHWA selected the Bay Bridge project for funding through the Congestion Pricing Demonstration program.

- The goals of the project include reducing congestion, improving air quality levels, providing additional transit and ridesharing alternatives, and actually testing congestion pricing. There are a number of reasons the Bay Bridge was identified for the first demonstration. The Bay Bridge is a highly congested corridor. It is an existing toll facility, and it has HOV lanes in operation during the morning peak hours. Express buses and BART are also in operation in the corridor, along with ferries. Further, because it is a bridge, there are few realistic convenient alternative routes.

- HOV modes in the corridor currently carry high volumes of traffic. BART currently accounts for 36 percent of the person trips in the corridor, while carpooling and vanpooling account for 24 percent and AC Transit carries about 6 percent.

- The Management Board overseeing the prqject has developed a number of alternative pricing strategies. The tolls currently being considered range from $2 to $4. The toll could be applied only in the morning, in the inbound direction of travel or during both the morning and afternoon. The tolls could be the same for the two time periods or they could be different. An off-peak discount could also be offered from the existing $1 toll. Caltrans has also indicated interest in a step charge. Under this concept, toll charges would increase during the peak-of-the-peak.

- The revenue generated from the project would be used to fund commute alternatives. These might include funding for BART, bus services, shuttle services, demand-responsive vans, ferry services, carpoollvanpool programs, park-and-ride facilities, security upgrades, BART parking, low income discounts, telecommuting, flextime, bike shuttles, and bridge improvements.

- Currently, delays of 20 minutes are common during the morning commute. The modeling analysis indicates that there is a four minute reduction in delay for every $1 increase in tolls. Thus, increasing the toil to $3 could decrease delay by about half.

- Legislative authority must be obtained to raise tolls on the Bay Bridge. Currently, focus groups, small group meetings with key opinion leaders, and a public opinion poll are being conducted.

- The focus groups have provided some interesting results. As might be expected, there is more opposition as the toll rates increase. Concerns were also voiced over how the revenues would be used. The off-peak discount was also not well received. The focus groups were conducted by modes. Most people indicated satisfaction with their current commute patterns and did not indicate they would change modes based on increased tolls.

- The equity issue has also been examined by/reviewing household incomes in the East Bay and the West Bay. The East Bay carpoolers and vanpoolers have much higher income levels than those in the West Bay.

- The planning phase of the project will be completed by the end of the year. A complete package on the congestion pricing program will be presented to the legislature in 1995. If legislative authorization is received, a new toll structure would be implemented in 1996.

Route 91 HOV Lane Public/Private Demonstration
Jerry C. Porter, California Private Transportation Corporation

Mr. Porter discussed the development of the Route 91 HOV lane in Orange County, California. He summarized the background and current status of the project, as well as the financing techniques and the anticipated toll structure. Mr. Porter covered the following points in his presentation.

- The project has been under development for about four years. Four private groups are involved in the planning, design, and construction of the facility. Route 91 currently experiences high levels of congestion, especially during the peak hours. Assembly Bill 680 is the key legislation that allowed this and three other toll projects in the state. All are “build, transfer, and operate” projects. When completed, the projects will be dedicated back to Caltrans, who will then lease them to the developers for a 35-year period. The legislation further stipulates that the facilities must supplement an existing highway.

- The Route 91 project will build and operate four lanes in the median of the existing freeway. The four lanes will provide a combination of carpool and toll facilities. Some people call these HOT lanes-for high-occupancy toll lanes. Toll collection will be totally electronic, even for HOVs. There will be no toll booths.

- Congestion pricing is at the heart of the project. There is a commitment to maintain the time savings for HOVs. Toll rates will vary depending on congestion levels. Automatic changeable message signs will be used to inform motorists of the current charges. HOVs are defined as vehicles with three or more occupants. HOVs will have to drive through a special lane to allow visual confirmation of vehicle occupancy levels. There is a provision in the agreement that allow a discounted charge to HOVs if needed to maintain the debt coverage ratio. It is not anticipated that this will be necessary, however.

- Additional agreements were needed on the prqject to address maintenance and other provisions. The financing plan was also more complex than a typical highway prqject. The non-recourse financing used means that the lenders can look only to prqject revenues for the debt coverage stream. The equity partners do not have any more at stake than their initial equity investment.

- The total prqject cost is $126 million. Approximately 15 percent of this is provided by the partners. Ground breaking on the project occurred ten months ago and construction is currently underway. Project completion is scheduled for December 1995, with the facility open to traffic in 1996.

HOV System Compatibility with Other Modes

Heidi Stamm, Pacific Rim Resources, Inc.-Presiding

Land Use as an Influence on Mode Choice: HOV Systems versus Rail Systems for Serving Suburban Areas

David E. Schumacher, Metropolitan Transit Development Board, San Diego

Mr. Schumacher discussed the role that land use factors play in evaluating how to "retrofit" public transportation systems into suburban areas, and whether these transportation systems should utilize HOV lanes and buses or rail. A paper on this topic was available. The following points were covered in Mr. Schumacher's presentation.

- I-15 is the main North-South corridor for the inland San Diego County area. The Northern portion of I-15 consists of low density suburban development. The Southern section includes higher density developments. A study is currently underway to examine potential improvements in the corridor including LRT, HOV lanes, and transitways.

- The ADT for I-15 is 170,000 to 250,000 vehicles per day and is predicted to be greater than 300,000 vehicles per day by the year 2015. Expansion is needed, but is not feasible because of right-of-way restrictions, environmental constraints, and a lack of parallel arterials. The only facility improvement currently planned is an extension of the existing eight mile HOV lane, the lane will be extended in both directions.

- The corridor is one of the fastest growing areas in the county with respect to housing and employment. The population is projected to increase 58 percent from 1990 to 2015, and employment is prqjectad to grow by over 36 percent. Due to this growth, the traffic problem is expected to become similar to that of Los Angeles within the next twenty years. There is adequate political and public support for transit improvements, but the area was designed for the automobile, which presents problems with retrofitting transit into the area.

- Fifty-six percent of LRT passengers in San Diego walk to the station. This indicates that pedestrian access to a station is very important to the success of a system. The population density in the I-15 corridor is low and the office parks are not located near the freeway. Pedestrian access to rail stations near the freeway would be virtually non-existent. This is one reason why a high-speed bus or HOV system may be a better alternative.

- Most of the individuals living in this area are employed in various suburban office parks. The employment parks employ fewer people than downtown areas, but occupy three to five times as much land. Each park could justify service, but these areas were not designed for transit.

- A system utilizing HOV lanes and buses would be more cost effective than rail because it would increase ridesharing and could serve a greater percentage of non-work trips. Areas like shopping malls and medical centers would be difficult to serve by rail because of their design.

- There are many areas where the sidewalks are located very close to the freeway or do not exist at all. This makes waiting for a bus potentially dangerous.

- Buses could take people closer to their office than rail. Minimizing the walking distance may encourage ridership.

Improving the Estimation Process for HOV Lane Demand in a Multi-Modal Corridor

John P. Long and John A. Gibb, DKS Associates

Mr. Long and Mr. Gibb discussed the problems associated with current HOV models, proposed model enhancements, and provided an overview of the HOV demand model developed for the Sacramento Council of Governments. The model has been used to determine the best way to phase HOV lanes and light rail on a section of US 50. A paper on this topic, written by Mr. Long, Mr. Gibb, and Mr. Gordon R. Garry was also available. The following points were included in their presentation.

- Two items need to be considered for the phasing of HOV lanes versus light rail: which should be built first, and the trade-offs between the two. When studying these items for the Sacramento study, there was concern that the current models may overestimate how many cars will actually use an HOV lane. This overestimation may further exaggerate tradeoffs between the two.

- Current HOV models usually consider HOV lanes as facilities parallel to the freeway lanes. There are various ways to model and connect the mixed flow lanes to the HOV lanes as well as different ways of assigning traffic to the lanes. Current models also assign virtually all HOVs to the lane even if there is only a slight difference in travel time.

- In developing the new model, counts were compiled from existing buffer separated or concurrent flow HOV lanes to determine the percentage of HOVs that actually use the lane. It was determined that usually less than 60 percent of the HOVs on the freeway were using the lane. If the data collected is accurate, than models that estimate 90 percent or even 100 percent of the HOVs on a freeway facility will use a new HOV lane are overestimating use. The study also indicated that there is no relation between the percentage of HOVs in the HOV lane and the flow in the mixed flow lanes.

- A few key areas of the model were targeted for improvement. It was believed that HOVs weaving from on-ramps to the median lane were not being accounted for in the models. This, in conjunction with distance travelled on the freeway, is a very important variable. In making a short trip, weaving over to the median lane and weaving back to enter and exit the HOV lane may be difficult and dangerous.

- Trip purpose and trip frequency were also identified as key factors. An individual going to work is probably more concerned with travel time then someone going to the doctor or to an appointment. Travel behavior, demographics, and other issues were also believed to be factors in the decisions to use an HOV lane.

- The new model considers the difficulty of moving across lanes of traffic to get into and out of the HOV lane, travel behavior, and demographic characteristics such as trip purpose and frequency, travel time savings, distance travelled, and age of the driver.

- The demographic and travel behavior data was collected on highway 101 in the San Jose and San Mateo area. This is a 30 mile facility which has a 3+ concurrent flow HOV lane. License plates of vehicles entering the freeway were videotaped and questionnaires were mailed those drivers. Questions included in the survey focused on HOV lane use, age, trip purpose, and frequency of HOV lane use. Traffic counts were also conducted on a ten mile section of highway 101, at the same time that the plates were being videotaped, to determine the congestion levels that the vehicles would encounter.

- The information from the surveys and the traffic counts were analyzed and used to develop a statistical model. The data had to be screened to ensure that people were recalling the right trips. A logit model was then fit to the data. A logit model was used because it allows different people under the same conditions to act differently. Individdals making trips, rather than the entire traffic stream, is used as the unit of analysis.

- A statistical hypothesis testing process was conducted with various study models. Models with trip specific information about the individual and trip purpose were more predictive than those which only depended on a volume to capacity (v/c) ratio. Time savings were important, but less so with non-work trips. Difficulty in changing lanes also had a significant effect. There was a threshold for how long the trip had to be before drivers would use the HOV lane. For trips under three miles, very few drivers used the HOV lane. Frequency of the trip was shown to be significant, and age had some effect.

- Drivers least likely to use the HOV lane are those with a short distance to travel during heavy traffic. The HOV lane offers these drivers little time savings and weaving across the mainlanes is a deterrent. The drivers who are most likely to use the HOV lane are those who benefit from the most time savings, those traveliing a long distance in heavy traffic.

- An alternate model was fit to non-work trips because they did not show as much sensitivity to time savings. Further research is needed to determine the significance of time for these trips. The key variables for these trips are the number of lanes that must be crossed to get into the HOV lane, and the distance travelled.

Demand Estimation and Modeling Experience-Part 1

Katherine F. Tumbull, Texas Transportation Institute-Presiding

Florida Interstate Highway System Plan Development and HOV Demand Estimation-An Empirical Analysis

Youssef Dehghani, Parsons Brinckerhoff Quade & Douglas, Inc.

Mr. Dehghani summarized the major elements of a paper co-authored by Marie-Elsie Dowell, Parsons Brinckerhoff, Inc., on the HOV demand estimation procedure used on the Florida Interstate Highway System Plan. This plan focused on the SR 874 corridor in the Miami area. Mr. Dehghani addressed the goals and objectives of the study, the HOV demand estimation procedures, and the preliminary results in his presentation.

- The Florida Interstate Highway System (FIHS) policy calls for constraining the expansion of limited access facilities to ten lanes-six general-purpose traffic lanes and four lanes dedicated exclusively to long distance through travel, HOVs, and possibly future rail transit. Thus, goals of the FIHS policy are to increase the person-carrying capacity of the interstate system, minimize environmental impacts, comply with Florida's growth management laws, support energy conservation, reduce congestion, provide for high speed travel, and develop an affordable system.

- This study focused on the SR 874 corridor in southwestern Miami. Currently, this divided expressway varies from four-lanes to six-lanes. The study looked at HOV demand in the corridor and alternative improvements.

- The study utilized the Florida Standard Urban Transportation Model Structure (FSUTMS). Additional procedures for estimating HOV demand were developed to complement the FSUTMS. First, the FSUTMS was used to generate traffic volumes for the general purpose lanes and through trips. The FSUTMS model was then validated based on a comparative analysis of the estimated and observed base year conditions. Capacity-constrained and unconstrained highway assignments were conducted to estimate excess demand. Selected link analyses were performed for all constrained and unconstrained highway assignments. The excess demand was calculated as the difference between the daily demand volume estimated for the general purpose lanes and the volumes estimated from the unconstrained assignments.

- The 1990 Census journey-to-work data was used as the base for developing the percentage of HOV trips that would use the facility. Additional data on vehicle occupancy levels was obtained for the corridor from Dade County. The HOV market share for commuters was approximately 12 percent. A similar figure was used for non-commuter trips. HOV demand was estimated from through trips based on the baseline HOV share for the corridor and a pivot point analysis to estimate diversion to HOV resulting from travel time savings.

- The results of this analysis provided useful initial forecasts of potential HOV demand in the SR 874 corridor. A number of areas for further research were also identified. The need for sketch planning tools and simple network-based models to estimate HOV demand were highlighted as two of the more important areas for additional research. The need for direct research focusing on developing a better understanding of ridesharing formation and estimation of HOV trip tables was also noted as important.

HOV Demand Estimation in Eastern Massachusetts

Karl H. Quackenbush, Central Transportation Planning Staff

Mr. Quackenbush presented a summary of the modeling techniques used by the Central Transportation Planning Staff (CTPS) in Boston to assist in the evaluation of HOV projects in Eastern Massachusetts. The objectives of the presentation, and the paper prepared for the conference, were to provide technical information to others interested in modeling HOV facilities and to demonstrate the important contributions modeling can make to the HOV planning process. Mr. Quackenbush highlighted the following elements in his presentation.

- HOV projects are being considered in Eastern Massachusetts for a number of reasons. Massachusetts is classified as a serious air quality non-attainment area and HOV lanes are one approach being examined to address these concerns. In addition, HOV lanes are a means of relieving roadway congestion and enhancing the efficiency of the transportation system.

- The area examined in this study includes a number of radial highways, as well as a rapid rail system. HOV was not viewed as a competitor to the rail system due to the different geographical markets served by each.

