HERO PROGRAM

2013 PERFORMANCE REPORT

PREPARED BY

CENTRAL TEXAS REGIONAL MOBILITY AUTHORITY

NOVEMBER 2014

CENTRAL TEXAS
Regional Mobility Authority

EXECUTIVE SUMMARY

The Highway Emergency Response Operator (HERO) Patrol Service Program is operated by the Central Texas Regional Mobility Authority (Mobility Authority), in partnership with the Texas Department of Transportation to improve the transportation systems in Williamson, Travis and Hays counties. The program is a cost-effective approach to preserve the existing capacity by minimizing the effects of incidents by quickly responding to, assisting, and clearing primary incidents from travel lanes. HERO also assists disabled motorists with basic services, such as providing limited amounts of fuel and changing a flat tire. By providing these services the program is able improve traffic operations, increase safety, and reduce environmental impacts caused by delays.

Incidents are unpredictable, caused by occurrences such as traffic crashes, spills from trucks, or mechanical breakdown of vehicles. They reduce capacity and lead to loss time, reduced productivity, wasted fuel, unnecessary pollution and secondary collisions. In 2013, HERO responded to over 10,000 incidents on the I-35 and US 183 corridors. Over 75% of these assists were detected by roving HERO trucks that patrol dedicated zones along the corridors. A major benefit of HERO, compared to other services and emergency responders, is by patrolling the corridor they are able to provide faster response times. This reduced response time not only benefits the motorist, but it also opens travel lanes quicker and reduces the delays for other drivers passing through the incident area. By operating on the most congested corridors in Austin, the benefits of the HERO Program extend far beyond the 10,000 individual assists.

The main objective of this report is to perform a Benefit to Cost (B/C) analysis of the HERO Program. An evaluation model developed by the Missouri Department of Transportation was utilized to determine the benefits of the program based only on reduced travel delay. An analysis of travel time savings calculated for the HERO Program produced a B/C ratio ranging from 11:1 to 19:1; or a benefit of $11- $19 for each $1 spent to provide the HERO Program.

Numerous independent studies of similar programs have evaluated the benefit of motorist assistance programs. For example, The Houston TranStar Program utilizes a similar approach when conducting a B/C analysis. Only benefits that are easily quantifiable are considered in the analysis and the benefits are expressed in terms of delay savings. In 2013, The Houston TranStar program yielded an estimated B/C ratio of 14.6:1. Other studies consider additional factors including the value of time, the value of fuel and the value of reducing secondary collisions in the calculation to determine the cost benefit of such programs. These studies have produced benefit to cost ranging from 2:1 to 36:1.

The HERO Program has the support of the Austin Police Department, Austin Fire Department and other first responders. Feedback from the traveling public has been overwhelmingly positive.

TABLE OF CONTENTS

HIGHWAY EMERGENCY RESPONSE OPERATOR (HERO) PATROL SERVICES PROGRAM PERFORMANCE REPORT

PROGRAM HISTORY

The Highway Emergency Response Operator Patrol Service Program was initiated by the Central Texas Regional Mobility Authority (Mobility Authority) in September, 2010, funded by a grant from the American Recovery and Reinvestment Act of 2009 (ARRA), with local share match provided by TxDOT. The program initially operated along a 31 mile segment of I-35 corridor from US 79 to the Travis/Hays County line. In 2011, STP-MM funding was awarded by CAMPO that made it possible to extend the program and expand the limits. In 2013, the program expanded the limits of I-35 from SH 130 to Yarrington Road and added US 183 from Lakeline Boulevard to I-35. The program now covers a total of 66 lane miles in Hays, Travis, and Williamson County.

PROGRAM PURPOSE

The primary purpose of the HERO Patrol Services Program is to minimize traffic congestion by clearing wrecked or disabled vehicles from the roadway lanes and providing traffic control at incident scenes to prevent secondary collisions. The program is a cost-effective alternative committed to preserving the existing capacity of the roadway by minimizing the disruption of traffic flow at incident sites.

