United States Department of Transportation

Federal Transit Administration

2006 EVALUATION OF THE LAS VEGAS METROPOLITAN AREA EXPRESS (MAX) BUS RAPID TRANSIT PROJECT

DECEMBER 1, 2006

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Task 2. Evaluation Assistance
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13. ABSTRACT (Maximum 200 words) This document was prepared for the U.S. Department of Transportation, Federal Transit Administration's (FTA) Office of Research, Demonstration and Innovation. It presents an evaluation of the Las Vegas Metropolitan Area Express (MAX) Bus Rapid Transit project and is one of a series of case study evaluations of BRT systems that comprise the national BRT Consortium. The content of this document follows the *Guidelines for the Evaluation of Bus Rapid Transit Demonstration Projects* developed by the Volpe National Transportation Systems Center. The specific elements that are the focus of the MAX BRT evaluation are derived from the *Characteristics of Bus Rapid Transit for Decision Making* published by the FTA in August 2004. These include running ways, stations, vehicles, fare collection, intelligent transportation systems (ITS) and service and operating plans. The objectives of the evaluation are to determine extent and impact of travel time improvements and system reliability; measure Ridership changes; evaluate impacts of BRT technologies; assess role of branding and marketing; examine how MAX has affected the wider Las Vegas transportation network; determine effect of MAX on land use and transit oriented development (TOD); and evaluate overall safety and security of MAX. The report also offers a number of lessons learned from the MAX program.		
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FOREWORD

The U.S. Department of Transportation's Federal Transit Administration (FTA) is conducting a series of case study evaluations of the 17 Bus Rapid Transit (BRT) systems that comprise the National BRT Consortium. The Las Vegas Metropolitan Area Express (MAX) project is one of the 17 projects. This report documents the second evaluation of the Las Vegas MAX BRT project to determine the full effects of its implementation as the system matured. MAX BRT service was implemented with the goal of providing faster, more reliable, and more accessible transit service in Northern Las Vegas.

MAX is one of 17 National BRT Projects that make up the BRT Consortium supported by FTA

Washington Group International and Wilbur Smith Associates – international planning and engineering firms - prepared the 2006 evaluation under contract to and with guidance from the FTA Office of Mobility Innovation. The evaluation is based on the *Guidelines for the Evaluation of BRT Demonstration Projects*, developed by the Volpe National Transportation Systems Center. The first evaluation, published in 2005 shortly after MAX began operations, was a welcome success.

The FTA is evaluating each of the projects in the National BRT Consortium to address the significant issues associated with the implementation and operation of BRT service. Sharing of this information with a broad audience of federal, state and local transportation agencies and consultants will greatly assist planners as they look to evaluate new transit options for their communities.

TABLE OF CONTENTS

Executive Summary .... **iii**

MAX Project Fact Sheet .... **vii**

1.0 Introduction

1.1 Evaluation Overview 1

1.2 MAX Evaluation Objectives 2

2.0 Project Elements **3**

2.1 Project and Corridor Description 4

2.2 Running Ways 4

2.3 Stations 5

2.4 Vehicles 7

2.5 Fare Collection 10

2.6 ITS 12

2.7 Service and Operations Plans 12

2.8 Branding and Marketing 13

3.0 System Costs **16**

3.1 Capital Costs 16

3.2 Operating Costs 18

4.0 Planning, Design, and Implementation **20**

4.1 Planning and Design 20

4.2 Vehicle Service, Maintenance and Operations Plan 20

4.3 Implementation and Management of the ITS Elements 23

4.4 Branding and Public Acceptance of Service 30

5.0 Evaluation of System Performance **33**

5.1 Travel Time 33

5.2 Reliability 42

5.3 Identity and Image 43
5.4 Safety and Security 52
5.5 Capacity 56

6.0 System Benefits 57
6.1 Ridership 57
6.2 Capital Cost Effectiveness 64
6.3 Operating Cost Efficiency 65
6.4 Land Use 68
6.5 Environmental Quality 71

7.0 Conclusions- Observations and Lessons Learned 73
7.1 MAX is a Success 73
7.2 What Works 74
7.3 Summary of Lessons Learned 75

List of Exhibits 79

List of Acronyms 81

Appendix

BRT MAX Service Questionnaire (Driver Survey and Summary of Results)

EXECUTIVE SUMMARY

Project Context

The introduction of the Metropolitan Area Express (MAX) Bus Rapid Transit (BRT) system in June 2004 heralded a new era for public transportation in Las Vegas, Nevada. This express transit service, introduced by the Regional Transportation Commission of Southern Nevada (RTC), features enhanced passenger comfort, stylish new vehicles and improved travel times. It was designed to complement existing Route 113 bus service in North Las Vegas, among the most heavily patronized bus routes in the region.

MAX is one of 17 BRT projects that comprise the Federal Transit Administration's (FTA) BRT Consortium. It initially distinguished itself as a rapid transit system using exclusive running ways, a planned optically guided station docking system and low floor vehicles offering level boarding. It has a totally new off-line fare collection system and uses rubber-tire 60-foot articulated vehicles with four wide doors to facilitate passenger loading and unloading. In short, it introduces all of the elements of BRT presented in FTA's *Characteristics of Bus Rapid Transit for Decision Making* document published in August 2004.

First Evaluation of MAX, 2005

The first FTA-sponsored evaluation of the new MAX system was completed in August 2005. It showed that implementation of MAX was a welcome success. Ridership on the new system jumped nearly 25%, travel times in many instances were cut by 50%, and customer satisfaction was hovering around 96% (those who rated the service as good or excellent). That is not to say that MAX was not without initial start-up difficulties. It was the first project in the U.S. to select an overseas vehicle manufacturer for the new system, which presented unique challenges, ones RTC was quickly able to overcome. However, a key element of the system's new technology – the advanced optical guidance system – proved unsuccessful in the wind, heat and sands of the desert climate. The optical guidance system was eventually discontinued as drivers quickly learned to successfully dock vehicles manually.

Update and Evaluation of the MAX System, 2006

As MAX entered its second full year of operation, a follow-up evaluation – based on the Evaluation Guidelines for BRT Demonstration Projects – was initiated in order to determine the full effects of its implementation as the system matured. This report presents the findings of the second evaluation. The tables following this executive summary present the characteristics of the existing MAX BRT and overall facts of the system, as well as a summary of the effectiveness of MAX (found in Section 7, Conclusions).

These tables and statistics reflect our overall findings but are only part of the results. Three key stakeholders in the MAX system - RTC management and staff, MAX riders and the MAX drivers – were key participants in this evaluation. Their willingness to share their experience, through interviews, surveys and frank discussion, provide valuable insight into the MAX program from the management, operator and user perspective. From these key players we have learned the following:

RTC Management and Driver Observations

The use of innovative and alternative technologies that are part of the MAX BRT system, including ITS, vehicles and ticket vending machines, required significant staff resources during start-up. However, RTC's experience shows that the investments in human resources are worthwhile. RTC worked with its operations contractor to find, retain and train the best employees available and reward them with training, improved working conditions and pay increases. They also fostered a team spirit creating pride in their work. As a result, staff turnover has been low, and performance and satisfaction high – major factors that contribute to MAX's success. Overall, RTC has energized its system with the MAX program and has since introduced several exciting new follow-on projects as a result.

Results of Rider Surveys

Riders overwhelmingly approve of MAX and confirm many of the concepts presented in the Characteristics of Bus Rapid Transit for Decision Making document, citing significantly reduced travel times, improved vehicle and station comfort, cleanliness and safety as reasons to use the service. When asked to give an "all things considered" rating of the service, nearly 97 percent of riders rated MAX as excellent or good. This compares with a similar rating of around 60 percent among riders on the standard CAT service.

Other surveys conducted among the wider Las Vegas community revealed that slightly less than half (40%) of residents had heard of MAX. By comparison, 90% of the population had heard of CAT, the transit agency. The lack of awareness about MAX is likely due to its service corridor, which is outside of the main business district and residential communities. As BRT service expands in Las Vegas, awareness of the brand should also increase.

Lessons Learned

- **Ridership results** – Overall Ridership is up nearly 40% since the start of the MAX service. Approximately 30% of MAX riders are new to transit and 10% of MAX riders previously drove to make their trip.
- **Traffic Signal Priority (TSP)** – The use of TSP at 10 intersections did not lead to any significant travel time improvement for the MAX system. This is most likely explained by the fact that there is little traffic congestion in the corridor and travel times are fairly constant.

- **Optical Guidance** - The added optical guidance costs were not necessary because highly trained drivers can dock the vehicles almost as precisely and the automated system proved ineffective in the Las Vegas climate.

- **Driver Training and Selection** - The MAX BRT drivers are a major asset to the system. Evidence for this can be shown not only in the public opinion of MAX service, but also the safe record of the drivers. Only one preventable accident occurred on MAX from the opening of service to November 2006. Although the exclusive bus lanes have some effect on the safety of the bus route, the drivers have had an even greater effect. The additional training, higher pay scale and extensive selection process for MAX drivers is a model that should be followed by other BRT systems.

- **Branding and Public Acceptance of Service -** The MAX system can definitely be deemed a success in terms of rider opinion. 91.1% of MAX riders rated MAX “excellent” or “good” and 91.7% of CAT Route 113 riders rated MAX “excellent” or “good”. Although the MAX brand is beginning to be recognized, there is still work to be done. In benchmark surveys, 47.9% stated no preference between MAX and CAT. This large number of respondents with no preference indicates that most Las Vegas Valley residents do not perceive a substantial difference between MAX and regular CAT service. As the MAX service is extended to other areas, it is anticipated that this brand recognition will improve substantially.

- **Operating Costs** - Operating costs for MAX were about 50% higher per vehicle hour than local CAT bus service, due to a number of factors, including additional attention to maintenance, use of more experienced drivers, and the higher cost of operating and maintaining a complex, foreign-made vehicle. However, since MAX operates at higher speeds, the difference in cost per vehicle service *mile* is not as great as the difference in cost per service *hour*. Most of the speed improvements are due to fewer stations and reduced dwell time.

  Dwell times on the MAX system were shorter for two reasons. First, MAX’s skilled drivers took advantage of the center cab position during station docking, which reduced the gap at the platform. Second, and more significant, is MAX’s proof-of-payment fare collection. This is evidenced by the fact that MAX’s dwell time savings occur during boarding, not alighting. (There was a 59% reduction in dwell time during boarding versus a slight increase in dwell time when alighting). Thus it seems likely that a BRT system using more conventional vehicles could make a significant reduction in operating costs per vehicle service miles if it uses the proof of payment fare collection method and consolidation of station stops as a means of reducing travel time.

CHARACTERISTICS OF MAX BRT LAS VEGAS

Running Way – Total Length 7.5 miles

Running Way Segregation – 4.5 miles exclusive, 3 miles shared
Running Way Marking – pavement markings and signs
Running Way Guidance – initial optical guidance for docking discontinued

Stations – Number = 23

Station Type – covered waiting areas
Platform Height – level boarding areas
Platform Layout – average length of platform is 65 feet
Passing Capability – via normal traffic lanes
Station Access – ADA compliant

Vehicles – Number = 10

Vehicle Configurations – 60' articulated specializes BRT vehicle
Aesthetic Enhancement – Unique MAX logos, interior finishes, & climate control
Passenger Circulation Enhancement – low floor and 4 doors on right side
Propulsion Systems – diesel electric

Fare Collection – On board random proof of payment

Fare Collection Process – on board random inspection by roving uniformed personnel
Fare Transaction Media – tickets sold from TVM at stations
Fare Structure – flat fare with transfers available

Intelligent Transportation Systems

Vehicle Prioritization – Traffic signal priority & queue jumper
Driver Assist and Automation Technology – initial optical guidance for docking discontinued
Operations Management – AVL/CAD and vehicle mechanical monitoring
Passenger Information – on board & to be implemented at stations
Safety and Security Technology – driver alarm
Support Technologies - APC

Service and Operating Plans

Route Length – 7.5 miles
Route Structure – single route with expansions planned
Span of Service – 7:00 AM – 11:00 PM
Frequency of Service – 12 min. (peak) & 15 min. (off peak)
Station Spacing – average; 0.4 miles

Capital and Operating Costs & Ridership

Capital cost - $20,162,430
Operating cost - $111 per hour
Ridership – 9800 per month Feb. 2006-July 2006

MAX LAS VEGAS, NV PROJECT FACTS

General Description:

MAX Las Vegas Boulevard North is a 7.5-mile, limited-stop transit line operating along Las Vegas Boulevard North between the Downtown Transportation Center (DTC) in downtown Las Vegas and Nellis Air Force Base at Craig Road. Prior to the start of MAX service on June 30, 2004, RTC's Citizens Area Transit (CAT) system operated Route 113 along the same corridor. MAX is an overlay express route that supplements, but does not replace, the preexisting local bus service, Route 113, which, prior to MAX was already one of the most heavily used routes in the CAT system, operating on 15-minute headways. MAX runs in a transit-only lane for 4.5 miles and in mixed traffic for about 3 miles.

- **Running Way:** The Las Vegas Boulevard North route is 7.5 miles in length. The southern 3 miles are roadways with shared traffic and the northern 4.5 miles have curbside exclusive bus lanes. The lanes are shared with the Route 113 bus service and right turning traffic.

- **Stations:** The major terminus is the Downtown Transportation Center (DTC). The DTC is a hub for many regular bus routes and has full passenger amenities including ticket office and TVMs, restrooms, inside waiting area and covered exterior. Along the MAX Route there are 23 stations that are exclusive to MAX. The 113 route has separate stops. Each station has a covered waiting area with TVM, soda/water vending machine, lighting, and passenger information signs are to be installed.

- **Vehicles:** 10 vehicles were purchased, 6 plus 1 in reserve at the DTC are required to operate the scheduled service. The shop margin is estimated at 0.6 vehicles. The CIVIS vehicle by Irisbus was selected for its low floor, multiple doors (4), and optical guidance features. It is an articulated vehicle about 60 feet in length with a capacity of 120. The exterior is streamlined with a center driver position.

- **Fare Collection:** Off-board random proof of fare. Uniformed armed security personnel under contract to RTC spot check fares using hand held electronic devices. Tickets are sold via ticket machines at each station and at a ticket window at the Downtown Transportation Center.

- **ITS:** Traffic Signal Priority and Queue Jumper, Automatic Passenger Counters on each door of the vehicle, Computer Aided Dispatch/Automated Vehicle

Location System, and on board passenger information display. The optical guidance system is not in use due to difficulties in maintaining contrast between markings and pavement.

- **Service and Operating Plans:** MAX operates from 5 AM to 7 PM with 12-minute headways and from 7 pm to 10 pm on 15-minute headways.

- **Branding / Marketing:** RTC initiated a naming contest for the CIVIS vehicle and determined Metropolitan Area Express (MAX) would be the brand name for this BRT class of service. Numerous public outreach activities, including a "Meet MAX" campaign helped launch the system.

- **Capital Cost:** The total costs of the system was $20,162,430

- **Operating Cost:** Contract operating costs were approximately $75.52 per hour for MAX service (operated by Veolia Transportation) compared to $52 per hour for CAT service. However, the basic total average vehicle operation costs for MAX were $93 per hour as of the end of fiscal year ended June 2005, when all other RTC costs are included. The total average operating cost of MAX as of December 2006 increased to approximately $111 per hour.

- **Ridership:** Total daily boardings increased from approximately 7,000 per day in 2004 to a high of 10,000 per day in January 2006 – an increase of 42%. Ridership has now leveled at approximately 9,800 per day, although problems with the Automated Passenger Counting (APC) is believed to have caused an undercount since early 2006.

1.0 INTRODUCTION

1.1 Evaluation Overview

This document presents an evaluation of the Metropolitan Area Express (MAX) Las Vegas Boulevard North BRT project in Las Vegas, Nevada. The MAX project was developed by the Regional Transportation Commission of Southern Nevada (RTC) and is part of the Citizen's Area Transit (CAT) system first established in 1992.

This evaluation is based on *Evaluation Guidelines for Bus Rapid Transit (BRT) Demonstration Projects* published by the Volpe National Transportation Systems Center (VNTSC) for FTA in February 2002. While the *Guidelines* document establishes the methodology for evaluation, the specific elements that are the focus of the MAX BRT evaluation come from *Characteristics of Bus Rapid Transit for Decision Making,* published by the FTA in August 2004.[1] The CBRT document, by identifying and categorizing the major elements of BRT, their relationship to BRT system performance and the resulting system benefits, provides planners and decision makers the basic information and data requirements necessary to successfully undertake an evaluation.

This report follows a previous report prepared by Booz Allen Hamilton, *Las Vegas Metropolitan Area Express Bus Rapid Transit (BRT) Demonstration Project*, FTA VA-26-7222-2005.1, that was completed in August 2005 and evaluated the first six months of MAX operations. That report was a first look at the early impacts of the MAX system. The present evaluation expands on the initial effort by using the additional data and operating experience and broadens several evaluation criteria to reflect the institutional experience and system impacts that have emerged with the additional experience that RTC has gained since it first began operations and management of MAX BRT in June 2004.

Specific information that is the basis for this evaluation includes the following:

- APC and AVL Data from RTC
- RTC's MAX and Route 113 Riders Surveys in April and October 2005
- RTC's 2004 and 2005 Annual Resident Surveys
- Interviews with RTC Staff
- Survey of MAX Drivers, see Attachment A

[1] The Evaluation Guidelines for BRT Demonstration Projects can be found at http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13831.html
CBRT report is available at *http://www.gobrt.org/CBRT-DecisionMaking.pdf*

1.2 MAX Evaluation Objectives

MAX BRT service was implemented with the goal of providing faster, more reliable and more accessible transit service in Northern Las Vegas. The overall objectives of this evaluation are to determine if RTC was successful in achieving this, and focus on the following:

MAX EVALUATION OBJECTIVES

- Determine extent and impact of improvements in travel times and system reliability
- Measure changes in ridership
- Evaluate impacts of new BRT technologies
- Assess role of marketing and brand development in MAX acceptance
- Investigate how MAX has affected the wider Las Vegas transportation network
- Determine the effect of MAX on land use and transit oriented development
- Evaluate overall safety and security of MAX

2.0 PROJECT ELEMENTS

Metropolitan Area Express or "MAX" is a new brand of express service operating on an arterial roadway. RTC is planning to use the brand in other corridors in Las Vegas. The MAX Las Vegas Boulevard North service includes each of the elements of a BRT system, as described in the *CBRT for Decision Making* document published by FTA in August 2004. Prior to beginning the evaluation, this section of the report provides a project and corridor description as well as a summary of each of the MAX BRT elements, presented on the following pages.

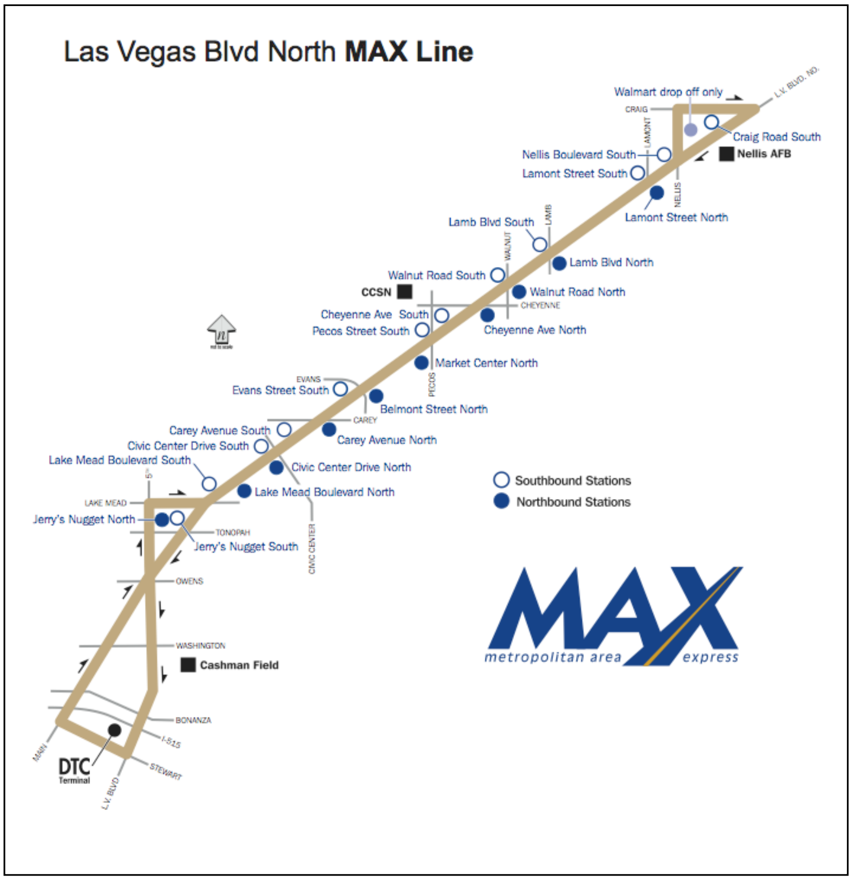


Figure 2-1: MAX system schematic map

2.1 Project and Corridor Description

MAX Las Vegas Boulevard North is a 7.5-mile, limited-stop transit line operating along Las Vegas Boulevard North between the Downtown Transportation Center (DTC) in downtown Las Vegas and Nellis Air Force Base at Craig Road. Prior to the start of MAX service on June 30, 2004, RTC's Citizens Area Transit (CAT) operated Route 113 along the same corridor. MAX is an overlay express route that enhances, but does not replace, the preexisting local bus service, Route 113. Prior to the introduction of MAX, Route 113 was one of the most heavily used routes in the CAT system, operating on 15-minute headways. MAX runs in a transit-only lane for 4.5 miles and in mixed traffic for about 3 miles.

MAX includes each of the major elements defined in *CBRT* report, specifically:

- Exclusive bus lanes
- Stations with raised curbs and passenger amenities
- Distinctive vehicles with low-floor boarding, multiple doors, and optical guidance
- Off board fare payment
- ITS
- Frequent and rapid service
- Branding and marketing

Most of the MAX project elements were implemented on opening day of the service, although the bus-only lane had already been in use on Route 113 since Fall 2003. After opening day, however, RTC adjusted the service somewhat, including an increase in MAX service frequency, a reduction in Route 113 service frequency, and the addition of a pair of MAX stations to facilitate transfers at Lake Mead Boulevard.