• The HOV modeling methods used by CTPS are fully integrated into the traditional four-step modeling process. The planning-level models are oriented toward regional and corridor evaluations. The models are implemented in UTPS and run on mainframe computers. The models are used primarily to predict HOV lane usage based on travel time savings, but they can also be used to predict HOV use based on different policy options or strategies.

• The modeling process involves network building, trip generation, trip distribution, mode choice, and trip assignments. Each of these steps was briefly described.

• The CTPS regional highway network is made up of 40,000 one-way links, and is tied to a zone system comprised of 888 internal zones and 102 external stations. The HOV facilities to be analyzed are represented in this network. The types of trips that will be assigned to the facility are restricted by a code. Buses using the facility are handled through a separate regional bus model.

• Regional person trips with at least one trip end in the study area are generated on a 24-hour basis for six purposes using DRAM/EMPL activity allocation models. Trip productions are stratified by geographic ring, household size, and either vehicle ownership or the number of workers. Trip production rates are estimated based on the results of a recent household survey, and trip attraction rates are generated using linear additive equations whose independent variables consist of employment by type and the number of households.

. The heart of the HOV modeling process is the mode choice and trip assignment elements. The process uses a multi-modal logit model to estimate work trip shares for single-occupant vehicles, two-person HOVs, three-person HOVs, and transit. The model was estimated with the 1991 household survey data and contains generically-specified time, cost, and traveler-specific variables.

• Developing the mode choice model was not easy, because there is only one HOV lane in the area, and thus, little local data. The prediction-success tables generated in the estimation process indicate a good deal of accuracy with transit versus non-transit alternatives, but much lower accuracy levels for different vehicle occupancy levels. The model also uses a generalized relationship for in-vehicle and out-of-vehicle times for the rideshare modes. The model is calibrated to 1990/1991 travel conditions.

• A number of outputs are produced by the model. First, traffic volumes and speeds for both the general purpose and the HOV lanes are produced. These results can be used to determine the viability of an alternative. They can also be used to modify alternatives for retesting. The model outputs can be used to estimate travel-time savings for HOVs and to estimate the person-movement capability of different alternatives. The results can further be used to evaluate possible impacts on other transit alternatives in the study area. This is especially important in Eastern Massachusetts, which has extensive bus and rail systems.

• This process has been used on three corridors in Eastern Massachusetts-two radial and one circumferential. In addition, it is being used in a system-wide HOV study to develop a long-range regional HOV plan. Enhancements, such as improving the accuracy of modeling different vehicle occupancy levels, are also being explored.

HOV and Multi-Modal Modeling in Florida

Patrick J. Coleman, KPMG Peat Mat-wick, Inc.

Mr. Coleman discussed the development and use of a multi-modal modeling process in Florida. The new model is an enhancement to the existing Florida Standard Urban Transportation Modeling Structure (FSUTMS) and is designed to provide additional flexibility in evaluating complex multi-modal alternatives. Mr. Coleman summarized the following elements from the paper presented for the conference, which was co-authored by Jeffrey M. Bruggeman, KPMG Peat Marwick, Inc.

• The FSUTMS has been used for many years by the Florida Department of Transportation (FDOT). The FSUTMS is a family of four modeling processes. These are the highway only process; the single-path, single-period transit (SPSP) process; the multi-path, single-period transit (MPSP) process; and the multi-path, multi-period transit (MPMP) process.

• In response to the requirements of the ISTEA and other policies, several urban areas in Florida are updating their long-range transportation plans. The need to incorporate multi-modal alternatives into these plans resulted in the recognition that improvements were needed to the FSUTMS . The revisions have been implemented incrementally with transit projects in Orlando and Miami, Interstate Master Plans in Central Florida, and multi-modal studies in Miami.

• The model structure for the updated system was based on a nested logit formulation developed for the Minneapolis-St. Paul area. This model has an auto versus transit nest, with drive alone and HOV auto submodes and walk versus auto access transit submodes. Further, the HOV has two, three, and four or more person vehicle occupancy submodes. This model was revised to better reflect modal choices in Florida cities. Changes included combining the three and four or more person HOV submodes, creating a further submode in the transit walk access to include local versus premium transit, and creating a nest below auto access for park-and-ride and kiss-and-ride trips. Further, when the model is used in the Miami area, a nest is added to local transit for local bus and jitney services.

- The revised model is sensitive to inputs for both highway and transit elements. Highway sensitivities include low-occupancy travel times and distance/costs, HOV travel times and distance/costs, parking costs, out-of-vehicle time, automobile ownership levels, and the central business district (CBD) attractiveness. Transit sensitivities include walk access time, automobile access time, first wait time, transfer time, fares, automobile ownership levels, and CBD attractiveness.

- The revised model estimates modal choice and auto occupancy levels. Thus, auto trips are output as both person trips and vehicle trips, with the latter used in the highway assignment process and evaluation. Transit trips are output only as person trips, with transit load factors incorporated in the transit assignment and evaluation. Auto access, including park-and-ride and kiss-and-ride, are converted to vehicle trips and output for inclusion in the highway assignment process.

- The FSUTMS process performs the highway assignment using an equilibrium assignment process for a full 24-hour trip table with an assumed peaking factor used to invoke the capacity constraint algorithm. This caused some problems with the overassignment of short trips and the speed differential between the HOV lanes and the general-purpose lanes. These issues have been addressed in the model improvements by placing time penalties on access links from the general-purpose lanes to the HOV facility.

- The multi-modal model improvements provide greater capabilities for regional and corridor studies. Further enhancements will be needed to ensure the model continues to respond to changing travel demand and trip patterns. Thus, the improvement process should be viewed as an ongoing effort.

HOV Demand Estimation Techniques Used for the New Jersey Turnpike HOV Study

C. David Dickey, Jr., Parsons Brinckerhoff Quade and Douglas, Inc.

Mr. Dickey discussed the HOV demand estimation techniques utilized in a recent study on the New Jersey Turnpike. The New Jersey Turnpike is a major north-south artery in the state that serves all classes of vehicles. Like many other facilities, the Turnpike experiences periods of heavy use and congestion. Mr. Dickey covered the following points from the paper prepared for the conference with Irving F. Perlman, Parsons Brinckerhoff.

- The purpose of the study was to assess the viability of implementing HOV priority measures along a 38-mile segment of the New Jersey Turnpike. A number of mainline HOV lane scenarios were examined. These included different vehicle occupancy requirements, as well as bus-only options. The traffic, operational, and air quality impacts of the different alternatives were examined.

- The short project schedule and the need to present detailed operational analyses resulted in the utilization of a unique application of existing HOV demand estimation techniques and general traffic operations analysis tools. Many HOV studies start with a preliminary assessment to determine if an HOV facility is warranted. A more detailed analysis is then conducted that examines the unique demands and issues in the corridor.

- In this study, data on traffic volumes, vehicle classifications, vehicle occupancy levels, travel speeds and delays, and peak-period operations were examined in the initial stage. A fatal flaw analysis was conducted to determine the feasibility of an HOV lane in the corridor. The analysis indicated that current HOV volumes met one of the fatal flaw criteria. High levels of recurring congestion, another of the preliminary study fatal flaws, was only found at some Turnpike toll plazas, however. As a result, a methodology was developed to expand the stage one-or preliminary demand analysis-to include **a** greater level of detail.

- The methodology utilized before-and-after mode shift analyses for mainline operations, HOV demands, the impact on revenue due to the mode shift, and the impacts of traffic operations on air quality. The components included in the methodology were traffic flow analyses, origin and destination travel time matrices, HOV demand estimation including mode shift analyses, air quality analyses, and revenue impact analyses.

- The traffic flow analyses included testing the peak hour volume/capacity relationships of the roadway based on the analysis techniques in the *Highway Capacity Manual.* Some refinements were necessary due to unique aspects of the Turnpike and the study, however.

- Origin and destination (O-D) travel time matrices were developed from the mainline flow analysis to identify travel times for trip O-D pairs on the Turnpike. The travel time differences were then used in the mode shift analysis.

- The HOV demand estimation process considered primary HOV diversion, secondary HOV diversion, and latent demand. It was assumed that 85 to 100 percent of the existing HOVs would divert into the HOV lane. It was further assumed that a volume of up to 10 percent of the HOVs on the Turnpike was a fair order-of-magnitude for the HOVs that would divert from parallel routes. Thus, the total number of primary and secondary diversions were estimated to equal current HOV volumes on the Turnpike.

- The latent demand, or mode shift, was determined using the mode shift algorithm in the FREQ model, with one iteration. Average travel time savings for each HOV scenario were used to determine the percent mode shift for each scenario. The percent mode shift was used to recalculate the HOV lane and general-purpose lane volumes.

- The air quality analysis included estimating vehicle emissions by multiplying the vehicle miles of travel by the sum of the emission rate in grams per mile of pollutant for each class of vehicle. Emission rates were calculated for hydrocarbons, carbon monoxide, and oxides of nitrogen, using data from the FREQ model.

- The revenue analysis examined the potential loss in revenue for each HOV scenario due to a mode shift from SOV to HOV. The change in revenue was calculated from the person O-D trip mode shift table which was converted into a vehicle O-D trip table by vehicle classification. This was necessary since toll rates vary by trip length.

- The methodology provided an appropriate level of detail for this study and was manageable within the short time frame. The results appear to be comparable to those that would have been obtained through other models.

Demand Estimation and Modeling Experience-Part 2

Katherine F. Turnbull, Texas Transportation Institute-Presiding

Development of an HOV Demand Estimation Procedure for Use in a Multi-Modal System Plan

Christopher M. Poe, Pennsylvania Transportation Institute

Mr. Poe summarized the development and use of an HOV demand estimation procedure which was developed by the Texas Transportation Institute for the Dallas District of the Texas Department of Transportation. The process was used to analyze a multi-modal system plan for the Dallas area. Mr. Poe covered the following points from a paper prepared for the conference and co-authored by Mr. Russell Henk, Texas Transportation Institute.

- The development of the multi-modal system plan represented the collective efforts of multiple agencies in the Dallas area. The planning effort was conducted by the Texas Transportation Institute (TTI) under contract to the Texas Department of Transportation (TxDOT). The North Central Texas Council of Governments (NCTCOG) and Dallas Area Rapid Transit (DART) were also involved in the planning process.

- The goal of the plan, which focuses on the year 2015, is to provide an intermediate step between the macroscopic level of planning conducted by NCTCOG and the detailed design and analysis performed by TxDOT. To accomplish this goal, a unique process was used to examine alternative scenarios for HOV and general-purpose lane improvements. The process involved five steps. These steps were: data input, development of different alternatives, cost analyses, prioritizing and selecting alternatives, and operational analyses.

- The process focuses on providing integrated, cost-effective solutions with an emphasis on peak-period operation. This analysis uses a more microscopic approach to analyze peak-period operation, interchanges between and along facilities, and shifts between highway and transit facilities. This approach allows for several additional alternatives to be analyzed in each corridor which may arise from the public review process or from changes in available funding.

- The first phase of the process included the collection and analysis of a wide range of information on existing conditions. This included data on vehicle volumes, occupancy rates, origin-destination information, and systemwide constraints. Future peak hour volumes were estimated based on this information.

- This information was used to analyze potential alternatives in each corridor. The alternatives evaluated included general-purpose lanes, express lanes, HOV lanes, and different combinations of these. To analyze these alternatives, an iterative procedure was used to estimate the split between peak hour general-purpose trips and HOV trips. In all cases, the person trips in each corridor were held constant during the peak hour.

- Adjustments in vehicle volumes due to congestion through both time and modal shift were built into the process. Using data from the Houston HOV lanes, a relationship indicated that HOV ridership increases proportionally with increased congestion levels. Houston and Dallas have different *K* and *D* factors, however. The *K* factor is the percentage of total traffic occurring during the peak hour and the *D* factor is the directional distribution of the traffic. The differences in the *K* and *D* factors were adjusted for the Dallas conditions and plotted on a graph. The results work well in the analysis of radial HOV and freeway facilities, although they do not appear as accurate with circumferential facilities.

- For each corridor, the NCTCOG ridership projections as a percent of average daily traffic were plotted against the daily traffic volume per lane. The locations on radial facilities in Dallas have good correlation with the Houston equation. The circumferential facilities in Dallas do not correlate well with the Houston model, which is not surprising, given that the Houston data are from radial facilities.

- Approximately ten to 15 alternatives were developed and examined for each freeway corridor. For example, in one corridor the alternatives examined included no-build, additional general-purpose lanes, express lanes, two HOV lanes, and one HOV lane. Both 2+ and 3+ vehicle occupancy requirements were evaluated. The critical lane volumes were then examined for each alternative. A maximum vehicle volume of approximately 2,400 vehicles per hour was used as the upper limit, as congestion continues to occur before and after the peak hour at this level.

- A cost analysis of the different alternatives was also conducted. This included estimating the congestion delay cost to identify the total cost to the public. Using this method, the no-build alternative was the most expensive option and the two-lane HOV alternative was the least expensive. The different alternatives were ranked based on these general costs. If two alternatives had similar costs, the option that provided greater system continuity or flexibility was rated higher.

- The last step examined the operational issues associated with each alternative. Concerns associated with weaving and merging were studied for all options.

- The methodology developed in this study appears to provide a reasonable tool for estimating future demand for HOV facilities during preliminary planning phases. The general approach could be easily modified and applied to other locations with regional data to account for local influences on HOV lane utilization.

Application of Simulation Models for Investigating HOV Systems

Vinton Bacon, University of California, Berkeley

Mr. Bacon summarized the results of a study assessing the potential use of simulation models as tools in the design and evaluation of HOV facilities. The Santa Monica Freeway corridor in Los Angeles was used to test the use of two computer simulation models, INTEGRATION and FREQ. Mr. Bacon highlighted the following points from the paper prepared for the conference with Loren D. Bloomberg, John R. Windover, and Adolf D. May, from the University of California, Berkeley.

- The purpose of the study was to assess the potential use of simulation models as tools in the design and assessment of HOV facilities. Two computer simulation models, INTEGRATION and FREQ, were used to simulate a portion of the Santa Monica Freeway corridor in Los Angeles. The results of the models were examined against field data and compared against one another. The strengths and weaknesses of both models were also examined to identify the best applications.

