Invited Student Paper: Strategies for High Intensity Bus: Best Practices for Operating Buses in Managed Lanes

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ABSTRACT
This paper examines high intensity bus (HIB) service in managed lanes in the US. The research questions are as follows: 1) What best practices are being deployed by transit agencies with notable systems? 2) What are the benefits of high intensity bus service? High intensity bus, also known as express bus in managed lanes, is an emerging transit option that was only federally recognized in the last five years, so little has been published on its best practices. This gap was addressed by analyzing recent statistics on high intensity bus and by interviewing a few of the top-performing agencies. Case studies were conducted of the systems in Virginia/DC, Los Angeles, Dallas, and Houston, and the research team observed which practices were distinctly successful. The research found that the best systems utilize express park and ride routes, neighborhood oriented routes, and transfer routes. The benefits of high intensity bus are often long-term and indirect.
INTRODUCTION

Addressing travel needs, particularly in congested corridors, seems to interminably challenge the thinking of planners and engineers. The primary options of roadway expansion and transit expansion face financial and physical limitations. One approach that simultaneously offers additional capacity for personal vehicles and transit riders is managed lanes that include express bus service, termed High Intensity Bus. Often, roadways are constructed by state departments of transportation and bus services are provided by local transit agencies. Managed lanes represent shared roadway use with a combination of pricing, vehicle eligibility, and access control (1). Personal vehicle access can range from a single occupant (who must always pay a charge) to two or more occupants for entrance. Some systems allow multiple occupant vehicles to travel without charge, while others may charge a fee for any personal vehicle. In 2012 a new category called High Intensity Bus (HIB) was introduced in MAP 21. It is expected to be a growing transit category that is one step above local bus and slightly less than a fixed guideway system. The FAST Act, signed December 2015, continues HIB by including funding under the State of Good Repair category. HIB is an important component among transportation strategies, but the clearest best practices for buses that operate in managed lanes are not readily identifiable. This research examines how some of the most successful US transit agencies operate and market their HIB services. This research establishes best practices from a set of cases, highlighting their characteristics and their measures of success. The research questions are as follows: 1) What best practices are being deployed by transit agencies with notable systems? 2) What are the benefits of high intensity bus service?

BACKGROUND

Since the inclusion of HIB in both MAP 21 and the FAST Act, the place of contemporary express bus service in the transportation toolbox has emerged. Historically, express buses traveled a number of miles closed-door and may have been on local streets, never entering a freeway. Over time, express buses began to operate on freeways, often in managed lanes. In managed lanes, the operating agency proactively manages demand and available capacity by applying various strategies to optimize traffic flow and/or vehicle throughput. Two decades of National Transit Database data (2) on buses operating in managed lanes show an increase in lane miles with rapid growth beginning in the late 1990s (Figure 1).

![Growth of Managed Lanes, US Total](image)

**FIGURE 1 Growth in US managed lane miles**

Note: Years 1997 to 2001 are in direction route miles; years 2002-2012 are in lane miles.
Data from 2014 (2) show continued emphasis on non-exclusive HIB lane miles. There are 50 systems with HIB ranging from one lane mile to more than 200 lane miles. Table 1 presents the top 25 systems operating with more than 24 lane miles. The systems identified for further analysis of best practices in this research are highlighted. Los Angeles Metro represents the median system, with Dallas DART right above it and Houston Metro right below it. Potomac PRTC has decades of operating experience and is among the nation’s top three HIB systems. By selecting these four systems, this research creates a framework of best practices for implementing HIB. For new systems, the median cases provide a set of median best practices to follow, and for established systems the Potomac PRTC system offers a perspective on one of the most extensive and long-serving systems achieved so far in the United States.