The Las Vegas Boulevard North corridor runs northeast from downtown Las Vegas, with service beginning at the Downtown Transportation Center (DTC). The right of way consists of a major arterial roadway, generally with two lanes in each direction and turning lanes at major signalized intersections. Land uses along the corridor primarily consist of strip and box store-type development. Small lot, low-cost residential neighborhoods are approximately one block away from the Boulevard. The population along the corridor is largely transportation disadvantaged with a high propensity for transit use.

2.2 Running Ways

MAX runs in an exclusive curbside bus lane for 4.5 miles of its 7.5 mile route with the remainder of the route operating in mixed traffic. The Nevada DOT converted a breakdown lane to a bus-only lane at the request of RTC; this was completed as part of the Boulevard reconstruction project. Stations are at the curb, except for the Downtown Transportation Center. Bus route 113 has a similar, but not identical, route, and uses the same curbside bus lane. There are 23 signalized intersections along the route. There are also a number of commercial driveways.

Figure 2-2:
More than half of MAX's 7.5 mile route is an exclusive curbside bus lane

2.3 Stations

MAX Las Vegas Boulevard North has 11 stations in each direction, plus the southern terminus (Downtown Transportation Center). At the northern terminus of the route, there is a drop-off only stop at the Walmart store on Nellis Blvd. All MAX stations are ADA-compliant and were designed to enhance customer comfort and convenience, promote system identity, and attract ridership. The station design features include elevated boarding areas, ticket vending machines, soda vending machines, sun and rain protection, benches and design treatments to facilitate blind and wheelchair-using customers (see Figure 2-1).

RTC added north- and south-bound stations at the intersection of Lake Mead and Las Vegas Boulevards in April 2005 to facilitate transfers to and from Route 210. These two stations have a different, less expensive, waiting area design compared to the original stations. Although some of the design features of the other MAX stations were not retained, the Lake Mead stations are equipped with similar passenger and ADA amenities including TVM's. Other features such as a raised curb for level boarding are more typical of a bus shelter (see Figure 2-3).

Figure 2-3: Typical MAX station (Jerry's Nugget South)

Figure 2-4: Lake Mead station with MAX ticket vending machine

Figure 2-5: Las Vegas Downtown Transportation Center

2.4 Vehicles

The CIVIS vehicles represent the key technology used to meet the project goals and to define the MAX brand; thus they are a major component of the capital cost of the project. The procurement, use, and management of CIVIS vehicles and related technology also contribute significantly to RTC's lessons for future BRT systems implementation. The CIVIS vehicle has special features, which individually and collectively contribute to system operation, passenger satisfaction, and brand image. These features include:

- a diesel-electric propulsion system intended to provide smoother acceleration;
- a center drive position for improved maneuverability;
- 22-year running life (compared to 12 years for standard buses);
- a carrying capacity of 120 passengers;
- continuous low-floor access;
- four wide doorways, and
- onboard bike racks.

Figure 2-6: MAX CIVIS vehicle exterior

Figure 2-7: Center Drive Position

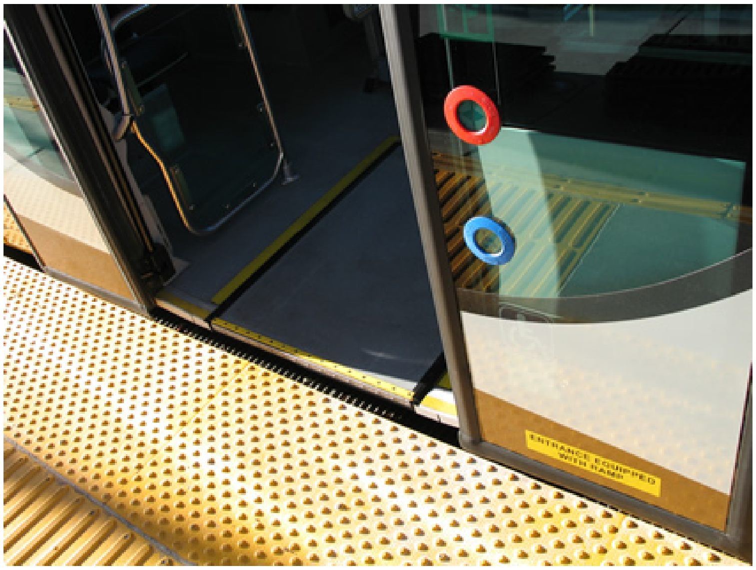


Figure 2-8a: MAX bus position with automatic docking

Figure 2-8b: MAX bus position at station using manual docking

Figure 2-9: Onboard Bike Rack

2.5 Fare Collection

The fare structure on MAX is the same as the rest of the CAT system. Monthly passes are valid for both classes of service. Unlike other CAT routes, however, MAX uses off-board, "proof of payment" fare collection, designed to reduce station dwell time and increase vehicle speed and reliability. The off-board fare collection system requires passengers who are not carrying a monthly pass to purchase tickets before boarding the vehicle from ticket vending machines located at each station, at the Downtown Transit Center, and in several off-route locations. Inspectors conduct periodic checks for proof of payment, which can be either a validated ticket or a pass. MAX is currently one of only two bus routes in the USA using proof-of-payment fare collection.[2]

[2] The other bus system using proof of payment is the Los Angeles Metro Orange Line, which opened in October 2005. Proof of payment is used on many bus systems around the world and on every new light rail system in the U.S. and Canada. It is also used on the Transitway portion of the Ottawa bus system.

Figure 2-10: Ticket Vending Machine

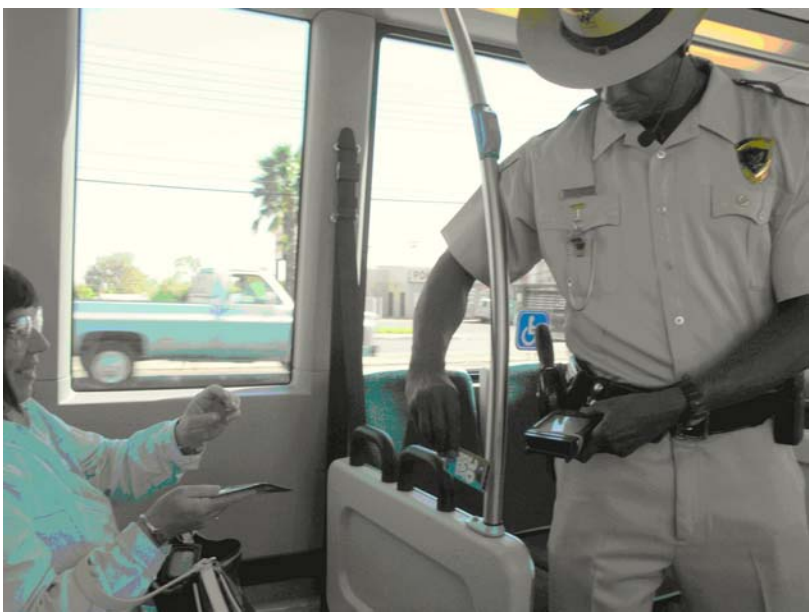


Figure 2-11: Uniformed security officer checking for fare proof of payment using Personal Digital Assistant

2.6 Intelligent Transportation Systems (ITS)

The MAX system also includes several Intelligent Transportation Systems (ITS) designed to ensure reliable operations and maintain a high quality of service as scheduled. Specific ITS elements include:

- Traffic Signal Priority (TSP), which seeks to reduce signal delay for transit vehicles, was implemented at 11 intersections along Las Vegas Boulevard North and one queue jumper priority treatment.
- A precision docking optical guidance system (OGS) intended to guide the vehicle into a precise docking at station platforms;
- Automated passenger counter (APC) sensors and Computer Aided Dispatch/Automated Vehicle Location (CAD/AVL) communications system designed to electronically communicate passenger boardings and vehicle locations;
- On-board electronic passenger information display.

The operation of these features is discussed in Chapter 4.

2.7 Service and Operations Plans

For its first implementation of a new brand of express service, RTC chose to overlay an existing local bus line (113), making only small changes in the route in order to reduce travel time, particularly in the portion closer to the Downtown Transportation Center. While MAX and 113 operate along the same basic route, they do not have common stops; thus it is not possible to wait for the first of the two that arrives.

MAX and Route 113 are scheduled independently, not with a joint headway. Prior to initiation of MAX, RTC operated Route 113 on 15 minutes headways from 5 am to 7 pm and with 30 minutes service from 7 pm to 5 am. After MAX started and riders began to switch services, RTC adjusted the 113 schedule to 30-minute headways all day.

As with other CAT service, Route 113 trips are scheduled to depart at specific clock times. MAX, on the other hand, is designed to operate on a headway-based schedule. Vehicles begin the trip at a set interval (the headway) after the start of the previous trip, without reference to a scheduled clock time. Service is frequent enough such that passengers are not expected to schedule their arrivals at bus stops. Therefore maintaining regular intervals between buses is the best way to reduce waiting time. MAX initially operated on 15-minute headways throughout its span of service (5 am to 10 pm) and as demand increased, the headways were reduced to 12 minutes before 7 pm.

2.8 Branding and Marketing

RTC incorporated both branding and marketing techniques to improve customer satisfaction and increase and retain ridership on the MAX service. Branding efforts concentrated on shaping and defining the product so that the customer would identify the product as a unique service with distinct characteristics. In the case of MAX, RTC set out to brand it as rapid transit service. Accordingly, the vehicles, stations, operating characteristics and internal vehicle comfort were designed to reflect rapid transit-type service. Marketing strategies, on the other hand, focused on communicating the distinct elements of the service to the general public and encouraging them to use it.

Branding

RTC viewed the branding of MAX as an essential step in the process of designing, developing and delivering a successful BRT product. The objectives of the exercise were to convey the MAX image as high quality, rapid transit service distinct from regular CAT Service. Accordingly, RTC gave the service an independent name with no connection to CAT and designed all aspects of the service to convey their targeted values. The vehicle was chosen specifically to reflect rapid transit characteristics and thus looks like a rapid transit vehicle with a sleek exterior, multiple doors openings, low-floor, automated passenger information and seating pattern more similar to a train than bus. Bus stops are referred to as “stations” and were likewise designed to be consistent with rapid transit characteristics with level boardings, passenger seating and lighting. The headway based operating plan and off-board fare collection system are also elements of the MAX brand and are more typical of rapid transit than regular bus service.

The branding of the MAX service has largely been successful. Members of the general public and community leaders both view the service as a distinct, higher quality and more desirable service as compared with regular transit service. Evidence of this is seen both from customer survey results and in frequent requests made to RTC specifically for more MAX service. RTC intends to retain the MAX brand as it expands BRT service to other parts of the region. In addition, RTC has since created another new brand of service, namely the “Deuce” a double-decker bus that provides service to the major casinos along the Las Vegas Strip.

As mentioned, marketing is a distinct strategy from branding. In some cases, however, RTC employed strategies that branded the service, and at the same time, increased public awareness for the new service. The main example of these strategies is the naming contest that RTC initiated for their BRT service in July 2001. The contest was publicized in RTC newsletters, television as well as general media. RTC received more than 3,000 suggestions and awarded the winning entry $500.

Marketing

When the key elements of the brand were defined, RTC initiated a public outreach campaign to increase awareness and knowledge of the new BRT service. RTC maintains an on-going contract with an advertising agency, but also carried out a significant portion of the marketing of the MAX service in-house. RTC estimates using one full time employee for the course of a year to carry out all activities related to the launching of MAX service.

RTC launched the MAX service on a variety of media, including the RTC website, quarterly newsletter and bi-monthly television show, both titled "On the Move." The agency also advertised MAX through a series of community outreach plans. The primary goals of these plans were to "(1) educate the community and youth along Las Vegas Boulevard North about MAX, its services, facilities and impact on air quality and traffic congestion (2) educate affected businesses about the project, milestones and activities that will affect them directly and (3) as a secondary, more long-term goal, this effort is also meant to educate individuals to future options, specifically to bring awareness about MAX as their commute choice." Other public outreach activities consisted of paid advertising; employer, youth, community, association, and government outreach, and a separate, website dedicated to MAX.

Figure 2-12: MAX marketing materials

According to RTC, the most valuable part of the launch campaign were the "meet MAX" events in February - March 2004 and May - June 2004. Event locations included major stores, housing projects, and a swap meet. The events were held twice due to the postponing of the launch date. A CIVIS vehicle and a ticket vending machine were brought to each location to demonstrate their use and generate excitement about the new look of transit.

RTC also made substantial efforts to reach students and seniors. The school program included a letter offering to give MAX presentations, pass holders, activity pages for children, and RTC promotional materials. RTC created a MAX brochure for direct mailings, a MAX poster for display, and gave out free ride passes at various special events and community fairs along the corridor. Most promotional materials were produced in both English and Spanish.

Three media events were scheduled throughout the MAX implementation process. On September 12, 2002, a CIVIS test vehicle was available to the media for an initial look. A MAX Vehicle Media Day was scheduled upon the arrival of the first official MAX vehicle on August 7, 2003. RTC held a press conference for the launch of MAX, June 30, 2004. MAX was dedicated to the residents along Las Vegas Boulevard North. The event included a band and color guard to salute MAX.

Figure 2-13: Opening Day Celebration

3.0 SYSTEM COSTS

BRT systems are designed as premium services and thus typically have higher costs as compared with standard bus services but lower costs as compared with similar premium services such as light rail. A key element of this evaluation, therefore, was to consider capital and operating costs associated with the MAX system. The following section discusses both the capital and operating costs of the project.

3.1 Capital Costs

The total capital costs associated with developing the MAX system is $20.2 million – this would rank among the lowest startup costs for a new BRT system in the U.S. As shown in Table 3-1, the majority of these costs are associated with vehicle procurement (60 percent), station design (27 percent) and the fare collection system (10 percent).

The following unit costs are provided for comparison to other systems:

- The first 20 stations were $230,680 per station for construction.
- The additional Lake Mead stations were $64,278 per station for construction.
- All station planning, design and construction was $247,923 per station.
- The first 5 CIVIS buses were $1,309,250 per bus.
- The second 5 CIVIS buses were $1,013,660 per bus.
- All vehicle costs, including training and inspection were $1,209,646 per bus.

Table 3-1: Overview of Capital Costs associated with the MAX service*

Item	Cost	% of Total Cost
Shelters		
Design / Planning	$1,173,516	
Construction of Initial Passenger Shelters	$4,152,232	
Construction of 2 Additional Passenger Shelters	$128,566	
	$5,454,304	27%
Optical Guidance		
Pavement Markings	$43,197	0.2%
Vehicles**		
Initial 5 CIVIS Buses	$6,546,250	
Driver and Maintenance Training	$141,150	
5 Additional CIVIS Buses	$5,068,300	
Vehicle Manufacturing Inspection	$340,760	
	$12,096,460	60%
Signal Priority		
Planning, Implementation & Evaluation	$138,028	
Hardware	$130,945	
	$268,973	1.3%
Fare Collection		
Fare Collection System	$1,800,686	
Ticket Vending Machine Service Design	$200,000	
	$2,000,686	10%
AVL		
Installation by Orbital	$298,810	1.5%
TOTAL	$20,162,430	

Notes on MAX Capital Costs

* The cost of purchasing the running ways (bus lane) is not included in costs as Nevada DOT provided this at no charge to RTC.

** The optical guidance costs in this chart are included in the cost of each MAX bus. The separate cost of the guidance system was $95,000 per bus, plus an initial $500,000 to prepare a study to determine location of pavement markings.

3.2 Operating Costs

Vehicle Operation & Maintenance

MAX service operation is performed under contract to Veolia Transportation (formerly ATC). Basic vehicle operating costs are included in the contract, which as of March 2006 was priced at $75.52 per hour. For comparison, the contract price for standard CAT bus service is $52 per hour (also provided by Veolia Transportation). This discrepancy is due to the lower costs of operating and maintaining standard buses and the higher standards required for BRT service. However, RTC pays some costs directly, such as fuel and tires. RTC's finance office adds these costs plus allocated management, planning, and overhead costs to arrive at a fully accounted cost.

For the Fiscal Year July 2004 to June 2005, the average total operating cost of MAX was $92 per hour (see Table 3-2). Operating cost per service hour increased by 20% for the next Fiscal Year (July 2005 to June 2006), to an average of $111 per hour. This increase was primarily due to added costs for station maintenance and fare checkers. As service hours increased in the first year it became evident that better and more frequent maintenance was needed to ensure that MAX service was viewed as a higher class of transit service. With the current hourly rate, the cost to provide MAX's current 35,000 service hours per month is $3.9 million per year. By comparison, the fully accounted cost for Route 113 is about $72 per vehicle hour. MAX thus costs 50% more than standard bus service on a per hour basis. The premium is less on a per mile basis, because of MAX's faster operating speed.

Table 3-2: MAX Operating Costs, July 2004 to December 2005

	July 04 - June 05	July 05 – June 06
Operating Cost	$3,127,300	$3,874,047
Service Hours	33,847	34,923
Average cost / hr	$92.39	$110.93
Average cost / mi	$7.24	$9.04

RTC has identified some of the separate components of MAX-related costs, including the following:

- *Station maintenance*: RTC expends about $84,000 per year for regular station cleaning and maintenance, plus another $25,000 for painting and repairs, for a total of $109,000.
- *Ticket vending machines*: Servicing costs are $1,200 per ticket vending machine per year; repairs not covered under the warranty are another $3,000 per machine per year. RTC expects this cost to increase by 55 to 60% when they are out of warranty. RTC has one technician dedicated to

TVMs and another one who services TVMs in addition to other fare collection equipment. Thus annual TVM servicing for 23 machines is currently about $97,000.

- *Security officers*: For 2006 the contract amount for providing security officers was $330,000 per year, including fare verification and security for cash-in-transit and fare box cash-in-transit. RTC estimates that the cost of the fare verification portion of the contract alone is $270,000.

On-going operating costs associated with the MAX service consists primarily of operating and maintaining the vehicles. Other on-going costs include station and TVM maintenance plus costs associated with enforcing the off-board fare collection system.

4.0 PLANNING, DESIGN AND IMPLEMENTATION

4.1 Planning and Design

RTC planned and designed the MAX BRT to provide high quality, rapid transit service. These goals meant that the BRT service would deviate significantly from existing operating procedures and that RTC would be implementing new technology and systems. Recognizing that much of the MAX service was ground-breaking, RTC developed a variety of techniques to ensure success as they implemented, managed and developed the MAX service.

In this section of the evaluation, we will review the implementation strategies used by RTC and examine their effectiveness and efficiency in terms of managing and developing a BRT service. Our analysis concentrates on three aspects of the implementation plan:

- Vehicle Service, Operations and Maintenance Plan;
- Implementation and Management of ITS Systems; and,
- Branding, Imaging and Public Acceptance of Service.

We will present our findings for each of these topics in terms of what management strategies were employed as well as an assessment of how effective the technique proved to be. We will also highlight key lessons associated with the management plan.

4.2 Vehicle Service, Maintenance and Operations Plan

When RTC selected the CIVIS vehicles as the signature vehicle for the MAX service, they understood that while the vehicle offered distinct advantages, it also presented challenges. The CIVIS vehicle, for example, is designed and manufactured in France and prior to this project, had not been sold in the United States. MAX, therefore, was the initial application of the vehicle technology to U.S. standards and conditions. In addition, RTC also had to develop mechanisms to ensure vehicles could be properly maintained and parts would be readily available. Recognizing these challenges, RTC adopted a series of management and implementation techniques to ensure vehicles would be effectively maintained, serviced and operated.

Vehicle Service Plan

The first step for an effective maintenance and operations system is to ensure the service plan works with the available number of vehicles. Although the first trip starts at 5 a.m. and the last trip starts at 10 p.m., MAX vehicles are in operation from 4 a.m. to 11 p.m. – 17 hours a day. Between 5 a.m. and 7 p.m., a MAX vehicle departs from the Downtown Transportation Center (DTC) every 12 minutes regardless of when the last vehicle returned. The round-trip cycle takes approximately 60 minutes to complete, thus requiring six vehicles to operate. To ensure no breaks in this schedule, RTC positions a spare vehicle at the DTC; if a vehicle is delayed or has problems, the schedule can be met. On average, 0.6 vehicles are not available for service on any given day.

RTC maintains 10 CIVIS vehicles; six vehicles are on the road and one is positioned at the DTC for a swap. This leaves two vehicles as spares and one vehicle (unofficially) available for special events. RTC and Veolia estimated that to maintain a 12 minute service, 10 vehicles is adequate, but maintenance requirements mean it would be difficult to operate a 10 minute service, which would require seven vehicles on the road plus one at DTC.

Vehicle Maintenance

As discussed, the CIVIS vehicle design includes new vehicle technology and systems not previously tested in the United States, such as an electric drive system with a diesel-driven generator and electric motors. Anticipating challenges associated with maintaining the vehicles, RTC developed a multi-pronged management plan that included:

- Identifying and selecting the best electronic technicians available;
- Providing these staff with extensive hands-on training;
- Requiring two-years of on-site after sales service to help with vehicle maintenance;
- Setting up on-going internal meetings to discuss maintenance that included conference calls with vehicle manufactures;
- Tracking parts usage to ensure frequently needed parts are in stock; and
- Taking advantages of vehicle technology such as on-board diagnostic systems to be proactive about vehicle repairs and maintenance.

As they did with the vehicle operators, RTC and Veolia also selected the best electronic technicians working for CAT and trained them extensively, both locally in Las Vegas as well as in France where they worked directly with the manufacturer. Technicians were also rewarded with salary increases and an opportunity to work on cutting-edge electronic systems. These strategies created a team spirit and fostered a sense of pride. To date, of the four mechanics currently assigned to MAX, three have been with the project since inception.

RTC also required a significant after-sales service component in their contract with Irisbus, the manufacture of the CIVIS vehicle. After-sales elements included a

CIVIS vehicle expert with appropriate language skills on-site in Las Vegas for two years. In addition, Irisbus promised to have a technical expert at the plant available 24 hours a day, seven days a week to troubleshoot when maintenance or operation problems arose. The Las Vegas and Irisbus teams also had weekly conference calls. RTC considered these services essential to their success. Irisbus and RTC effectively became partners in the successful implementation of the CIVIS vehicles, a relationship that greatly enhanced the success of vehicle implementation.