- There are a number of models that can simulate various aspects of HOV facilities. These can be divided into travel demand models and traffic flow models. Travel demand models are needed to determine the modal choice of commuters and hence the demand for the roadway. Traffic flow models are used to determine the traffic conditions that result from a given mode split. The two models used in this study, FREQ and INTEGRATION, can be categorized as traffic flow models. Both contain a number of features that are typical of travel demand models, however.

- The first version of FREQ was developed in 1970 by Adolf D. May and others at the University of California, Berkeley. The model has gone through a number of modifications yielding the current parallel versions FREQl IPL and FREQllPE. FREQ simulates the performance of a mainline freeway divided into subsections. Each subsection represents a change in the supply and/or demand along the freeway. The subsections are assumed to be physically homogeneous and the demand is evenly spread across an individual time slice. The current version allows the user to specify 38 subsections of freeway and to simulate a total of 24 time slices.

- The INTEGRATION computer simulation model was developed in 1984 at the University of Waterloo in Ontario, Canada. Updates to the model were developed at Queen's University in Kingston, Ontario. The model was designed explicitly for use with IVHS facilities and is capable of simulating integrated freeway/arterial corridors. INTEGRATION is a relatively new model and studies using the model are limited. The model simulates vehicles on an individual basis allowing it to perform traffic assignment based on dynamic queuing.

- As part of an effort to simulate the entire Santa Monica Freeway (I-10) corridor with the INTEGRATION model, the freeway portion of the corridor was coded with FREQ and INTEGRATION. Due to time limitations, this study analyzed only the eastbound freeway mainline network with both models. This network consists of roughly nine miles of the I-10 freeway between the San Diego Freeway (I-405) and the Harbor Freeway (SR-110). The time period analyzed was between 6:30 A.M. and 2:30 P.M. The analysis focused on adding an HOV lane with an estimated capacity of 1,600 vehicles an hour. A 2+ vehicle occupancy level was used on the facility.

- A series of sensitivity analyses were conducted using both models. In both cases, the percentage of persons in HOV vehicles had to be converted into a percentage of HOV vehicles. This was accomplished with a simple spreadsheet. First, the existing number of vehicles (135,800) was multiplied by the existing occupancy (1.12) to yield the total number of passengers in the network. (152,096). Given the percentage of passengers in HOV vehicles, the spreadsheet was used to calculate the percentage of high-occupancy vehicles in the network. This calculation was needed since both models use the number of vehicles as their input. As the percentage of HOV passengers changes, the total number of vehicles to be simulated will change as well. The spreadsheet also calculated the total number of vehicles that resulted from any change in the percentage of passengers in HOV vehicles.

- Simulation runs were then made using both models for the baseline conditions and the HOV alternatives. For these runs a total of eight hours of demand were used, but the simulation time was nine hours to allow for all of the vehicles to exit the network. This is important because queued vehicles must be allowed to clear the network in order to calculate the travel times for all of the simulated vehicles. For all of the simulation runs the parameters of interest were the average trip speeds and trip times for both HOV and non-HOV vehicles.

- Changes in trip time and vehicle speeds were examined for the different alternatives. For example, the run with 20 percent HOV passengers and 10.2 percent HOV vehicles represents essentially the existing conditions with an HOV lane added. In this scenario, average speeds increase to about 49 mph and average trip times decrease to 5.7 minutes. The HOV vehicles enjoy most of the benefit, with a trip time of just under four minutes, while the non-HOV vehicles only receive about a six second average trip time improvement from the baseline.

- The study results indicate that both the FREQ and the INTEGRATION models simulated an existing real-world condition and generated results that matched expected results from the field. The FREQ model focuses primarily on the freeway portion of a corridor, while the INTEGRATION model can be used for an entire freeway corridor.

CALINK: An HOV Travel Demand and Simulation Modeling Framework

William R. Loudon, JHK & Associates

Dr. Loudon summarized the design, development, and methodology of CALINK, an HOV travel demand and simulation modeling framework. The development of the modeling framework was conducted by JHK & Associates for the California Department of Transportation. Dr. Loudon covered the following points from a paper prepared for the conference and co-authored by Michael Ausiam, California Department of Transportation.

- The goal of the project was to develop a software program for predicting the impacts from HOV facilities. The focus was on improving methods for forecasting mode shift, route diversion, and mobile source emissions resulting from HOV facilities and other freeway operations strategies. The model framework integrates a regional planning model with the FREQ freeway simulation model and the DTIM emissions model.

- Existing transportation planning models are capable of forecasting HOV demand, their ability to accurately estimate the operational effects of HOV facilities, such as average delay, speed, and queuing, is limited. Further, planning models are often not able to represent the travel time differences between occupancy levels that may be introduced by HOV or ramp meter facilities. Freeway simulation models, on the other hand, are capable of more accurately estimating travel times by link and evaluating the operational impacts of HOV facilities. These models are not designed to predict regional mode shift or route choice, however, and are not capable of estimating all of the effects of HOV facilities on demand.

- By developing an interface between a transportation planning model and a freeway simulation model, the CALINK model framework can produce more accurate estimates of HOV demand forecasts, the operational and emission impacts of HOV facilities, and the interrelationship between the two. The CALINK software has been developed to produce a direct linkage between the freeway simulation software FREQ and the SYSTEM II, MINUTP and TRANPLAN transportation planning software packages. Only minimal adaptations are required to link CALINK with most other regional planning software packages. The emissions model framework also provides the structure within which different emission rate models may be used.

- Within the general model system structure, the planning and simulation analysis is executed in an iterative process. Estimates of mode split and assigned traffic volumes produced by the planning model are input to FREQ via the planning/ simulation model interfaces to produce new revised freeway and ramp speeds. The revised speeds are then input to the planning model for use in a new mode split assignment. The process is repeated until the travel speeds and volumes converge from iteration to iteration.

- Several methodologies were tested to determine the best approach to achieve travel speed and volume convergence. It was determined that using a running average of speeds and volumes from iteration to iteration results in a stable convergence pattern. Further, several validation runs were conducted to determine how well the model replicated actual 1990 baseline conditions as reflected by volumes, speeds, and queues. In the validation of traffic volumes, the accuracy of CALINK predictions were found similar to that generated by the planning model. Validation of speeds and queues indicated that CALINK performs significantly better than planning models because it properly locates queues and speeds in space and time and can therefore predict delay more accurately.

- The I-880 corridor in Alameda County of California was used to test CALINK. Four scenarios were evaluated using the CALINK Interface software. A 1990 no-build scenario was first modeled using the 1990 network and 1990 volumes. This was used to validate CALINK. A 1995 no-build scenario was modeled using a 1990 network and 1995 volumes. This was considered the base against which other scenarios were evaluated. The third scenario consisted of implementing an HOV lane in the I-880 study corridor. The fourth scenario combined HOV facilities, ramp metering, and ramp meter bypass lanes for HOV vehicles.

- The outcome of this analysis produced logically consistent results. When an HOV lane was added to the 1995 baseline, the freeway vehicle miles of travel (VMT) increased because the added capacity attracted some external trips to the freeway. Conversely, VMT on the parallel arterial decreased, as many trips diverted to the freeway. The overall area VMT decreased, mainly because some single occupant vehicles (SOVs) converted to carpools to take advantage of travel time savings in the new HOV lane. Further, because of the increased capacity and lower VMT, freeway, arterial, and areawide speeds increased.

- There are several advantages of CALINK. First, it is based on proven and reliable tools that are being used by most transportation agencies throughout the country. CALINK was designed with a modular structure that allows it to work with most commonly used transportation planning models including SYSTEM II, MINUTP, TRANPLAN, and EMME/2. CALINK is transferrable to any region that has developed a network model for transportation planning purposes. Further, it is fully automated and can operate on a single personal computer. CALINK's travel demand modeling component allows the user to assess regional effects, mode shift, and route diversion caused by the deployment of HOV lanes and other traffic management services. The freeway simulation component allows the user to perform detailed analysis of traffic operations at freeway mixed-flow lanes, HOV lanes, and ramps. Finally, CALINK's emissions analysis component allows the user to assess the impact of HOV lanes on air quality by facility type, emission type and impact region.

Arterial HOV Treatments

Bob Huddy, Southern California Association of Governments-Presiding

Arterial Street HOV Treatment in the City of Los Angeles

John E. Fisher, City of Los Angeles

Mr. Fisher discussed the issues associated with arterial street HOV facilities and specific projects in the Los Angeles area. He also described other related projects that can enhance bus operations in the arterial street environment. Mr. Fisher covered the following points in his presentation.

- A number of bus-only special treatments are used in Los Angeles. The oldest application is to exempt buses from the no-left turn provision at many intersections. Buses are also exempt from mandatory right-turn lane provisions at some intersections. Special bus entrances are also used at some facilities-such as the multimodal transfer center at Union Station. This allows buses to move quickly in and out of the station.

- The ten-block bus lane on Spring Street in downtown Los Angeles provides buses with faster travel times through the downtown area. The Spring Street HOV lane was opened in 1974. A short bus lane is also operated on Flower Street, providing buses with direct access to the Bunker Hill area.

- Traffic signal priority is another approach for providing buses with travel time savings. The Ventura Boulevard Bus Priority Signal Timing Project was implemented in 1986. Emitters on buses can activate an extension or advancement of the green phase of the signals. An evaluation indicated that average travel time savings improved by 4.2 percent, partly because operators used the system only when they were behind schedule. Delays at intersections were reduced by 21 percent, however.

- Priority treatments have also been provided for LRT and heavy rail in the Los Angeles area. LRT operates on some surface streets, taking as much as 50 percent of the street capacity. Improved signal timing has also been used to enhance rail operations on arterial streets. In some areas the signals are set to detect the presence of a rail vehicle and to change the signals to green as the vehicle progresses down the street.

- Caltrans has also implemented a number of priority treatments for buses, carpools, and vanpools. One extensive treatment is the use of HOV bypass lanes at most metered freeway entrance ramps. The city tries to coordinate surface street HOV treatments approaching the freeway HOV bypasses. A nHOV right turn only lane leading into the HOV bypass lane is one example of this. At other locations, one of two left turn lanes is for HOVs only.

- The Harbor or I-110 Transitway, which is currently under construction and is scheduled to open in 1996, will provide an exclusive elevated HOV lane. It ends approximately one mile from the downtown area, however. One-way streets will be extended to provide HOVs using the Transitway direct access into and out of downtown.

- A number of HOV treatments were used to help move traffic after the January 17, 1994, Northridge earthquake. HOV treatments and the automated traffic signal system played major roles in helping to respond to the earthquake. HOV detour routes were developed for traffic diverted from the freeway. These routes moved HOV traffic around the severed portions of the freeway. This provided HOVs with significant travel time savings. Special traffic signal timing and phasing were also used along the HOV surface street routes to provide additional travel time savings.

Arterial HOV Treatments in Metropolitan Toronto

Thomas W. Mulligan, Metropolitan Toronto Transportation Department

Mr. Mulligan provided an overview of arterial street HOV applications in the Toronto area. He discussed the background of HOV planning and operation in Toronto, provincial and municipal policies, the current status of projects, and future plans. Mr. Mulligan covered the following points in his presentation.

- The population of the Greater Toronto Area (GTA) is currently approximately four million people, and it is forecast to increase to six million within the next twenty years. Metropolitan Toronto is a federation of six local municipalities and is responsible for water filtration, sewage works, local transit, major arterial roads, and traffic signal controls. Local municipalities are responsible for local land use planning, local roads, and other local services.

- The GTA is well served by transportation services including local and major roads, highways, buses, subways, and commuter rail. Inadequate capacity, traffic congestion, and environmental concerns are issues in the area, however. This is especially true in developing suburban areas. Changes in land use, TDM, HOV treatments, and other approaches are all being used to address these concerns.

- HOV lanes on arterial roads are one of the techniques being implemented to respond to these issues. In many areas, the needed right-of-way is not available to expand arterial streets. From a policy perspective, arterial street HOV development focused initially on good opportunities, 3+ vehicle occupancy levels, curbside operations, and providing priority to transit first. Other key aspects of the development of the arterial street HOV network include utilizing a grid network, integrating with existing rapid transit lines, providing priorities for buses, and focusing on suburban areas.

- Implementation of the arterial street network will occur in stages. The Dundas Street HOV lane was opened in 1992 in conjunction with the City of Mississauga. Additional arterial street HOV lanes were opened in 1993. Currently a total of seven arterial street HOV lanes are in operation between 7:00 A.M. and 10:00 P.M., and 3:00 P.M. to 7:00 P.M., Monday through Friday.

- A number of supporting programs are also being implemented to enhance the arterial street HOV projects and to encourage greater use of HOVs. These include ridesharing strategies, carpool parking facilities, travel information centers, employer outreach programs, and enforcement programs.

- Issues to be considered with arterial street HOV facilities include obtaining public and policy support, public education and marketing, and enforcement. A special information program was developed around the 3 + Diamond Rider theme. Newspaper, radio, brochures, and a special news conference were used to educate the public and promote the project. Extra efforts were also made to educate the media.

- The preliminary monitoring and evaluation program indicates positive results from the system. Transit travel time savings are averaging about five minutes. Approximately ten to 20 percent of vehicles using the roadway segments are in the HOV lanes. There have been some problems with violators, but increased enforcement levels have begun to address this.

- A number of lessons have been learned from implementation of the Toronto arterial HOV lanes. Policy and public support is critical. The lanes must be planned, designed, and operated in a safe and efficient way. Enforcement must also be present. Coordination with all agencies and groups is important. Public and media education programs and marketing programs are also needed.

Automatic Vehicle Identification for Puget Sound Region

Ellen N. Bevington, Seattle Metro
Kern L. Jacobson, Parsons Brinckerhoff Quade & Douglas, Inc.

Ms. Bevington and Mr. Jacobson discussed the development of a regional transit traffic signal priority system in the Seattle metropolitan effort. This process has involved three counties, four transit operators, and almost 40 jurisdictions. Ms. Bevington summarized the rationale for the system and the background to the study. Mr. Jacobson highlighted different elements of the study.

- The majority of the bus service operated by Seattle Metro use the arterial street system. Approximately 75 to 80 percent of the annual service hours are operated on the arterial street network. This is common for most transit systems. Thus, Metro and other transit operators are severely impacted by increasing congestion levels on arterial streets. Congestion causes slower bus operating speeds, which may require adding buses to a route. Metro spends almost $500,000 annually on schedule maintenance to address problems caused by congestion.