**TABLE 1 Top 25 HIB Systems as of 2014 (case studies in yellow)**

<table>
<thead>
<tr>
<th>Transit Agency</th>
<th>Non-Exclusive High Intensity Bus (lane miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Clara Valley Transportation Authority (VTA)</td>
<td>247.8</td>
</tr>
<tr>
<td>Orange County Transportation Authority (OCTA)</td>
<td>240.8</td>
</tr>
<tr>
<td><strong>Potomac and Rappahannock Transportation Commission (PRTC)</strong></td>
<td><strong>208.2</strong></td>
</tr>
<tr>
<td>Regional Public Transportation Authority</td>
<td>169.0</td>
</tr>
<tr>
<td>City of Phoenix Public Transit Department</td>
<td>117.7</td>
</tr>
<tr>
<td>King County Department of Transportation - Metro Transit Division</td>
<td>98.2</td>
</tr>
<tr>
<td>Central Puget Sound Regional Transit Authority (ST)</td>
<td>91.3</td>
</tr>
<tr>
<td>MTA New York City Transit (NYCT)</td>
<td>77.3</td>
</tr>
<tr>
<td>Antelope Valley Transit Authority (AVTA)</td>
<td>77.2</td>
</tr>
<tr>
<td>Transportation District Commission of Hampton Roads (HRT)</td>
<td>72.8</td>
</tr>
<tr>
<td>Fairfax Connector Bus System (Fairfax Connector)</td>
<td>69.5</td>
</tr>
<tr>
<td>Dallas Area Rapid Transit (DART)</td>
<td>66.1</td>
</tr>
<tr>
<td>Los Angeles County Metropolitan Transportation Authority</td>
<td>65.9</td>
</tr>
<tr>
<td>Foothill Transit</td>
<td>62.3</td>
</tr>
<tr>
<td><strong>Metropolitan Transit Authority of Harris County, Texas (Metro)</strong></td>
<td><strong>61.0</strong></td>
</tr>
<tr>
<td>Martz Group, National Coach Works of Virginia (NCW)</td>
<td>59.8</td>
</tr>
<tr>
<td>Golden Gate Bridge, Highway and Transportation District (GGBHTD)</td>
<td>58.1</td>
</tr>
<tr>
<td>Washington Metropolitan Area Transit Authority (WMATA)</td>
<td>56.6</td>
</tr>
<tr>
<td>Miami-Dade Transit (MDT)</td>
<td>52.4</td>
</tr>
<tr>
<td>Denver Regional Transportation District (RTD)</td>
<td>50.6</td>
</tr>
<tr>
<td>Metropolitan Council</td>
<td>48.5</td>
</tr>
<tr>
<td>Suffolk County Department of Public Works - Transportation Division (ST)</td>
<td>46.9</td>
</tr>
<tr>
<td>New Jersey Transit Corporation (NJ TRANSIT)</td>
<td>35.8</td>
</tr>
<tr>
<td>City and County of Honolulu Department of Transportation Services (DTS)</td>
<td>34.7</td>
</tr>
<tr>
<td>Broward County Transit Division (BCT)</td>
<td>24.6</td>
</tr>
</tbody>
</table>
Congestion in major urban areas is steadily increasing. According to Higgins (3), “often the congestion problems at suburban activity centers have spilled over onto through traffic routes in the vicinity and [have] affected mobility of those going to urban centers.” As opposed to the older idea that transit can positively reduce congestion, today we recognize that HIB simply offers an alternative for people stuck in traffic congestion (4). HIB does, however, tend to reduce the requirements for downstream parking. Millard-Ball et al. (5) write of the reduced need for parking as a result of ridesharing by carpoolers and transit users. Through the utilization of express buses, commuters are able to access central business districts (CBD) and other centers more quickly due to the exclusion of frequent stops. The travel time of express buses can be further reduced when the bus travels on a managed lane. Critical to attracting riders is the travel speed. According to Scott and Soja (6):

> The most successful transit options will be those which compete most closely with the automobile, and that means that they should be able to connect many low density communities, provide relatively immediate response times, and overall door-to-door costs and travel times which approximate those of the automobile (pp153).

Outwater et al. (7) writes about two categories that influence choice rider decisions to utilize transit. The first category includes variables in the traditional mode choice model, including fare, travel time, passenger income and auto availability. The second category comprises elements not generally used in the model such as reliability, station comfort, on-board amenities and the availability of real-time information. Another consideration by Outwater et al. is how aware potential users are of transit service proximate to their origins. They write that most travelers are informed of transit options within walking distance of their home, but fewer are aware of services beyond three miles.