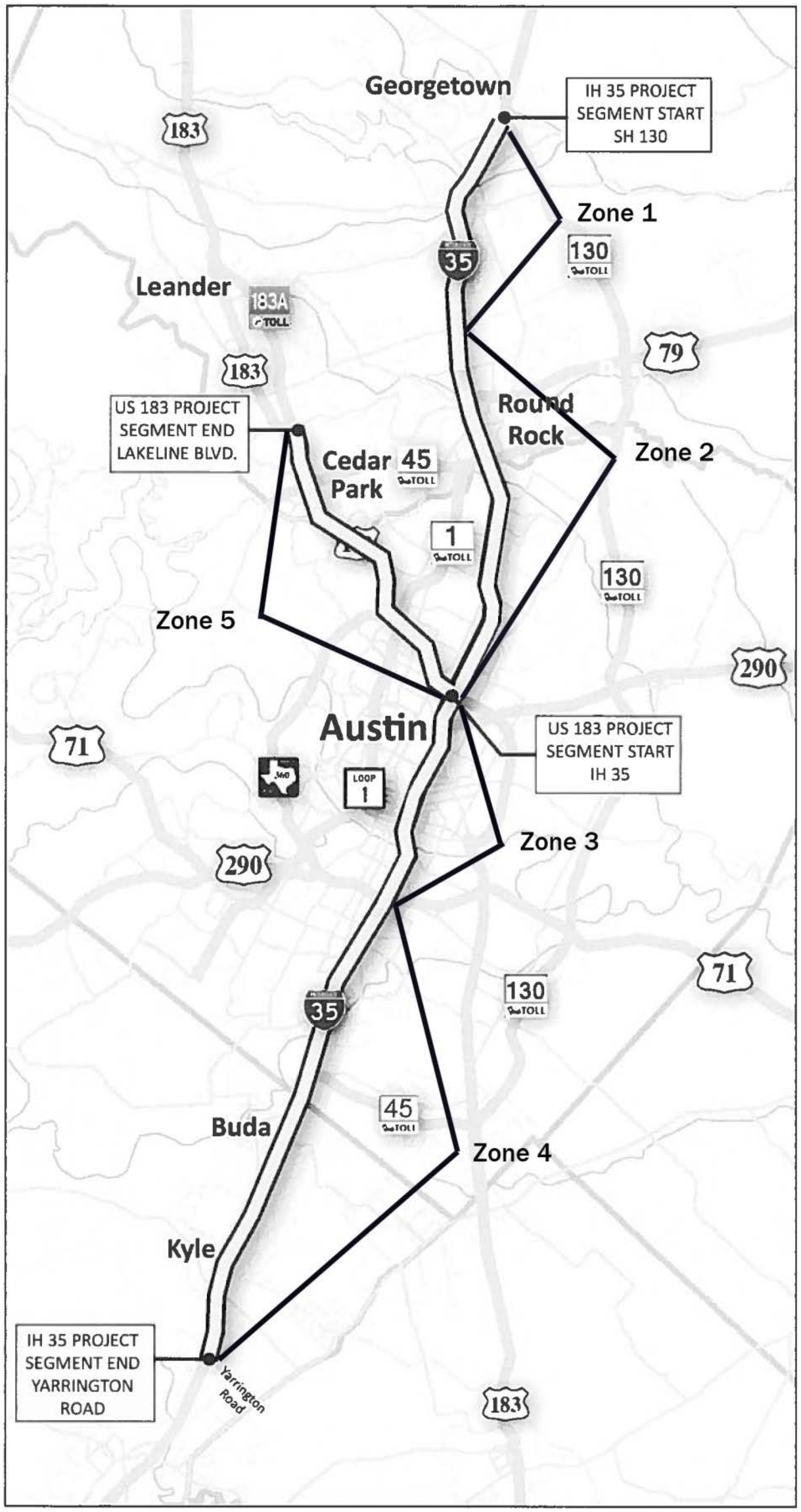
GENERAL DESCRIPTION OF SERVICES

The services provided by the program through a private contractor include patrolling I-35 from SH 130 to Yarrington Road and US 183 from Lakeline Boulevard to I-35 and rendering motorist assistance (i.e., clearing disabled vehicles from travel lanes, changing flat tires, jump-starting batteries); mitigating and clearing light debris and minor non-hazardous spills from the highway; assisting the Austin Police Department (APD), the Austin Fire Department (AFD), and other first responders during incidents, and immediately reporting hazard materials spills to the appropriate authority.

The Contractor provides vehicles and personnel to patrol five (5) zones, between 6:00 AM to 8:00 PM, Monday through Friday, except for Mobility Authority approved holidays, unless otherwise requested by the Mobility Authority as additional services.

Route	Zone Limits (north to south)		Approximate Centerline Mileage	Number of HERO Patrol Vehicles
I-35	Zone 1	SH 130 to FM 3406	11	1
	Zone 2	FM 3406 to I-35 / US 183	14	1
	Zone 3	I- 35 / US 183 to Hwy 71	9	2
	Zone 4	Hwy 71 to Yarrington Rd (Co Rd 159)	20	1
US 183	Zone 5	I-35 to Lakeline Blvd	12	1
		Total	**66 miles**	**6 vehicles**

HERO SERVICE CORRIDOR MAP



2013 PERFORMANCE HIGHLIGHTS

- The Program has assisted with over 10,000 incidents.
- The total cost of the program in 2013 was $1,541,113.
- The 2013 Benefit/Cost ratio based only on reduced travel delay, ranges from **11:1 to 19:1.** This means that for every $1 spent on the HERO Program there is a benefit of between $11 and $19 resulting from travel time savings.
- 2013 crash counts provided by the Austin Police Department show a decrease of over 800 accidents from 2012 on the corridors serviced by HERO.
- The Program services the most congested roadways in Texas according to TxDOT's 2013 Most Congested Roadway rankings. The annual hours of delay for the segment of I-35 from SH 71 to US 183 are estimated at 788,640 hours per mile during peak periods.
- Reported statistics indicate an average HERO clearance time of approximately 12 minutes. That is, from the time the HERO Patrol was notified of the incident until the time that HERO services were no longer required.
- Over 80% of assists involved providing traffic control during incidents and breakdowns which contributes to maintaining traffic flow, increasing safety, and reducing the chances for secondary incidents.
- HERO operators responded to and cleared over 60% of incidents without other responder involvement.
- The average wait time calculated from surveys submitted from assisted motorists is under 4 minutes.
- There is strong support for the program from the general public as indicated by very positive comments from those motorists assisted, favorable press coverage, and numerous letters of commendation from businesses and public agencies.
- The program has received the endorsement of numerous civic organizations and public agencies, including the Austin Police Department and the Austin Fire Department.

2013 ACTIVITIES PERFORMED SUMMARY

Total Assists for 2013	***10,032***
General Location of Assists	
Zone 1: I-35: SH 130 to FM 3406	12%
Zone 2: I-35: FM 3406 to US 183	26%
Zone 3: I-35: US 183 to Hwy 71	23%
Zone 4: I-35: Hwy 71 to Yarrington Rd (Co Rd 159)	12%
Zone 5:US 183: I-35 to Lakeline Blvd	27%
Roadways	
Assisted on Main Lanes	88%
Assisted on Frontage Roads	12%
Direction of Assist	
Northbound	47%
Southbound	53%
Location on Roadway	
Left Shoulder	5%
Right Shoulder	66%
Median	-
Left Lane	4%
Center Lane(s)	4%
Right Lane	10%
Access Ramp	1%
Exit Ramp	3%
Gore Area	4%
Other	3%
Assist Types	
Debris Removal	18%
Disabled Vehicle	67%
Abandoned Vehicle	11%
Single -vehicle crash	0%
Multi-vehicle crash	3.3%

REPRESENTATIVE BENEFIT/COST ANALYSIS

For the purpose of a program performance comparison, a model developed in a study for Missouri Department of Transportation and presented in a report entitled "*Evaluation of Freeway Motorist Assist Program*" dated February 2010 (see ***Attachment A***) was utilized to determine a Benefit/Cost ratio for the HERO Program considering only the benefits based on reduced travel delay. This initial analysis does not take into consideration other benefits derived from air quality benefits, savings to law enforcement agencies, and increased safety. The analysis shows that the B/C of the HERO Program – strictly based on reduced travel delay – ranges from **11:1 to 19:1**.