- Intersections account for most of the delays experienced by buses on arterial streets. This ultimately is the driving force for signal improvements that provide some type of priority for transit. Although there has been interest in improving signal systems to enhance transit operations for over 20 years, it is just within the last five to ten years that both the technology and public policy have combined to make it a realistic option. Elected officials are much more supportive of transit, and traffic engineers are more open to different ideas.

- There are a number of general goals for the study. One goal is to work with the traffic engineering community to select a technology, test and implement that technology, and to support the development of control strategies and the ultimate ownership and maintenance of the system. A second goal is to conduct an interactive evaluation process to select the best technology. A third goal is to develop ongoing coordination mechanisms to institutionalize the management and operations of the system. Although the systems should be maintained by traffic engineering departments, transit operators will need to be continually involved to communicate schedule changes, new services, and other modifications.

- Metro is using a negotiated procurement process in the selection of the signal priority system. This is not a low bid process. Rather, this procurement method allows for the development of technical specifications and evaluation criteria for use in selecting the technology. The initial tests are also being kept small. The transit signal priority system will be tested initially in two corridors; one with 27 signals and one with five. Extensive testing of the selected system is planned in these corridors.

- Once the technology has been tested and accepted, it is anticipated that a long term agreement will be executed with the successful team. Any public agency in the state will have access to this agreement. This will reduce costs and time for other municipalities and will help ensure a coordinated system.

- The consensus building process has not been easy. Bringing together transit, traffic, and transportation professionals, and policy makers, from all the different agencies takes time and a good deal of effort.

- There are two basic elements of any signal priority system. One is the component that allows the bus to communicate with the traffic signal controller and the other element is the logic package that drives and directs the traffic signal. The system is being designed to meet the needs of today as well as those over the next five to ten years. The system will be expandable to accommodate additional functions in the future. A wide range of technologies are available to meet this requirement.

- There are numerous logic unit packages or signal control strategies that can be used to provide transit vehicles with priority at traffic signals. These include conditional priority strategies, extending green time or truncating red time, adoptive strategies, and lift strategies. The conditional priority strategy is being used in Bremerton, Washington.

- The procurement is focusing primarily on the automatic vehicle identification (AVI) system, the communication between the bus and the traffic signal. It is important that similar AVI systems be used throughout the area, although control systems can be different. Selection criteria for the AVI technology was developed early in the study. A wide range of technologies are being explored for the system.

- A range of communication and control strategies can be used between the transit vehicles and the traffic signals. Approaches vary in the level of sophistication and the type of priority provided.

- Extensive computer simulations have been run to evaluate the potential benefits of different control strategies. A one-third reduction in total system delay was identified in the preliminary analyses. The system currently in operation in Bremerton has resulted in an approximately 10 percent travel time savings.

- It is important to develop realistic expectations when starting a project like this. These should focus on the critical issues and the technologies appropriate to address these concerns. It is also important to establish good working relationships among the different agencies.

Contraflow Bus Lane on Arterial Streets-Taipei's Experience
S. K. Jason Chang, National Taiwan University

Dr. Chang discussed the use of contraflow bus lanes on urban arterials in Taipei, Taiwan. Currently contraflow bus lanes are in operation on two major arterial streets: Xin-Yi Road and Zen-Eye Road. Dr. Chang covered the following elements in his presentation.

- Like other major cities, Taipei has a problem with serious traffic congestion. A variety of approaches are being taken to address these concerns. Although a rapid rail system is being implemented, buses still represent the backbone of the transit system. Ridership on buses has declined recently, however.

- Contraflow bus-only lanes were implemented on two major arterial streets, Xin-Yi Road and Zen-Eye Road, in 1989. The roads, which are parallel, connect the older downtown area with the newly developing business and residential area to the east. The Xin-Yi bus-lane is more heavily used, with approximately 80-100 buses during the peak hour.

- One of the contraflow bus lanes was implemented by modifying a two-way street into a one-way street with a bus lane. Near-side bus stops are used in most cases to help speed the movement of buses. Diamond markings are used on the lanes, along with extra signs.

- Evaluations have been conducted on the lanes, focusing on travel speed changes, travel time savings, and accident rates. Ridership levels and operating costs have also been monitored. Travel speeds for buses increase dramatically in the morning peak hour. Accident rates have not changed significantly, but there have been three pedestrian fatalities. Ridership has increased on some of the routes using the lanes.

- The contraflow lanes appear to be working well. Further analysis is needed to determine if the lanes should be open to carpools. Additional HOV lanes are also being considered in other parts of the city.

HOV Systems Operations

William A. Kennedy, California Department of Transportation-Presiding

Managing HOV Facilities

Mike Raney, Metropolitan Transit Authority of Harris County

Mr. Raney discussed the experience with raising the minimum vehicle occupancy requirements from two (2 +) to three (3 +) persons in the peak hours on the Katy Freeway (I-10 West) HOV lane in Houston, Texas. He also provided an overview of the HOV lane system in Houston and future plans for the expansion of different elements. Mr. Raney included the following points in his discussion.

- There are currently approximately 60 miles of HOV lanes in operation in Houston. All of the HOV facilities have a minimum vehicle occupancy requirement of 2 + , except the Katy Freeway HOV lane, which has a 3+ minimum occupancy requirement during the morning and afternoon peak hours. The decision to raise the occupancy requirement was made based on the high vehicle volumes experienced at the 2+ level; travel speeds were as low as 35 miles per hour and travel time reliability was degraded during the peak hours.

- The number of carpools at the 3 + level was lower than at the 2+ requirement, but the total number of people using the lane was similar. Both the number of carpools and the number of people using the facility have continued to increase over time. Recent studies indicate that the average peak hour speed on the Katy HOV lane is at least 55 mph. Increasing the occupancy requirements on two other HOV lanes is being considered.

- Enforcement has been a problem, with the variable occupancy requirement on the Katy HOV lane. Most of the problems relate to 2+ carpools entering the lane just before the start of the 3 + period. Also, police vehicles-both marked and unmarked-with just one officer are allowed to use the lane. Both of these issues have caused public perception problems.

- A few serious accidents, including two fatalities, occurred during the past year, these were all the result of wrong way movements in the HOV lane. Alcohol was involved in one of the fatalities. Enforcement measures have been increased considerably since these accidents. The number of officers assigned to the HOV lanes has been increased to 18.

- The HOV lanes are monitored by at least two police officers during all hours of operation. Violators receive a $75 ticket. Today the violation rate is about four percent. Most of the enforcement is administered at the exit points of the HOV lanes.

HOV System Operations in the Seattle Area

Rob Fellows, Washington State Department of Transportation

Mr. Fellows talked about the past, present, and future of the HOV system in the State of Washington. He described recent studies conducted by the Washington Department of Transportation (WSDOT) examining vehicle occupancy requirements and supporting policies and facilities. Mr. Fellows discussed the following elements in his presentation.

- There are currently approximately 95 miles of HOV lanes in Washington State, the majority of these in the Seattle area. Another 60 miles of HOV lanes are under construction. Future plans include a total system of approximately 288 miles. Most of the HOV lanes are concurrent flow lanes, located on the inside of the freeway. A few barrier separated HOV lanes are in operation, however. Further, there are some concurrent flow HOV lanes located on the outside freeway lanes. The HOV lanes operate on a 24 hour basis.

- WSDOT adopted a formal procedure for examining HOV policies, and created an interjurisdictional policy committee, made up of representation from transit agencies, WSDOT, the state patrol, and local jurisdictions. This committee helps develop recommendations for consideration by senior WSDOT members and FHWA representatives. The development of the HOV policies occurred over a two year period and the document is updated periodically.

- In 1991, WSDOT undertook a demonstration project lowering the vehicle occupancy requirement on the I-5 North HOV lanes from 3 + to 2+. A preliminary analysis of this demonstration indicated that many 3+ carpools disappeared. The number of two person car-pools increased initially, but appeared to then level off. Transit ridership appears to have stabilized or even decreased slightly, although prior to the demonstration transit ridership had been increasing.

- The increased number of vehicles in the HOV lane and the freeway design, which includes a lane drop, caused a bottleneck at the end of the HOV lane in the afternoon northbound direction. Congestion at this bottleneck resulted in an increase in travel times for all drivers of approximately 3 to 5 minutes.

- The 2 + vehicle occupancy requirement is still in effect today on the I-5 North HOV lane. The demonstration did result in agreement on a performance standard for future HOV lanes, however. This standard sets a minimum speed of 45 mph that must be maintained during 90 percent of the peak-period over a three month period before a change in the occupancy requirement will be considered.

- There may be cases where converting an existing general purpose traffic lane to an HOV lane is justified in Washington. For example, on I-90, WSDOT implemented a project that was a combination of lane conversion and lane addition through restriping. Currently, there is an effort to formulate a policy to identify when lane conversion is or is not acceptable. It is anticipated that this will be added to the overall WSDOT HOV policies.

- The issues associated with inside and outside HOV lanes continues to be discussed in the Seattle area. On highway 405, the HOV lane is partially on the outside lane and partially on the inside lane. To continue on the HOV lane, HOVs must cross the general purpose traffic lanes in a fairly congested area. In general, outside HOV lanes are used where there are no parallel arterials and where buses need to make frequent stops. The purpose behind outside HOV lanes is to provide buses with easy access to exit ramps to pick up riders. Studies are currently being conducted to determine the advantages and disadvantages of HOV lanes that are located on the inside and outside lanes.

- In addition, a number of studies are underway examining operational issues. Studies are being conducted examining travel markets, lane conversion, safety, and enforcement. In addition, there are four corridor access studies, and studies to address arterial HOV facilities, direct connectors, and a central HOV corridor through Seattle. Each individual study has its own advisory group.

HOV System Operations in Orange County
Joel El-Harake, California Department of Transportation

Mr. El-Harake summarized the current status of HOV lanes in Orange County and discussed plans for a comprehensive HOV system in the county. Mr. El-Harake summarized the following points in his discussion of the Orange County system.

- The HOV program in Orange County began in 1985. The first HOV lanes were a rehabilitation project on Route 55. Initially, the shoulder lanes were reserved for HOV travel during a 90-day demonstration project. Although there was skepticism regarding the HOV concept, severe congestion in the corridor prompted a willingness to undertake an initial demonstration. For example, the average daily traffic on Route 91 doubled between 1981 and 1986.

- Caltrans decided to use the shoulder on Route 55 for the HOV lane as an easy and inexpensive alternative. Although the project was initiated as a 90-day demonstration prqject, it was extended to six months, to one year, and then became a permanent facility. The HOV lane moves almost the same number of vehicles as an average mixed flow lane.

- The HOV lanes on Route 405 have also been a success. This project is 24 miles long with lanes in each direction.

- To continue the commitment to HOV lanes, Orange County has 12 freeway to freeway exclusive HOV direct connections planned. Four of these connections are currently under construction. These direct connections are part of a vision for an HOV system, not just HOV corridors.

- Drop ramps are also a significant part of the long term HOV plan. Eight drop ramps are planned, and three are under construction at the present time. Drop ramps are also being considered on the toll facilities in Orange County.

- Two key elements of any HOV design are flexibility and forgiveness of the design. Capacity problems resulting from the merging of two HOV lanes from two different freeways into a single HOV facility could be a problem in the future. To address this concern, a dual lane HOV system was designated in some areas,

- Another important aspect that must be considered in the design and operation of HOV lanes is accessibility. In addition to drop ramps and freeway to freeway connections, HOV lane egress and ingress points are located every mile and a half in Orange County. Access locations are important in terms of lane utilization and violation rates. Although the HOV lanes are buffer separated, the painted access points are used to reduce violations by single occupant vehicles. The violation rate has decreased from 30 percent to a current rate of 3 percent. This is due in part to the high fines for violators. A driver in a single occupant vehicle in the HOV lane is fined $271. Furthermore, if the single occupant vehicle crossed the painted buffer, there is an additional $271 fine, resulting in a total fine of $542.

Bay Area HOV Facilities
H. David Seriani, California Department of Transportation

Mr. Seriani discussed the implementation and enforcement of HOV lanes in the San Francisco Bay Area. He described the history of HOV lanes in the area, and the future goals and plans. Mr. Seriani highlighted the following points in his presentation.

- In the nine Bay Area counties, there are currently 155 lane miles of contiguous, part time HOV lanes. Plans for the year 2005 encompass an HOV system with more than 400 lane miles.

- In the early 1980s, political pressure resulted in the opening of an HOV lane on Route 580. After two weeks, the HOV lanes were changed back to mixed flow traffic due to the underutilization of the HOV lanes and high levels of congestion in the mixed flow lanes. Legislation was passed prohibiting HOV lanes in the unincorporated area of Almeda County. Although there will probably be a need for HOV lanes in this area in the future, this will not be possible until the legislation is repealed.

- The California Highway Patrol is responsible for enforcement. Adequate enforcement is important to reduce the violation rates on HOV facilities. Enforcement of many of the HOV lanes in the Bay Area is difficult because the right-of-way width is generally small. Current HOV lanes have a median shoulder width varying from two feet to fourteen feet. Where there is a fourteen foot shoulder, officers can pull violators over adjacent to the HOV lane. In areas where the shoulder is narrower, violators are forced over to the right shoulder. Future HOV facilities will be designed and constructed with better enforcement areas. Signs posting the violator fines are being used in an attempt to reduce HOV lane violations.

- On Route 237 in Santa Clara, the HOV lane is located on the right hand side. This is a signalized facility and the intersections and the left turns would interfere with a HOV lane in the middle of the facility. Real-time changeable message signs have been installed to eliminate confusion about when HOV lanes are open and closed.

- The San Francisco Bay Bridge initially had a bus-only lane in the early 1970s. A short time after the lane opened, carpools were allowed in the lane. Today there are four HOV lanes, two on the left side and two on the right side. These four lanes, which can be used by buses and 3 + carpools, carry anywhere from 38 percent to 50 percent of the people crossing the bridge in the morning peak-period. The Bay Bridge HOV lanes provide a travel time savings of approximately 20 minutes.

Marketing HOV Systems

Heidi F. Van Luven, Maryland State Highway Administration-Presiding

The Program to Gain Public Acceptance of Tennessee's First HOV Lanes

Luanne Grandinetti, Tennessee Department of Transportation
Janice E. Nolen, Regional Transportation Authority

Ms. Grandinetti and Ms. Nolen discussed the marketing efforts that accompanied the opening of the I-65 HOV lane in the Nashville area. Ms. Grandinetti and Ms. Nolen covered the following elements in their presentation.