Studies show that there is a connection between the provision of bus amenities and increased bus ridership. Best practices from Bus Rapid Transit (BRT) systems can be adopted to increase the attractiveness of HIB systems. Transit Cooperative Research Program’s (TCRP) Report 118 (8) notes that new BRT systems experienced higher ridership increases than expected because of features including vehicle attributes, ITS applications, and BRT branding. Some of the most commonly used incentives include on-board amenities, vehicle technological advances and discounted fares. In 2004, all of the aforementioned incentives were applied when creating the Metro Area Express (MAX) in Las Vegas. The MAX bus system was an innovative project sponsored by the Federal Transit Administration and was intended to “increase capacity, improve passenger comfort and convenience… (9).” To accomplish the goal, the MAX was equipped with a host of on-board amenities including interior bike racks, multiple-door boarding and off-board fare collection. By having the fare collector located off-board, doors opened simultaneously allowing patrons to enter or exit the bus. Using both doors increased boarding and alighting time, increasing the vehicle’s average speed. In extremely hot climates rapid door opening and closing helped retain the interior climate of the bus.

For New York City, a TRB report entitled “Effects of Fare Incentives on New York City Transit Ridership” (10) showed that the introduction of fare incentives boosted ridership. During the mid-1990s, the New York transit agency introduced free intermodal transfers and express bus fare reductions. Several other transit agencies including those in Houston, Los Angeles and Seattle have permitted free transfers with some variations.

Important to agencies that are considering bus service in managed lanes are questions about attracting riders to the buses. Strategies that appeal to riders are clearly travel time and...
cost, but in addition there may be other benefits that enhance the transit experience, such as fare incentives, perceptions of safety and guaranteed ride home programs. Technological advances in fare payment methods, vehicles and on-vehicle technologies are available to optimize services.

METHODOLOGY
This research provides a new perspective on HIB based on the latest data and a review of key transit systems currently using HIB. The methodology consisted of internet searches, literature reviews, expert interviews, and an analysis of all of the agencies currently offering HIB. From the list, four successful HIB operations were identified. System characteristics, incentives, and technology applications were extracted to provide a summary of best practices. Cities represent the east, west and southern areas of the United States. An interview instrument facilitated data retrieval, standardized queries to each agency, and better informed our study of each agency. Finally, the information gathered was assessed and synthesized to determine best practices.

EXPRESS BUS SERVICE STRATEGIES
Transit agencies run express bus service in managed lanes using several strategies. Barker and Polzin (4) identified six strategies that are in use (Figure 2). The first of these, Dedicated Routes, is most like rail, with buses stopping at stations on the facility granting patron access. In the Express and Park and Ride option, patrons board a bus at a parking lot and the vehicle travels non-stop to the destination. With the Neighborhood-Oriented Services option, buses circulate collecting passengers along a typical bus route, then enter the facility and travel non-stop to the destination. Similarly, buses in the Feeder Service option circulate in the neighborhood collecting passengers. However, upon arrival at the facility the bus route ends and patrons transfer to a bus that will travel non-stop on the facility. The Reverse Commute Service option allows for patrons traveling from the urban core to locations on the edge. Timed Transfer Route Network introduces major activity generators outside the central business district. The implication in this option is that patrons may board or disembark at the on-line station locations and connections are pulsed to the destination to diminish wait time.

BENEFITS OF BUSES IN MANAGED LANES
Express bus service in managed lanes is a growing transit strategy that offers a number of advantages. In traditional economic terms the total combined advantages are termed “benefits,” and the total benefits less costs are termed “net benefits.” Benefits may occur to users, to the local population, and/or to society at large. Benefits are typically calculated over a specified time period for comparison under different alternatives, such as a “with express bus” scenario and a “without express bus” scenario. Lane management strategies may be adopted to increase capacity, control demand, provide more choices to users, improve safety, and generate revenue (11). Additional objectives of express bus include improved transit system operating efficiency, direct benefits to users, increased auto-to-transit mode shifts, increased mobility, more accessibility, greater social equity, improved public health, and reduced environmental impacts (12 & 13).

The benefits of the express bus strategy, as expressed in the literature, are summarized in Table 1 and are individually described in the following subsections. According to an express bus benefit-cost analysis by Sullivan and Burris (14), “the majority of benefits are derived from travel time savings.” However, in the long-term express bus service can improve the overall...
FIGURE 2 Transit operating options using managed lanes (4).
efficiency of the entire transit system, influence modal choice, and even stimulate multimodal
development. Express bus benefits that are indirect, qualitative and long-term are not typically
included in conventional benefit-cost models (12 & 13). Excluding these important benefits from
a benefit-cost analysis can result in an incomplete analysis that could lead transportation officials
toward a sub-optimal decision. Unfortunately, conventional analysis of express bus relies
primarily on direct traffic impacts and total travel time impacts. Even worse, there are few if any
integrated models that analyze comprehensive change to a total traffic network. If additional
benefits such as those listed in Table 2 are considered, decision makers gain a more complete
picture of the advantages of express bus.