B/C ANALYSIS BASED ON REDUCED TRAVEL DELAY

$TD_{No\text{-}HERO} = TD_{HERO}\ [t_{R\text{-}No\text{-}HERO}^2 / t_{R\text{-}HERO}^2]$

(Source: "Evaluation of Freeway Motorist Assist Program", 2010)

Where:

$t_{R\text{-}HERO}$ = Response time with HERO

= 12 min + clearance time *(Source: HERO Program 2013 Data)*

$T_{R\text{-}No\text{-}HERO}$ = Response time without HERO

= 20 min + clearance time *(Source: Required APD Response Time)*

Assume Clearance Time = 10 to 20 min (with or without HERO)

(Source: "Evaluation of Freeway Motorist Assist Program", 2010)

$TD_{No\text{-}HERO}$ = T_{HERO} [(20+clearance time)^2 / (8+clearance time)^2]

= T_{HERO} [(20+10)^2 / (8+10)^2] to T_{HERO} [(20 +20)^2 / (8+20)^2]

= 2.78T_{HERO} to 2.04T_{HERO}

Total 2013 Annual Weekday Delay on the I-35 and US 183 HERO Service Area = 5,259,664 hours

(Source: Calculated from INRIX Data)

Assume: Total Delay Attributed to Incidents = 33% *(Source: FHWA)*

Assume: Breakdowns/Non-Crashes = 96% *(Source: Calculated from HERO Data)*

Assume: HERO Travel Delay savings only apply to Breakdowns/Non-Crashes

Total Delay on I-35 and US 183 HERO Service Area Attributed to Breakdowns =

(0.96)(0.33)(5,259,664 vehicle hours) = 1,666,262 hours

Assume: HERO operates 6:00AM to 8:00PM Monday-Friday (excluding holidays)

Total Annual Operation Days = 365 x 5/7 – 15 Holidays = 246 days per year

Total Annual Hours of Operation = 14hours/day x 246 = 3,444 hours

% operating hours per year = 3,444/365x24 = 0.393

Annual hours of delay due to breakdowns during HERO Operating Hours (TD_{HERO}): 0.393(1,666,262)

= 654,841 hours

$TD_{No\text{-}HERO}$ = 2.78TD_{HERO} to 2.04TD_{HERO}

$TD_{No\text{-}HERO}$ = 2.78(654,841) to 2.04(654,841)

= 1,820,457 to 1,335,875 hours

Delay Savings with HERO: 1,820,457 – 654,841 = 1,165,617 hours (High End)

1,335,875 – 654,841 = 681,034 hours (Low End)

Assume: $24.50/vehicle hour (Source: TxDOT/TTI)

Benefit = $24.50 x (681,034 hours to 1,165,617 hours)

= $16,685,343to $28,557,607

Current Annual Cost of HERO Program = $1,541,113 (includes mobilization) *(Source: HERO 2013 Program Data)*

B/C Ratio = $16,685,343/$1,541,113 to $28,557,607/$1,541,113

= 11:1 to 19:1

Benefit/Cost Results Per Zone

Utilizing the same model, a Benefit/Cost analysis for each zone of the program was conducted. Each zone produced a positive B/C ratio, indicating a favorable impact in each service area and a return in travel delay savings. The results are presented in the chart below. It should be noted that due to the greater annual hours of delay experienced in Zone 3, two HERO vehicles patrol this service area.

Zone	Annual Hours of Delay (hours) (Source: INRIX DATA)	Time Delay Savings with HERO Program (low to high range) (hours)	B/C Ratio (low to high range)
1	250,947	33,509 – 57,351	3:1 to 5:1
2	854,070	111,739 – 298,687	11:1 to 18:1
3	2,650,601	336,056 – 898,304	16:1 to 27:1
4	936,697	125,076 – 214,072	12:1 to 20:1
5	567,349	73,462 – 125,733	7:1 to 12:1

Other Benefits of HERO that were not considered in the analysis include:

- Value associated with the decrease in fuel consumption and vehicle emissions.
- Value received by over 10,000 motorists in 2013.
- Increased availability of Austin Police Department Officers; approximately 1400 Hours (Calculated at 14 minutes per response that HERO did not require a police response).
- 10% decrease in accidents on I-35 and US 183 in the area patrolled by HERO in 2013 (APD statistics - excludes Zone 1 since not in Austin city limits).
- Value of lives saved, injuries prevented, and costs avoided by reduction in crashes.

HERO PROGRAM DETAILED SCOPE OF SERVICES

Based on direct observation on the highway or via requests for services through dispatch, the HERO Contractor responds to and provides three general categories of service:

1. **Removal of light debris** (e.g., tires, hubcaps, ladders, buckets, lumber, upholstered cushions, mattresses, bicycles, etc.) from the travel lane or shoulder of the roadway.
2. **Locating, assisting, and/or removing disabled vehicles**
3. **Assisting other emergency and support response personnel as requested**, concerning a crash or other emergency on the highway segment. When notified of an incident through dispatch, the HERO Patrol operator shall arrive on the scene within fifteen (15) minutes (on average per month) and immediately initiate service.

DEBRIS REMOVAL

Debris removal includes the pick-up of roadway litter and debris that is obstructing traffic and that poses a hazard to motorists. Debris may include but is not limited to tires, hubcaps, ladders, buckets, lumber, upholstered cushions, mattresses, bicycles, etc. For dead animals that pose a traffic hazard, the HERO Patrol operator will relocate the carcass out of the travel lanes and/or well off of the shoulders and then notify the proper authority charged with removing the animal.