- In September 1993, Tennessee's first HOV lanes opened on I-65 between Nashville and Brentwood, which is a suburb south of Nashville. The facility is eight miles long. The Tennessee Department of Transportation (TDOT) incorporated the HOV lanes into an existing freeway improvement project in response to the requirements of the ISTEA and the higher federal funding share provided for HOV lanes.

- The HOV lane has achieved a high level of political and public support, largely due to a collaborative approach by TDOT, the Regional Transportation Authority, and other state and local jurisdictions. The marketing effort to introduce the HOV lane was a cooperative effort by these agencies and further strengthened the political and public support for HOV lanes in middle Tennessee.

- Transportation planning for the Nashville/Middle Tennessee region has focused primarily on adding capacity by expanding the existing roadway network. Although the 1980 Major Route Plan included HOV lanes in most of the interstate corridors, when the I-65 corridor was widened in the early 1980s, HOV lanes were not included. The 1990 update of the Major Route Plan omitted any reference to HOV lanes, because there was no policy commitment to the HOV lanes at that time. Increasing traffic congestion, concerns that there would be gridlock in the future, and the 1990 Clean Air Act Amendments contributed to a change in policy.

- The I-65 HOV lane begins in Brentwood, a wealthy community south of Nashville in suburban Williamson County. Williamson County has the highest per capita income of any county in Tennessee, and is one of the fastest growing counties. It's population grew 155 percent between 1980 and 1990. It has several suburban style office parks and numerous housing developments. Brentwood is also the location of the first transportation management association (TMA) in Tennessee. As a result of the efforts of the Brentwood Area TMA, local businesses and the community in general are aware of the transportation issues, especially the need for ridesharing.

- The expansion of this segment of I-65 included adding a third general purpose lane, as well as the HOV lane. The HOV lanes are non-separated concurrent flow lanes in the inside lane. The HOV lanes are operational inbound from 7:00 A.M. to 9:00 A.M., and outbound from 4:00 P.M. to 6:00 P.M. Although the HOV lanes are new to the area, they represent a key element of the long range plan. For this reason, it was important that the marketing efforts establish a foundation for future HOV lanes.

- Currently the ADT on I-65 is approximately 65,000 vehicles. This level of traffic **is** not typically a candidate for HOV lanes, because congestion is not a major problem. Thus, the message communicated to the public was that the HOV lanes are being implemented in anticipation of future traffic congestion, not to solve an existing traffic problem. Air quality concerns were also emphasized because Nashville is a nonattainment area. The marketing program also focused on developing accurate expectations. This inlcuded communicating that the lane would not look too full when it was opened.

- Specific messages were targeted to different audiences. Policy makers were generally aware of the air quality issues, but needed a better understanding of the other reasons for the HOV lanes. On the other hand, the general public needed to know the basics, including what an HOV lane is, and how to use it. Transportation and law enforcement personnel needed more technical information, such as how it would be used, maintained, and enforced. Finally, the business community needed to understand why the HOV lane was being implemented, and the effect it may have on their employees.

- Both free media and paid advertising were used in the marketing effort. Messages were conveyed using a newsletter to public policy makers, and a direct mailing to 38,000 residents. Paid media included both newspapers and TV. For every paid dollar of advertising, another dollar's worth of advertising was provided. Bus bench boards, signs on buses and outdoor billboards were also used.

- One tactic that proved to be very effective was hosting a lunch for radio and television traffic reporters. The DOT commissioner was the main speaker at this event, which included a short presentation, and a question and answer period. In addition, some traffic reports were sponsored as part of the marketing campaign. Transportation and law enforcement officials were also targeted. A seminar on the HOV lanes was held to provide technical information, and to help refine some of the details about the project. Meetings were also held with the Chamber of Commerce and other groups within the business community to help them understand the project.

- There was a great deal of promotion at the opening event, which was held in the morning rush hour. The Governor opened the lane at a park-and-ride lot.

- The cost of the campaign was just over $100,000. TDOT paid for the advertising and mail expenses, and for the media spots. The RTA paid for the production costs of the advertising. Broad support was received from local and state officials. There are two additional HOV projects currently in the planning stages, and a regional HOV study is being conducted by an engineering consultant.

- A few lessons were learned from the marketing effort. The Sunday full page advertisement may not have been as cost effective as other medium. More radio advertising may have been better. Billboard placement could have been better; most of the billboards were in corridors other than the I-65 corridor. One of the key findings was that each of the many audiences needed messages targeted specifically to them. It is also important to try every approach you can think of to get attention, both free and paid. It is the total package that is important, and both free and paid alternatives are needed for success.

Marketing I-80 in New Jersey
James J. Snyder, New Jersey Department of Transportation

New Jersey has one of the nation's most successful HOV facilities on the Exclusive Buslane serving the Lincoln Tunnel, and has experienced an HOV lane failure on the Garden State Parkway (GSP). Learning from these experiences and others, New Jersey embarked on a $2.5 million federally funded marketing campaign to support the new HOV lane on I-80 in suburban Morris County. Mr. Snyder discussed this marketing effort. He included the following elements in his presentation.

- The I-80 HOV lane opened on March 7, 1994. It is a concurrent flow HOV lane that operates only in the peak-period. A 2+ vehicle occupancy requirement is used. It was an important event in New Jersey. It was important for this facility to be successful because of past concerns with the GSP and because it is the first step in a larger HOV program. Construction began this year on a 21-mile HOV lane on I-287, and the New Jersey Turnpike Authority is examining other HOV facilities.

- The GSP HOV lane was a success from an operating standpoint. A number of mistakes were made during implementation, however, and the press and public raised numerous concerns. The decision to close the HOV lane on the GSP was not an operational decision, but a political decision fueled by pressure exerted by the press.

- When the feasibility study for I-80 was initiated two years ago, a public opinion survey of 1200 people and executive interviews with key decision makers in the region were part of the process. Results indicated that although the GSP project was ten years old, many people still remembered it. This indicated the need to not only market a new HOV lane for I-80, but also convince decision makers that the I-80 project was different than the GSP.

- Fortunately, New Jersey has an outstanding relationship with the local FHWA office. FHWA recognized the importance of the HOV lane and provided $2.5 million for the marketing campaign. The marketing effort was a multimedia campaign focusing on an audience of approximately seven million people.

- There were six goals to the marketing campaign. These were:

  - Heighten public awareness of the HOV mission.
  - Build constituencies and partnerships with employers, and elected officials at the local, county, and state level.
  - Increase public confidence.
  - Develop accurate expectations.
  - Encourage HOV facility use and mode shift.
  - Enhance future HOV project planning.

- A number of marketing and public information strategies were used. The first strategy was targeted to media relations with the print media. Editorial board briefings were held with the newspapers and reporters were provided with ongoing status reports. A complete media data sheet on the initial operation was disseminated to all of the media before noontime on opening day. This helped the reporters make their deadlines, and it fostered the perception of cooperation.

- The second strategy targeted television and radio. One of the highlights of this effort was a half hour interview on the HOV lane for the New York City ABC station. This interview reached an audience of 7 to 10 million people. Traffic reporters were also briefed on a regular basis.

- The third strategy targeted special events. A number of press conferences were held at different points in the project development.

- The fourth strategy targeted mailings and distributions. One million people were reached through direct mailings to commuters, and through fliers in automobile registration. and license renewal notices. Inserts were provided for employers to put in internal newsletters. Desk top displays for employers to put in public places provided information directly to employees were also used. Letters were sent to police chiefs, judges, and local elected officials explaining the lanes. Palm cards about the HOV lane were distributed to motorists at toll booths. Every violator receives a brochure about the benefits of the HOV lane, and why it should not be abused. Letters are responded to, typically in three days or less. Congressional and legislative aids, who are responsible for answering letters to elected officials, were also briefed and provided with a number of standard responses. An I-80 hotline was maintained. On the first day the lane opened, 50-60 calls were received. Six weeks later, the calls were down to 3-4 per day, and last week, there were only about 2-3 calls.

- Advertising was expensive. The media was very cooperative, however, and additional ads were often provided for free.

- The speakers bureau arranged over two dozen presentations in the three month period before the lane opened. The HOV message was also incorporated into the employer trip reduction program. This made the HOV message a part of 100 trip reduction briefings that were conducted in the same three months. Overall, more than 2,000 employers were covered.

- The HOV lane is working very well. As of last week, the peak hour volume was 1,200 vehicles carrying 2,800 people. This means that one-third of the people traveling on I-80 during rush hour are now using the HOV lane. An extensive evaluation program is being conducted, which will include an evaluation of the different marketing strategies.

Marketing Features and Benefits of Carpool Lane-s
Donna Carter, Frank Wilson and Associates

Ms. Carter discussed her experience marketing carpool lanes. She included the following points in her discussion.

- Many HOV lane projects are implemented in conjunction with major highway reconstruction programs. This can make marketing difficult. In most cases, the best approach is to present the system as a whole, and to provide a perspective that looks at the HOV lanes as part of a multimodal system.

- A good deal of research has been conducted, focusing on the reaction of motorists to HOV lanes and carpooling. Focus groups, interviews, and surveys were used as part of this research. One finding is that people find the terminology, particularly the name HOV, to be confusing.

- Research also seems to indicate that people think in terms of time, not miles. Consequently, HOV incentives should be presented in terms of time. At the same time, there is a need to focus on more than just time savings. A minimum time savings of 20 to 30 minutes was identified by some motorists before they would consider using an HOV lane. Marketing not just the HOV lane, but the total multimodal system, may help overcome this thinking. Elements such as HOV bypass lanes became an important strategy component. Ensuring that HOV lanes do provide travel time savings and are part of a regional system is also important. Preferential parking, park-and-ride facilities, and other incentives are all part of the total system.

- Research also indicates that people tend to overestimate the HOV violation rate. In some areas, commuters thought that violations were as high as 50 to 70 percent. In reality, violations were under 5 to 10 percent. It is' important that the marketing effort emphasize that the lanes are enforced, that violators will be fined, and explain what actions will result in a fine.

- Safety must also be emphasized, especially in California where the high number of uninsured motorists make safety an important consideration. Unless motorists are educated, the perception exists that HOV lanes are not very safe. HOV lanes often look different which may contribute to a perception that HOV lanes are less safe.

- It is important that marketing efforts continue once an HOV lane is opened. Ongoing communication with the public about the benefits of HOV lanes and how to use them is critical. The HOV message needs to be continually reinforced among commuters.

Lane Conversion Strategies-Historical Experiences

Karla Snyder-Petty, Federal Highway Administration-Presiding

Santa Monica Freeway Diamond Lanes: An Overview and Evaluation

John W. Billheimer, Systan, Inc.

Mr. Billheimer discussed the evaluation of the Santa Monica diamond lanes completed during the 1970s. His discussion was accompanied by a paper he wrote that was originally presented at the Transportation Research Board Annual Meeting, Washington D.C., 1978. Mr. Billheimar included the following points in his presentation.

- The Santa Monica diamond lanes opened in March 1976. The project took one the busiest freeway mainlanes in the nation away from general purpose traffic and restricted it to use by buses and 3 + carpools. Bumper to bumper traffic, 30 minute freeway delays, ramp meter delays, numerous accidents, upset motorists, and negative press all occurred on the first day of use. As time went on, the freeway operations improved, but public opinion and the media response got worse. After 21 weeks, the project was halted by a US District Court decision mandating additional environmental impact studies.

- Ramp metering was implemented in the two years prior to the opening of the diamond lanes. Prior to ramp metering, speeds in mixed flow lanes were approximately 50 mph; when the diamond lanes opened, speeds dropped to approximately 40 mph. Speeds on the surface streets also decreased slightly when the diamond lanes were implemented. By the end of the project, trips using the mixed flow lanes were 1 to 4 minutes longer due to freeway delay, and 1 to 5 minutes longer due to delay at the metered ramps. Speeds in the diamond lanes were approximately 52 mph. The ramp metering provided more travel time savings to HOV lane users than the diamond lanes did, and did not create any controversy.

- The number of 3 + carpools on the freeway increased by 65 percent after implementation of the diamond lanes. After the diamond lanes closed, the occupancy rate remained slightly higher than it had been before the project. Express bus service increased fourfold, and ridership increased threefold during use of the facility. Although violation rates were initially high on the diamond lane, the violation rate was down to approximately 10 to 15 percent by the end.

- The implementation of the diamond lanes resulted in a significant increase in accidents. Accidents increased by a factor of 2.5 over the life of the project. The increase in accidents may be attributed to the significant speed differential between the diamond lane and the adjacent general purpose lanes, and the unlimited access to the diamond lane. There was a significant increase in the number of rear-end accidents in the lane next to the diamond lane.

- After implementation of the diamond lanes, the freeway served 2 percent fewer people in 10 percent fewer vehicles, and the corridor served 1 percent more people in 5 percent fewer vehicles. Carpools increased 65 percent, and bus ridership more than tripled. The diamond lane speeds were faster and more consistent than before the project was implemented.

- Some of the expected benefits did not materialize. These included fuel savings and air quality impacts. In addition, there were a lot of negative impacts. For example, accidents increased significantly, mixed flow traffic lost more time than carpoolers gained, and media and public opinion was solidly against the project. In fact, a survey of motorists indicated that 86 percent of the drivers surveyed in the corridor, including more than 50 percent of the carpoolers, thought that the project was either worthless, or actually harmful. As a result, the future of preferential treatment projects was impaired in California and elsewhere.

- It has been suggested that the Santa Monica diamond lanes failed due to inadequate marketing, and if the project had been marketed correctly, the outcome might have been different. However, the marketing plans for the Santa Monica diamond lanes included almost all of the things that should have been done. In fact, $350,000 was spent on marketing. By contrast, the I-394 project in Minnesota, generally regarded as one of the best marketed projects, spent $400,000 on marketing. There are one or two things that could have been better. For example, the marketing effort could have been started earlier, and there could have been more constituency building with politicians. There was a lot of constituency building done both with politicians and other public agencies, however, once public sentiment turned against the project, the politicians and other public agencies also turned against the project, and Caltrans was left to defend the project alone.

- Both positive and negative lessons *were* learned from this project. On the negative side, the accident rate represents a significant problem, while on the positive side, the performance of the ramp meter bypass lanes was terrific.