Direct Benefits

The two primary direct benefits typically considered in most evaluations of express bus are
traffic congestion and travel time. Congestion can be measured either as hours saved per year,
vehicle travel speed, or peak delay in vehicle-hours per day. Travel time savings are typically
measured as the value of travel time saved, bus frequency in vehicle-trips per hour, and on-time
performance. Other ways of calculating these two most common benefits include total capacity
in people per traffic lane, increased mobility in passenger-miles per hour, and ridership
distribution in peak vehicles per hour. Other important direct benefits that are typically
considered include energy conservation (fuel savings), pollution reduction (reduced emissions),
and accessibility (access to destinations).

Indirect Benefits

Social equity is a key indirect benefit, measured as the degree to which the system is affordable
and accessible to low-income population segments. A related concept is the fair allocation of
public road space, given the fact that buses carry far more passengers during peak periods than
regular traffic lanes. While pollution prevention is often used in express bus models,
improvements to public health (in quality-adjusted life years) are less common, perhaps because
the benefit is more indirect (15). The same is true of traffic safety (measured as the value of
accidents prevented) and downstream parking congestion. Lastly, express bus systems can
promote, over the long-term, transit-oriented development, compact urban densities, and
walkable communities. These indirect benefits are highly valued yet rarely included in the
analysis of express bus benefits.

Incentives

In order to actualize the above described benefits, a large number of drivers must be incentivized
to mode shift from cars to transit, specifically to express bus. Cost factors are an important
incentive. Discounted blanket pricing, such as SelectPass on the Washington, DC Metro, allows
passengers to pay one monthly amount at a discount (16). Free or discounted parking and transit
is available to commuters New York, San Francisco, and Washington, DC. A recent study of
transit incentives found that when free parking at the destination was available, transit incentives
were not as effective (17). More specific information is available on a case-by-case in the
following section.
Table 2. Benefits of Express Bus Service in Managed Lanes.

<table>
<thead>
<tr>
<th>Category</th>
<th>Benefits</th>
<th>Measured As…</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Benefits</td>
<td>Reduced traffic congestion</td>
<td>hours saved per year</td>
</tr>
<tr>
<td></td>
<td>Increased vehicle travel speed</td>
<td>vehicle-miles per hour</td>
</tr>
<tr>
<td></td>
<td>Increased ridership</td>
<td>passengers per vehicle-mile</td>
</tr>
<tr>
<td></td>
<td>Increased trips</td>
<td>passengers trips per mile</td>
</tr>
<tr>
<td></td>
<td>Ridership dispersed over time</td>
<td>peak ridership per mile</td>
</tr>
<tr>
<td></td>
<td>Decreased peak delay</td>
<td>vehicle-hours per hour</td>
</tr>
<tr>
<td></td>
<td>Increased on-time performance</td>
<td>percent of on-time trips</td>
</tr>
<tr>
<td></td>
<td>Increased bus frequency</td>
<td>vehicle trips per hour</td>
</tr>
<tr>
<td></td>
<td>Value of travel time saved</td>
<td>dollars per year</td>
</tr>
<tr>
<td></td>
<td>Reduced vehicle repairs</td>
<td>repairs per year</td>
</tr>
<tr>
<td></td>
<td>Value of reduced vehicle repairs</td>
<td>dollars per year</td>
</tr>
<tr>
<td></td>
<td>Energy conservation/reduced fuel use</td>
<td>gallons per day</td>
</tr>
<tr>
<td></td>
<td>Value of fuel saved</td>
<td>dollars per year</td>
</tr>
<tr>
<td></td>
<td>Reduced carbon footprint</td>
<td>no. of vehicles on the road</td>
</tr>
<tr>
<td></td>
<td>Pollution prevention/reduced emissions</td>
<td>tons per day</td>
</tr>
<tr>
<td></td>
<td>Value of reduced emissions</td>
<td>dollars per year</td>
</tr>
<tr>
<td></td>
<td>Total capacity increased</td>
<td>people per traffic lane</td>
</tr>
<tr>
<td></td>
<td>Increased mobility</td>
<td>passenger-miles per hour</td>
</tr>
<tr>
<td></td>
<td>Increased accessibility to jobs, schools and healthcare</td>
<td>accessible in (x) minutes</td>
</tr>
<tr>
<td>Indirect Benefits</td>
<td>Overall system efficiency</td>
<td>total operating costs per vehicle mile</td>
</tr>
<tr>
<td></td>
<td>Overall service efficiency</td>
<td>total operating costs per passenger mile</td>
</tr>
<tr>
<td></td>
<td>Social equity</td>
<td>consumer savings and affordability</td>
</tr>
<tr>
<td></td>
<td>Space allocation</td>
<td>maximum #of passengers accommodated per mile</td>
</tr>
<tr>
<td></td>
<td>Public health</td>
<td>quality-adjusted life years and health costs</td>
</tr>
<tr>
<td></td>
<td>Increased traffic safety</td>
<td>accidents per year</td>
</tr>
<tr>
<td></td>
<td>Value of accidents prevented</td>
<td>dollars per year</td>
</tr>
<tr>
<td></td>
<td>Reduced parking congestion</td>
<td>spots available per year</td>
</tr>
<tr>
<td></td>
<td>Multi-modal development</td>
<td>urban density at transit nodes</td>
</tr>
<tr>
<td></td>
<td>Income growth</td>
<td>household income per year</td>
</tr>
<tr>
<td></td>
<td>Improved labor participation</td>
<td>unemployment rate</td>
</tr>
<tr>
<td></td>
<td>Increased property value</td>
<td>property tax income</td>
</tr>
</tbody>
</table>
CASE STUDIES
Below are the findings from our interviews with transit officials in the Virginia/DC suburbs, Los Angeles, Dallas and Houston. These top performing systems have similar characteristics while exhibiting unique outreach strategies to reach riders.