The Contractor personnel are not required to handle hazardous materials, but they are responsible for reporting hazardous material spills as specified by the Texas Commission on Environmental Quality (TCEQ).

LOCATE, ASSIST, AND/OR REMOVE DISABLED VEHICLES

Assisting motorists with removing disabled vehicles from roadway. Such services may include:

- changing flat tires,
- giving air to low tires,
- adding gasoline/diesel,
- adding water to radiators,
- providing battery jump starts,

- performing minor vehicle repairs where feasible if they can be remedied quickly (fifteen (15) minutes maximum),
- relocating the vehicle out of a travel lane or off of a shoulder
- calling towing service if needed,
- calling for emergency service if needed,
- transporting stranded motorists to a safe location off the roadway,
- providing cell phone service, and/or
- providing drinking water to stranded motorists.

Prior to providing services, the HERO Patrol Operator advises the motorist of the following:

1. *Moving, fueling, servicing the vehicle or calling a towing service is being provided free of charge by the Central Texas Regional Mobility Authority through funds made available by CAMPO.*
2. *The HERO Patrol Operator will attempt minor repairs **not to exceed approximately fifteen (15) minutes** once the vehicle is cleared from the travel lanes.*
3. *Should repairs not prove feasible or solve the problem, the motorist will be allowed up to three (3) telephone calls using the HERO Patrol Operator's cellular telephone to make arrangements for further service, towing, or transportation.*
4. *All costs for further service, towing, or transportation by a third party must be paid by the motorist.*

ASSIST OTHER EMERGENCY AND SUPPORT RESPONSE PERSONNEL

The HERO Patrol Operator also renders assistance to other emergency and support response personnel when requested. At the scene of an incident, HERO Patrol Operators follow the instruction of, and obey the orders of on-scene law enforcement personnel. Such services include:

- providing initial and updated on-site information to the dispatcher as conditions change or routinely (i.e., every 15 minutes) as appropriate depending on incident conditions;
- immediately notifying the appropriate dispatch center of:
  - an incident requiring emergency services,
  - major incidents resulting in road or lane closures of more than one (1) hour,

  - fires near or on the roadway,
  - large spilled loads or large debris,
  - roadway icing or flooding;
- responding to and initiating clearance procedures for minor, property-damage-only vehicle crashes that pose a safety hazard or result in traffic congestion;
- extinguishing minor vehicle fires and reporting larger fires to the proper authority;
- mitigating the impacts of motor vehicle fluid spills (i.e., lubricants, fuels) in quantities less than five (5) gallons. Such services may include providing quick clean-up using absorbent materials;
- assisting APD, other authorized law enforcement or other emergency and support response agencies establish traffic control and scene protection using signs, flares, cones, flagging, flashing lights, etc. during incidents;
- observing dynamic message signs (DMS) and traffic flow conditions and reporting major problems to proper authorities; and
- reporting road damage to proper authorities.

HERO PROGRAM DOCUMENTATION AND PERFORMANCE REPORTING

The provisions of the contract with the HERO Contractor require that monthly and quarterly activity reports be prepared and submitted to the Mobility Authority summarizing: (1) the daily logs, (2) motorist comment cards and request of services forms and (3) an overall safety report reflecting the Contractor's safety assignments and/or on-the-job safety incidents involving an HERO Patrol Operator. This information is intended to describe the overall performance of the HERO Patrol Program, and it includes the following:

- incident response, roadway, and incident clearance times based on when:
    - ✓ the HERO Patrol Operator was notified of an incident and when they arrived at the scene (i.e., response time);and
    - ✓ the HERO Patrol Operator left the scene of the incident (i.e., incident clearance time. That is, from the time the HERO Patrol was aware of the incident until the time that HERO services were no longer required);
- whether the incident is isolated or occurred as a result of a prior incident (i.e., secondary incident);
- on-site participation by other emergency and support responders (i.e., specific law enforcement, fire and rescue, emergency medical services, towing and recovery, transportation, coroner, environmental quality, or media agencies); and
- motorists' feedback regarding the timeliness and quality of HERO Patrol response.

Secondary captured information of interest includes the following:

- method of HERO Patrol Operator incident notification (i.e., observed through routine patrol or dispatched);
- the regional location of each incident including the travel direction, municipality, county, and milepost;
- the roadway location of each incident including the right or left shoulder, lane designation, access or exit ramps, etc.;
- the nature of each incident including whether it involved an abandoned vehicle, debris, a non-injury crash single-vehicle or multi-vehicle crash, an injury crash single-vehicle or multi-vehicle crash, a fatality crash single-vehicle or multi-vehicle crash, fire, non-hazardous material spill, hazardous material spill, etc.; and
- the nature of HERO Patrol services provided including marking and reporting abandoned vehicles, clearing debris, providing minor mechanical assistance (i.e., changing a flat tire,

providing fuel, etc.), relocating vehicles from the travel lanes, provide traffic control and scene protection for other responders, etc.

All HERO Patrol log data is provided daily to the Contractor's Program Manager, and monthly to the Mobility Authority in an electronic database format. The database structure was reviewed by the Texas Transportation Institute (TTI) with particular attention focused on performance measures. Several comments received from TTI were incorporated and the reporting form was subsequently approved by the Mobility Authority.

The reports summarize all of the available information contained in the daily activity logs and the motorist comment cards, including written comments provided by motorists describing their experiences. The statistics contained within these reports are used by the Mobility Authority to measure the utilization, effectiveness, and performance of the HERO Patrol Program. These reports also allow the Mobility Authority to evaluate stops and assists by zone, assist categories, personnel shifts, etc.