- Although this project prompted Caltrans to implement a policy against taking away a mainlane for an HOV lane, taking away a lane has worked in some places. The Santa Monica diamond lanes were implemented on one of the busiest freeways, however, and combined with the 3+ carpool requirement, resulted in a shock to the traffic system that was hard to overcome.

A Perspective on the Santa Monica Diamond Lanes
Dave Roper, Roper and Associates

Mr. Roper discussed his perspective on the Santa Monica diamond lanes. Mr. Roper included the following points in his presentation.

- Prior to the implementation of the Santa Monica diamond lanes, there was congestion on the freeway, but it was no worse than on other freeways in the Los Angeles area. Caltrans initially had political support on the project. When the public and media turned against the project, however, the politicians also abandoned their support. A number of politicians used their position against the diamond lanes to help win reelection.

- Although the diamond lane was carrying many people, the public just saw an empty lane. Although accidents did increase a little, the public saw accidents all of the time. An effort was made by the public to change the vehicle occupancy requirement from 3 + to 2+, but Caltrans would not make this change.

- People came up with all kinds of ways to beat the system. Under one-“rent a student”-commuters would rent a student for a dollar, then all of the students would ride back to Santa Monica together in the HOV lane and start over again. People used dummies as passengers. You would get a $25 ticket then; today, a $271 fine is imposed.

- Perhaps the public had a right to be upset. The bottom line is that it was a political decision to remove the HOV lanes.

- The Santa Monica diamond lanes set the HOV program in Los Angeles back ten years. At Caltrans, the words diamond lanes were not even mentioned. It was very difficult to even open reasonable dialogue; the subject was too controversial.

- In New Jersey, there was a take away lane project on the Garden State Parkway a few years ago, this project was also terminated. But now New Jersey has successfully implemented an HOV lane on I-80. History does not have to be repeated. It is better to have a good project and keep it, than to develop the perfect project, with significant time savings for carpools, and lose it.

Lane Conversion Strategy for the I-80 HOV Lane in New Jersey
Barbara L. Fischer, New Jersey Department of Transportation

Ms. Fischer provided an overview of New Jersey’s experience in implementing an HOV facility on I-80. Her findings were also discussed in a paper. Ms. Fischer included the following points in her discussion.

- The decision to implement HOV lanes on I-80 was made after construction for an expansion on I-80 had begun. The decision was made approximately half way through the project; at this time, one third of the new lane was open to general purpose traffic. The HOV facility, called the diamond express lanes, has been open since March, and has been fairly successful.

- The HOV facility primarily serves two kinds of trips. These are the suburb to suburb commute and part of the commute into New York City. The average trip length served is 40 miles. The cross section of the entire freeway is four lanes in each direction. During the peak-period in the peak direction, the inside lane is restricted to 2+ HOVs, motorcycles, and buses.

- The 10.5 mile HOV facility is an inside lane, concurrent flow facility, and is not separated from the general purpose lanes. Ingress and egress is continuous. The eastbound HOV lane is operated in the morning peak-period, and the westbound HOV lane is operated in the evening peak-period. All other times, the lanes are open to general purpose traffic. There is a 9 foot inside shoulder in both directions. For enforcement purposes, the shoulder is 14 feet on one side and 4 feet on the other side in some locations.

- In 1991, there were up to 700 2+ HOVs using this section of I-80. Eleven percent of the traffic was 2+ carpools, and there were 20 to 40 buses along the corridor. There was significant congestion. Since the lane opened, there is congestion in the three general purpose lanes, which provides an incentive to use the HOV lane. The HOV lane carries approximately 1,000 vehicles an hour, moving one third more people in half as many vehicles as the general use lanes. There is a 5 to 10 percent violation rate. Four troopers patrol the ten-mile segment. Large trucks are allowed in all the general purpose lanes, which has resulted in some complaints that they are blocking general purpose traffic. This may be more of a problem of perception, than a real operational problem.

- A project steering committee was formed to review the consultant's study findings, offer suggestions, reach consensus, and recommend particular courses of action to the New Jersey Department of Transportation (NJDOT) Commissioner. The committee involved NJDOT as well as outside agencies, including the state police, FHWA, county agencies, and New Jersey Transit.

- Alternatives considered initially included four general purpose lanes, and three general purpose lanes and an HOV lane. Although projections indicated that the facility would not be congested when the lanes opened if there were four general purpose lanes, estimates for five to ten years indicated that traffic operations would be better if the HOV lane were implemented.

- Construction staging was an important factor. Three miles of the additional lane had already been opened to general purpose traffic when the HOV study began. There was also one mile that was complete, but had not yet been opened. Commuters could see that it was finished, and, rather than keep it closed for three years until the construction work for the HOV lane was complete, it was opened to general purpose traftic.

- There was another three mile section that was scheduled for paving and opening. In this section, the new lanes looked different due to a different surface material, which served as an advantage when the decision was made to delay the opening. Construction drums were placed along the length of the lane, and it was striped as a very wide shoulder. The final paving was deferred until the construction was completed. Interim signing was the last thing to be done, and will be replaced by permanent signs.

- Telephone surveys were conducted with commuters and executives as part of the planning process. Public information centers, to meet with the public one on one, were not used. Because the last HOV facility in New Jersey, implemented on the Garden State Parkway in 1980, was shut down, public acceptance of the HOV lanes on I-80 was especially critical.

- The marketing campaign emphasized that HOV lanes are the way of the future, and a good long-term transportation improvement. The marketing campaign, which emphasized the benefits to both users and non-users, included radio and television advertisements, talk shows, a newsletter, press releases, a speakers bureau, and posters. $2.5 million was spent on the marketing campaign, and it seems to have worked. The press has been fair. There has been positive press, but some operational problems have also been noted by the press.

- Some of the most successful aspects of the project included the multi-agency steering committee, the public relations, the traftic characteristics of I-80, the construction staging measures, postponing the final construction in those three miles, the flexibility in putting up interim signing, and the effective and visible enforcement.

- There were elements that could have been better, however. For example, more direct involvement by the I-80 commuters would have been good. More detailed analysis of the key locations of significant congestion would have also helped. It would have been better to introduce it as an additional lane rather than a general purpose lane that changes to an HOV lane in the best of approaches. Finally, partnering with the contractor would have facilitated the construction changes.

The Dulles Toll Road Experience

William C. Jeffrey, Virginia Department of Transportation

Mr. Jeffrey discussed the Dulles Toll Road experience. Mr. Jeffrey included the following points in his discussion.

- The Dulles corridor connects Washington D.C. with the Dulles airport. In 1962, the Dulles access road opened from 28 to I-495, concurrent with the opening of the Dulles Airport. In 1982, we entered into an agreement with the Airport Authority, and began construction of the Dulles Toll Road, from 28 to I-495. In 1983, a Dulles connector road was constructed, extending access from the airport past I-495 to I-66. This provided a direct link into the Washington D.C. area, and made what was previously a 45-50 minute trip into a 25 minute trip.

- However, the volumes on the facility increased much faster than expected. One year after opening, the facility was near capacity. The high volumes may be explained by the relatively low toll rate, which is about eight to nine cents per mile, and the fact that all of the parallel facilities were at capacity.

- In 1988, with the traffic volumes still increasing, Virginia Department of Transportation (VDOT) decided to use the center roadway to the airport as an HOV facility, and the Airport Authority agreed. But the Congressional Oversight Committee vetoed it, although they did agree that buses could be allowed on the facility. It important to remember that this project is in the Airport Authority right of way. Everything must be approved not only by the Airport Authority, but also by the Congressional Oversight Committee.

- Then VDOT widened the toll lane to six lanes. All of the counties along the corridor, the state legislature, and Congress wanted the new lanes to be HOV lanes. So the facility opened as an HOV 3 + facility in September 1992. VDOT felt that an HOV 2+ was not an HOV. Looking back, this may have been one of the biggest mistakes.

- Congress asked VDOT to suspend the HOV operation. At this time, local and state elections were being held in Virginia, and the HOV lanes became a campaign issue. Congress ordered that the HOV restriction be lifted in July. The VDOT Secretary extended it another year, until April 1994. The Secretary appointed a task force to look at all of the options and alternatives in the corridor. Today there are no HOV lanes. Rather, there are six conventional lanes, and three conventional lanes on the access road in the middle.

- VDOT did not do much marketing initially. Since then, a four-year $3 million campaign has been initiated. Numerous pieces of legislation were passed in 1993 requiring VDOT to look at different issues associated with HOV lanes.

- A task force, which included representatives from state and local jurisdictions, Congress, the public, and VDOT was established to look at these issues. The task force looked at a number of issues, including:

  - An HOV facility on the access road, but no HOV facility on the toll road.

  - Use of the median shoulder as an HOV lane during the peak-period.

  - Widening the toll road for $25 million.

  - An HOV facility on the access road.

  - Widening the access road.

  - An HOV facility in the median, where a rail facility is ultimately planned.

  - Congestion pricing. This suggestion was quickly abandoned, however.

- A roadway improvement alternative was suggested by the task force, and accepted by the board. As a result, a 2+ HOV lane will be added. The board also agreed to provide funds to assist in building rail in the corridors. The existing rail line will be extended from Falls Church to the airport, and eventually to Williamsburg. The rail extension is being targeted for the year 2005. The ultimate typical section will include three conventional lanes, one diamond lane, three conventional lanes on the access road to the airport, and rail.

- One problem with the initial project was the construction sequence. Part of the facility was completed before the entire facility was. Three possible alternatives were considered. These included not opening it, opening it to HOVs, and opening it to general purpose traffic. The decision was made to open it to general purpose traffic, and then take it back for the HOVs when all the construction was completed. This appears to have been a mistake. More marketing may have also helped the project.

- Another important consideration is demographics. In this case, the demographics are different in the Dulles corridor than they are in other corridors in the Washington D.C./Northem Virginia area. Commuters in the Dulles corridor do not work for the Federal government, and they often need a car as part of their job. It is important to identify factors such as these in the planning phase. It is also important to decide if there are enough incentives to get people out of their cars.

The California Perspective on Lane Conversions
J. Michael Auslam, California Department of Transportation

Mr. Auslam discussed Caltran's perspective on lane conversions. Mr. Auslam also provided a paper on this topic. Mr. Auslam included the following points in his presentation.

- Since the 1976 Santa Monica diamond lane project, HOV lane conversions have been discouraged in California. Since that time, HOV lanes have been implemented as added lanes. Lane conversion applications in California are limited. Lane conversions are used only for construction staging, prqject continuity, and emergency measures.

- An example of a construction staging application of lane conversion is the HOV lane on Route 91 in Riverside County. In this case, the Route 91/I-15 interchange was constructed first, and the plan was to delay striping the new lanes until the east and west segments were complete. Pressure from the public and the press resulted in a change in plans, however. Caltrans decided to open the lanes to mixed flow traffic, and when the connecting segments were completed, the lanes were re-striped as HOV lanes.

- An example of a project continuity application of lane conversion is the connection of an existing HOV segment with one under construction on Route 85, near San Jose. In this case, the southbound inside lane through the interchange was re-striped for HOV use in 1990. This re-striping was executed to connect the existing HOV lanes to the north with the HOV lanes under construction to the south. When construction is complete, there will be 25 miles of continuous HOV lanes. This project was successful because the Route 85/280 interchange currently comes to a dead end, and there is capacity available for lane conversion. Furthermore, no congestion was created by this conversion. It is important to allow the public to see the logical progression of construction, so they can see the plan unfolding.

- HOV conversions have also been used as emergency measures to help compensate for the loss of capacity caused by disasters. For example, the 1989 earthquake in San Francisco resulted in the collapse of major freeway segments. To encourage ridesharing, numerous shoulder and bridge lane conversions were implemented in the north part of the San Francisco Bay area to help move traffic during the reconstruction process.

. The recent Northridge earthquake caused the collapse of major freeway structures in the Los Angeles area. One of the structures destroyed was on the Santa Monica I-10, and two other structures collapsed in the Washington Fairfax area. As a result of these collapses, the mixed flow traffic had to detour on a longer route that weaved through arterial and side streets, while the HOVs were allowed to remain on the freeway. The detour was in place for about 3 months while construction crews worked 24 hours a day, 7 days a week, to re-open the collapsed freeways and bridges. When construction was complete, the freeway reverted back to mixed flow.

- Another example of an emergency measure in Los Angeles is the I-5/Route 14 interchange. In this case, temporary HOV lanes were established on Route 14. These lanes provided travel time savings of 10 minutes for HOVs, who were able to bypass a two mile long traffic queue. Volumes on the HOV lanes average about 2,000 vehicles per hour in the morning peak-period, but were as high as 2,200 vehicles per hour in the peak hour. Caltrans is currently evaluating the feasibility of retaining these HOV lanes on a permanent basis.

. All of these lane conversions were successful because there was strong local governmental support, the conversion appeared logical to the motorists, they did not result in congestion in the mixed flow lanes, and they had the support of local traffic authorities, who did an excellent job working with Caltrans to educate the public and the media. Presenting a logical plan to the public and not giving false promises is critical to successful projects.

Lane Conversion Strategies---Studies and Future Conversions

Karla Snyder-Petty, Federal Highway Administration-Presiding

Lane Conversion in Seattle

Leslie N. Jacobson, Washington State Department of Transportation

Mr. Jacobson discussed the status of projects in the Seattle area converting general purpose lanes into HOV lanes. He also discussed the policies addressing this developed by the Washington State Department of Transportation (WSDOT). He included the following elements in his presentation.

- The first bus-only ramp was opened in downtown Seattle in 1970. This ramp was successful and was extended initially as a bus-only lane and then extended into a freeway HOV lane. There is generally a favorable attitude toward HOV lanes in the Seattle area due in part to environmental concerns.

- In 1991, WSDOT established a policy which essentially eliminated the possibility of converting an existing general purpose traffic lane into an HOV lane. In 1992, this policy was modified, however. The current policy states that when new capacity options are proposed, one of the alternatives to be considered shall be the conversion of a general purpose lane to a HOV lane. This change in policy allowed one of the three general purpose lanes to be converted into a HOV lane during the recent construction on I-5 South.

- On I-90, 12 lane miles of roadway were converted into a barrier separated, reversible, HOV facility. There was a significant effort to gain public approval and acceptance of this change. Consensus building began before the final decision was made to convert the lanes. The three aspects of this process included public involvement, agency coordination, and securing the support of elected officials.