Potomac & Rappahannock Transportation Commission – PRTC
PRTC serves suburban Virginia and its bedroom communities in the area business district including Washington, DC and Arlington, Virginia. This well-established community has a 40 year commuting culture, so overt marketing is not done. Current managed lanes operate on I95 and are planned for I66 and I395. The facilities follow a familiar pattern of beginning with other operating scenarios and later converting to managed lane status. I95 began as a busway and later allowed high occupancy vehicles (HOV). I66 and I395 currently operate as HOV, but the portion inside the beltway is expected to begin tolling in 2017. I95 requires personal vehicle occupancy of 3+; I66 is 2+ and is only HOV during peak hours. PRTC buses circulate in neighborhoods throughout the region then access the managed lanes replicating the Neighborhood-Oriented Service.

Incentives, Branding and Technology
Attractiveness of the system is related to time and cost. There are other transit agencies operating in Virginia and Washington, DC and all have adopted a regional fare card (SmarTrip) recognized by all systems. Discounts are provided through use of the card. The largest financial incentive is a federal incentive offered through the Internal Revenue Service (18) that allows a commuting transit fare reduction. The amount allowed is currently $255 per month. The downside is that the government alters the amount available and in a prior year, the allocation fell to $130. The most common way patrons access the benefit is through their employer. The amount of the discount is included in the SmarTrip Card. Area realtors provide PRTC with information on people new to the area and newcomers are provided a welcome pack introducing the service.

Ridership
Ridership levels declined over the past two years and are attributed to two primary factors. First, the number of federal government and contract jobs in the Virginia/Washington, DC area decreased by 100,000 since 2011. Second, the allowance for the IRS discount was $130 during much of that period, only recently rising to $255 monthly.

Evaluation and Success
PRTC evaluates success by conducting triennial customer satisfaction surveys that are traced and compared. Employee incentives are provided that are partially tied to the number of complaints. Data are collected on costs and passenger trips per mile, however, their perspective is that ridership is driven as much by outside forces as by service quality.