ATTACHMENTS

Attachment A **EVALUATION OF FREEWAY MOTORIST ASSIST PROGRAM**

Attachment B **HOUSTON TRANSTAR 2013 ANNUAL REPORT**

ATTACHMENT A

Organizational Results Research Report

February 2010
OR10.018

Evaluation of Freeway Motorist Assist Program

Prepared by
University of Missouri-Columbia,
HDR Engineering and Missouri
Department of Transportation

FINAL REPORT
RD 09-004

Evaluation of Freeway Motorist Assist Program

By
Carlos Sun
University of Missouri – Columbia
Department of Civil and Environmental Engineering
E2509 Lafferre Hall
Columbia, MO 65211
Phone (573) 884-6330
Fax (573) 882-4784
E-mail csun@missouri.edu

Venkat Chilukuri, Tom Ryan, Michael Trueblood
HDR Engineering
326 S. 21st Street, Suite 400
St. Louis, MO 63103
Phone: (314) 425-8300
Fax: (314) 425-8301
E-mail: venkat.chilukuri@hdrinc.com

MoDOT Project Monitor: Tom Blair, District-6
MoDOT MTI Liaison: William Stone, Organizational Results

September 30, 2009

TECHNICAL REPORT
STANDARD TITLE PAGE

1. Report No. OR10-018	2.Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FINAL REPORT: Evaluation of Freeway Motorist Assist Program		5. Report Date February 2010
		6. Performing Organization Code FHWA MO-2009-004
7. Author(s) Sun, C., Chilukuri, V., Ryan, T. and Trueblood, M.		8. Performing Organization Report No. NA
9. Performing Organization Name and Address University of Missouri E2509 Lafferre Hall Columbia, MO 65211		10. Work Unit No.
		11. Contract or Grant No. Task Order MTI RI07-006, RD 09 - 004
12. Sponsoring Agency Name and Address Missouri Department of Transportation 2271 St. Mary's Blvd. Jefferson City, MO 65109 Federal Highway Administration U.S. Department of Transportation Washington, D.C.		13. Type of Report and Period Covered Final Report, April 13 – September 30, 2009
		14. Sponsoring Agency Code
15. Supplementary Notes		
16. Abstract This evaluation of the Motorist Assist (MA) program in St. Louis estimated that MA has an annual benefit-cost ratio (B/C) of 38.25:1 using 2009 dollars. This estimate was based on nationally accepted AASHTO methodology and was based on 1082 secondary crashes reduced per year and an average crash value of $72,350/crash. This B/C is an astonishing figure that is larger than all of the B/Cs reported in literature for other similar freeway service patrol programs. One factor that contributed to this B/C was the large secondary crash reduction ratio estimated using actual data from the years prior to and after MA was first deployed in 1993. Other factors include the low cost of operations and the high cost of secondary crashes. MA is a critical component of an overall Traffic Incident Management (TIM) strategy. Responders, such as the police, validate this perspective by commenting that MA is better equipped to handle traffic control, which allows the police to take other actions such as investigating the incident. The evaluators recommend for MA to be strengthened.		
17. Key Words Motorist Assist, Freeway Service Patrol, Secondary Crashes, Benefit-Cost Analysis	18. Distribution Statement	

19. Security Classif (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	52	

Form DOT F 1700.7 (8-69)

RESEARCH RESULTS

A sustainable transportation system requires better utilization of available limited resources to deliver a **safe** and **efficient** transportation system. Sustainability is the act of balancing the environmental, community, and economic needs of the man-made and natural environments in which we live for present and future generations.

MoDOT is a national leader in developing and implementing Traffic Incident Management (TIM) elements as part of a Missouri transportation system. From the successful Motorist Assist (MA) programs in St. Louis and Kansas City to its statewide Emergency Response (ER) efforts on major interstates, MoDOT is partnering with other emergency response staff to better use resources to deliver a quicker, safer clearance of incidents along major congested roadways. Through these TIM efforts, MoDOT and its partners are providing a more sustainable transportation system addressing the three elements of sustainability: environment, community and economy through the achievement of a safer and more efficient transportation system.

This research document builds on an earlier document that evaluated the St. Louis MA program, and establishes and updates current benefits of this program. The following is a summary of findings:

<u>St. Louis Motorist Assist Program</u>

- **Benefit-cost ratio is 38.25 to 1**
- **Reduced 1,082 secondary crashes per year with annual net social benefits of $78,264,017**
- **Reduced $ 1,130,000 in annual congestion cost**
- **Supports Community Emergency Response**
    - **Safer and Quicker Incident Response and Clearance**
    - **Reduction in ER resources for TIM activities freeing them up for other Community needs**

The three elements of sustainability are present in the St. Louis Regional TIM activities. Environmental issues pertain to both natural and man-made. Improved air quality and safer transportation facilities are direct benefits for the community.

The community's transportation needs are better served when regional partners work cooperatively together to maximize limited resources. Having the right person (i.e. MA Operator) doing what they are trained for (i.e. traffic control) can save lives and time while improving the quality of life for those living in or traveling through the community.

A region's economy is strongly linked to how well its transportation system performs. The movement of people and goods impacts everyone from travel expenses to products purchased. Improving safety and reducing traffic congestion gained through TIM activities will save lives, time and money.

Everyone wins – the traveling public gains improved safety and reduced travel times at less cost. Emergency Response gains improved safety within incident sites and reduction in time spent on scene through quicker coordinated clearances. Highway agencies (e.g. MoDOT) gain improved traffic flow along their transportation facilities with results in improved satisfaction of the traveling public that financially supports regional emergency response and highway agencies.

EXECUTIVE SUMMARY

A sustainable transportation system requires better utilization of available limited resources to deliver a **safe** and **efficient** transportation system. MoDOT is a national leader in developing and implementing Traffic Incident Management (TIM) elements as part of the sustainable transportation system in Missouri. From the successful Motorist Assist (MA) programs in St. Louis and Kansas City to its statewide Emergency Response efforts on major interstates, MoDOT is partnering with other emergency responders to better utilize resources to deliver a quicker, safer clearance of impacting incidents along major congested roadways. Through these TIM efforts, MoDOT and its partners are providing a more sustainable transportation system that helps to achieve the two foremost objectives of providing safer and efficient travel in Missouri.