The CIVIS vehicle maintenance team acknowledged that they have had parts supply problems; early in the project they underestimated the time required for spare parts to get from France to Las Vegas and the impact of custom requirements on parts delivery. Most of these problems have been overcome, primarily by identifying high usage items, typically parts associated with the drive train system, and keeping these items in stock.

Lastly, RTC and Veolia also recognized that with the CIVIS vehicles, communication between drivers and technicians is more important as compared with the CAT fleet. This is because the CIVIS vehicles have on-board diagnostics that give drivers information about CIVIS vehicles, including mechanical issues. They trained the drivers to understand the diagnostic system and communicate this information to the maintenance team. As a result, they have been able to identify problems earlier and avoid others all together.

Vehicle Operations

RTC recognized that drivers are ambassadors for MAX and therefore viewed them as an essential component of a successful service. In addition, RTC acknowledged that as compared with CAT vehicles, operating the CIVIS required increased skill and experience. As a result, RTC and Veolia developed an operator service quality plan built around selecting the most experienced and best performing drivers, providing them with additional training, and establishing and fostering team spirit.

Veolia set a variety of criteria to determine which drivers would be eligible to work on the MAX project, including having:

- At least two years of driving experience;
- An impeccable safety record– operators with no preventable accidents in the past two years and not more than one preventable accident over the last six years;
- Good attendance;
- No unexplainable customer complaints.

In addition to meeting these criteria, drivers interested in MAX had to be willing to make a one-year commitment to the project. In exchange, Veolia offered potential MAX drivers pay increases and intensive training. MAX drivers received 80 hours of training behind the wheel, much more than provided for other services. As with the maintenance team, Veolia also worked to create team spirit among the drivers, whereby the MAX drivers recognize themselves as "the best of the best."

MAX operators have proven to be an integral element of the success of the MAX service. To date, only two drivers have left MAX, both to drive RTC's new double-deck bus service, the Deuce. Currently there are 26 active drivers on the MAX schedule, plus two inactive drivers and 11 on the MAX waiting list. MAX operations also have an exemplary safety record; between January 2005 and May 2006, MAX drivers went 514 days without a preventable accident.

Lessons Learned

RTC developed a successful plan both with regard to initial implementation of MAX and on-going operations. The Study Team identified two key lessons that can be taken from RTC's experience maintaining and operating CIVIS vehicles.

After sales service is essential. After sales service is especially critical when implementing new technology and in cases where products are developed overseas. On-going open conversation with the vehicle supplier meant RTC was able to solve problems quickly and efficiently and avoid service disruptions.

Investments in human resources are worthwhile. RTC worked with its contractor to find, retain and train the best employees available and reward them with training, improved working conditions and pay increases. They also fostered a team spirit creating pride in their work. As a result, staff turnover has been low, and performance and satisfaction high.

4.3 Implementation and Management of the ITS Elements

As noted previously, RTC implemented several intelligent transportation system elements as part of the MAX service, several of which were highly innovative and prior to MAX, had not been widely implemented in the United States. Three of the most visible ITS elements used in MAX are:

- Optical Guidance System and Precision Docking;
- Traffic Signal Priority and Queue Jumper Technology; and,
- Automatic Passenger Counters and AVL/CAD systems.

Optical Guidance System and Precision Docking

RTC considered precision docking an essential feature of MAX; docking vehicles flush with the raised station platforms would reduce vehicle dwell time by ensuring all passengers could enter from any one of the vehicle's four doors. To make precision docking easier and more reliable, RTC procured and installed an optical guidance system. The system operates by installing pavement markings that are tracked by an on-board video camera, allowing the system to dock vehicles without operator effort, thereby improving the accuracy of the docking.

After installing the system, however, RTC discovered problems. Reading the pavement markings required a sufficient amount of contrast between the pavement and the markings. Las Vegas is extremely dry; consequently roads accumulate dust and dirt and there is no rain to clean the surface. The build up of dirt quickly resulted in insufficient contrast between the markings and the roadway, making the system unreliable.

RTC tried a variety of techniques to resolve the problem, including re-painting the pavement markings, and was ultimately able to provide sufficient contrast with weekly power-washing of the pavement markings. While this solved the problem, it was an expensive solution. At the same time, drivers demonstrated that they were able to dock the vehicles manually by following the pavement markings and taking advantage of the center drive position. As a result, RTC determined that the optical guidance system was not a cost-effective technology for the Las Vegas region and they were able to meet the requirement with manual docking.

However, one could say that this was an expensive lesson. The cost for optical equipment for each bus was $95,000. In addition, the pavement markings cost $43,000, and there was a $500,000 initial study investment to accurately determine the proper location of markings. In all, the optical system cost nearly $1.5 million, or roughly 7% of the entire system cost.

Transit Signal Priority

Transit signal priority (TSP) is one of the core MAX components, intended to increase speed and reliability. Eleven signalized intersections on the MAX route were equipped with TSP logic to reduce signal delay. In addition, one intersection was equipped with a "queue jumper" to reduce bus wait time at the intersection (see section 4.2.3).

There are several operating constraints designed into the TSP programming logic in order prevent excessive delay to other traffic. Once a vehicle is given priority, the signal controller must be back in synch with surrounding signals within one cycle length. TSP functions cannot be called in consecutive cycles due to the compounding effects on synchronization and the disruption of traffic flow. No traffic movements, including pedestrian movements, can be skipped in any one cycle. Some of the potential TSP functions at certain intersections were disabled because of software and hardware limitations that prevented them from being implemented given the constraints listed above.[3]

TSP Effectiveness

How effective is the transit signal priority system at reducing travel delay? RTC provided us with automatic vehicle location data for MAX on days with the Transit signal priority system enabled and disabled. A comparison of these travel time data lets us determine the effect of TSP on MAX's travel time.[4]

The dataset contains door open and close time, passengers on, passengers off, and scheduled trip start time. However, the AVL system did not successfully record data for each stop. The Downtown Transportation Center (DTC) stop is often missing from each trip record (RTC is aware of this problem.) Therefore, it was impossible to compare end-to-end trip times. We instead chose the longest segment for which complete information was available for most trips. For southbound trips, almost every trip departure from the Craig terminal was recorded. The trip end time was taken as door open at Tonopah (Jerry's Nugget), the last stop before the DTC. For northbound trips, the trip start time was taken as door close at Tonopah (Jerry's Nugget), and the trip end time was taken as door open at Cheyenne Avenue, which is five stops before the end of the line. Using a further destination would have greatly reduced the sample size because the number of observations recorded per stop dropped off dramatically beyond Cheyenne, presumably due to technical problems. Furthermore, Cheyenne Avenue is the northern-most traffic signal equipped with TSP; looking at further stops is therefore unnecessary to evaluate the effects of TSP.

Southbound Trips

There were 1,049 matched pairs of observations of southbound trips from Craig Avenue to Tonopah; 389 of these were with TSP functioning. There were two outliers in the dataset (trips of 53 and 92 minutes) which were removed. All other trips were under 29 minutes. A regression model of trip duration in minutes was estimated. The explanatory variables are: trip using transit signal priority (TSP), day of the week, and peak or non-peak; all of these are indicator variables having the value 0 or 1. A "peak" trip was defined as one occurring between 7 am and 7 pm. (Analysis of the data reveals that there is not much variation in mean trip time during this long period.) As shown in Table 4-1, the first model shows that the mean trip time was just over 18 minutes and was 1.4 minutes (1 min, 22 seconds) longer in the peak period and just over 1 minute shorter on Sundays. There were

[3] See RTC, FAST. *Transit Signal Priority Implementation Summary Report.* June 15, 2005.

[4] The data for MAX with TSP off were from Thursday, September 15, 2005 to Saturday, September 24, 2005 (10 days). The data for MAX with TSP in operation were from Tuesday, September 27, 2005 to Monday, October 1, 2005 (7 days).

no other significant differences by day of the week. The use of TSP was not statistically significant. Perhaps TSP only makes a difference during the peak period, when there is more traffic congestion. To test this, we estimated a second model including a term representing the interaction between peak period and TSP on. This model suggests that there was no effect of TSP in the peak, contrary to our assumption. However, in the off peak, trips with TSP functioning were 0.5 minutes (30 seconds) quicker (coefficient significant at the 90% confidence level).

Table 4-1: Regression Model of MAX Travel Time with and without Signal Priority – Southbound Trips
(Dependent Variable: Travel Time in Minutes)

	coeff.	t	coeff.	t
Constant	**18.09**	94.59	**18.22**	85.34
TSP	-0.17	-1.29	**-0.49**	-1.80
Sunday	**-1.07**	-4.68	**-1.07**	-4.69
Monday	0.11	0.46	0.12	0.48
Tuesday	0.24	1.05	0.24	1.07
Wednesday	-0.04	-0.16	-0.04	-0.14
Friday	0.03	0.17	0.03	0.17
Saturday	-0.22	-1.06	-0.22	-1.05
Peak	**1.38**	9.04	**1.21**	6.23
Peak*tsp			0.42	1.35
Adjusted R Square	0.10		0.10	
Std. Error of the Estimate	2.03		2.03	
Observations	1,047		1,047	

Table notes: Coefficients that are significant at the 90% confidence level or higher are shown in bold. Peak" refers to 7 am to 7 pm.

Northbound Trips

There were 555 matched observations of northbound trips from Tonopah to Cheyenne Avenue; 202 of these were with TSP functioning. The variables used are the same as for southbound trips. The model results (Table 4-2) show that peak trips average a bit over a minute longer than non-peak trips and that Saturday trips are slightly shorter. The first model shows that TSP actually made trips slightly longer, but by an inconsequently amount (0.22 minutes, or 13 seconds). The second model includes an interaction term for peak-period TSP trips. This model reveals that peak period trips with TSP were not statistically different from peak trips without TSP, but off-peak trips with TSP were about 30 seconds longer, contrary to expectations of improved travel time with TSP. This result was significant at the 90% confidence interval.

Table 4-2: Regression Model of MAX Travel Time with and without Traffic Signal Priority – Northbound Trips
(Dependent Variable: Travel Time in Minutes)

	coeff.	t	coeff.	t
Constant	**10.81**	51.31	**10.65**	41.71
TSP	**0.22**	1.70	**0.54**	1.66
Sunday	-0.12	-0.50	-0.12	-0.49
Monday	-0.34	-1.44	-0.35	-1.48
Tuesday	-0.32	-1.54	-0.32	-1.56
Wednesday	-0.20	-0.83	-0.20	-0.83
Friday	-0.03	-0.15	-0.02	-0.10
Saturday	**-0.35**	-1.69	**-0.34**	-1.67
Peak	**1.19**	6.76	**1.37**	5.70
Peak*tsp	-	-	-0.38	-1.08
Adjusted R Square	0.07		0.07	
Std. Error of the Estimate	1.45		1.45	
Observations	555		555	

Table notes: Coefficients that are significant at the 90% confidence level or higher are shown in bold.
"Peak" refers to 7 am to 7pm.

Discussion of Results

These results show that TSP hastened southbound off-peak trips by about 30 seconds, but *slowed* northbound off-peak trips by about the same amount. Recall that off-peak in this case means 5 am to 7 am or 7 pm to 10 pm. These findings were statistically significant. However, they represent only a 3% decrease in travel time southbound and a 5% increase northbound. Based on these results, we conclude that there is little or no benefit from the TSP installation in this case.

Why did we fail to find an effect of TSP? One possibility is the limitations of the data provided. Due to gaps in the recording of AVL data by stop, the trips analyzed do not include the Tonopah to DTC segment in either direction, and therefore do not take into account the effects of TSP on Owens and on Main Street. Also, the northbound data only go as far as Cheyenne, although this is the northernmost intersection equipped with TSP. Unless traffic congestion is much more severe at the two TSP-equipped intersections not included in this analysis, complete data would be unlikely to change the conclusions, since we have included 8 of the 10 TSP intersections.

A more likely explanation for the failure to find a travel time benefit from TSP is simply that there is insufficient traffic congestion in this corridor to generate significant signal delays during most times of the day. Travel times are fairly constant throughout the day. Southbound trips between 5 and 6 am average 17.3 minutes (the fastest hour of the day); trips between 4 and 5 pm average 20.0 minutes (the slowest hour). The difference is only 16%, and most of this is probably due to the greater number of passengers boarding and alighting at the later hour.

Queue Jumper

The single "queue jumper" in the system is located at Jerry's Nugget southbound station where Las Vegas Boulevard North crosses Tonapah. A request to "jump queue" is triggered when the induction loops in the right-turn only lane sense a vehicle and the vehicle transmits an Opticom infrared signal. A request, therefore, will only be triggered when a vehicle is waiting at a red light. Upon receiving the request, the traffic signal controller displays a special white bar signal, indicating a bus-only green. This signal lets the driver continue straight from the right-turn only lane, before other traffic is released. The Jerry's Nugget southbound station is an excellent location for the technology because the road drops from three to two lanes, creating the potential to delay a transit vehicle waiting to merge out of a station.

RTC has experienced minimal problems with the technical functions of the queue jumper system; in some cases members of the public who do not understand the system have called the police, reporting a vehicle running a red light. RTC used the technology strategically to ensure the service met its operating criteria.

The deficiencies in the AVL data, as discussed in the previous section, mean that we have no travel time data that includes the queue jumper; it may have an effect on travel time, but we were unable to measure it. However, 95% of bus operators surveyed believe that it helps to speed service (see section 5.2).

Off-Board Proof of Payment Fare Collection System

RTC implemented the off-board fare collection system to reduce vehicle dwell time at stations; off-board fare payment is also consistent with the characteristics of rapid transit services. An off-board proof of payment fare collection system means that passengers buy their tickets from automated ticket vending machines (TVMs) before they board the vehicle. Tickets are periodically checked by “fare checkers” who board buses at random and ask passengers to show valid fare media. MAX was the first experience with both off-board proof of payment systems and using automated ticket vending machines in the Las Vegas valley.

Wackenhut Security has a contract with RTC to provide fare verification and security on the MAX system. Although the fare checkers are security personnel, their responsibility on MAX is to collect fares. Drivers are still responsible for enforcing service rules. Two Wackenhut officers ride MAX at all times; they never board vehicles together and typically ride in opposite directions. When they board the vehicle, they ask all passengers on the vehicle to show proof of payment. With two officers riding MAX at all times, Wackenhut is able to check approximately 20 percent of passengers, meaning a commuter can expect to be checked an average of once a week. RTC believes this level of checking is sufficient to create a perception that a ticket inspection is likely.

When a passenger is caught without valid fare, the security officer will ask the individual to get off at the next stop and purchase a ticket. At this time, the officer will also explain how the system works. Officers are able to check fare evaders against a list of previous offenders that is updated daily and available via hand held personal digital assistants (PDA) carried by the officers. In 2005, Wackenhut filed about 500 reports per month, a number that has increased in proportion to MAX ridership. About three-quarters of the reports are related to fare enforcement, and most of the rest are for loitering. Almost all (98%) of the fare-related reports are warnings for no ticket, expired ticket, or no valid ID. In 2005, about 10 summonses were given per month for fare evasion. That number is up to 40 to 50 summons in lieu of arrest (SILA) packages per month for 2006. Fare evaders are given two warnings before receiving a SILA. RTC considers the current number of summonses manageable.

RTC’s experience with off-board fare collection is positive. Passengers have adapted to both using the TVMs and purchasing their tickets before they board MAX. Taking fare collection away from the drivers has reduced vehicle dwell time. The officers also provide an increased sense of security both on board the vehicles and at the stations, a service that is well appreciated by drivers and passengers. Officers also help RTC in other ways, such as reducing station loitering and reporting vandalism.

Lessons Learned

RTC identified a series of intelligent transportation systems deemed essential to creating a rapid transit service. In some cases new systems were implemented easily and in others less so but in every case, installing and operating new technologies required considerable staff resources. Because staff was able to spend time on implementation and adjust systems on the ground, however, they were able to use the technology effectively and improve the quality of the transit service.

Experience with the MAX ITS systems also created opportunity for transferability of technologies from MAX to the wider transit network. An excellent example of technology transfers is the TVMs. After installing TVMs at the MAX stations and DTC, RTC expanded use of the machines to other locations; many of these TVMs are among the most productive machines in the RTC transit network.

4.4 Branding and Public Acceptance of Service

As discussed, when planning and designing MAX, RTC branded the service so that it would be distinct from existing CAT services and attract a higher portion of "choice" riders. The branding exercise was successful; after one year of operations, MAX ridership increased by nearly 40 percent, from 7,000 daily riders to 9,800, and survey results show a majority of people identify MAX as providing faster and more reliable services (see Chapter 6).

As the Study Team examined the impact of the MAX brand, it became apparent that the experience with MAX has also played an important role in shaping the perception and expectation for transit service delivery. Indeed, the successful implementation of MAX on Las Vegas Boulevard is leading to expansion of the service to other parts of the RTC service area. In addition, our research suggests that experience implementing MAX has been at least partially responsible for both RTC staff's willingness to experiment with additional innovative transit services and the community's willingness to accept them.

Additional MAX Routes

After successfully implementing a premier rapid transit service, RTC was able to obtain the cooperation of local governments to expand the MAX service into a broader system of BRT services. The City of Las Vegas, for example, has agreed to use existing right-of-way to create a center-running exclusive busway through Downtown and on Grand Central Parkway. This new route will be branded as MAX with the same colors and look as the existing MAX. The station designs will be context-sensitive and reflect the cultural resources of the surrounding community.

In 2005, RTC released an RFP seeking to purchase 50 vehicles similar to those used on the first MAX route, to be used on in the summer of 2008 for the Boulder Highway MAX and the Downtown Connector MAX. Seven manufacturers responded to the RFP. In June 2006, RTC announced a deal with the Wright Group of Northern Ireland, UK to procure 50 StreetCar BRT vehicles, which have rail-like styling, in the manner of the CIVIS (see Figure 4-1). Unlike the CIVIS, the StreetCar does not have optical guidance. ISE Corporation of San Diego will provide hybrid diesel electric engines.

Figure 4-1: An illustration of one of the 50 new BRT vehicles to be added to the MAX fleet. This vehicle is being manufactured by the Wright Group of Northern Ireland. It will resemble the CIVIS but will not have optical guidance.

Regional Fixed Guideway

The MAX experience has also influenced other regional transportation projects. Las Vegas has been examining the potential of using BRT technology for the proposed regional fixed guideway, a 33-mile long-distance transit service bisecting the Las Vegas Valley, since 2002. During this time, the community has been considering both bus and rail technologies. After considerable debate and after MAX was successfully implemented, the RTC Board voted in April 2006 to designate rubber-tire rapid transit technology such as MAX, as the Locally Preferred Alternative for further consideration in an environmental impact statement and alternatives analysis. The Downtown Connector MAX would effectively be the first stage of the RFG.

New Transit Services and Products

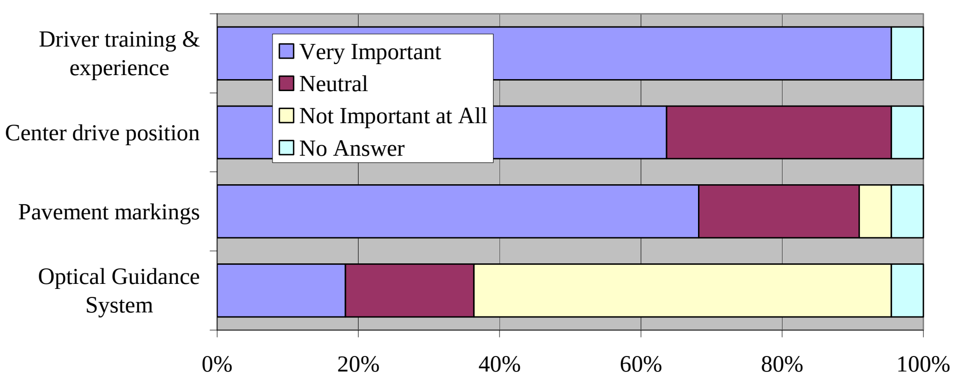
RTC also launched a new double decker bus service, the “Deuce”, operating along the Las Vegas strip (see Figure 4-2). The service commenced in late October 2005 and was designed to accommodate larger volumes of passengers; up to 97 people can fit on each bus. Although the Deuce operation plan is more consistent with regular CAT service, it provides another example of the RTC implementing innovative services.

Figure 4-2: Deuce, RTC's new double decker bus, operates on the heavily traveled Las Vegas strip.

Lessons Learned

RTC successfully used the MAX experiment to develop an appreciation for and understanding of the potential of alternative rapid transit technologies. They also demonstrated an ability to implement alternative services, innovative technology, and new ideas. Two new features of the system – the center drive position on MAX vehicles and pavement markings – were deemed very important by a majority of drivers for docking the vehicles, and for making precise stops (See Table 4-3). The Optical Guidance system, originally implemented for this same purpose, was deemed "not important at all" by a majority of MAX drivers. Success with these projects has effectively increased community support for RTC sponsored initiatives and ideas. RTC, in turn, has built on this support to promote other services.

Table 4-3:
Importance of MAX features in docking the vehicle for precise stops*



* See MAX BRT Service Questionnaire (Driver Survey) in Appendix.

5.0 EVALUATION OF SYSTEM PERFORMANCE

The MAX BRT system introduced a number of key performance attributes aimed at improving the pre-existing CAT conventional bus service in Las Vegas. Our evaluation of system performance is presented in this section and covers a number of the MAX system attributes that have been identified in FTA's CBRT document for decision making. These include:

- Travel Time (both actual and perceived)
- Reliability (actual on-time performance as well in terms of passenger and driver perceptions);
- Identity and Image (based on surveys and media)
- Safety and Security (actual crime, passenger perceptions and traffic issues)
- Capacity (vehicle capacity and passengers per hour per direction)

Each of these attributes is discussed below.

5.1 Travel Time

End-to-end travel time on MAX would be expected to be faster than Route 113 because of the following factors:

- Fewer stations means that there is less travel time loss due to acceleration and deceleration, and potentially less variability among runs that make many stops compared to those that make few stops.
- Proof-of-payment fare collection eliminates the need to pay while boarding and permits boarding passengers to use all four doors. This policy, plus the additional, wider doors and the level boarding (no steps) are expected to significantly reduce dwell times at stops compared to Route 113.
- The traffic signal priority requests and the single queue jumper may also help reduce travel time, or at least its variability.
- The exclusive bus lane may also have reduced travel time.