LA Metro
Under Los Angeles Metro, express bus service in managed lanes has evolved into four distinct types over the past 50 years: express bus service in HOV and regular freeway lanes (1950’s and 1960’s), express bus service in transitway HOT lanes (El Monte Transitway in 1976 and Harbor Transitway in 1996, includes the Silver Line), peak period bus in dedicated street lanes with limited stops and signal priority (Rapid Bus Line, early 1990s), and bus rapid transit (Orange Line in 2006). Per the National Transit Database, LA has 104.4 lane miles and 2.3 million revenue miles operated in a managed lane configuration. LA Metro express buses go from
parking lots to the managed lanes, replicating the *Express and Park-and-Ride Routes* configuration. The Silver Line express bus enters the downtown and travels in a managed lane configuration on city streets.

**Incentives, Branding, and Technology**
LA Metro periodically promotes new segments and new features of the system using billboards, pamphlets on buses, website banners, and sometimes ads in newspapers for the Latino and African American communities. Usually the entire metro system is marketed. Most of the technological advances are associated with the Orange Line. The Orange Line has all-door boarding and uses in-line stations so passengers cannot board without paying. All-door boarding currently is being piloted on the Silver Line. LA Metro credits all-door boarding technology with improvements in running time and schedule adherence; however, the agency does not expect all-door boarding to improve ridership because of its potential to increase fare evasion. Other technology is on-time messaging of the next bus coming, which is being considered but not yet in the planning stage.

**Ridership**
Although there are more commuters on the Orange Line than on the Silver Line, ridership on both lines and throughout the system is decreasing. The Silver Line merged with another line in December 2015 and since then their combined ridership is decreasing. However, when measured by itself, Silver Line ridership is increasing (the only increase in the entire system) by +15.6 percent from 2014-2016. For comparison, ridership on the Orange Line is decreasing by -10.8 percent from 2014-2016.

**Evaluation of Success**
LA Metro monitors service performance in terms of availability (accessibility and connectivity), quality (in-service on-time performance and customer complaints), quantity (frequency and average load factor), and effectiveness (boardings per service hour, cost per passenger mile, passenger miles per seat mile, and a Route Performance Index). The Route Performance Index (RPI) is comprised of 3 indicators:

- **Utilization of Resources:** passenger boardings per revenue service hour operated
- **Utilization of Capacity:** passenger miles per seat mile
- **Fiscal Responsibility:** subsidy per passenger

The RPI ranges from 0 to 1.8 by service category (e.g., local bus, shuttle, express bus, etc.), with 1.0 indicating average and less than 1.0 indicating below average. If the RPI falls below 0.6 then that line needs serious attention. Each indicator is equally weighed.

**DART**
The Dallas Area Rapid Transit (DART) installed its first managed lane (HOV) in October of 1991. Four years later, Route 283 was introduced as the agency’s first express bus to operate on a managed lane. The route traveled from Garland to downtown Dallas on a reversible HOV lane. Today, the DART express bus system operates on over 35 lane miles and 594,759 revenue miles. DART’s express bus system attracts riders from outside of their 13-city service area, but the predominant market is the suburban choice rider. These commuters are from the eastern, southern, and outside region of Dallas but they all have the same destination—downtown Dallas. As a result, routes 282, 278 and 206 are express routes that were designed to serve those areas
respectively. DART’s express buses go from parking lots to the managed lanes replicating the Express and Park-and-Ride Routes configuration.

Incentives, Branding, and Technology

Over the years, DART’s marketing strategies have changed with the times. Initially, the agency took the traditional route by sending out press releases, submitting newspapers ads and putting up billboards. DART also ran promotions that offered free rides to try their new routes as they were being introduced into the market. As the times advanced, so did DART’s marketing tactics. Now the agency advertises their transit services online, posts trailblazer signs along the highway and offers partnerships with companies in an effort to gain ridership from companies’ employees.

DART has applied a multitude of technological enhancements to their bus system that benefit both the commuters and the agency itself. For example, all new buses, including express, have video cameras and DART promotes that feature as a safety element. The recordings allow DART police to monitor the facility in real time and to react accordingly. There are other proactive tools that DART uses such as electronic display boards and advanced onboard technology. The electronic display boards, also called “info-tainment”, provide information to the riders such as where the next stop is, where the rider is relative to the next stop and if there are any detours. This system works in cooperation with the buses’ onboard technology. Transit Master, a software system utilized by DART, has “connection protection” which helps prevent riders from missing their connecting buses. The connection protection feature is currently in pilot testing, but the software works by utilizing the buses’ GPS capabilities to predict when a bus will miss a connection. When the problem occurs, the connecting bus will be contacted and requested to wait for the arriving bus.