- A number of strategies were used to inform the public of the plans for the HOV lane. These included public meetings, flyers, newsletters, newspaper advertisements, and media involvement. There was only one major concern raised at the public meetings. This issue, which was voiced by a small neighborhood group, concerned the fact that construction of the noise walls were linked to the construction of the HOV lanes.

- The main goal of the agency coordination effort was to obtain agency support, preferably written support. Official briefings, formal council briefings, and informal discussions were held to inform elected officials of the project status and to encourage their support.

- A research project is currently being conducted to evaluate this program. The evaluation will include public surveys, and will examine traffic data, including vehicle occupancies and travel times, accident analysis, and the effect of public transit.

- The public surveys are being conducted to identify changes in commuter modes, to determine opinions about the lane conversion, and to evaluate how effective the public education effort was. Spot checks indicate free flow operations on the HOV lane, with approximately 600 vehicles per hour.

- The Seattle experience to date indicates that converting an existing general purpose lane into an HOV lane can be clone successfully. Such a project should be well planned, however, and should include a major focus on consensus building.

The Proposed HOV Lane Conversion for I-75 and I-85 in Atlanta

Arthur B. Riddle, Georgia Department of Transportation

Mr. Riddle discussed the plans for HOV lanes in Atlanta, Georgia. These projects, which are scheduled to open later this year, involve the conversion of existing general purpose lanes into HOV lanes. Mr. Riddle included the following points in his presentation.

- The regional development plan adopted in 1975 by the Atlanta Regional Commission (ARC) has included preferential treatment of HOVs. In the 1970s and 1980s, the Atlanta freeway system underwent extensive rebuilding. New inside lanes for HOV use were part of these improvements.

- In 1979, however, the decision was made to allow general purpose traffic to use these lanes because little congestion was anticipated. Today the freeway system in Atlanta is nearing capacity, and vehicle volumes continue to increase every year.

- For the last two years, the Georgia Department of Transportation (GaDOT) has been planning to convert these lanes into HOV lanes, with a 2+ vehicle occupancy requirement. The conversion of these lanes is scheduled to occur later this year.

- A major marketing effort is planned because these represent the first HOV lanes in Georgia. The marketing program will include an educational program to inform the public of the purpose of the HOV lane, how they will operate, and the benefits the lanes will provide. Plans are being made to meet with large employers and convince them to provide special incentives for HOV users.

- A marketing firm will be utilized to conduct market research activities, to design the educational classes, and even to inform GaDOT employees on the purpose of the HOV lanes. GaDOT employees will meet with the public and help with the educational classes. All of these activities are being conducted in an attempt to gain public acceptance of the HOV lanes.

- The inside lanes on I-75 and I-85 were built 14 feet wide. To convert the lanes, a solid white 8 inch line will be painted on each side of the existing dashed line. This will provide a 3 foot buffer zone, in addition to existing 6 to 10 foot wide inside shoulders. Cameras, loop detectors, and overhead changeable message signs will also be incorporated into the HOV system.

- The success of the HOV lanes will depend on the effectiveness of the marketing effort, utilization of the rideshare program, cooperation from large employers, and the development of additional supporting facilities, such as park-and-ride lots.

Public Attitudes Toward Lane Conversion

Paul Jovanis, University of California, Davis

Mr. Jovanis discussed the results of surveys conducted to assess the public perception of HOV lanes in California. Mr. Jovanis covered the following points in his presentation.

- The objective of this study was to evaluate public perception of HOV lanes in general, with special emphasis on HOV conversion. The study was prompted by the experience with the Santa Monica diamond lanes, which involved conversion of general purpose lanes and by interest in lane conversion in areas where the addition of new HOV lanes is not an option. To assess the public opinion, a literature review was completed, focus groups were held, and a survey was conducted. The survey utilized a computer aided interview format.

- Approximately 1,100 people over the age of 18 who lived in cities with HOV lanes were included in the survey. Thus, people with some knowledge of HOV lanes, and who might use the HOV lane were targeted in the survey. The procedures to select the participants and the survey process are described in a paper that was presented at the 1994 TRB Annual Meeting, and will be published in a forthcoming edition of the TRB Research Record.

  - Females comprised 55 percent of the sample, 60 percent were home owners, and 72 percent were employed, with the other 28 percent largely retired individuals or college students. There were 460 responses from the Los Angeles area, 575 from the Bay Area, and a few from the San Diego area. This allowed a separate analysis to be conducted in each of the two regions.

  - Results indicated that there is more support for HOV lane conversion in the Bay Area than there is in the Los Angeles area. This may reflect the general perception that the Bay Area places more value on transit, while commuters in Los Angeles prefer to drive alone. Thirty-three percent of the respondents in the Bay Area favored lane conversion over the addition of a new HOV lane, or reconstruction of the shoulder. This number dropped to 27 percent in the Los Angeles area.

- In March 1994, a similar survey was conducted in the Sacramento area. A total of 606 respondents were included in this study. In general, there was a good deal of agreement in the responses among the residents in three areas.

- The first part of the survey included a series of questions and statements which participants responded to on a four point scale. The scale ranged from strongly agree to strongly disagree.

  - The first statement was that HOV lanes were not fair to non-users and people who cannot carpool. Seventy percent of the people in both Los Angeles and San Francisco disagreed or strongly disagreed with this statement. The second statement was that carpool lanes are a strong incentive to carpool. Approximately 73 percent of the participants agreed or strongly agreed with this statement. In response to the statement that carpool lanes were a safety hazard, 70 percent disagreed or strongly disagreed. As a whole, these results indicate very strong support for HOV lanes. In Sacramento, the responses were even more supportive of HOV lanes.

- The next section of the survey asked respondents to identify their preference among the following three options: build a new lane, rebuild the shoulder, or convert a lane into a carpool lane, given a desired objective.

- When the objective was to have the biggest improvement in traffic flow, building a new lane was the most common choice. This was followed by rebuilding the shoulder lane conversion.

- When implementing the HOV lane with the least expense and with the least construction time and traffic delays was the objective, lane conversion was identified as the preferred choice.

- The most significant question was the last one, which asked respondents the identify the preferred alternative for a freeway that they commonly used. Responses indicated that rebuilding the shoulder was the most preferred alternative. On average in all the regions studied, however, 30 percent of the respondents supported the lane conversion option.

- The survey results seem to indicate that the public appears to be receptive to at least the concept of converting a mixed use lane to an HOV lane. The notion of alleviating congestion was the most important factor in any of **the** analyses conducted. This indicates that the lane conversion option should not be summarily dismissed. Lane conversion can be successful if the implementation is well managed, and includes marketing and public support activities.

Strategies for Optimizing Roadway Space
Christopher Leman, Institute for Transportation and the Environment

Dr. Leman discussed HOV conversion and related issues. This topic was also addressed in a paper prepared for the conference. Dr. Leman included the following elements in his discussion.

- Most evaluations of HOV lane construction have failed to consider the impact on transit. In many ways, the relative position of transit is diminished by the construction of new HOV lanes. Furthermore, new HOV lanes may produce additional single occupancy vehicles (SOVs). The result of the new capacity created by removing buses and carpools from the general purpose lanes is similar to building a new general purpose lane for SOVs. The costs often associated with new HOV lanes tend to be fairly high. All of these factors warrant a cautious approach to the construction of new HOV lanes.

- There have been several cases where a facility was designed as an HOV lane, but has been converted back to a general purpose lane. There are also a number of examples where vehicle occupancy requirements have been reduced or relaxed. Many years ago, exclusive lanes were called bus lanes. Now these lanes are HOV lanes, and acceptable occupancies are as low as 2+ persons per vehicle.

- There are no safeguards to avoid this type of degradation. One reason occupancy requirements have been reduced on some facilities is the dreaded empty lane syndrome. As a result, there are less efficient HOV facilities that do not pursue the original goals of mass transit. One of the most successful HOV facility in the world is the contraflow lane on the approach to the Lincoln Tunnel in New York City. It carries more people in the peak-period than any other facility.

- A more careful examination of lane conversion alternatives is needed, given the high cost of HOV lanes and these issues. It is rare for conversion studies to be conducted. Conversion was not even evaluated as an option in many recent studies.

- There may be more public opposition to new HOV lanes than to converting existing lanes for HOV use. The fact that there is a lot of money being spent to market new HOV lanes should not be forgotten.

- It is important to compensate for any potential uses associated with conversion. For example, in Toronto, the Ministry of Transportation responded to public concern about conversion and made adjustments as necessary. This resulted in a facility that was more attractive to the public. It is important that transportation engineers make a concerted effort to seriously consider lane conversion in the future.

HOV Design and Safety Issues

Charles J. O'Connell, California Department of Transportation-Presiding

Effective HOV Design with Non-Standard Features: The Cross Westchester Expressway Experience

Bernard Kalus, HNTB Corporation

Mr. Kalus discussed his experiences retrofitting a barrier separated HOV lane onto the Cross Westchester Expressway. A paper on the Cross Westchester experience was also available. The following points were covered in his presentation.

- Congestion is one of the most serious problems facing many metropolitan areas today. At the same time, issues related to the environment, the economy, right-of-way availability, and numerous regulations prevent simply widening the roadways. In response, innovative methods to use existing facilities more efficiently must be developed. HOV lanes are one example of using roadways more efficiently.

- The Cross Westchester Expressway corridor is a very heavily travelled corridor. This corridor was one of the first candidates the New York State Department of Transportation considered for a possible HOV facility.
- The Cross Westchester Expressway is located just north of New York City. Like many other cities around the country, people have started moving out of New York City. Westchester County was one of the first places in the New York area that people moved to.

- The Cross Westchester expressway acted as a magnet for development. Since opening of the Expressway in 1989, almost 50 percent of all new development in the county has occurred within two miles of the corridor. This has caused the volumes on the Expressway to exceed capacity.

- Three design alternatives were developed to help reduce congestion in this corridor. The first was a basic rehabilitation, which maintained the facility as a six lane freeway and implemented some operational improvements. Another design added a lane in each direction, resulting in an eight lane facility. A third design included a barrier separated, reversible HOV lane. A reversible lane was a reasonable alternative because although the Cross Westchester Expressway is located in a suburb-to-suburb commute corridor, it has an unbalanced directional distribution, peaking in the eastbound direction in the morning, and in the westbound direction in the evening.

- Each of the three design alternatives satisfied the goals and objectives established for the corridor, but the HOV option was the only one that satisfied all of the goals and objectives. Further, it did the best job of accommodating future growth. The only problem was that the HOV alternative is estimated to cost approximately $500 million for the eight miles of reconstruction. Much of this cost is due to the frequency of bridges that carry or cross the mainline. There are 30 bridges in the eight mile section.

- Modified alternatives were developed to help reduce this cost. For example, the lane and shoulder widths were reduced underneath the bridges. The typical cross section includes I I foot lanes, 4 foot left shoulders, and a full outside shoulder.

- If a reduced cross section was implemented throughout the entire corridor, approximately $100 million could be saved. Safety concerns had to be addressed, as did the issue of whether FHWA would approve the reduced standards.

- Since New York had very little experience in the area of HOV lanes, other agencies that had experience with reduced lane and shoulder widths were examined. Houston and California were the leaders in this area. The Houston system was used as a basis for the research and development for the construction of the HOV lanes on the Cross Westchester Expressway.

- Preliminary analysis indicated that reducing the shoulders would cause the barrier separations to interfere with the line of sight to a 6 inch object. As a result, the three main points considered were the reduction of lane width, the reduction of shoulder width, and the obstruction of sight to a 6 inch object.

- It was discovered that the modifications being considered have been used in a number of places. Caltrans has had this kind of facility for over twenty years, and Houston, Denver, and Boston also have experience with reduced width facilities. Accident rates in these cities before and after implementation of the HOV lanes with reduced standards were compared. In most cases, the accidents decreased with the implementation of the HOV lanes. Apparently the level-of-service improvements overshadowed any safety impacts of the reduced sight distance.

- Left shoulder reductions seem to have very little, if any, impact on traffic operations. Right shoulder reductions, however, should be avoided at all costs. Studies indicate that improvements to a roadway to allow sight of a 6 inch object are not very cost effective.

- All of the research indicated that the modifications proposed were safe, if correctly implemented. A priority list of reductions was developed. This list suggested that reductions should be made in the following order:

  - The left shoulder should be reduced to 4 feet.

  - The right shoulder should be reduced from 10 feet to 8 feet.

  - The lane width should be reduced to 10 feet.

  - The left shoulder should be reduced to two feet.

  - The right shoulder should be reduced, but never eliminated.

- The corridor was analyzed using the prioritized list to find where reduced standards could save money. Forty-seven sites were found where reduced lane and shoulder widths would reduce the cost, and minimize the impact on the right-of-way, and the environment. Cost estimates were prepared for these areas to determine potential savings. Fifteen of the sites chosen were evaluated in greater detail, modification to these 15 sites resulted in savings of more than $60 million in construction costs. But only three of the 15 reduced width locations were accepted by FHWA.

- Four lessons were learned from this experience:

  - If federal funding is involved, FHWA should be involved very early in the planning process

  - Do not expect blanket approval from FHWA.

  - Cost impacts alone are not sufficient to justify FHWA approval.

  - There may be differences in the approaches of different FHWA districts.

Freeway Signing Needs for HOV Users
Marty T. Lance, Texas Transportation Institute

Ms. Lance discussed user information needs for HOV lanes and ways to present this information to drivers. A paper on this topic was also available. The following points were covered by Ms. Lance in her presentation.

- The Manual on Uniform Traffic Control Devices (MUTCD) does not contain a specific signing policy for HOV lanes. As a result, signing practices differ throughout the country. A range of drivers, from experienced bus drivers to unexperienced or unfamiliar drivers use HOV lanes. Thus, signing should take these differences into consideration.

- According to a 1971 highway user information need study, drivers need information on:

  - Control, which includes stopping, starting, **and** controlling speed.

  - Guidance, which includes reacting to traffic and weather conditions.

  - Navigation, which includes following a route **or** planning a trip.

- Drivers have expectancy regarding road conditions, signs, access, when information should appear, and what the information should look like. HOV signs should follow driver expectancy and need to be distinguishable from the freeway signs.

- Extensive information needs to be relayed at the entrances of HOV lanes. Information on occupancy requirements, permitted vehicles, time of day restrictions, and future access points must be conveyed. This information should be presented so that drivers can determine their eligibility and make a smooth transition into the lane and not experience information overload.