In fact, the end-to-end travel time on MAX was found to be faster than Route 113. Based on the data presented in this section, fewer stations and proof-of-payment are factors. However, the traffic signal priority has not significantly changed travel time. Although the exclusive bus lane is believed to have an effect, we have no data on Route 113 travel time prior to its deployment.

AVL Travel Time Data

The AVL system provides on time performance (OTP) reports showing departure times at each the terminus and at pre-assigned time points. For both MAX and 113, there are 5 time points including the DTC. The time points for the two routes are not in the same places, except at each end. The data provided by RTC had many missing observations for the DTC time point. According to DTC, the AVL system is not consistently measuring the time at which the bus leaves the Downtown Transportation Center. We followed their advice in measuring travel time from the subsequent timepoint, adding in the scheduled travel time from the DTC to the first time point (and from the last time point to the DTC in the southbound direction) to produce estimates for the entire route. [5]

We summarized a week's worth of OTP data using a regression model with minutes of travel time as the dependent variable and indicators for day of the week and peak starting time as independent variables.[6] The peak period was defined as 7 am to 7 pm, every day of the week. Route 113 serves trips from 10 pm to 5 am that are not served by MAX. These Route 113 overnight trips were coded with an indicator variable so they could be accounted for separately.

The results for northbound and southbound trips are shown in Tables 5-1 and 5-2. The intercept in each of these ordinary least squares models can be interpreted as the average travel time, in minutes, for a baseline trip. In our case, a baseline trip is an off-peak trip on a Thursday (and that is not an overnight trip, in the case of Route 113). The independent variables tell us how travel times varies by peak, off peak, and overnight periods, and by day of the week. The t-statistic, which is the coefficient divided by its standard error, tells us if the difference is statistically significant. If the t-statistic is greater than 1.65, we can be 90% confident that the coefficient is not zero (in other words, for 9 out of 10 sample data sets we will be right); if it is greater than 1.96, we can be 95% confident (in other words, we will be right for 19 out of 20 samples).

[5] Following the Route 113 schedule for July 2006, we added 7 minutes to the southbound trips to account for the Washington Street to DTC segment, except in the overnight (10 pm to 5 am) period, where we added 6 minutes. For northbound 113 trips, we added 9 minutes for the DTC to Washington segment during the 7 am to 7 pm period, 7 minutes during the overnight period, and 8 minutes at other times. For MAX, following trip data prepared for the October 2006 schedule, we added 9 minutes to account for the DTC to Jerry's Nugget segment northbound and 8 minutes to account for the same segment southbound, at all times. Note that for both MAX and 113 the south and north routings are different, hence the different travel times. Schedule data were provided by Jacob Simmons of RTC.

[6] The week of data was for August 25 to 31, 2006.

Table 5-1: Regression Model of MAX and 113 Travel Time, Northbound
(coefficients in bold type are statistically significant at the 90% level or higher)

	MAX		113	
	coeff.	*t Stat*	*coeff.*	*t Stat*
Intercept	**29.2**	33.96	**39.2**	29.96
Peak	**2.7**	4.23	**4.9**	5.05
Fri	-1.2	-1.27	-0.4	-0.30
Sat	**-1.8**	-1.86	0.1	0.05
Sun	-1.4	-1.48	-2.2	-1.54
Mon	0.1	0.13	-1.7	-1.22
Tues	0.5	0.48	-1.0	-0.75
Wed	0.1	0.06	-1.3	-0.93
Overnight	-	-	**-3.5**	-3.23
Adjusted R Square	0.04		0.28	
Standard Error	5.77		5.89	

Table 5-2: Travel Time and Speed Differences by Time Period, MAX and 113, Northbound (using estimates from Table 5-1)

	MAX		113		Time Savings	
Time Period	**Min**	**MPH**	**Min**	**MPH**	**Min**	**%**
Peak	31.9	14.3	44.1	10.4	12.2	28%
Off peak	29.2	15.7	39.2	11.7	10.0	26%
Overnight	-	-	35.6	12.9	-	-
Peak vs. off-peak	9%	-9%	13%	11%		
Route Miles	7.619		7.667			

The model reveals that the average Route 113 trip time northbound is more than 39 minutes in the off-peak and more than 44 minutes in the peak (recall that the peak is here defined as 7 am to 7 pm). By contrast, MAX northbound averages 29 minutes in the off-peak and less than 32 minutes in the peak. This translates into a 28% reduction in end-to-end travel time in the peak and 26% in the off peak (see Table 5-2). The findings for southbound trips (Tables 5-3 and 5-4) are similar: 33% reduction in travel time due to MAX in the peak and 26% in the off-peak.[7]

Overall, the variability of travel time is less for MAX than for 113. The difference between peak and off-peak travel time is 14% for 113 northbound and 13% for 113 southbound, but 9% for MAX northbound and only 3% southbound (see Peak vs. Off Peak, Tables 5-2 and 5-4). Compared to all the other days of the week, MAX was a bit faster on weekends (1.8 minutes faster Saturday, northbound only; 1.4 to 1.9 minutes faster on Sunday).

Table 5-3: Regression Model of MAX and 113 Travel Time, Southbound
(coefficients in bold type are statistically significant at the 90% level or higher)

	MAX		**113**	
	coeff.	***t Stat***	***coeff.***	***t Stat***
Intercept	**27.3**	64.87	**37.1**	23.68
Peak	**0.9**	2.88	**5.0**	4.09
Fri	-0.5	-1.07	0.9	0.55
Sat	-0.7	-1.43	0.8	0.49
Sun	**-1.9**	-4.05	0.6	0.41
Mon	-0.4	-0.80	2.3	1.49
Tues	0.5	1.10	**3.5**	2.24
Wed	0.7	1.47	**4.9**	3.07
Overnight	-	-	**-6.5**	-4.86
Adjusted R Square	0.07		0.37	
Standard Error	2.88		6.75	
Observations	532		272	

7 The previous evaluation of MAX produced for FTA showed travel time savings of 38%- 42% during several time periods. One explanation for the somewhat lower time savings documented here is that the previous study compared MAX to Route 113 prior to MAX service. Many 113 riders changed to MAX when the service became available, and the lower ridership on MAX has possibly resulted in lower dwell times and faster service.

Table 5-4:
Travel Time and Speed Differences by Time Period, MAX and 113, Southbound
(using estimates from Table 5-3)

	MAX		113		Time Savings	
Time Period	**Min**	**MPH**	**Min**	**MPH**	**Min**	**%**
Peak	28.2	15.2	42.2	10.2	14.0	33%
Off-peak	27.3	15.7	37.1	11.5	9.8	26%
Overnight	-	-	30.6	14.0	-	-
Peak vs. Off-peak	3%	-3%	14%	12%		
Route Miles	7.131		7.136			

The sources of the travel time savings for MAX will be explored below. However, we should point out that these trips were measured on essentially the same route at the same level of traffic congestion, and that both routes use the bus lane where it is available. Therefore, the differences observed are not due to differences in traffic congestion, nor to the bus lane (although the bus lane might have an effect compared to not having it). Further, the slowing of Route 113 peak service, compared to off-peak or overnight, is not primarily due to increased traffic congestion in the peak, because if that were the source, MAX would be equally effected (although somewhat mitigated by the availability of traffic signal priority at some signalized intersections for MAX only). Longer dwell time and more frequent stops due to more stop requests is more likely to be the source of the peak-period delay on 113. MAX travel time is less sensitive to the number of passengers, based on this comparison of peak and off-peak travel time.

Perceived Travel Time

Perceived travel time is a key factor in the decision to take public transit. In an April 2005 survey of MAX riders, more than 90% of respondents indicated that their travel time had decreased since riding MAX, and two thirds indicated it had decreased by 11 minutes or more.[8] In an October 2005 survey the responses were very similar: 88% said their travel time had decreased, and 61% said it had decreased by 11 minutes or more. The travel time savings was similar for different

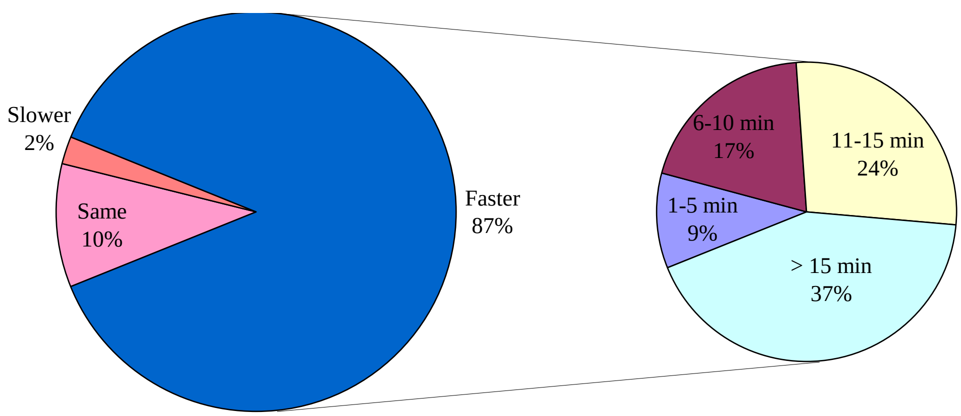
[8] RTC conducted on-board passenger surveys in both April and October of 2005. The second survey was conducted to ask additional questions, gauge changes in opinion, and verify the validity of responses to the first survey. Each round of surveys targeted 225 MAX passengers and 225 Route 113 passengers.

trip purposes (work, errands, leisure or family/friend visits). Table 5-5 and Figure 5-1 show the responses to the travel time change question.

Table 5-5: Has your travel time changed since riding MAX?

	April 2005		October 2005	
Response	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Yes, 1-5 minutes faster	16	7.1%	20	9.0%
Yes, 6-10 minutes faster	38	16.9%	39	17.5%
Yes, 11-15 minutes faster	60	26.7%	54	24.2%
Yes, More than 15 minutes faster	90	40.0%	82	36.8%
No, about the same	19	8.4%	23	10.3%
Yes, slower	2	0.9%	5	2.2%
Total	225	100.0%	223	100.0%

Figure 5-1:
Has your travel time changed since riding MAX? (October 2005)



MAX riders were asked the main reason they prefer to ride MAX. In April 2005, 72.4% listed faster travel time among the main reasons for choosing MAX. In October 2005, this figure declined to 64.3%.

In both April and October, 69.3% of respondents rated the speed of MAX travel as excellent. In comparison, only 5.8% and 12% of CAT riders rated the speed as excellent (see Table 5-6).

Table 5-6: Rate the speed of travel on MAX and CAT

	April 2005		October 2005	
	MAX	**CAT 113**	**MAX**	**CAT 113**
Excellent	69.3%	5.8%	69.3%	12.0%
Good	28.4%	47.6%	29.8%	44.0%
Fair	2.2%	31.6%	0.9%	34.7%
Poor	0.0%	14.7%	0.0%	8.9%

Wait and Transfer Time

The majority of MAX riders transferring from other routes (52.8%) indicated that their wait at the transfer point was between 1 and 5 minutes; only 11% waited 16 minutes or more. Route 113 riders were much more likely to have a longer wait: only 26.6% waited 1 to 5 minutes and 34% waited more than 16 minutes. Table 5-7 shows the responses to this wait time inquiry.

Table 5-7: For riders transferring from other CAT/MAX routes, how long did you wait at the location you transferred? (October 2005)

	MAX		CAT 113	
Response	**Frequency**	**Percentage**	**Frequency**	**Percentage**
1-5 minutes	38	52.8%	25	26.6%
6-10 minutes	12	16.7%	22	23.4%
11-15 minutes	14	19.4%	15	16.0%
16-20 minutes	2	2.8%	12	12.7%
More than 20 minutes	6	8.3%	20	21.3%
Total	72	100.0%	94	100.0%

In both April and October, 60% of respondents rated MAX wait time as excellent (see Table 5-8). In comparison, only 3% to 7% rated Route 113 wait time as excellent. More than one quarter of respondents said that Route 113 wait time was poor, but not a single person said that MAX wait time was poor.

Table 5-8: Rate the Wait Time at MAX and CAT Stations

	April 2005		October 2005	
	MAX	CAT 113	MAX	CAT 113
Excellent	59.6%	2.7%	60.4%	6.7%
Good	36.9%	32.9%	38.2%	32.4%
Fair	3.6%	35.1%	1.3%	35.6%
Poor	0.0%	29.3%	0.0%	25.3%

Station Dwell Time

The combination of level boarding, proof-of-payment fare collection, and multiple doors should reduce dwell time. Dwell time is also directly affected by the number of people boarding, the number alighting, and crowding on the vehicle. Because Route 113 and MAX may have different amounts of activity per stop, we cannot directly compare dwell time per stop. Therefore we estimated a regression model of dwell time for both MAX and 113 as a function of ons and offs (data on total load on the vehicle were not available).

The AVL data were cleaned by eliminating stops at the termini where every observation had unreasonably high dwell time. RTC believes that these readings are the result of the inability of the AVL system to distinguish between the end of one trip and the beginning of the next at the terminus. There were also some unrealistically high dwell times at other stops. Therefore, we capped the dwell time for all observations at 100 seconds. With the data cleaning, we were still able to use 91% of the observations for 113 and 97% for MAX.

The results of regression models for Route 113 and MAX are shown in Table 5-9. On average boarding time is faster by more than 2 seconds per person on MAX compared to 113. The model suggests that alighting time per person is slightly slower on MAX on average. However, because the constant term (which can be interpreted as the estimated delay with no people boarding) is lower on MAX, the estimated delay *per stop* is lower for MAX unless there are more than 15 people alighting and no one boarding. The average dwell time per stop is graphed in Figure 5-2 assuming that the number of people alighting per stop is fixed at five and the number boarding varies. With as few as 10 people boarding per stop, MAX has an advantage of 30 seconds lower dwell time per stop than Rt. 113. This advantage increases as the number of boardings per stop increases.

Table 5-9: Dwell Time Model Results

	Rt. 113	MAX
Constant (sec)	16.5	9.0
On (sec)	3.9	1.6
Off (sec)	1.0	1.5
n used	2,471	43,748
Total n	2,711	45,273
% used	91%	97%

Table notes: Dwell time capped at 100 seconds. Excluding the Walmart stop (#1281) for route 113 and excluding the DTC stop (#4269) for MAX. The complete 113 model is (standard errors in parentheses):

Dwell time = 16.5 + 3.9 (0.36) ON + 1.0 (0.15) OFF

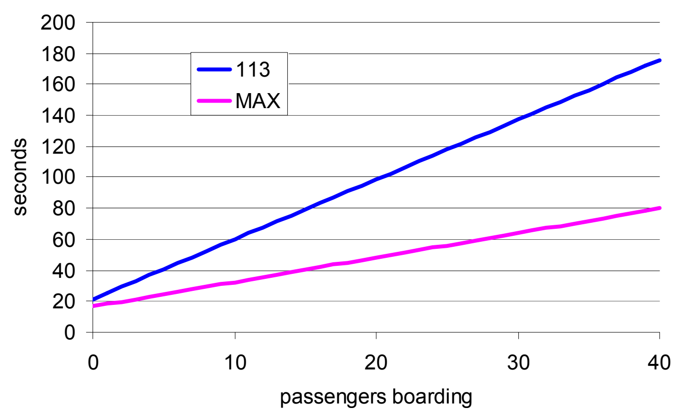
adj. R-sq = 0.256

For MAX:

Dwell time = 9.0 + 1.6 (0.023) ON + 1.5 (0.011) OFF

adj. R-sq = 0.334

Figure 5-2: Estimated Station Dwell Time
assuming 5 passengers alighting



5.2 Reliability

In theory, MAX service may be more reliable than Route 113 for the following reasons:

- Traffic signal priority and queue jumper reduce the variation in delay at signalized intersections.
- Proof of payment fare collection (with use of multiple doors) reduces the difference in dwell time at times of lower or higher demand and thus reduces variability in trip times.
- Fewer stops may also lead to less of a difference in delay due to the number of stops made between high-demand and low-demand times of day.
- MAX is operated on a headway-based schedule.
- Our analysis of AVL running time data showed that MAX travel time varies less between the peak and off-peak than route 113, and also less between different days of the week, although the latter result is based on limited data. In addition, there is more variation among trip times for Route 113. The standard deviation of running time (for a week's worth of data) is 7.5 minutes for Route 113 southbound and 6.8 Route 113 northbound but only 5.9 minutes for MAX northbound and 3.0 minutes for MAX southbound.[9]

Passengers may also perceive MAX to be more reliable than Route 113 because it has a higher scheduled service frequency and is much less likely to be overcrowded. MAX is seen as more reliable than Route 113: 96% of MAX riders surveyed gave a positive rating (excellent or good) for reliability (see Table 5-10). In contrast, only 50% to 54% gave a positive rating for Route 113.

Table 5-10: Rate the Dependability of MAX and CAT

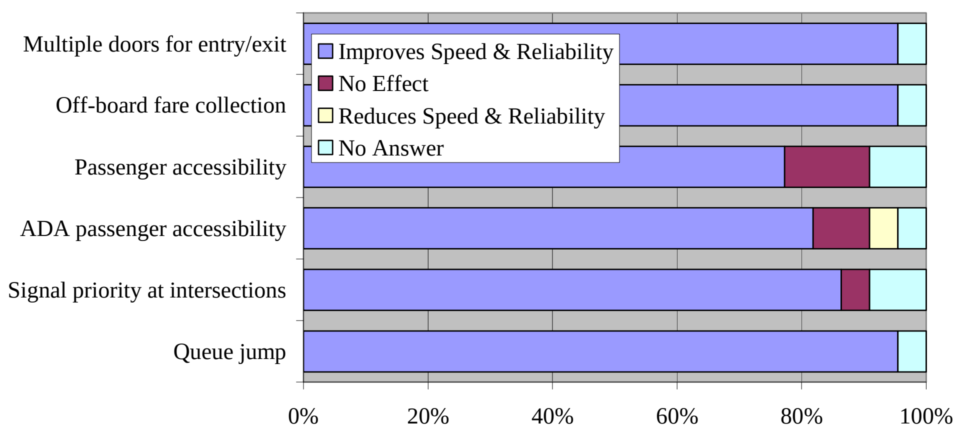
	April 2005		October 2005	
	MAX	CAT 113	MAX	CAT 113
Excellent	59.6%	7.1%	66.2%	19.6%
Good	37.3%	42.2%	30.2%	34.2%
Fair	2.2%	24.9%	3.1%	28.4%
Poor	0.9%	25.8%	0.4%	17.3%

9 The calculation of standard deviation of trip times excludes Route 113 trips starting at times when MAX does not operate, namely 10 pm to 5 am.

Driver Assessment of Reliability and Speed

In addition to passenger surveys, the evaluation team conducted a driver survey that asked drivers to rate various MAX features for their contribution to route speed and service reliability as compared to the standard CAT vehicle. Almost all (95%) felt that multiple doors for entry and exit, off-board fare collection, and the queue jump improved speed and reliability. Most (86%) felt that signal priority at intersections improved speed and reliability and one driver (5%) felt this had no effect. 18 of the drivers (82%) felt that ADA passenger accessibility improved speed and reliability, two drivers (9%) felt this had no effect and one driver (5%) felt the ADA passenger accessibility reduced the speed and reliability on MAX compared to CAT service. 17 of the drivers (77%) felt that passenger accessibility improved speed and reliability and three drivers (14%) felt this had no effect. These results are summarized in Figure 5-3 below.

Figure 5-3: Driver Assessment of MAX features for route speed and reliability compared to CAT



5.3 Identity and Image

Image and branding are considered key components of BRT, as they help distinguish BRT from conventional bus operations and contribute to attracting riders who might otherwise not use the conventional bus service (in this case, the CAT service). Image, as noted in the Characteristics of BRT document, relates to 'style, aesthetics and compatibility' of MAX's physical elements. Branding refers to the system's identity. We have three primary tools to evaluate public perception of the MAX image and branding. These are:

- Results from two surveys conducted among MAX and Route 113 riders;
- RTC's semi-annual benchmark survey of residents conducted with the general public
- News articles collected from regional media**.**

Based on these results, we have been able to determine that image of the MAX service by its riders is generally perceived in a very positive way, with the vast majority of users having a very positive image of the system. Note the following:

- 91% of passengers surveyed rated MAX station appearance as excellent or good
- 98% of passengers surveyed rated MAX vehicle appearance as excellent or good
- When all things are considered, 91-97% of passengers surveyed overall rated MAX as excellent or good – a very strong endorsement of the identity and image
- Outside of the users, however, MAX's identity is relatively unknown. A majority (97%) of Las Vegas area residents surveyed in RTC's annual benchmark surveys have never ridden MAX and only 40% have ever heard of it. This reflects both the location of the service and the overall usage of transit in an automobile driven urban environment.

The following sections present a breakdown of the rider and benchmark surveys as well as the media coverage related to MAX image and branding.

Passenger Opinion Surveys

The passenger survey provides insight into how transit riders view attributes of service that shape its identity and image. Among the many service attributes that MAX and 113 riders were asked to rate are appearance, design, cleanliness, and safety of the vehicles and shelters, and the quality of information provided at stops. The passenger ratings for these routes for both MAX and Route 113 are shown in Table 5-11. Almost all MAX riders (88% or more) gave positive ratings (excellent or good) for all of these attributes. CAT riders were much more likely to give negative ratings. The positive rating share for MAX was 22 to 57 percentage points higher than for CAT.