This research document builds on an earlier document that evaluated the St. Louis MA program to establish and update current benefits of this program. The following is a summary of findings:

- St. Louis MA Program benefit-cost ratio was 38.25:1
- St. Louis MA Program reduced 1,082 secondary crashes per year
- St. Louis MA Program reduced $1,130,000 in annual congestion cost

The Motorist Assist (MA) program is St. Louis is a freeway service patrol program that performs critical Traffic Incident Management (TIM) functions such as incident detection, verification, traffic control and clean up, and, in addition, motorist assists. In 2003, an evaluation of MA concluded that the benefit-cost ratio (B/C) of MA was 11.2:1. That evaluation analyzed data immediately before and after the deployment of MA and produced a crash reduction factor that is used by this current study. The alternative to using a crash reduction factor would be to extrapolate the "without MA" trendline 19 years or to regress the number of secondary crashes on factors such as incident duration, lane blockage, hourly flow, and time of the day. Figure "I", reproduced from the previous study, illustrates graphically the significant differences in secondary crash trends before and after MA is implemented. This evaluation updates the previous study to reflect: 1) the temporal (longer hours) and spatial (wider coverage) expansions of MA; 2) the use of better safety and traffic data; 3) improved secondary crash methodology; 4) the use of national guidelines, the AASHTO Redbook, for analyzing highway user benefits; 5) the use of statistically significant differences between secondary and primary crash characteristics; and 6) proper discounting to update to present dollar values.

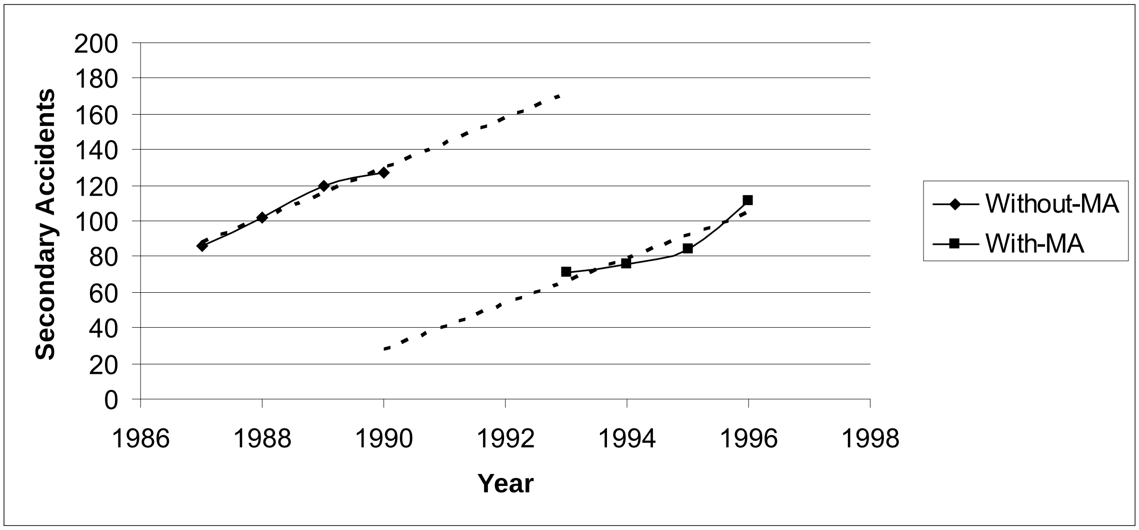


Figure I. Secondary Crashes Before and After MA on I-270 (UMC, 2003)

The report in 2003 only examined two freeways, namely I-70 and I-270, since MA's initial coverage was limited in scope. Now there is full MA coverage on all freeway segments, therefore the benefits and costs are both increased. However, the benefits increased much more than the cost. Also, the crash data shows an interesting differentiation between primary and secondary crash characteristics. Table I shows that there is a higher percentage of both fatal and PDOs for secondary crashes that is statistically significant. Specifically, average secondary fatal crashes are 0.829% per year compared with 0.337% per year for primary. The more severe crashes dominate costs, thus secondary crashes cost more and are more severe than primary crashes on the average.

This fact illustrates the importance of incident management programs in general and MA specifically. AASHTO published the "Redbook" in 2003 that recommended higher valuation for severity than some other sources and also a larger discount rate of 3%. In the previous study, a more conservative rate of 2% was used. The discovery of the difference in severity between secondary and primary crashes coupled with the larger discount rate led to an increase of valuation of average crashes from $30,000/crash (2002) to $72,350/crash (2009 dollars).

Table I. Crash Percentage by Severity

Year	Secondary				Primary			
	Fatal	Disabling Injury	Minor Injury	PDO	Fatal	Disabling Injury	Minor Injury	PDO
2000	1.15	2.20	22.93	73.72	0.28	2.21	25.51	72.00
2001	0.62	1.24	23.26	74.88	0.32	2.42	24.61	72.66
2002	1.02	2.54	20.36	76.08	0.38	2.26	24.41	72.95
2003	0.79	2.03	22.94	74.24	0.26	2.25	24.51	72.99
2004	0.48	2.63	20.36	76.53	0.31	2.43	23.85	73.41
2005	0.82	2.11	21.87	75.20	0.31	1.95	25.57	72.16
2006	0.91	2.17	22.37	74.54	0.26	2.02	23.57	74.14
2007	0.75	2.25	22.47	74.53	0.30	2.15	23.23	74.32
2008	0.66	2.51	18.34	78.50	0.34	2.42	24.15	73.09
Weighted Average	0.829	2.026	21.89	75.25	0.337	2.18	24.28	73.20

Actual field data from Missouri was used in this study. Some simulation and mathematical modeling were performed for analyzing mobility benefits and estimating delays. However, no simulation and mathematical modeling were performed as part of the safety and crash analysis of MA. Average crash characteristics from St. Louis were used to develop the methodology for extracting secondary crashes.

The new B/C estimated for MA is 38.25:1 annually using 2009 dollars. This is a staggering value when compared to other highly effective safety countermeasures. Even if all the costs were not fully captured, the benefit is nonetheless an incredibly large number.