In addition to the onboard technology advances there are some mobile advances as well, such as the Go Pass mobile app. Riders have the option to download this app to their smartphone and do everything from planning their trip to receiving updates on the location of their bus. If a rider is not interested in downloading an app, they have the option to text DART their bus stop number to find the buses’ location. With all of these mobile advances, Wi-Fi seems to be a logical addition to the DART bus. Currently DART’s MAX express bus is testing this feature and it will be further tested on a UT Dallas route this fall. The problem with providing Wi-Fi is that there are some dead zones in some areas, resulting in poor cell coverage. Therefore, although there is interest in this area, DART has decided not to provide this service on all buses until they can provide credible service and determine if the cost of keeping it up and running is feasible.

Ridership

Ridership on express buses has had substantial growth from the time there were no managed lanes to the inception of express buses on managed lanes. However, since then there has not been continual growth. When route 283, the first express bus used on managed lanes, first began there were about 780 passengers a day and then it reached a peak of about 1300 passengers a day in 2008, but since then the ridership has dropped down to 900-1000 a day. A similar situation occurred with route 206, which began in 2000, the bus started with 380 boardings a day and it grew to over 1000 and reached a peak of 1300 in 2008 but has since dropped to around a 1000. The rise and drops in ridership correlates with the city’s gas prices and employment rates. When
there was a gas spike in 2008, ridership increased, but when the recession hit the nation, resulting in a higher unemployment rate, ridership dropped.
Evaluation of Success
The success of DART’s bus system is measured quarterly based on whether or not the system meets the standards of the Route Performance Index (RPI). The board requires that services have a statistical number of performances that is determined by the RPI. Once the board sets a goal, if a system drops below the goal, the board requires that you make changes and market to reach the set goal.

METRO Harris County (Houston)
Houston METRO’s predecessor, the City of Houston’s Office of Public Transportation implemented a nine-mile contra flow lane demonstration project on the North Freeway (IH-45N) in August 1979 using federal, state, and local funds. Based on the success of the demonstration project, a decision was made to expand the HOV program and build permanent HOV lanes in Houston’s radial freeway corridors. METRO Park & Rides are direct nonstop service to Downtown, the Texas Medical Center or other major employment centers in the METRO service area. Park & Ride facilities also serve as staging areas for vanpools and carpools. Houston Metro’s express buses go from parking lots to the managed lanes replicating the Express and Park-and-Ride Routes configuration.

Katy (I10) was the first of four managed facilities in Houston. For Katy Freeway 2+ are free during weekday peak hours, but must pay at other times. For the other three facilities, 2+ are free during peak hours. Single occupants must pay on all facilities at all times.

Incentives, Branding, and Technology
Due to challenges with limited parking spaces and high seating capacity utilization at several lots, METRO does not do system wide marketing for these services on a regular basis. Historically, route level promotions have included free and/or discounted rides, commute save calculations, and grandfathered fares as well as shifts from monthly to time activated fare media as well as stored value card electronic and smart card media. The majority of METRO’s fixed route bus service on HOV/HOT lanes is commuter, or Park & Ride bus service. Due to METRO’s distance based fare system, the riders on these services tend to attract more non-low income and non-minority riders than METRO’s local bus service. Virtually all of the riders are making home-to-work trips in the morning and work-to-home trips in the afternoon.

Ridership
Park and Ride bus ridership has decreased slightly over the year on a system wide basis. There were 718, 251 Park & Ride boardings in June 2016 compared to 746,808 boardings in June 2015, a decrease of 28,558 boardings (or a loss of 4 percent) despite the same number of weekdays in June 2016 as June 2015. Metro suggests a higher ridership loss in 2015 due to weather. Houston’s economy is heavily impacted by the oil and gas industry and low oil and gas prices have resulted in significant layoffs, which directly affect METRO’s ridership.