Table 5-11: Passenger Rating of Vehicles and Shelters,

MAX and CAT riders

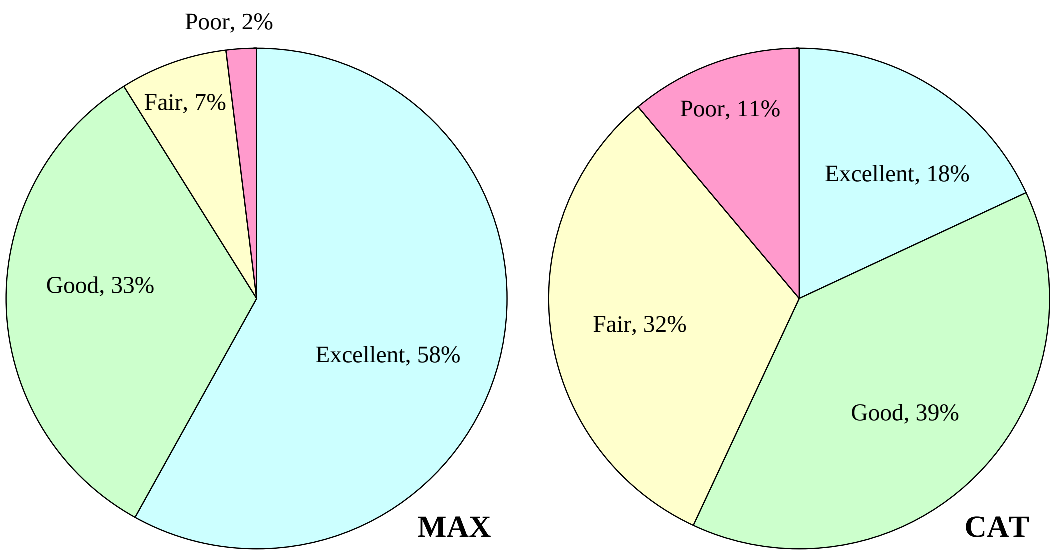
	MAX				Aggreg.	CAT				Aggreg.	Diff. MAX-
	Excel	Good	Fair	Poor	Positive	Excel	Good	Fair	Poor	Positive	CAT
Cleanliness of Vehicle	69.8	29.3	0.9	0.0	**99.1**	15.6	37.8	34.7	11.6	**53.4**	**45.7**
Cleanliness of Station	52.9	35.6	10.7	0.4	**88.5**	4.9	26.7	37.8	30.7	**31.6**	**56.9**
Safety of Vehicle	64.9	31.1	2.2	1.3	**96.0**	21.3	47.1	24.0	7.0	**68.4**	**27.6**
Safety of stations	50.2	40.9	7.1	1.8	**91.1**	13.8	34.7	23.0	19.1	**48.5**	**42.6**
Quality of Info at stops	46.2	41.8	8.9	2.2	**88.0**	20.9	44.4	23.6	10.9	**65.3**	**22.7**
Quality / Condition Shelters	51.1	41.3	6.7	0.9	**92.4**	10.2	36.4	31.1	21.3	**46.6**	**45.8**
Appearance / Design Shelters	48.9	41.8	6.7	1.3	**90.7**	13.8	37.8	28.9	18.7	**51.6**	**39.1**
Appearance / Design Vehicle	62.2	36.4	1.3	0.0	**98.6**	19.1	49.8	23.6	7.6	**68.9**	**29.7**

Passengers were also asked to give an “all things considered” rating of MAX and CAT route 113 services. MAX was rated considerably higher than CAT, with 96.9% of MAX riders rating the service as “excellent” or “good” in April and 91.1% “excellent” or “good” in October (see Table 5-12 and Figure 5-4). This aggregate positive rating was only 62.2% in April and 56.9% in October for the CAT service, with most positive responses in the “good” category rather than in the “excellent” category.

Table 5-12:
All things considered rating of MAX and CAT by riders of the service

	April 2005		October 2005	
Response	**MAX**	**CAT**	**MAX**	**CAT**
Excellent	66.7%	12.9%	57.8%	18.2%
Good	30.2%	49.3%	33.3%	38.7%
Fair	3.1%	26.2%	7.1%	32.4%
Poor	0.0%	11.6%	1.8%	10.7%

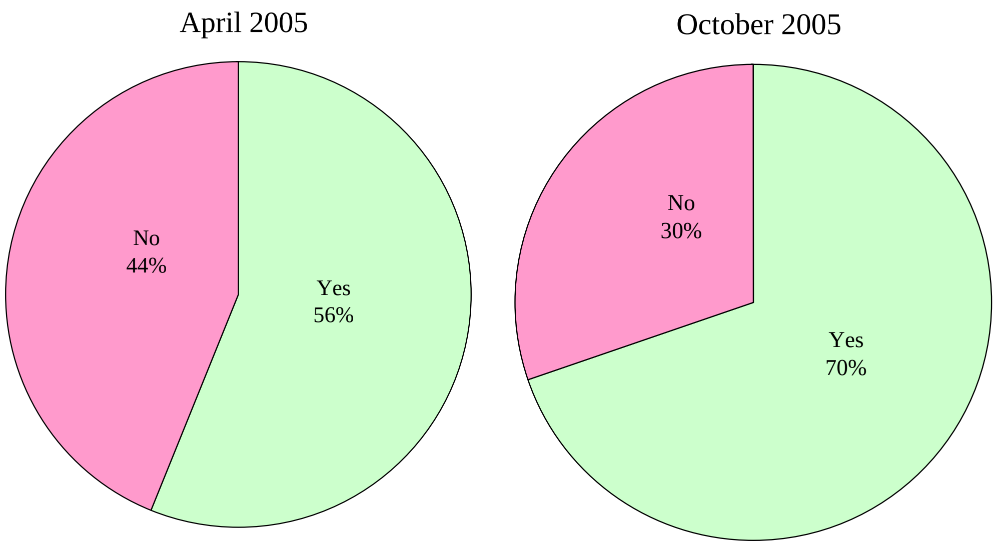
Figure 5-4: Overall Rating of MAX / CAT Service (October 2005)



Passengers Survey of Opinion of Alternative Mode

Opinions of riders on the service they are using is one way to gauge the performance of the service; however to truly measure the identity and image, it is more useful to look at responses by riders of the alternative mode. In other words, what opinions do CAT Route 113 riders hold about MAX and vice versa. Transit riders on both CAT and MAX were asked whether they have ever ridden the alternative mode of transit offered in the study corridor. As expected, the overwhelming majority of MAX riders indicated they had ridden CAT (99.1% in April and 97.3% in October). As shown in Figure 5-5, the percentage of CAT riders who had ridden MAX increased by a statistically significant amount from the April to the October survey (from 56% to 70%), indicating that CAT riders were becoming increasingly agreeable to try MAX.

Figure 5-5: Survey of CAT riders, "Have you ever ridden MAX?"



Riders on both CAT and MAX who had ridden the alternative mode of transit were then asked their opinion of the overall rating of that alternative mode. In other words, CAT riders who had ridden MAX were asked to rate their experience on MAX, and MAX riders who had ridden CAT were asked to rate their experience riding CAT. Table 5-13 and Figure 5-6 show the results of this inquiry.

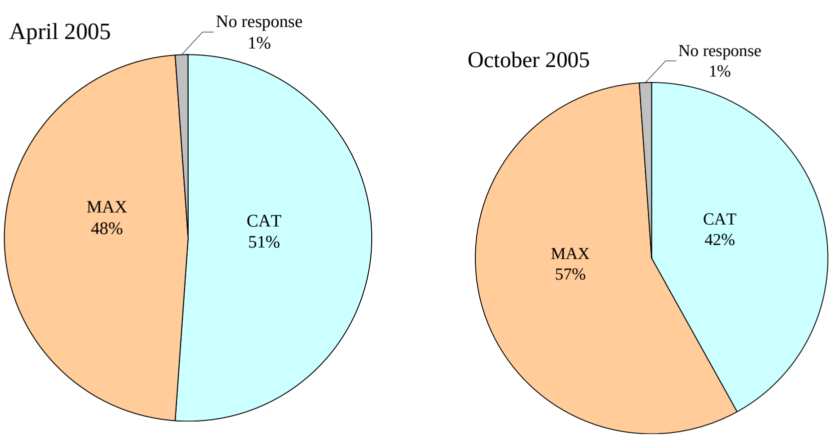
Table 5-13:
Overall rating of MAX service by CAT riders and CAT service by MAX riders

	April 2005		October 2005	
Response	**MAX rating**	**CAT 113 rating**	**MAX rating**	**CAT 113 rating**
Excellent	54.0%	12.6%	54.8%	15.1%
Good	38.1%	29.6%	36.9%	29.2%
Fair	4.8%	34.1%	5.7%	37.0%
Poor	3.2%	23.8%	2.5%	17.8%
No Answer	0.0%	0.0%	0.0%	0.9%

Clearly, the MAX service is deemed “excellent” or “good” not only by MAX riders, but also by CAT riders. The aggregate positive score given to overall MAX service by CAT riders was 92.1% in April and 91.7% in October as compared to an aggregate positive score of 42.2% for CAT Route 113 amongst MAX riders in April and 44.3% in October.

As a follow-up question, riders on both modes of transit in the study corridor were asked whether they prefer to ride CAT or MAX. As shown in Figure 5-6, a statistically significant increase in riders who preferred MAX to CAT Route 113 occurred from April to October. In April 2005, more CAT respondents selected CAT as the preferred mode (51.1%) to MAX (47.6%). In October 2005, the opinion had shifted to favor MAX (56.9%) over CAT (42.2%) amongst CAT riders. MAX riders consistently preferred MAX to CAT, with 96.9% of MAX riders preferring MAX in April and 92.0% of MAX riders preferring MAX in October.

Figure 5-6: Survey of CAT riders, “Do you prefer to ride CAT or MAX?”



Although the majority of CAT riders preferred MAX, they had still chosen not to ride the service on the day of the survey. Respondents were therefore asked the main reason why they chose not to ride MAX. Responses were:

- MAX does not stop close to my destination (17.8%)
- MAX is inconvenient for my trip (17.3%)
- MAX does not have enough stops to choose from (13.3%)

Resident Surveys

RTC conducts yearly benchmark surveys of 600 Las Vegas Valley adult residents.[10] In the 2004 and 2005 surveys, respondents were asked questions about name recognition, familiarity, use, and opinion of the Metropolitan Area Express (MAX).

Respondents were asked if they had heard of the Regional Transportation Commission (RTC) or the various modes of public transit service offered by the RTC: Citizen's Area Transit (CAT), Metropolitan Area Express (MAX), and in 2005, the Deuce Double-Deck bus system. Only a minority (41.5% in 2004 and 39.1% in 2005) had ever heard of MAX. By comparison, 90% (2004) to 95% (2005) had heard of the CAT system. This discrepancy shows that MAX could be better publicized. However, it should be borne in mind that the Las Vegas Boulevard corridor, the only one with MAX service in 2004-2005, represents a small portion of the Las Vegas Valley.

Of those who heard of both CAT and MAX in 2004, about half (50.4%) preferred to ride MAX transit if given a choice, less than one third (29.6%) preferred to ride CAT transit, and 20% did not indicate a preference. In 2005, 19.2% preferred MAX, 28.9% preferred CAT, and 47.9% gave no preference. This large number of respondents with no preference suggests that most Las Vegas Valley residents do not perceive a substantial difference between MAX and regular CAT service, probably because many of them have never ridden MAX or CAT, even if they have heard of these services.

Respondents were subsequently asked why they preferred to ride one service over the other. In 2004, the primary reasons for MAX preference were:

- Faster travel (30.6%)
- More modern/new (25.6%)
- More reliable / on time (12.4%)

Primary reasons for CAT preference were:

- More accessible/closer (38.0%)
- More route service (23.9%)
- More familiar with CAT service (18.3%)

In 2005, the majority of respondents showing a preference for MAX stated the primary reason was the service was faster (52%). Primary reasons for CAT preference were bigger service area / more routes (19%), familiarity with CAT (16.4%) and availability (12.3%)

[10] The 2004 benchmark survey had 599 valid respondents interviewed from December 5-17, 2004. The 2005 benchmark survey had a total sample size of 600 Las Vegas Valley residents interviewed from January 16-23, 2006.

In 2005, respondents were asked if their opinion of various RTC services were favorable or unfavorable. On the whole, respondents had the most favorable opinion of the Deuce double deck bus service (76.3%), followed closely by MAX (75.2%).

In addition to awareness and perception of MAX, respondents were asked if they had ridden the system and reasons for riding or not. In 2004, 97% of respondents indicated they had never ridden MAX. The top three reasons for not riding were:

- No MAX service near my home (41.2%)
- Never heard of MAX transit (26.1%)
- Prefer to drive my car (18.2%).

In 2005, the percentage of respondents who had never ridden MAX decreased to 88% of the respondents reporting that they had never ridden MAX. Reasons were similar to the 2004 study, with the most frequently cited reason for not riding MAX being private ownership of a vehicle (29.8%). The next most commonly cited reason was the absence of the MAX system in their area (14.5%) and no need for MAX (14.4%).

Media Coverage

Articles were published in the *Las Vegas Review-Journal* and *Las Vegas SUN* in May and June 2004 anticipating the service, in February 2004 at the time of the "Meet MAX" events, in Sept 2002 along with the testing of the CIVIS vehicle, in August 2001 when the MAX name was announced and occasionally throughout the implementation process. Articles also appeared in the New York Times, Construction Connection, Henderson Home News, Las Vegas Business Press, and various transit industry publications. The articles focused on MAX as a part of the transit package RTC is planning to offer, discussed the concept of bus rapid transit and explained the details of the line.

There was coverage of the start of service in the Las *Vegas Review-Journal*, *Las Vegas SUN,* and *CITYLIFE* on July 1, 2004. The articles discussed the opening ceremonies and the service in general. The *Review-Journal* article said the system has drawn praise from the Sierra Club and that other agencies are watching MAX's performance. The SUN article included positive comments from a resident of North Las Vegas and the Sierra Club. However, Nevadans for Equal Access complained about the lack of sidewalk access at some stations. The *Las Vegas Mercury* of July 8, 2004 also covered the MAX opening: "Is the hype justified? Pretty much. A spot-check that involved riding the route on a weekday finds that the buses are clean, well-run and nicely air-conditioned. Of course, it's too early to tell if MAX will succumb to those most frequent of riders' complaints – breakdowns and tardiness – but an informal survey of MAXers reveals they're pleased, with only a few minor peeves." The author claimed the center drive position blocks the view of upcoming stops and appreciated the presence of security guards.

Customer Comments

RTC indicates that overall customers have been very satisfied with the MAX system. Investigation of the customer comment records indicates that comments have been fairly steady since the inception of MAX. Early comments about the need for a bus stop at Walmart were answered with a stop to unload passengers, although no boarding stop could be added due to the absence of a fare machine. Failures with some of the automated fare machines that occurred in the beginning have been rectified. Many of the MAX comments revolve around complaints about Wackenhut security or fare policies, which is to be expected, as this is the first fare collection system of this type in Las Vegas. Other comments included complaints about operators passing people up due to the focus on speed of travel on this route.

5.4 Safety and Security

Crime

The creation of new, high quality, well-maintained MAX stations, and the presence of security personnel, may improve the sense of safety and security for transit users while waiting and riding the service. The evaluation team investigated passenger survey data, crime statistics, and CAT incident reports and interviewed key personnel to determine if there has been an impact on community safety, or perceptions of safety.

The Wackenhut security personnel add to the sense of security on the buses and in stations. Wackenhut reports indicate that only a few security incidents (injuries, assault, burglary, drug activity) occur each month. RTC has a policy against loitering that is enforced by Wackenhut security officers. If a bus arrives and the passenger fails to board, an officer will ask the passenger why he or she is at the station. Waiting for someone is an acceptable response, but otherwise if a person does not have an intention to use transit, the officer will ask him or her to leave the station. This policy is intended to keep vagrants out of stations. Approximately 20% of incidents reported by Wackenhut concern loitering.

Wackenhut officers do not enforce RTC rules such as prohibitions on eating or carrying open containers: this enforcement is the responsibility of the bus driver. RTC reports that for the most part drivers and Wackenhut employees have a good relationship, watching out for each other and helping one another. Drivers on the CAT system have indicated that they would like security officers on their buses too. The only negative aspects of having Wackenhut security personnel on board have been comments from passengers regarding where they stand and how they ride the vehicle. Some passengers say they are intimidated by their presence.

The hypothesis of the evaluation study team is that MAX's high quality; well-maintained stations and the presence of security personnel have improved both the actual and perceived safety both at stops and on board. Tables 5-14 and 5-15 and Figure 5-7 and 5-8 give riders' ratings of MAX and CAT Route 113 in terms of vehicle safety and station safety.

Table 5-14:

Rate the Safety of MAX / CAT Vehicle

	April 2005		October 2005	
Response	**MAX**	**CAT 113**	**MAX**	**CAT 113**
Excellent	68.9%	12.0%	64.9%	21.3%
Good	29.8%	62.2%	31.1%	47.1%
Fair	1.3%	20.0%	2.2%	24.0%
Poor	0.0%	5.8%	1.3%	7.6%
No Answer	0.0%	0.0%	0.4%	0.0%

Figure 5-7:

Rate the Safety of MAX / CAT Vehicle (October 2005)

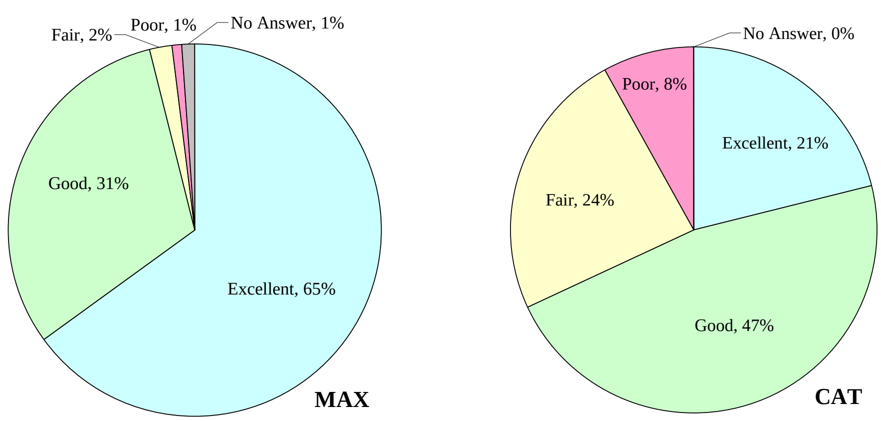
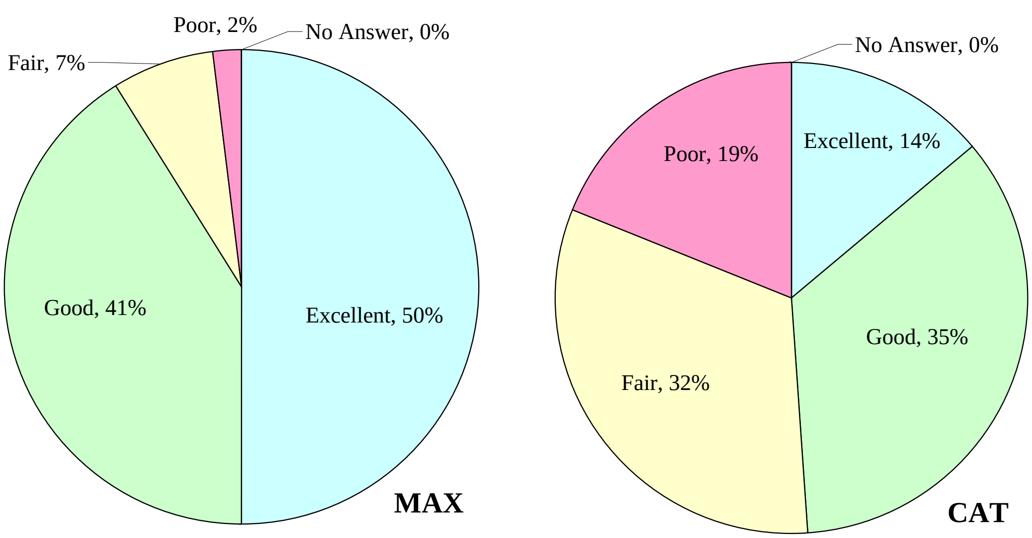


Table 5-15:
Rate the Safety of MAX Stations / CAT Stops

	April 2005		October 2005	
Response	**MAX**	**CAT 113**	**MAX**	**CAT 113**
Excellent	53.8%	3.1%	50.2%	13.8%
Good	38.7%	54.2%	40.9%	34.7%
Fair	6.7%	32.4%	7.1%	32.0%
Poor	0.9%	10.2%	1.8%	19.1%
No Answer	0.0%	0.0%	0.0%	0.4%

Figure 5-8:
Rate the Safety of MAX Stations / CAT Stops (October 2005)



As shown in the tables above, MAX riders considered their vehicles much safer than CAT riders considered their vehicles. MAX was given an aggregate positive score (excellent and good) of 98.7% in April and 96.0% in October for vehicles, while CAT's aggregate positive score was 74.2% in April and 68.4% in October. The biggest difference however is in the number of riders giving the vehicles an "excellent" rating with only 12% and 21.3% giving CAT an "excellent", but the majority of MAX riders (68.9% and 64.9%) giving MAX an "excellent" rating. Scores for stations and stops were similar to those for vehicles, with 92.5% aggregate positive ratings in April and 91.1% in October for MAX stations compared to 54.3% in April and 48.5% in October for CAT stops. Only 3.1% of riders gave CAT Route 113 an "excellent" rating for station/stop safety in April and 13.8% in October. Clearly, riders consider the MAX service much safer than CAT Route 113.

In addition to survey data, interviews with the transit agency and corridor communities indicate an enhanced feeling of safety and security along the corridor with the implementation of MAX. Prior to MAX, CAT Route 113 was known as a route with a higher potential for crime. Generally, the route served a rough crowd. There is a lot of anecdotal evidence that having the Wackenhut officers on-board is helping crime. The officers assist in reporting graffiti and other incidents. Evidence in an enhanced sense of security in the corridor includes merchants and shopkeepers reporting that are keeping their stores open for longer hours.

The evaluation team investigated crime in the corridor using incident summaries for Las Vegas Boulevard from January 2000 to April 2006 provided by the North Las Vegas Police Department. Although anecdotally the corridor may "feel" safer, there is no evidence to suggest that crime rates overall or in any specific incident category have decreased measurably due to the presence of the MAX service or the additional Wackenhut fare evasion security personnel in the corridor.

Traffic Safety

Using revenue fleet miles and vehicle accidents for the entire RTC system, Route 113 and MAX Las Vegas Boulevard North, the number of accidents per 100,000 revenue vehicle miles was calculated. Based on this calculation, 40.6% fewer accidents occur on MAX than on the RTC system as a whole. 56.5% fewer accidents occur on MAX than on Route 113, indicating that MAX is twice as safe. Injury rates remain similar to the RTC system as a whole.