- Advance signing would be one way to avoid driver information overload. One suggestion is to place signs indicating which side the motorist would enter the HOV lane one to one-half miles prior to the entrance. Signs relaying occupancy requirements, vehicle and time of day restrictions should appear about one quarter of a mile from the entrance. A sign listing vehicles which are not permitted on the HOV lane should follow this sign. Directly over the entrance, the occupancy and time of day requirements should be displayed again. This sign should be large and easy to read for motorists who may have missed previous signs.

- Once on the HOV lane, real-time information can be provided by lane use control signals. Speed limit signs for the HOV lane should appear on the right side of the lane. The signs should be standard speed limit signs with the addition of a diamond in the top corner. Emergency response signs, indicating where a motorist should go in case of a breakdown, should also appear on the HOV lane.

- Advanced signing of exits, similar to those on freeways, should be used. The signs should also contain the destination and location of future exit points. Guide signs with arrows pointing out the specific exit location should indicate the destination. Warning signs at HOV entrances are needed to alert motorists travelling on the HOV lane to merging traffic.

- The MUTCD classifies traffic signs into three different categories: regulatory, guide, and warning. HOV lane signs should also use these three categories. The regulatory signs should include information on vehicle types, occupancy, and time of day restrictions. These signs should be black on white panels. The warning signs should provide information on when the lane will end or when traffic will be entering the lane. These signs should be black on yellow panels. Guide signs should inform drivers of upcoming exits and should be white on green. The white on black diamond should appear on all three types of signs.

- Signs on HOV lanes should appear on overhead structures whenever possible except for speed limit or guide signs. These signs do not contain a large amount of information and can be easily read when mounted on the barrier.

- A few changes to the MUTCD would alleviate some of the problems with HOV signing. These changes include the use of the term HOV lane in addition to the reservation of the diamond symbol exclusively for HOV lanes, the additional text explaining HOV regulatory signs, and the inclusion of a typical signing layout.

Tight HOV Designs and Construction Detours that Work

George R. Hale, HNTB Corporation

Mr. Hale discussed the operation of HOV facilities with reduced cross sections. He also outlined some of the effects construction of freeway and HOV lanes may have on traffic conditions. He described various roadways and discussed the operation of different HOV facilities. A paper on this topic was also available. Mr. Hale included the following elements in his discussion.

- Reduced cross sections are often considered due to limited right-of-way. There are many treatments to minimize the impact of reduced cross sections; however, these include the use of the edge of the foundation of the sign structure for the vertical wall section and use of a taper into the barrier to maintain as much shoulder as possible. The placement of lighting may also influence the configuration of reduced cross sections. Additional lighting using the median may justify a new barrier configuration to avoid an accordion shape along the barrier.

- A number of treatments can be used to help manage traffic during construction. For example, one of the first things done on a construction site in California is the erection of some type of visual screening on top of the temporary barrier, so drivers are not distracted by the construction work. This has been extremely effective, although it should be recognized that visual screening may restrict sight distance.

- Construction activities often cause detours through areas with less than desirable roadway conditions. Fortunately, motorists seem to be able to adjust to the temporary conditions. Providing adequate signing and advanced information about detours is important for motorists.

- Construction access to the median may also be a problem with many projects. Access points should be identified early in the process and adequate taper distances should be provided.

- It appears that most areas where a tight design has been used, drivers become used to the reduced sections and ad-just their behavior accordingly.

Safety Experience of the Pie-IX Boulevard Contraflow Bus Lanes and Other Corridors in Montreal

Robert Olivier, Societe de Transport de la Communaate Urbaine de Montreal

Mr. Olivier discussed the impacts a contraflow bus lane has on traffic operations in Montreal. A paper on this topic was also available. Mr. Olivier included the following elements in his presentation.

- The contraflow bus lane was implemented in place of a subway that was planned. The lane, which operates during peak hours, is eight kilometers long, and has 39 intersections.

- Traffic signals are used to alert drivers and pedestrians of the contraflow bus lane. The system is operated mainly with traffic signals and signs, but there are still some intersections with cones. In some places, intersections with small streets are being completely closed.

- When the system is operating and the bus lane is being used, there is a sign with a red X to show that the lane is closed. Green arrows indicate allowable movements.

- The buses are equipped with a blinking arrow to help alert motorists. A radio communication system is also used to help bus operators, central dispatchers, and other transit personnel. There are separate traffic lights for the buses. Overhead signals notify drivers if there is an obstruction in the zone being entered.

- As passengers leave the bus shelter, there are signs reminding them to look for the buses. Safety is a major concern, since the buses are travelling opposite the direction expected. Pedestrian crossings are also clearly marked.

- The bus shelters are equipped with telephones that are connected to the 911 service. Overhead signs provide information on bus schedules and can be used to alert passengers of any problems.

- The contratlow bus lane began operations in mid 1990. In the first six months, there were sixteen accidents involving buses. Most of these were caused by automobiles making illegal left turns. Since then, the accident rate has continued to decrease. In the first five months of 1994, there has only been one bus accident. The accident rate for the curb side buses has also decreased. The total number of accidents has decreased, although the number of buses has almost doubled.

- There have only been three pedestrian accidents in the contraflow bus lane, all of which occurred during the first year of operation. Two of the accidents were minor, the third was a pedestrian trying to commit suicide. There have not been any fatal accidents.

- When the intersections were looked at one by one, it was discovered that some of them were quite dangerous. As a consequence, left turn restrictions have increased. Initially, left turns were prohibited only during peak-periods. Now left turns are prohibited throughout the day at some intersections.

- Passengers were asked to evaluate the overall safety of the lane. Ninety-two percent thought it was safe overall, and 68 percent thought the left turn aspect of the system was safe. Walking to the median shelter, and walking within the shelter was also considered safe.

- Potential actions to improve the system may include limiting left turns to one or two intersections, increasing enforcement of illegal left turns, continuing education for drivers and pedestrians, and adding traffic signs.

Bus Transit Operations on HOV Systems

Steve Parry, Los Angeles County Metropolitan Transportation Authority-Presiding

The Impact of HOV Facilities on Transit

Vukan R. Vuchic, University of Pennsylvania

Dr. Vuchic discussed the impact that HOV facilities have on bus operations. A paper on this topic written by Dr. Vuchic, Shinya Kikuchi, Nikola Krstanoski, and Yong Eun Shin was also available. Dr. Vuchic highlighted the following elements in his presentation.

- In the 1970s, the importance of creating a separate right-of-way for transit to make it competitive with the automobile was recognized. Excellent bus systems were developed around the world to create more balanced transportation systems.

- Bus services in most cities operate on arterial streets and highways with general purpose traffic. Buses on these routes make frequent stops to pick up and drop off passengers. In order to attract more commuters, transit systems need to provide an attractive alternative to personal autos. Approaches to accomplish this could include attractive buses, special infrastructure, and high performance services.

- Bus transit systems should utilize a separate right-of-way to provide higher speeds, increase reliability, and enhance safety. Priority treatments give buses a more distinctive image, in addition to enhancing performance.

- For a bus system to be complete, routes need to serve multiple origins and destinations throughout the day. A system that centers on a single location, such as a downtown area, and provides service only during the peak-periods will only attract commuters and will not provide adequate mobility to individuals without automobiles. Transit systems that focus primarily on commuter traffic may be the least distinctive of all priority systems.

- The implementation of separate HOV lanes has helped promote HOVs, and has increased the efficiency of highway facilities. Previously, exclusive bus facilities were not always filled with buses, which created the empty lane syndrome. Now, HOVs are allowed to use many of these facilities, on the premise that bus service will not be compromised.

- A number of issues arise when busways are changed into HOV facilities. On the positive side, travel times are reduced for vanpools and carpools, congestion is decreased on parallel general purpose lanes, and the productivity of the entire facility is increased. On the negative side, the performance of buses is decreased due to the mixed flow, bus service loses the distinct advantage previously held, and consequently some bus patrons may divert to automobiles or carpools. This may result in a loss of revenue to the transit system. The positive impacts affect non-bus users and all the negative impacts affect bus users and bus operators.

- A study was conducted at the University of Pennsylvania to determine whether lane conversion or lane addition was more favorable. This study suggested the best case was to take a facility without any HOV or transit system, and convert a lane for exclusive bus use. The worst case was to add an HOV lane. If HOVs are to share a lane with the buses, the best case was implementation of a 4 + vehicle occupancy requirement **on** the HOV lane.

- The current trend in some cities is to transition from very favorable conditions for transit to the least favorable conditions for transit. This is counterproductive, because it does not discourages the use of SOVs, as required by the Clean Air Act Amendments of 1990 and the ISTEA. This trend needs to be reversed by treating buses as a priority mode of transportation, rather than as a supplementary mode of transportation.

- The study recommended that conversion of existing lanes should take precedence over the addition of new lanes. It also suggested that transit funds should not be used for HOV facilities unless the development of the HOV facilities would benefit buses. Further, changes in bus or HOV facilities should be subjected to the environmental impact statement process. Finally, the study suggested that HOV facilities should not be developed as a substitute for busways.

- Although HOV facilities are an effective and positive way to maximize the number of riders, the success of HOV facilities should not come at the expense of transit ridership. The public should be educated on both the long range goals of the area, and the transportation system.

Bus Transit Issues and Services on Connecticut HOV Lanes

Lisa Rivers, Connecticut Department of Transportation

Although representatives from the Connecticut Department of Transportation were unable to attend the conference, a paper on this topic written by Ms. Rivers was made available. The paper included the following points.

- There are currently two 10 mile long HOV facilities in Hartford, Connecticut. These HOV lanes are separated from the general purpose traffic lanes, and have a 2+ vehicle occupancy requirement. Access to the HOV lanes is provided via the mainlanes, and via direct access ramps. Information about use of the HOV lanes is provided through signs and through low wattage radio broadcasts.

- The HOV lanes have improved on-time performance and consistency for transit and HOVs. Some commuter express routes that operate on the HOV lanes have realized a five minute reduction in travel time.

- Following a reduction in the minimum occupancy requirement in 1993, HOV lane utilization increased dramatically. HOV lane utilization increased from 3 15 to 913 vehicles in the three hour morning peak-period.

- Both of the HOV facilities terminate prior to the downtown area. A study is currently in progress to determine the potential for extending these facilities into the city of Hartford. There is also a project under consideration to install traffic signal pre-emption at various intersections to further reduce commuter express bus travel time, this would be implemented in conjunction with an HOV lane on one of the routes.

The El Monte Busway: A Twenty-Year Retrospective

Carol Silver, Los Angeles County Metropolitan Transit Authority

Ms. Silver discussed the El Monte Busway and the changes that have occurred in operations over the years. A paper on this topic written by Jon Hillmer and Steven T. Parry, both from the Los Angeles County Metropolitan Transit Authority, was also available. Ms. Silver covered the following topics in her presentation.

- The El Monte Busway links the San Diego Valley area to downtown Los Angeles. The construction of the facility began in 1969, and over seven miles were complete by 1973. The first segment operated from Santina Avenue to the Long Beach Freeway. The El Monte bus station initially had parking spaces for 700 automobiles.

- The western segment of the facility opened a year and a half later. A one mile extension into downtown Los Angeles was complete in 1989.

- A number of features make the El Monte Busway an exceptional transit system. It has two on-line stations located at the University and the Medical Center, and the El Monte Station, which is off-line. Ten express bus routes access the busway and interface with ten local service routes at the El Monte Station. At the El Monte bus station. There are 1,800 parking spaces at this facility and access ramps connecting to Del Mar Avenue and the I-7 10 Freeway are provided. The busway has extensive feeder lines, as well as park-and-ride facilities. Pedestrian walkways are located at the University and Medical Center stations to provide easier and safer access for bus riders.

- Service on the busway has continued to evolve. In the beginning, the El Monte Busway served approximately 4,000 riders daily on 30 peak and 42 off-peak trips. Three years later, there were 270 peak and 225 off-peak vehicle trips. In 1976, there were 330 peak and 495 off-peak vehicle trips. Also in 1976, the busway was opened to 3 + carpools.

- In retrospect, it appears that even though the running time of buses has not changed, allowing HOVs on the busway has had a detrimental effect on the buses. The price of parking, the length of the commute, and other factors have made carpooling more attractive than taking the bus for many commuters. As a result, ridership levels have decreased in recent years. Eliminating HOVs from the busway would have a negative impact on ridesharing overall, however.

Proposed Bus Operations and Facilities on the I-110 Harbor Transitway

R. Scott Page, Los Angeles County Metropolitan Transit Authority

Mr. Page discussed the plans for the existing busway along the I-l 10 Harbor Freeway in Los Angeles. He summarized the different alternatives for this transitway and the advantages of each. A paper on this topic written by Mr. Page, Stephen T. Perry, and Jon Hillmer, from the Los Angeles County Metropolitan Transportation Authority, was also available. Mr. Page summarized the following points in his presentation.

- The Harbor Transitway runs from downtown Los Angeles to the Artesia Station. It encompasses approximately 10.3 miles of exclusive guideway with 2.6 miles elevated, and 7.7 miles at-grade. There are two lanes in each direction and nine on-line stations. Eight of the stations will have park-and-ride lots with a total of 2,750 parking spaces. Currently there are six existing bus routes using the Harbor Freeway with 3,000 riders daily. On the local routes, there are approximately 9,300 daily riders.

- There were three alternatives that were considered for further study. The first alternative maintains operation of the existing express routes, and includes modification of the local surface street routes to connect to the stations. The second alternative would create a single hub HOV system. The Artesia Station would act as the hub. Under this system, high frequency express service would be provided to downtown Los Angeles. Current Harbor Freeway express routes would be redesigned to act as feeder routes. The final alternative was a dual hub HOV system linking the Harbor Transitway and the El Monte Busway. Linking these two systems would reduce the layover time, and would reduce costs. This option would increase capacity and reduce trave times.

- The hub and spoke concept was designed to provide an interface point where short distance, lower demand, and low frequency routes could feed into a common hub. Passengers then change buses to utilize the high speed service. Many airlines operate using this concept.

- These are a number of issues that must be worked out with the alternative. Transit services must be integrated to eliminate duplication and reduce operating costs. Existing terminals must be redesigned or expanded to increase capacity. The El Monte Bus Station is one of these terminals. Articulated buses must be acquired and modification of the existing facilities will be needed to accommodate theses buses. A new fare structure and new fare collection procedures will need to be established. Finally, procedures to comply with the competitive bidding guidelines mandated by FTA will need to be developed.

APPENDIX
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