Evaluation of Success
As with many transit properties, the primary evaluation of success is reflected in increased ridership, minimizing complaints, increased efficiency, and improved effectiveness. While ridership comparisons are fairly straightforward, complaints are not. In the age of social media, it is often that case that multiple customers on the same trip may complain about service thereby inflating the raw data beyond a normalized calculation of complaints per trip.
Summary

Each case study city reflects high quality express bus service and has taken advantage of the improved travel speed available on the managed lanes. There is general acknowledgement that ridership is a result of employment strength, congestion levels and parking availability and pricing. Each system offers fare convenience through a smart card of some kind with most attaching a discount to frequent card use. A guaranteed ride home provides a level of confidence to riders in case of an emergency. These things that are in common are established benefits therefore these best practices may be transferrable to other cities. Variations create an advantage in some markets and several systems are applying technological advances to improve the customer experience. The interviewees indicated that even when recent technology has not yet been applied, advances are in consideration or planning stages. In the near future real time information will be available for mobile devices in all locations.

TABLE 3 Summaries of Case Study Agency Characteristics

<table>
<thead>
<tr>
<th>System</th>
<th>Service Configuration</th>
<th>Initial year operation as HOV:</th>
<th>Managed Lane</th>
<th>Congestion Ranking (20)</th>
<th>Superior Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRTC</td>
<td>Neighborhood-Oriented</td>
<td>1969 as bus only lane</td>
<td>I95; 3+ personal vehicle free: 1 or 2 pay requirement; pay is variable based on congestion</td>
<td>1</td>
<td>Welcome packet to new area residents; luggage racks and reading lights on buses; SmarTrip discount; Promotion of IRS discount; Guaranteed ride home for registered commuters</td>
</tr>
<tr>
<td>LA Metro</td>
<td>Express Park and Ride Routes &amp; Transfer Route Network</td>
<td>1976 El Monte Transitway and 1996 Harbor Transitway</td>
<td>I10 and I110; Single occupants pay</td>
<td>2</td>
<td>Piloting all-door boarding; Guaranteed ride home for registered commuters; Retains managed status on select city streets</td>
</tr>
<tr>
<td>DART</td>
<td>Express Park and Ride Routes</td>
<td>1995 HOV with bus</td>
<td>I30; graduated payment for 1+ and 2+</td>
<td>8</td>
<td>On-board video cameras; transfer connection guarantee; mobile phone routing schedule information; Guaranteed ride home for registered commuters</td>
</tr>
<tr>
<td>Houston METRO</td>
<td>Express Park and Ride Routes</td>
<td>1979 contraflow</td>
<td>I10; free for 2+ during peak hours; payment required off peak</td>
<td>11</td>
<td>Free and discounted rides; mobile app; smart card media; luggage racks and reading lights; Guaranteed ride home for registered commuters</td>
</tr>
</tbody>
</table>
Study Limitations
It should be noted that systematic data for bus service categorized as HIB is not requested as part of the National Transit Database reports for ridership and operating costs. The HIB data that are available are extremely limited and only reflect lane miles. The official HIB designation is relatively new so there are not decades of data from which to draw. These limitations make large scale data assessments cost and time restrictive. The research reported in this paper used case studies to glean what could be learned from the largest systems in different parts of the country.

Conclusions
The growth in managed lane miles is clearly evident. What makes them successful needs to be illuminated. This paper identified the top 25 managed lane systems in the nation. Case study analyses identified which superior techniques and incentives to attract riders were being applied. These techniques included:

- The Express Park-and-Ride Route configuration
- Welcome packet for new area residents
- Smart card discounts
- Promotion of the IRS discount
- Luggage racks and reading lights in buses
- Piloting of all-door boarding
- Guaranteed ride home for registered commuters
- Retaining managed status on select city streets
- Transfer connection guarantees
- Mobile phone routing schedule information
- On-board video cameras
- Free and discounted rides

Current practice focuses on ridership growth as a measure of success. According to the interviewees, service quality is not the primary way to lure riders. Ridership is materially affected by the economy and employment rates. In fact, growth in ridership is linked to a number of variables that are independent of service quality. Key among them is employment level. Drops in employment due to recession, oil prices, or other factors are typically associated with reduced ridership. Therefore, there is a weak link between ridership and transit in general, and because of this one agency transitioned to HIB in spite of ridership stagnation.

Current practice also cites congestion reduction as an important benefit of transit. In reality, congestion may go down at first only to increase back to the equilibrium level in spite of increases in transit. HIB offers long term and indirect benefits that makes it desirable regardless of ridership and congestion levels. These benefits include:

- System wide efficiency
- Social equity
- Increased traffic safety
- Reduced parking congestion
- Income growth
- Increased property value
1. Multi-modal development
2. Improved public health
3. Reduced environmental impacts
4. Increased mobility
References