In addition to having lower accident rates on MAX, the preventable accident rates on MAX are substantially lower than on the system as a whole. Since the opening of MAX, only 4% of the accidents have been preventable, compared to an RTC system average of 25% of accidents being preventable. Only one preventable accident occurred on MAX since the opening of service. Since January 2005, they have gone over 17 months without preventable accidents.

Two elements contribute to this safe record on the MAX system, the exclusive bus lanes and the drivers. In order to determine which has more effect, the number of preventable accidents in the corridor on Route 113 before the exclusive lanes was compared to the number of preventable accidents after the lanes were put in place. The preventable accident rate decreased to almost 1/3 of the rate prior to implementation of the exclusive lanes. However, the preventable accident rate on MAX is 1/20 of that on Route 113 today. Therefore, although the exclusive bus lanes have some effect on the safety of the bus route, the drivers have even more effect. The additional training, higher pay scale and extensive selection process for MAX drivers is a model that should be followed by other BRT systems.

5.5 Capacity

The CIVIS vehicle has a maximum capacity of 120 passengers, including standees. The MAX LVBN service operates at a maximum frequency of 5 trips per hour (12 minute headway). Thus the maximum number of passengers per hour per direction is 600 (5 x 120). Given the current vehicle supply of 10 vehicles, frequency could be increased to 6 trips per hour (10 minute headway). This would increase capacity to 720 passengers per hour per direction.

6.0 SYSTEM BENEFITS

The primary benefits associated with implementation of BRT are identified in the Characteristics of BRT documents as follows:

- Higher Ridership
- Cost Effectiveness
- Operating Efficiency
- Community Benefits
- Transit Supportive Land Development
- Environmental Quality

This section of our evaluation examines each of these potential benefits as they relate to the implementation of the MAX BRT.

6.1 Ridership

Change in Riders

Ridership on MAX increased steadily from the start of service in July 2004 to January 2006, and was level through July 2006 (see Figure 6-1). Total corridor ridership grew from about 7,000 boardings per day in May 2004 to a high of 10,000 in January 2006. RTC believes that problems with the Automatic Passenger Counting system led to undercounting of ridership following January 2006. The reported figures show average daily ridership in the corridor of 9,600 to 9,800 between February and July 2006, except for March, which showed an unusual drop in MAX ridership that is almost certainly due to an error in the counting system.

The share of the transit market in the Las Vegas Blvd. North corridor that was using MAX increased from 21% in the first month of operation to a high of 65% in April 2006, and has remained roughly constant since (see Figure 6-2). Most of the gain in market share happened within the first year of operation.

How does the gain in the LVBN corridor compare to changes in ridership in the CAT system? We compared average daily boardings, converted to an index with January 2004 equal to 100 (Figure 6-3). As of July 2006, more than two years after the start of MAX service, system ridership had increased 24% and LVBN corridor ridership had increased 38%. (Note that the March 2006 data appear to be incorrect, as explained above.) Most of the faster growth in corridor ridership compared to CAT occurred between June and October 2004—the first few months of MAX service.

Figure 6-1:
Average Boardings per Day, MAX and 113, January 2004 to July 2006

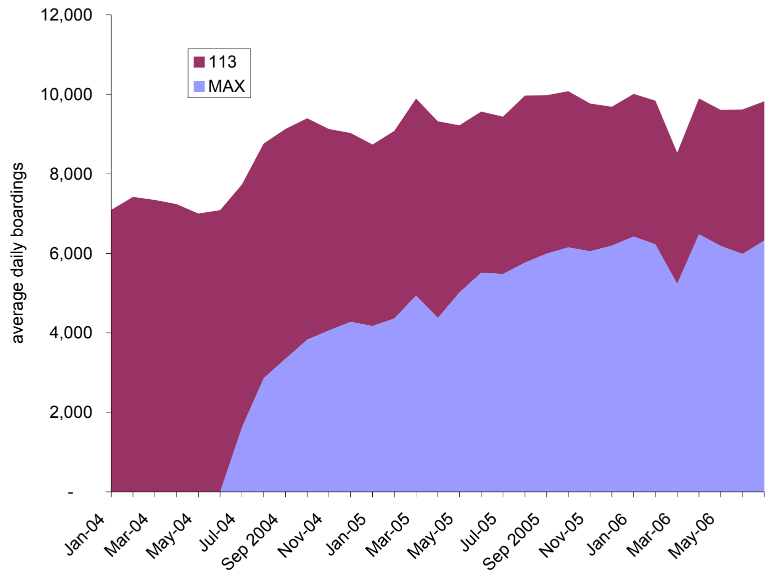


Figure 6-2:
MAX share of Las Vegas Blvd. North Public Transit Market

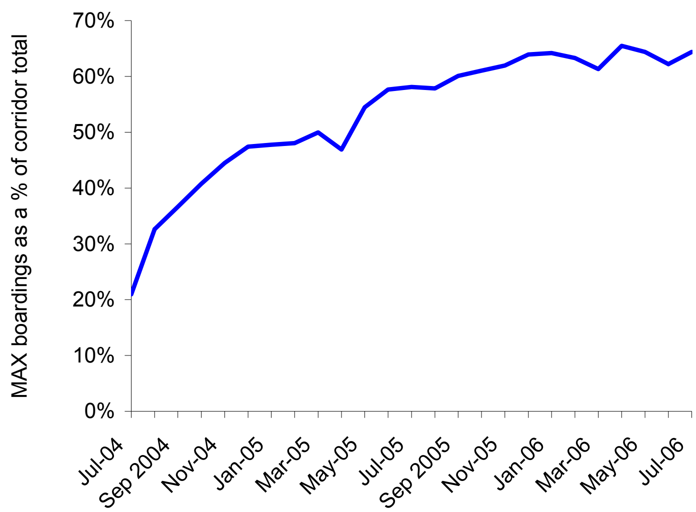


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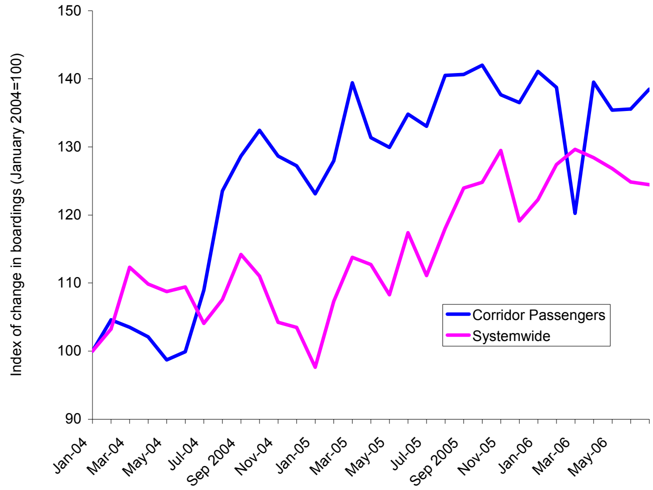
Figure 6-3:
Index of Changes in Boardings, LVBN Corridor and Systemwide



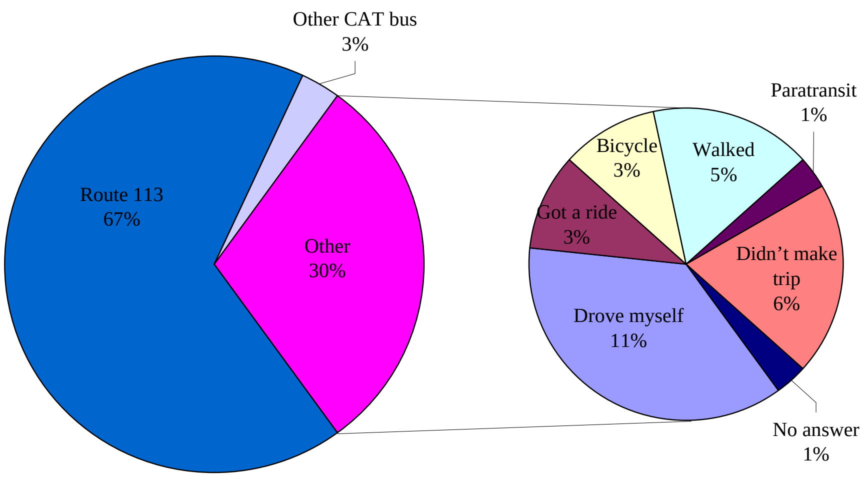
Source of New Riders

Some MAX riders were previously using Route 113, but others were newly making the trip by transit. Passenger surveys in April 2005 and October 2005 provide data on how passengers previously made the trip (see Table 6-1 and Figure 6-4).

Table 6-1: Previous mode of MAX riders

	April 2005		October 2005	
Response	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Drove myself	21	9.3%	25	11.1%
Got a ride from someone	6	2.7%	7	3.1%
Bicycle	1	0.4%	7	3.1%
Walked	13	5.8%	12	5.3%
Paratransit	1	0.4%	3	1.3%
Didn't make trip	12	5.3%	14	6.2%
CAT bus route 113	165	73.3%	151	67.1%
Other CAT bus route	6	2.7%	4	1.8%
No answer	0	0.0%	2	0.9%
Total	225	100.0%	225	100.0%

Figure 6-4: Previous mode of MAX riders (October 2005)



The majority of MAX riders (approximately 70%) were previously using CAT Route 113. Another 3% were previously using other CAT routes (3%). The remaining 30% are new transit riders. Of those riders new to transit, the largest group previously drove a car (10% of all riders). The next largest group, 6% of the total, did not make the trip previously. The remaining categories were walked (5%), bicycled (3%) and got a ride (3%), and paratransit (1%).

Demographics of Riders

It is also useful to compare the characteristics of riders new to transit to the characteristics of those who previously used Route 113 or another CAT route. These new riders were not attracted to Route 113, but with the new MAX service in place, they are now willing to take transit. This comparison allows us to understand the type of people that are attracted to BRT service.

Those who previously used another mode as a whole group are similar to previous CAT Route 113 riders in terms of trip purpose, trip frequency, race, and gender. They are however more likely to be employed full-time and more likely to be younger riders than previous CAT Route 113 riders. MAX riders who previously drove a car to make the trip differ from MAX riders as a whole in many ways however. These previous auto users are:

- More likely traveling to and from work (80% versus 64% for all MAX riders);
- More likely employed full-time (84% versus 70% for all MAX riders);

- More likely male (68% versus 55% for all MAX riders);
- More likely African American (40% versus 30% for all MAX riders);
- Less likely white (20% versus 27% for all MAX riders); and
- Less likely to use MAX every day for their trip (40% versus 61% for all MAX riders).

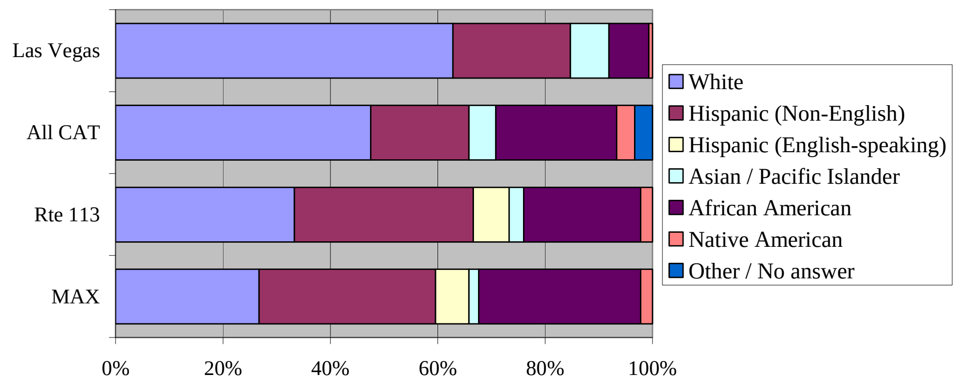
It is also useful to compare new MAX riders to those previously using Route 113 in terms of socioeconomic status, use of the CAT system, and other factors. This comparison can be made using the passenger survey data. This analysis will assist in understanding which people are attracted to ride BRT and if BRT can influence perceptions of transit.

In order to provide a demographic profile of MAX riders several surveys were consulted. First, in April 2002, RTC conducted an Origin-Destination Survey of the entire CAT system. This document provided a demographic profile of CAT riders in comparison with the Las Vegas Valley from the 2002 Las Vegas Perspectives document. These riders and resident profiles were compared to the 2005 MAX and CAT Route 113 surveys to determine how the demographics of typical BRT and non-BRT riders compare to the system in general. The four categories that were compared were ethnicity, age, employment status and gender. Table 6-2 and Figure 6-5 show the ethnicity of riders on MAX, CAT Route 113, the CAT system and Las Vegas.

Table 6-2: Rider ethnicity

<table>
<tr><th>Response</th><th>MAX</th><th>Rte 113</th><th>All CAT</th><th>Las Vegas</th></tr>
<tr><td>White</td><td>26.7</td><td>33.3</td><td>47.5</td><td>62.8</td></tr>
<tr><td>Hispanic
(Non-English speaking)</td><td>32.9</td><td>33.3</td><td rowspan="2">18.3</td><td rowspan="2">21.9</td></tr>
<tr><td>Hispanic (English-speaking)</td><td>6.2</td><td>6.7</td></tr>
<tr><td>Asian / Pacific Islander</td><td>1.8</td><td>2.7</td><td>5.0</td><td>7.2</td></tr>
<tr><td>African American</td><td>30.2</td><td>21.8</td><td>22.5</td><td>7.4</td></tr>
<tr><td>Native American</td><td>2.2</td><td>2.2</td><td>3.4</td><td>0.7</td></tr>
<tr><td>Other / No answer</td><td>0.0</td><td>0.0</td><td>3.3</td><td>0.0</td></tr>
</table>

Figure 6-5: Rider ethnicity

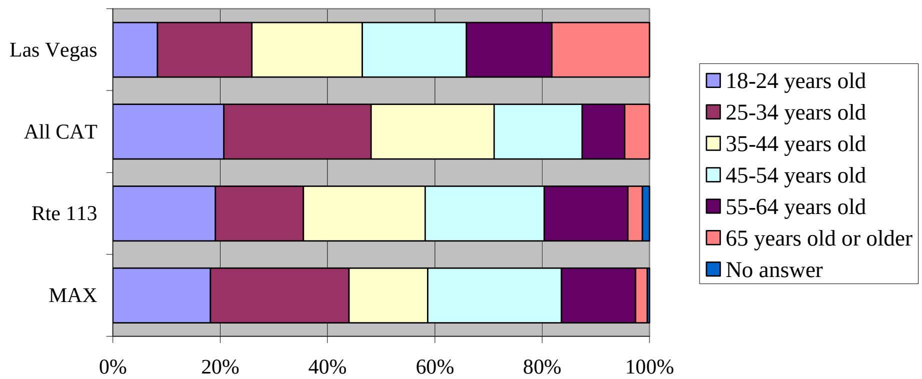


The ethnicity of riders on MAX differs somewhat from that of Route 113, the CAT system in general and the Las Vegas valley region. MAX riders are more likely to be African American and are less likely to be White than Rte 113 riders. Both MAX and Rte 113 riders are less likely to be White than CAT services and Las Vegas in general. Both Rte 113 and MAX have a greater proportion of Hispanic riders than the CAT system and Las Vegas. Table 6-3 and Figure 6-6 show the age of riders on MAX, CAT Route 113, the CAT system and Las Vegas.

Table 6-3: Rider age

Response	MAX	Rte 113	All CAT	Las Vegas
17 years old and under	N/A	N/A	6.7	N/A
18-24 years old	18.2	19.1	19.3	8.3
25-34 years old	25.8	16.4	25.6	17.6
35-44 years old	14.7	22.7	21.4	20.6
45-54 years old	24.9	22.2	15.3	19.4
55-64 years old	13.8	15.6	7.4	15.9
65 years old or older	2.2	2.7	4.3	18.2
No answer	0.4	1.3	0.0	0.0

Figure 6-6: Rider age

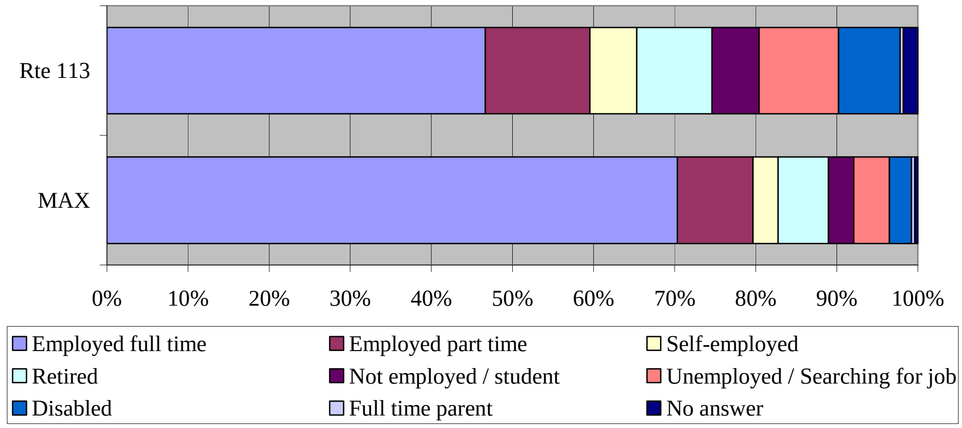


The age of MAX riders is similar to that of Rte 113 riders and CAT services in general. MAX, Rte 113 and all CAT services tend to serve the younger portions of the Las Vegas valley population. The employment status of MAX and CAT Route 113 was asked on the MAX/CAT corridor surveys; however comparable data is not available for the CAT system or the Las Vegas valley. Table 6-4 and Figure 6-7 show the employment status of riders on MAX and CAT Route 113.

Table 6-4: Employment status

Response	MAX	Rte 113
Employed full time	70.2	46.7
Employed part time	9.3	12.9
Self-employed	3.1	5.8
Retired	6.2	9.3
Not employed / student	3.1	5.8
Unemployed / Searching for job	4.4	9.8
Disabled	2.7	7.6
Full time parent	0.4	0.4
No answer	0.4	1.8

Figure 6-7: Employment status



In comparing MAX riders to Rte 113, MAX tends to have substantially more full-time employees. These riders would presumably have a higher value of time and therefore place more importance on a quick trip. Table 6-5 shows the gender of riders on MAX, CAT Route 113, the CAT system and Las Vegas.

Table 6-5: Rider gender

Response	MAX	Rte 113	All CAT	Las Vegas
Female	45.3	44.4	46.9	52.7
Male	54.7	55.6	53.1	47.3
No answer	0.0	0.0	0.0	0.0

The gender of MAX riders is similar to that of Rte 113 riders and CAT services in general. MAX, Rte 113 and all CAT services tend to serve more males than the proportion of Las Vegas valley residents.

6.2 Capital Cost Effectiveness

The total capital cost of the project, including vehicles but excluding the bus lane, was $20.1 million. Given 7.5 route miles, the unit cost is $2.7 million per route mile. Excluding vehicle acquisition, the cost is $1.1 million per route mile. This figure is considerably less than the cost of the Orange Line (Los Angeles) exclusive busway, and less than the cost of the Silver Line (Phase I) per mile. However, it is considerably more than the San Pablo Rapid (see Table 6-6).

The vehicle cost amounts to $1.2 million per vehicle, comparable to the articulated dual mode buses used for Boston's Silver Line phase II, but twice the price of the articulated CNG buses used on the Los Angeles Orange Line.

Table 6-6: Comparison of BRT Project Capital Costs
(millions of dollars, unless otherwise indicated)

Project Name	Running way	Length (Miles)	Total Vehicle Cost	Total Infra-structure Cost	Total Capital (Vehicle + Infra) Cost	Infra-structure Cost per Mile	Vehicle Cost per Vehicle
San Pablo Rapid	mixed traffic	14	4.2	3.2	7.4	0.2	0.3
Las Vegas MAX – Las Vegas Blvd N	curb bus lane (4.5 mi)	7.5	12.1	8.1	20.2	1.1	1.2
Boston Silver Line Phase I	curb bus lane (2 mi)	2.3	13.0	14.3	27.3	6.2	0.8
Boston Silver Line Phase II	busway tunnel (1 mi)	1	42.0	566.9	608.9	566.9	1.3
Los Angeles Orange Line	busway with at-grade intersections (14 mi)	14	19.0	304.0	323.0	21.7	0.6

6.3 Operating Cost Efficiency

Operating cost efficiency is best measured by operating cost per passenger. This measure can be decomposed into two components: vehicle unit cost (cost per service hour), and intensity of use (passengers per vehicle service hour). The first component reflects the cost of producing a unit of transit service; the second reflects the efficiency with which that unit is deployed in terms of producing passenger boardings.

Figure 6-8 graphs the first component, passengers per vehicle service hour, for MAX, Route 113 and the corridor average. Initially MAX had low utilization. Its introduction attracted some riders from Route 113, thereby lowering that route's intensity of use, at least until service was reduced to compensate for the ridership switch. By December 2004, the two routes had the same average intensity of use, although this represented a 20% reduction from the level prior to MAX, dropping from 58 to 46 people per vehicle hour. Between December 2004 and October 2005, the intensity of use of MAX increased steadily, from 46 people per vehicle hour to 66. This figure has held roughly constant since then (the apparent decline of March 2006 is due to a data recording problem). However, the intensity of use of Route 113 declined during this period, as more riders shifted to MAX. Thus the overall corridor average passenger boardings per vehicle service hour remains lower in July 2006 than it was before MAX was introduced (52 passengers per vehicle service hour compared to 58, a decline of 10%).

Figure 6-8: Intensity of Use, MAX compared to 113

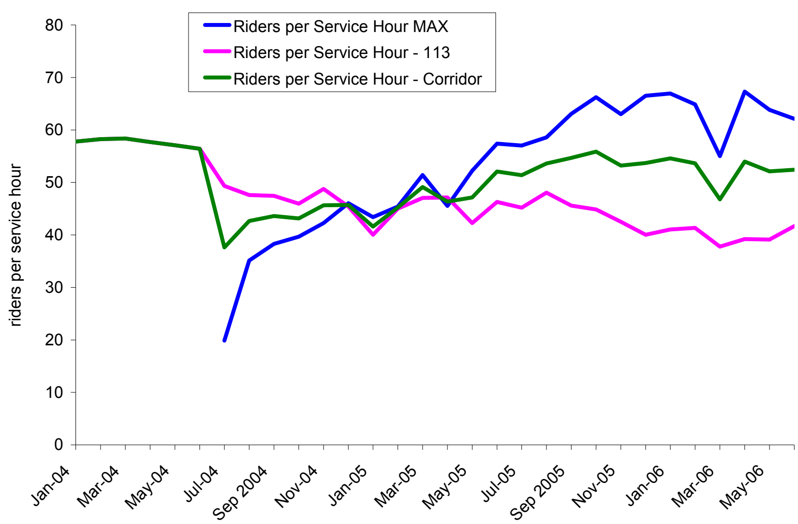
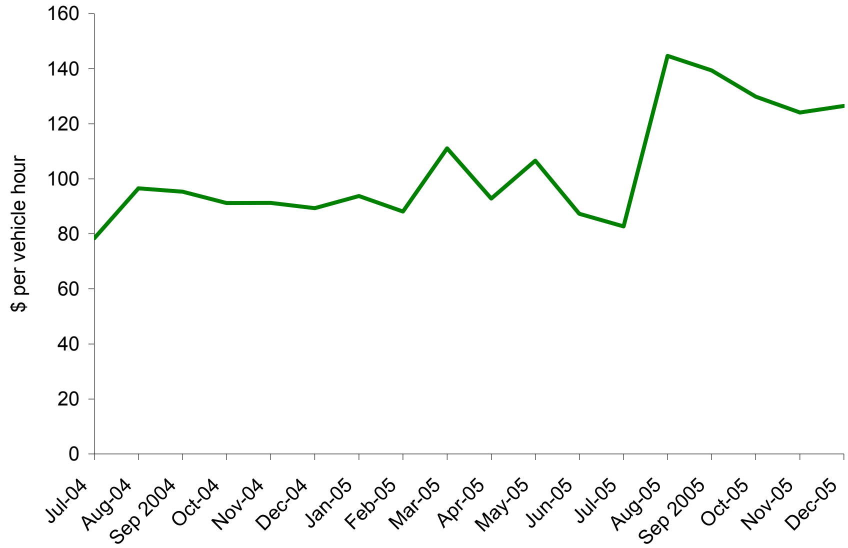


Figure 6-9: MAX Operating Cost per Vehicle Hour



The second component is operating cost per vehicle hour. The full overhead cost for MAX averaged $92 per hour between the July 2004 opening and July 2005 (see Figure 6-9). The average cost from August to December 2005 was $111, a 21% increase.

The product of these two components, vehicle operating cost and intensity of use, gives operating cost per passenger boarding. This measure declined steadily from start of service to July 2005 as intensity of use increased, as shown in Figure 6-10. However, with the increase in unit costs beginning in August 2005, total cost per boarding has increased. The Figure also shows net cost per boarding. This is simply cost per passenger boarding less revenue per passenger boarding, which has hovered around $0.50 consistently since the start of service.[11]

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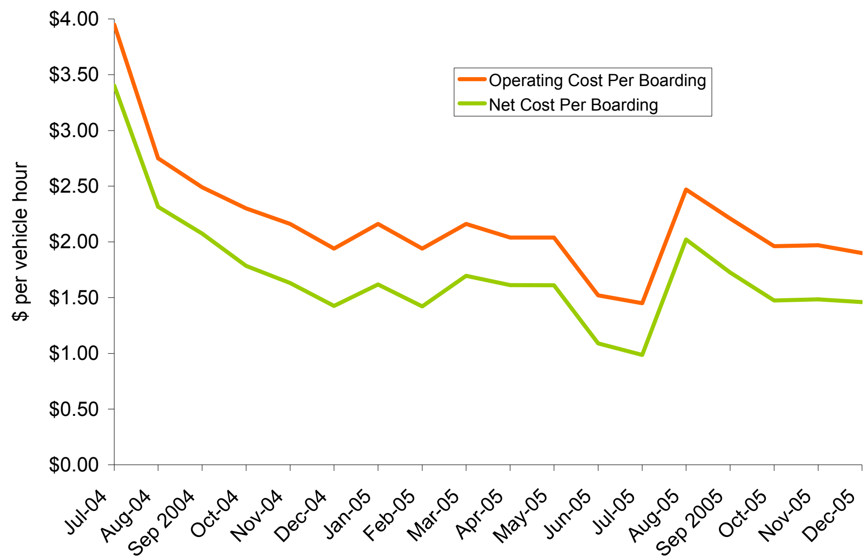
11 RTC estimates MAX operating revenues by crediting to MAX all TVM sales of one-ride tickets except those sold at TVMs located on the Strip and by allocating pass revenues based on the percentage of pass usage, as estimated based on the fare payment control counts. As of June 2006, RTC was waiting for a software change to the PDAs used to check fares. RTC expects the change will produce better estimates of use of different fare media.

Figure 6-10: MAX Operating Cost per Boarding



6.4 Land Use

Land use regulations and policies are controlled largely by local governments in the Las Vegas region. The MAX BRT service along Las Vegas Boulevard North crosses three political jurisdictions: the City of Las Vegas, the City of North Las Vegas, and an unincorporated area of Clark County known as Sunrise Manor. Approximately 1.5 miles of the route are located in the City of Las Vegas, between the Downtown Transportation Center (DTC) and Owens Avenue. The three-mile segment of the route between Owens Avenue and North Pecos Road is located in the City of North Las Vegas. The remaining three miles between North Pecos and Craig Road are in Sunrise Manor (Clark County). This section describes existing land uses and land use policies with regard to transit-supportive development in each of these three jurisdictions.

City of Las Vegas

In the City of Las Vegas the MAX corridor is mostly commercial with some residential uses on adjacent streets. The Cashman Field sports and convention complex is also along the route. The southern-most portion of the corridor lies with the Downtown Redevelopment Area, where new commercial and residential redevelopment projects are planned. However, most City of Las Vegas development projects are further to the south in the core downtown area. The majority of land use immediately surrounding the DTC is of medium to high density and therefore supportive of transit.

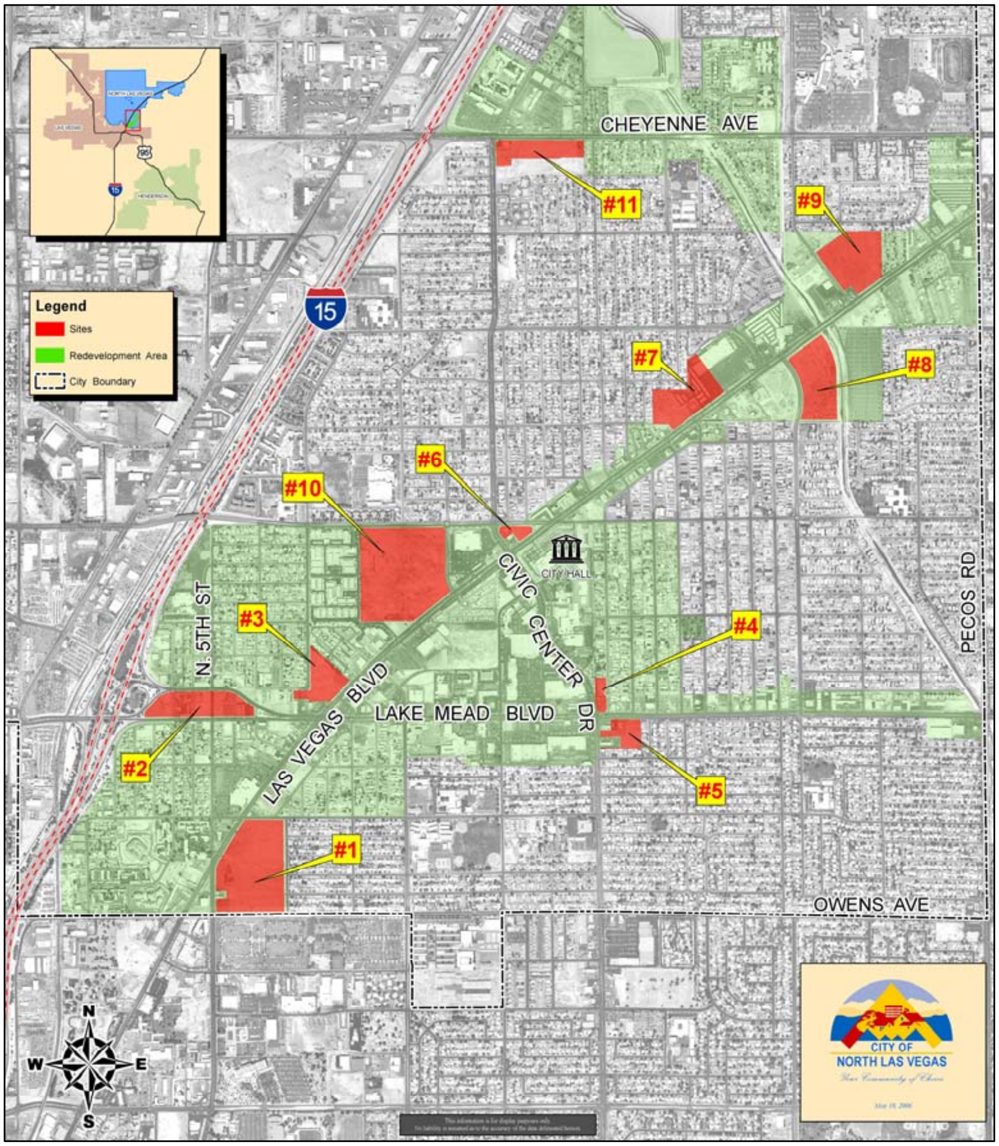
City of North Las Vegas

The majority of the MAX corridor along Las Vegas Boulevard North in the City of North Las Vegas is zoned for commercial use. Adjacent land use is predominantly single-family residential. Other land uses within the corridor include casino-hotel-entertainment uses and public uses, including the City Hall Complex.

The City's development and redevelopment efforts are focused primarily along the 5th Street Corridor in anticipation of the Regional Fixed Guideway, a regional transit project that is currently proposed for that corridor. The 5th Street Corridor Plan is an extensive land development and transit improvement plan emphasizing Transit Oriented Development (TOD) and covering the area from Owens Avenue north to the Las Vegas Beltway.

As of this writing, there have not been any significant new development projects along the MAX corridor in North Las Vegas since the start of service. However, the City of North Las Vegas has identified several redevelopment areas along the corridor. These areas are primarily of a general commercial, retail nature, with some limited opportunities for Planned Unit Development (PUD). The locations identified as redevelopment opportunities are shown in Figure 6-11.

Figure 6-11: Opportunities for Redevelopment: North Las Vegas



The 5th Street and Las Vegas Boulevard North corridors intersect in the area between Lake Mead Boulevard and Owens Avenue, known as the "Gateway Area". This site is shown in Figure 6-11 and identified as Location #2. The city has identified this site as a focus area for redevelopment. Specifically, it has been identified as a strong candidate for high-density office and commercial development. The level of density along with the proximity to Interstate 15 ramps and to both the 5th Street and MAX corridors make this area a candidate for TOD. Property acquisition in this area is programmed in the City's 2006-2010 Capital Improvement Program.

Redevelopment of the government complex adjacent to the Civic Center Drive station is also planned. This project will include pedestrian and landscaping improvements, with the potential to improve access on foot from the Civic Center Drive MAX station.

The City of North Las Vegas has proposed an ordinance that will allow mixed-use and transit-oriented development under various residential and commercial land use scenarios. Under the proposal, any mixed-use development must meet at least one of several criteria. Along the MAX corridor these criteria include; amount of infill development; contribution to revitalization of a redevelopment area; and location within ¼ mile of a BRT or LRT stop. There has also been discussion about reduced parking requirements within ¼ mile of BRT/LRT stations. Further consideration, however, has been tabled primarily because many of the planned transit improvements, other than MAX, are several years away, and the City does not want to permit high-density, mixed-use development with reduced parking before the transit infrastructure arrives. The City is also developing a new Comprehensive Master Plan to be completed in 2007. The draft plan calls for mixed-use zones along Las Vegas Boulevard North, due to its proximity to BRT.

Clark County/Sunrise Manor

The northern segment of the MAX corridor is located in Sunrise Manor, an unincorporated area administered by Clark County. The majority of the corridor is zoned as general highway frontage, in some cases specifying commercial or residential uses. The zoning has recently been changed to permit mixed uses at higher densities and to encourage pedestrian- and transit-oriented elements.

6.5 Environmental Quality

According to the passenger survey of October 2005, about 11% of MAX's 6,150 average daily riders in that month previously drove alone, and another 3% got a ride. Thus, MAX displaced 14% x 6,150, or 861 auto trips, providing some air quality benefits.

The CIVIS buses used for MAX are as low-polluting as other new buses in the CAT fleet, and considerably cleaner than the oldest buses. They thus have a net positive impact on reducing fleetwide emissions.

7.0 CONCLUSIONS – OBSERVATIONS and LESSONS LEARNED

7.1 MAX IS A SUCCESS

The MAX BRT project on Las Vegas Boulevard North can be termed a transit success story. Ridership in the corridor increased by 38%, rider satisfaction is high, and extensions are planned and being implemented.

As noted in the introduction to this Evaluation Report, the project incorporates all of the major elements of BRT as described in the *Characteristics of Bus Rapid Transit for Decision-Making (CBRT)*. That is: running way, stations, vehicles, fare collection, intelligent transportation systems, and service and operating plans. Within this report, we have provided for each of these major elements the following:

- Description
- Capital cost
- Operating cost
- System performance
- System Benefits

Figure 7-1, MAX – BRT Effectiveness Summary, provides an overview of the positive impact each of the major BRT elements has had on the overall system's success. The table summarizes the following BRT elements:

1. Exclusive running way
2. Pavement markings at stations for vehicle guidance
3. Stations
4. Vehicles
5. Proof of payment fare system
6. Ticket Vending machines (TVMs)
7. Traffic Signal priority and Queue jump
8. Automatic Vehicle locator/Computer aided dispatching (AVL/CAD)
9. Frequency of service/headway
10. Hours of operation

Each element is presented in terms of the following measures:

- Quantity of the element; length, each, or system
- Capital cost
- Operating cost
- Assessment of the degree of positive impact that the element contributes to the overall success or acceptance of the MAX project. The CBRT document includes travel time and reliability as factors to be used in evaluating a BRT project's performance. We have added passenger acceptance. For a qualitative analysis we have rated each BRT element as high, medium, or low.
- Comments focus on the particular component or part of the BRT element that contributes to the positive impact.

7.2 What Works

MAX drivers were asked to rank the features of the system that contribute most to its overall success. The three features the drivers identified were multiple doors for entry and exit (20 drivers chose), off-board fare collection (20 drivers chose) and the queue jump (14 drivers chose). Only 4 drivers chose the center drive position (although drivers did consider center position important for precision docking); 3 drivers chose the signal priority; and 3 drivers chose the passenger features. No driver chose the communications equipment as being a major factor in MAX success.

Our study confirms that off-board fare collection, combined with multiple-door and level boarding, is a key factor in reducing travel time and thus increasing ridership. The dwell times on MAX are much lower than on standard service, and do not increase as rapidly with increases in passenger boardings. The importance of this effect can be seen when comparing peak vs. off-peak times on MAX and its parallel Route 113 service. Travel time increases on average by 5 minutes during the peak on 113, but by only 1 to 3 minutes on MAX.

The total travel time saving in the peak period was 12 minutes southbound and 14 minutes northbound. How much of this is attributable to reduced dwell time? We estimated the number of seconds of time savings per boarding, alighting, and per stop using a regression model. Data from the APC system show that there are about 75 ons and 75 offs per trip in the peak period on both MAX and route 113. Table 7-1 combines these data with the regression results to estimate the time savings *per trip* due to reduced dwell time. As shown in line 3 of Table 7-1, we calculate that 13 minutes of the Rt. 113 travel time, but only 5.7 minutes of MAX travel time, is the result of boarding delay during the 7 am to 7 pm period. Thus MAX saves 7.6 minutes per trip solely because of faster boarding and alighting. In line 4 we compare this time savings to the total time savings per trip estimated in Section 5.1. The conclusion is that speedier dwell time accounts for more than half the total travel time savings.

Table 7-1: Calculation of Time Savings per Trip due to Dwell Time Reduction during Peak (7 am to 7 pm)

	Pas-sengers Boarding	Pas-sengers Alighting	Stops	Total	% Due to Reduced Dwell
1. Activities per Trip					
113	75	75	26	-	
MAX	75	75	12	-	
2. Seconds per Activity					
113	3.9	1.0	16.5	-	
MAX	1.6	1.5	9.0	-	
3. Minutes per Trip					
113	4.9	1.3	7.2	13.3	
MAX	2.0	1.9	1.8	5.7	
difference	2.9	-0.6	5.4	7.6	
4. Total Time Savings per Trip (from all sources)					
Southbound				14.0	54%
Northbound				12.2	62%

Sources: 1. Estimated from APC data on average boardings and alightings at each stop during 7 am to 7 pm peak.

2. From Table 5-9. 3. Product of lines 1 and 2, divided by 60.

4. Difference shown in line 3 compared to travel time savings from Tables 5-2 and 5-4.

Where does the rest of the travel time savings come from? Since we conclude that TSP had little effect, the time savings must be due principally to a reduction in the number of stops. Fewer stops means less time lost to acceleration and deceleration, and probably less signal delay because the bus is better able to keep up with traffic signal progression.

7.3 Summary of Lessons Learned

In addition to the conclusions cited above, several lessons learned are worthy of mention as a result of our evaluation of the MAX system. These are:

Vehicle Procurement

After sales service for vehicles is an essential feature, and particularly critical when vehicles use new technology or are developed overseas – both of which added complications in this case. Ongoing, frequent conversation with the vehicle supplier meant RTC was able to solve problems quickly and efficiently and avoid service disruptions

Overall Intelligent Transportation Systems (ITS)

Installation and operation of new technologies requires considerable staff resources. The ability to spend time on implementation and adjust systems on the ground enabled staff to use the technology effectively and improve the quality of the transit service. Experience with the MAX ITS systems also created the opportunity for transferability of technologies from MAX to the wider transit network.

An excellent example of technology transfer are the ticket vending machines installed for MAX. After installing TVMs at MAX stations and the Downtown Transportation Center, RTC expanded use of the machines to other locations; many of these TVMs are among the most productive in the RTC transit network.

While the automatic optical guidance system proved ineffective in Las Vegas, RTC adapted to manual guidance. This was accomplished by training drivers to use the long tangents approaching each station and special pavement markings to keep to the preferred vehicle path and to dock close to the curb.

ITS: Traffic Signal Priority and Queue Jumper Technology

The use of Traffic Signal Priority at ten intersections did not lead to any significant travel time improvement for the MAX system. This is a significant finding, considering the expected results of TSP and promotion of this technology at BRT systems around the country. There are several possible explanations for this result. One possibility is the limitations of the data that prevented us from examining end-to-end running time and thus did include two of the ten intersections with TSP and did not include the single queue jumper. However, since traffic congestion is not more severe at the two TSP-equipped intersections not included in this analysis, complete data would be unlikely to change the conclusions.

A more likely explanation for the failure to find a travel time benefit from TSP is simply that there is insufficient traffic congestion in this corridor to generate significant signal delay during most times of the day. Travel times are fairly constant throughout the day. Southbound trips between 5 and 6 am average 17.3 minutes (the fastest hour of the day); trips between 4 and 5 pm average 20.0 minutes (the slowest hour). The difference is only 16%, and most of this is probably due to the greater number of passengers boarding and alighting at the later hour.

Figure 7-1: MAX - BRT Effectiveness Summary

		Cost Data		Degree of Positive Impact on			
BRT Element	**Description**	**Capital ($)**	**Operating ($)**	**Travel Time**	**Reliability**	**Passenger Acceptance**	**Comments**
Running Way (exclusive)	7.5 mi (4.5 mi)	N/A	N/A	_	Not Rated	_	Costs part of N. Las Vegas Boulevard reconstruction, paid by NVDOT. Curbside bus lane shared by MAX & 113.
Pavement Markings at Stations for vehicle guidance	At each station; installed for optical guidance	43,000	N/A	Medium	Medium	_	While OGS proved to be inappropriate technology for Las Vegas, pavement markings have been useful to drivers when they dock vehicles.
Stations	22	5.45 mil	100,000-115,000/year	Medium	Medium	High	Raised curbs provide level boarding, improving service speed, service reliability, and passenger comfort.
Vehicles	10	10.65 mil	N/A	High	High	High	Vehicle design is an essential element of service speed (multiple doors), service reliability, and passenger comfort.
Fare Collection System							
Proof of Payment Fare Collection System	On board, random checking	N/A	270,000/year	High	High	High	Allows free flow boarding at multiple doors that reduces dwell time
Ticket Vending Machine (TVM)	23 machines; 1 at each station plus DTC	2.0 mil	100,000	High	High	High	TVMs at each station eliminates the need to sell tickets on board
ITS							
TSP	11	270,000	N/A	Low	Low	_	No significant change in travel time.
Queue Jumper	1	N/A	N/A				No data.
AVL/CAD	On each vehicle	299,000	N/A	_	Medium	_	
Passenger Information	On each vehicle and at each station	N/A	N/A	_	_	_	No data. Service Information Signs are to be installed at each station
Optical Guidance (OGS)	10 vehicles	1.45 mil	N/A	_	_	N/A	OGS proved to be inappropriate technology for Las Vegas; also drivers able to dock vehicles manually.
Service Plan							
Service Hours	5:00 am to 10:00 pm	_	92 – 111 / hr	_	_	High	In October 2005, survey 96% of riders rated the dependability of MAX good or excellent.
Service Frequency	Headway-based schedule 12 min peak 15 min off-peak	_	_	_	High	High	Same as above, high grades from riders
Station spacing	0.7 mi. avg.	_	_	High	High	Medium	Passengers request for more stations.
Branding/Marketing	Unique MAX brand, rapid transit elements, publicity events	_	N/A	_	_	High	Surveys show increased public awareness of MAX

Operating Costs

Operating costs for MAX were about 50% higher per vehicle hour than local bus service. Some of this difference is due to additional attention to maintenance and use of more experienced drivers, and some is due to the higher cost of operating and maintaining a complex, foreign-made vehicle. Because MAX's service conditions permit higher speeds, the difference in cost per vehicle service *mile* is not as great as the difference in cost per service *hour*. Most of the speed improvements are due to fewer stations and reduced dwell time. Dwell times were shorter for two reasons. First, MAX's skilled drivers took advantage of the center cab position during station docking, which reduced the gap at the platform and helped speed boarding. Second, and more significant, is MAX's proof-of-payment fare collection. This is evidenced by the fact that time savings occur during boarding, not alighting. Thus it can be concluded that a BRT system using more conventional vehicles could make a significant reduction in operating costs per vehicle service miles if it used proof of payment and consolidation of station stops as a means of reducing travel time.

Branding, Imaging and Public Acceptance of Service

RTC branded the new BRT service as MAX - separate and distinct from other existing CAT service. Survey results showed a majority of people identified MAX as providing faster and more reliable services than local bus. Moreover, despite the potential for longer walk time due to increased station spacing, MAX's share of corridor ridership increased gradually from 21% in the first month of service to 65% in less than two years. Transit riders are certainly satisfied: more than 91% rated MAX "excellent" or "good".

Although the MAX brand is beginning to be recognized, recognition has been limited, since the Las Vegas Boulevard North route represents a pilot project in only one part of a large region. In a survey of Las Vegas region residents, 48% did not have a preference between MAX and local bus service, suggesting that most Las Vegas Valley residents do not yet appreciate the substantial difference between MAX and standard CAT service. As MAX service is extended to other areas, brand recognition should improve substantially.

Driver Training and Selection

MAX drivers are a significant asset to the system, as shown by the high ratings given to MAX service quality and the nearly spotless safety record of its drivers. Only one preventable accident occurred on MAX from the opening of service to November 2006. Although the exclusive bus lanes have some effect on the safety of the bus route, the drivers have had an even greater effect. The additional training, higher pay scale and extensive selection process for MAX drivers is a model that should be followed by other BRT systems.

List of EXHIBITS

FIGURES

Figure 2-1: MAX system schematic map

Figure 2-2: More than half of MAX's 7.5 mile route is an exclusive curbside bus lane

Figure 2-3: Typical MAX station (Jerry's Nugget South)

Figure 2-4: Lake Mead station with MAX ticket vending machine

Figure 2-5: Las Vegas Downtown Transportation Center

Figure 2-6: MAX CIVIS vehicle exterior

Figure 2-7: Center Drive Position

Figure 2-8a: MAX bus position with automatic docking

Figure 2-8b: MAX bus position at station using manual docking

Figure 2-9: Onboard Bike Rack

Figure 2-10: Ticket Vending Machine

Figure 2-11: Uniformed security officer on-board MAX

Figure 2-12 MAX Marketing Material

Figure 2-13 Opening Day Celebration

Figure 4-1: An illustration of one of the 50 new BRT vehicles to be added to the MAX fleet. This vehicle is being manufactured by the Wright Group of Northern Ireland. It will resemble the CIVIS but will not have optical guidance.

Figure 4-2: Deuce, RTC's new double decker bus, operates on the heavily traveled Las Vegas strip.

Figure 5-1: Has your travel time changed since riding MAX? (October 2005)

Figure 5-2: Estimated Station Dwell Time

Figure 5-3: Driver Assessment of MAX features for route speed and reliability compared to CAT

Figure 5-4: Overall Rating of MAX / CAT Service (October 2005)

Figure 5-5: Survey of CAT riders, "Have you ever ridden MAX?"

Figure 5-6: Survey of CAT riders, "Do you prefer to ride CAT or MAX?"

Figure 5-7: Rate the Safety of MAX / CAT Vehicle (October 2005)

Figure 5-8: Rate the Safety of MAX Stations / CAT Stops (October 2005)

Figure 6-1: Average Boardings per Day, MAX and 113, January 2004 to July 2006

Figure 6-2: MAX share of Las Vegas Blvd. North Public Transit Market

Figure 6-3: Index of Changes in Boardings, LVBN Corridor and Systemwide

Figure 6-4: Previous mode of MAX riders (October 2005)

Figure 6-5: Rider ethnicity

Figure 6-6: Rider age

Figure 6-7: Employment status

Figure 6.8: Intensity of Use, MAX compared to 113

Figure 6.9: MAX Operating Cost per Vehicle Hour

Figure 6-10: MAX Operating Cost per Boarding

Figure 6-11: Opportunities for Redevelopment: North Las Vegas

Figure 7-1: MAX - BRT Effectiveness Summary

TABLES

Table 3-1: Overview of Capital Costs associated with the MAX service

Table 3-2: MAX Operating Costs, July 2004 to December 2005

Table 4-1: MAX Southbound

Table 4-2: MAX Northbound

Table 4-3: Importance of MAX features in docking the vehicle for precise stops

Table 5-1: Regression Model of MAX and 113 Travel Time, Northbound

Table 5-2: Travel Time and Speed Differences by Time Period, MAX and 113, Northbound

Table 5-3: Regression Model of MAX and 113 Travel Time, Southbound

Table 5-4: Travel Time and Speed Differences by Time Period, MAX and 113, Southbound

Table 5-5: Has your travel time changed since riding MAX?

Table 5-6: Rate the speed of travel on MAX and CAT

Table 5-7: For riders transferring from other CAT/MAX routes, how long did you wait at the location you transferred? (October 2005)

Table 5-8: Rate the Wait Time at MAX and CAT Stations

Table 5-9: Dwell Time Model Results

Table 5-10: Rate the Dependability of MAX and CAT

Table 5-11: Passenger Rating of Vehicles and Shelters, MAX and CAT riders

Table 5-12: All things considered rating of MAX and CAT by riders of the service

Table 5-13: Overall rating of MAX service by CAT riders and CAT service by MAX riders

Table 5-14: Rate the Safety of MAX / CAT Vehicle

Table 5-15: Rate the Safety of MAX Stations / CAT Stops

Table 6-1: Previous mode of MAX riders

Table 6-2: Rider ethnicity

Table 6-3: Rider age

Table 6-4: Employment status

Table 6-5: Rider gender

Table 6-6: Comparison of BRT Project Capital Costs

LIST OF ACRONYMS

APC – Automatic Passenger Counter

ATC Vancom – Now Veolia, the company that operates MAX and CAT for RTC

Deleted:

BRT – Bus Rapid Transit

CAD / AVL – Computer Aided Dispatch/Automated Vehicle Location system

CAT – Citizen's Area Transit, the transit agency for Southern Nevada, a division of RTC

CBRT – Characteristics of Bus Rapid Transit for Decision-Making, August 2004

CIVIS – Specialized BRT Vehicle built by Irisbus

DTC – Downtown Transportation Center (Las Vegas)

FTA – Federal Transit Administration

ITS – Intelligent Transportation System

LVBN – Las Vegas Boulevard North

MAX – Metropolitan Area Express, BRT System in Las Vegas, NV

MPO – Metropolitan Planning Organization (RTC is an MPO)

NVDOT – Nevada Department of Transportation

PDA – Personal Digital Assistant

RTC – Regional Transportation Commission of Southern Nevada

TSP – Traffic Signal Priority (also called Transit Signal Priority)

TVM – Ticket Vending Machine

Veolia – MAX service operation is performed under contract to Veolia Transportation (formerly ATC)

BRT MAX Service Questionnaire

Thank you for taking the time to fill out this survey. We are part of a research team conducting an evaluation of the MAX service for the Federal Transit Administration. We value your opinions and appreciate your assistance with our evaluation.

1. Did you drive vehicles for CAT prior to driving on the MAX route?

- ☐ Yes
- ☐ No – I'm a new driver
- ☐ No – I worked for another ATC operation in another part of the country

2. How long have you been driving for CAT?

☐ Less than 1 year ☐ Between 1 year and 3 years
☐ Between 3 and 5 years ☐ Between 5 and 10 years
☐ More than 10 years

3. How long have you been driving the CIVIS vehicle on the MAX route?

- ☐ Since service began – about 2 years
- ☐ Less than 2 years but more than 1 year
- ☐ Less than 1 year

4. Do you still sometimes drive CAT routes?

☐ Yes ☐ No

5. Generally speaking, do you prefer driving the CIVIS over CAT vehicles?

☐ Yes ☐ No ☐ Other: ______________________________

6. Please rate how the CIVIS compares with standard CAT vehicles for the following features:

	Better	**Neutral**	**Worse**
Driver Comfort/Ride	☐	☐	☐
Passenger Comfort	☐	☐☐	☐
Vehicle Handling/ Maneuverability	☐	☐	☐
Safety – on road performance	☐	☐	☐
Driver sense of security & safety	☐	☐	☐
Overall Vehicle Performance	☐	☐	☐

7. The CIVIS vehicle has a center drive position. Based on your experience driving from the center position CIVIS vehicle as compared with driving from the left hand position with CAT vehicles, how do the following features rate:

	Better	**Neutral**	**Worse**
Forward visibility	☐	☐	☐☐
Left Side visibility	☐	☐	☐
Right side visibility	☐	☐	☐
Rear visibility	☐	☐	☐
Lining up with curb/platform	☐	☐	☐
General operations	☐	☐	☐

8. How difficult it is to make a stop close to the curb and at the designated door locations?

	Very Difficult	Neutral	Not Difficult at All
Challenge of docking vehicle	☐	☐	☐

9. How important are the following features are helping you dock the vehicle and make precision stops?

	Very Important	Neutral	Not Important at All
Driver training & experience	☐	☐	☐
Center drive position	☐	☐	☐
Pavement markings	☐	☐	☐
Optical Guidance System	☐	☐	☐

10. How does each of the following MAX features services contribute to route speed and service reliability as compared with standard CAT service:

	Improves Speed Reliability	No Effect	Reduces Speed & Reliability
Multiple doors for entry/exit	☐	☐	☐
Off-board fare collection	☐	☐	☐
Passenger accessibility	☐	☐	☐
ADA passenger accessibility	☐	☐	☐
Signal priority at intersections	☐	☐	☐
Queue jump	☐	☐	☐

11. Taking into consideration the entire service, including passenger comfort, vehicle maneuverability and route speed/service reliability, please identify the top three system features you feel contribute most to the success of MAX.

	Ranking
Multiple doors for entry/exit	____
Off-board fare collection	____
Center drive position	____
Passenger features	____
Communications equipment	____
Signal priority	____
Queue jump	____

BRT MAX SERVICE QUESTIONNAIRE

1. Did you drive vehicles for CAT prior to driving on the MAX route?

22	Yes
0	No - I'm a new driver
0	No - I worked for another ATC operation in another part of the country

2. How long have you been driving for CAT?

0	Less than 1 year	1	No Answer
0	Between 1 year and 3 years	11	Between 5 and 10 years
1	Between 3 and 5 years	9	More than 10 years

3. How long have you been driving the CIVIS vehice on the MAX route?

15	Since service began - about 2 years
4	Less than 2 years but more than 1 year
3	Less than 1 year

4. Do you still sometimes drive CAT routes?

9	Yes
13	No

5. Generally speaking, do you prefer driving the CIVIS over CAT vehicles?

21	Yes	
0	No	
1	Other:	I drive all three equipment, but I like to drive CIVIS most.

6. Please rate how the CIVIS cmpares with standard CAT vehicles for the following features:

	Better	Neutral	Worse	No Answer
Driver Comfort/Ride	21	1	0	0
Passenger Comfort	19	2	0	1
Vehicle Handling/Manueverability	22	0	0	0
Safety - on road performance	20	2	0	0
Driver sense of security & safety	21	1	0	0
Overall Vehicle Performance	21	1	0	0

7. The CIVIS vehicle has a center drive position. Based on your experience driving from the center position CIVIS vehicle as compared with driving from the left hand position with CAT vehicles, how do the following features rate:

	Better	Neutral	Worse	No Answer
Forward visibility	20	2	0	0
Left side visibility	17	5	0	0
Right side visibility	17	4	1	0
Rear visibility	13	7	1	1
Lining up with curb/platform	17	5	0	0
General operations	21	1	0	0

8. How difficult is it to make a stop close to the curb and at the designated door locations?

Challenge of docking vehicle

1	Very difficult
1	Neutral
19	Not Difficult at All
1	No Answer

9. How important are the following features in helping you dock the vehicle and make precision stops?

	Very Important	Neutral	Not Important at All	No Answer
Driver training & experience	21			1
Center drive position	14	7		1
Pavement markings	15	5	1	1
Optical Guidance System	4	4	13	1

10. How do each of the following MAX features services contribute to route speed and service reliability as compared with standard CAT service:

	Improves Speed & Reliability	No Effect	Reduces Speed & Reliability	No Answer
Multiple doors for entry/exit	21			1
Off-board fare collection	21			1
Passenger accessibility	17	3		2
ADA passenger accessibility	18	2	1	1
Signal priority at intersections	19	1		2
Queue jump	21			1

11. Taking into consideration the entire service, including passenger comfort, vehicle manueverability and route speed/service reliability, please identify the top three system features you feel contribute most to the success of MAX.

Ranking		Number of Drivers Choosing
2	Multiple doors for entry/exit	20
1	Off-board fare collection	20
4	Center drive position	4
6	Passenger features	3
7	Communications equipment	0
5	Signal priority	3
3	Queue jump	14

BRT MAX SERVICE QUESTIONNAIRE

2. How long have you been driving for CAT?

0	Less than 1 year	0.00
0	Between 1 year and 3 years	0.00
1	Between 3 and 5 years	0.05
11	Between 5 and 10 years	0.50
9	More than 10 years	0.41
1	No Answer	0.05
22	Total	

3. How long have you been driving the CIVIS vehice on the MAX route?

15	Since service began - about 2 years	0.68
4	Less than 2 years but more than 1 year	0.18
3	Less than 1 year	0.14
22	Total	

4. Do you still sometimes drive CAT routes?

9	Yes	0.41
13	No	0.59

6. Please rate how the CIVIS cmpares with standard CAT vehicles for the following features:

	Better	Neutral	Worse	No Answer	
Driver Comfort/Ride	**21**	**1**	**0**	**0**	0.95
Passenger Comfort	**19**	**2**	**0**	**1**	0.86
Vehicle Handling/Manueverability	**22**	**0**	**0**	**0**	1.00
Safety - on road performance	**20**	**2**	**0**	**0**	0.91
Driver sense of security & safety	**21**	**1**	**0**	**0**	0.95
Overall Vehicle Performance	**21**	**1**	**0**	**0**	0.95

7. The CIVIS vehicle has a center drive position. Based on your experience driving from the center position CIVIS vehicle as compared with driving from the left hand position with CAT vehicles, how do the following featurs rate:

	Better	Neutral	Worse	No Answer	CIVIS	CAT
Forward visibility	**20**	**2**	**0**	**0**	0.91	0.00
Left side visibility	**17**	**5**	**0**	**0**	0.77	0.00
Right side visibility	**17**	**4**	**1**	**0**	0.77	0.05
Rear visibility	**13**	**7**	**1**	**1**	0.59	0.05
Lining up with curb/platform	**17**	**5**	**0**	**0**	0.77	0.00
General operations	**21**	**1**	**0**	**0**	0.95	0.00

8. How difficult is it to make a stop close to the curb and at the designated door locations?

Challenge of docking vehicle

1	Very difficult	0.05
1	Neutral	0.05
19	Not Difficult at All	0.86
1	No Answer	0.05
22	Total	

9. How important are the following features in helping you dock the vehicle and make precision stops?

	Very Important	**Neutral**	**Not Important at All**	**No Answer**			
Driver training & experience	**21**			**1**			
Center drive position	**14**	**7**		**1**	0.64	0.32	
Pavement markings	**15**	**5**	**1**	**1**	0.68	0.23	0.05
Optical Guidance System	**4**	**4**	**13**	**1**	0.18	0.18	0.59

10. How do each of the following MAX features services contribute to route speed and service reliability as compared with standard CAT service:

	Improves Speed & Reliability	**No Effect**	**Reduces Speed & Reliability**	**No Answer**			
Multiple doors for entry/exit	**21**			**1**	0.95		
Off-board fare collection	**21**			**1**	0.95		
Passenger accessibility	**17**	**3**		**2**	0.77	0.14	
ADA passenger accessibility	**18**	**2**	**1**	**1**	0.82	0.09	0.05
Signal priority at intersections	**19**	**1**		**2**	0.86	0.05	
Queue jump	**21**			**1**	0.95		

11. Taking into consideration the entire service, including passenger comfort, vehicle manueverability and route speed/service reliability, please identify the top three system features you feel contribute most to thesuccess of MAX.

Ranking		**Number of Drivers Choosing**
2	Multiple doors for entry/exit	**20**
1	Off-board fare collection	**20**
4	Center drive position	**4**
6	Passenger features	**3**
7	Communications equipment	**0**
5	Signal priority	**3**
3	Queue jump	**14**

BRT MAX SERVICE QUESTIONNAIRE

GRAPHS KEY

6. Please rate how the CIVIS cmpares with standard CAT vehicles for the following features:

	Better	Neutral	Worse	No Answer
Overall Vehicle Performance	21	1	0	0
Driver sense of security & safety	21	1	0	0
Safety - on road performance	20	2	0	0
Vehicle Handling / Manueverability	22	0	0	0
Passenger Comfort	19	2	0	1
Driver Comfort/Ride	21	1	0	0

7. The CIVIS vehicle has a center drive position. Based on your experience driving from the center position CIVIS vehicle as compared with driving from the left hand position with CAT vehicles, do the following features rates:

	Better	Neutral	Worse	No Answer
Forward visibility	20	2	0	0
Left side visibility	17	5	0	0
Right side visibility	17	4	1	0
Rear visibility	13	7	1	1
Lining up with curb/platform	17	5	0	0
General operations	21	1	0	0

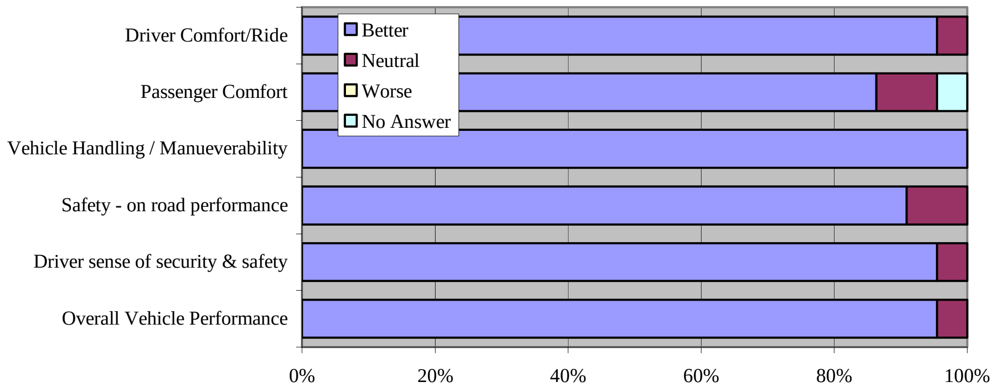
9. How important are the following features in helping you dock the vehicle and make precision stops?

	Very Important	Neutral	Not Important at All	No Answer
Optical Guidance System	4	4	13	1
Pavement markings	15	5	1	1
Center drive position	14	7		1
Driver training & experience	21			1

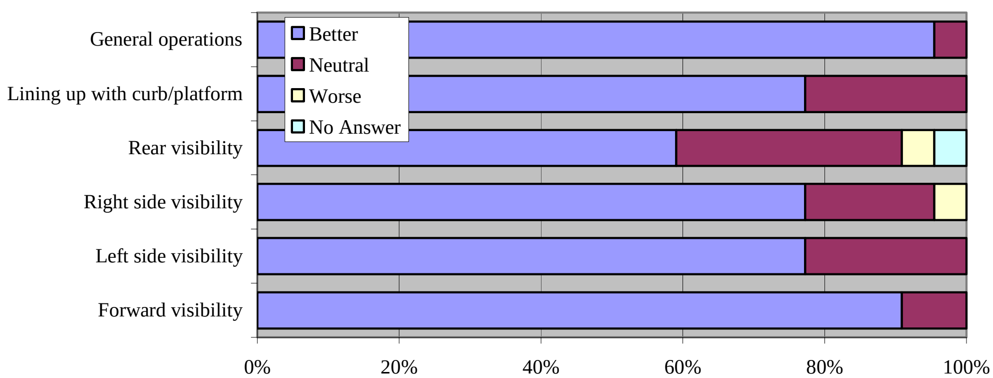
10. How do each of the following MAX features services contribute to route speed and service reliability as compared with standard CAT service:

	Improves Speed & Reliability	No Effect	Reduces Speed & Reliability	No Answer
Queue jump	21			1
Signal priority at intersections	19	1		2
ADA passenger accessibility	18	2	1	1
Passenger accessibility	17	3		2
Off-board fare collection	21			1
Multiple doors for entry/exit	21			1

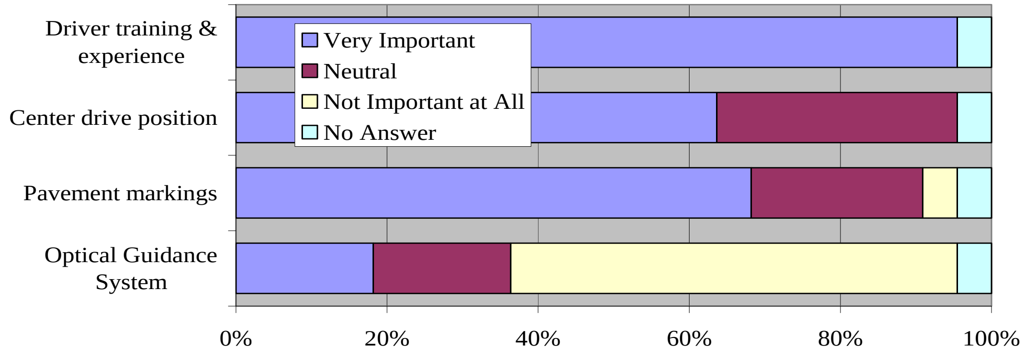
COMPARISON GRAPH



VISIBILITY GRAPH



DOCKING GRAPH



SPEED COMPONENT GRAPH