MA is a critical component of an overall Traffic Incident Management (TIM) strategy. Interviews with police agencies consistently affirm the service patrol's excellent working relationship with police, and the service patrol's value in handling traffic control in TIM which enables police to focus on other TIM duties that are more suitable for police. As a result of the benefit-cost analysis, evaluators recommend that Freeway MA should be continued and strengthened as a regional TIM component

GLOSSARY

B/C	Benefit-to-cost ratio: a popular method for assessing the societal benefits against the costs of a particular project or alternative.
Gateway Guide	The Intelligent Transportation Systems initiative in St. Louis, Missouri, which includes a regional Traffic Management Center.
FSP	Freeway Service Patrol: a service provided by departments of transportation that involve patrolling sections of roadways, managing incidents, and assisting motorists.
IPC	Incident Progression Curve: a curve displaying the queue resulting from incidents over time and space that is used for classifying secondary crashes.
MA	Motorist Assist: a freeway service patrol program in the St. Louis region that includes Emergency Response in the off hours.
TIM	Traffic Incident Management: the systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and safety and mobility impact of incidents.
TMC	Traffic Management Center.
ER	Emergency Response: are resources, including police, fire, ambulance, wrecker services, etc., needed to assist in clearance of incidents from transportation facilities
VMS	Variable Message Sign.

TABLE OF CONTENTS

1. INTRODUCTION

This report presents the results from a benefit-cost (B/C) analysis of the Motorist Assist (MA) program in St. Louis, Missouri.

1.1 Coverage and Scope of Motorist Assist

The MA Program debuted on February 1st, 1993, in the St. Louis region. Initially, only four vehicles patrolled just three routes with a total centerline mileage of 31.5 miles. The hours of operation were limited to the morning and evening peak periods only. In 1996, the program was expanded by nine operators and four trucks. The additional manpower and equipment allowed for an increase in both the number of centerline miles patrolled and expanded the hours of operation to 5:00AM to 12:00PM and 1:00PM to 7:30PM. Another expansion in 2001 added I-44 and I-64/US 40 from west of Mason Rd into St. Charles County as patrol areas. In August 2002, MA began patrolling on Saturday and Sunday for the first time. Currently, MA trucks patrol St. Louis area freeways from 5:00 a.m.-7:30 p.m., Sunday to Sunday and include the following roadways:

- Route 364-Page Avenue I-270 to Rte. 94
- I-44 Six Flags Road to Downtown St. Louis
- I-55 Highway A (Festus) to Downtown St. Louis
- I-64/Rte. 40 Rte. 94 to Downtown St. Louis
- I-70 Mid Rivers Mall Drive to Downtown St. Louis
- I-170 all
- I-270/I-255 Riverview Drive to Jefferson Barracks Bridge

The coverage map is shown in Figure 1.1.

Figure 1.1 Motorist Assist and Gateway Guide Coverage (MoDOT, 2009)

1.2 Purpose of Motorist Assist

The purpose of the MA Program is to promote freeway safety and expedite the flow of high volume traffic by assisting disabled motorists in the patrol areas, clearing roadways of stalled vehicles and debris, and assisting emergency personnel at accident locations. MA improves the flow of traffic and increases safety by detecting and responding to incidents quickly, removing incidents in a timely manner, and providing high-visibility traffic control devices at incident scenes. Figure 1.2.1 illustrates some of the services that MA performs. Specific services include:

- Push a disabled vehicle out of a traffic lane
- Provide traffic control at an incident scene
- Remove debris from the roadway
- Establish initial containment of a hazardous materials spill
- Give directions to a lost motorist
- Mark an abandoned vehicle with the date and time to expedite removal by police
- Contact police to tow an abandoned vehicle impeding traffic flow
- Make basic repairs to a disabled or stalled vehicle
- Provide a stranded motorist a ride to a safe location
- Allow a motorist the use of a cellular phone
- Change a flat tire
- Dispense fluids such as gasoline or engine coolant

Figure 1.2.1 Example of MA Operator Assisting in Debris Clean Up

In addition to the many primary functions, throughout its existence MA program has accepted several secondary purposes. For instance, major accidents require a prolonged presence of emergency personnel to provide a "buffer zone" between moving traffic and the incident scene and to close necessary traffic lanes or even an entire freeway. MA helps to fill this role by ensuring safety at an accident scene and by maintaining a presence at the point of a lane or freeway closure. An additional secondary function is checking for state property damage. Each roundtrip of MA on a beat serves as a basic inspection for malfunctions and damage to the freeway system. Lighting facilities not working and damaged guard rails are just a couple examples of the types of problems possibly noted by MA. Also, since the inception of Gateway Guide, the Intelligent Transportation System (ITS) for the St. Louis region, MA has become an integrated component of the system. Operators in the field provide information on traffic problems resulting from both recurrent congestion and incidents. Details of incident location and approximate clearance time are provided to dispatchers at Gateway Guide's Transportation Management Center (TMC), which in turn transmit the information to the public via ITS outlets such as the media, dynamic message boards, and the Gateway Guide website.

1.3 Interactions with Other Agencies

Since incident management is an important role of FSPs such as MA, it is important to understand the context of Traffic Incident Management (TIM) and the roles of each of the factors. The factors involved with TIM usually include police, fire, 911 dispatch, towing and recovery, emergency medical services, hazardous materials (HAZMAT), transportation agencies, and the media (FHWA, 2000). The success of TIM depends not only on each partner performing capably, but also on the efficient coordination among all the partners. While there might be some overlap in some of the functions, there are certain functions that are particular to a specific partner. In the case of MA, some functions such as debris removal, traffic control, detection, and verification can be performed by others, such as the police. However, MA/TR is the most suitable partner for many of those functions because of the training, equipment, and its role as part of the overall Intelligent Transportation Systems' (ITS) deployment in St. Louis. One could argue that some functions, such as traffic control, can also be performed by the police. However, many police agencies prefer that MA handle such functions so that the police can be freed up for other tasks such as accident investigation, and MA operators have more traffic control equipment than other responders such as arrow boards, barricades, and cones. The following police agencies were contacted to obtain their qualitative assessment of their working relationship with MA:

- Jefferson County Police
- Pevely Police Department
- Festus Police Department
- Arnold Police Department
- St. Louis City Police
- St. Louis County Police
- Eureka Police Department

Due to availability, only three interviews were conducted. The telephone interviews were with Captain David Kaltenbronn of Pevely Police Department, Lieutenant David Wilson of Eureka Police Department, and Chief Tim Lewis of Festus Police Department. The overwhelming response from the interviews was that MA was extremely valuable as responders in TIM and that they complement well the other responders such as police. Captain Kaltenbronn said that MA operators are pleasant to work with and communicate well with the police. He was extremely satisfied with MA. His agency is composed of ten road officers and fourteen officers total. He said that when an officer performs traffic control, it takes away from other functions such as doing accident investigations or handling other residential or commercial issues. Lieutenant Wilson echoed the same sentiment that MA operators communicated well with the police and that they were quick to respond. Lieutenant Wilson said that MA operators were better equipped to handle some of the traffic issues because they had more training in traffic and possessed more suitable equipment. The Eureka police department is composed of 25 officers and is responsible for a section of I-44 as well as a ten square mile region that includes the Six Flags amusement park. The police sentiments can be best summed up the words of Chief Lewis: “We need it [MA], don’t get rid of it.”

2. LITERATURE REVIEW

This literature review contains eighteen additional references that had not been used in the 2003 Evaluation of the Motorists Assist in St. Louis. Also, the web pages from the departments of transportation of 12 states are reviewed. This review contains basic information for the operation of the Freeway Service Patrols (FSP) of 22 cities in the 12 states, and information on the B/C from ten cities. The B/C ranged from 2:1 to 36:1 with an approximate average of 13.5:1. All of the references agreed that service patrols reduced incident times, promoted better highway service, and improved safety. One limitation of this literature review is that each city or state used the variables that it deems relevant to calculate the B/C. Since the operation schemes were so different between states and sometimes between cities in the same state, it became almost impossible to establish comparisons between them. For example, in the Evaluation of the Service Patrol Program in the Puget Sound Region, Washington, the intent was to compare the performance of the FSP between the cities of Seattle and Tacoma and determine if one was performing better that the other. The investigation concluded that both cities were performing fairly under their different schemes. The methods used in evaluations included direct analysis of crash, assist, and traffic data; simulation-based analysis; mathematical modeling and queue modeling; and surveys.

2.1 Review of Motorist Assist Evaluations

Most references mentioned that there was no agreed upon definition of what a secondary incident was, so each researcher had to establish the relationship between primary and secondary incidents. Since most states filed each incident separately, researches relied on queuing and traffic flow theory to establish relationships between incidents. There had been issues about the reduced number of secondary crashes found normally on databases. Current literature stated that incidents on freeways account for approximately 60% of all congestion delay in the United States (Pal et al., 1998; Skabardonis et al., 1999; Khattak et al., 2004; Chou, 2008). Incidents that cause delays included vehicle breakdowns, debris in the roadway, spilled loads, abandoned vehicles, pedestrians on the roads, crashes, or any other incident that causes a reduction in the capacity of the road. Since the 1960's, the departments of transportation (DOTs) of several states and cities in the United States implemented various forms of Freeway Service Patrol programs (FSP) to help minimize the effects that these incidents have on the performance of the highways and to help improve safety for the drivers. FSP programs proliferated in the 1970's and 80's, mainly because of availability of federal and local funds, and because of the DOTs and general public acceptance. But in the 1990's, due to budget constraints, the need rose for evaluating the benefits of the FSP programs and comparing them to the programs costs. Program costs were readily available from financial statements since the implementation of the programs, but estimating the benefits from the programs required making a comparison between the effects of an incident that is managed through a FSP program versus the effects of the same or a similar incident managed under normal conditions (without FSP program).

Donnell et.al. (1999) presented an evaluation of the Penn-Lincoln Parkway Service Patrol. The Pennsylvania DOT contracted a local towing company that provides assistance during traffic peak hours in the Penn-Lincoln Parkway using only three tow trucks. For this study, the authors had access to an extensive State Police database of incidents that occurred prior to the implementation of the service patrol. Data from similar accidents that occurred prior and post implementation of the FSP were paired and the incident response time, incidence clearance time, vehicle-hours of delay, fuel consumption and vehicle emissions of the similar incidents were directly compared. The study showed that due to the assistance of the service patrol, the incident response times were reduced by an average of 8.7 minutes, incidents were cleared an average of 8.3 minutes faster, and the system experienced 547,000 hours less of total delay and the monetary savings was 6.5 million dollars per year. This resulted in a benefit-to-cost ratio of 30:1.

The methods used to collect data from FSP evaluations were varied. Two of the largest data collection experiments, performed by Skabardonis et al., published the results of data collected on the I-880 highway (1997) and the I-10 freeway 1999), both located in Los Angeles, California. Both databases were collected using probe vehicles to determine vehicle trajectories, loop detectors to determine volumes and lane occupancy, and incident records from the police and the FSP. Specifically for the I-10 project, the researchers deployed 7 probe vehicles at 5.7 minute headways to record the type of incident (e.g. crash, breakdown, other), the severity (as the number of lanes closed), the description of the vehicles, the location, and the type of help present (e.g. police, FSP, other). Statistical analysis was performed. The lognormal distribution was found to provide the best fit to the data. Approximately 50% of the incidents reported during the I-10 experiment were vehicle breakdowns located on the shoulders. The researchers concluded that incident durations were greatly affected by the incident type, the severity of the incident, and the type of assistance provided.

Pal, Latoski, and Sinha evaluated the Hoosier Helper program in northern Indiana (1998). The Hoosier Helper program started operations in 1991 with three pickup trucks and three vans that provided services between 6:00 am and 8:30 pm, and in 1996 expanded to a 24 hour operation. Data collected from the service logs for the daytime and 24 hour service periods revealed that approximately 70% of the incidents required the FSP to perform small services such as changing flat tires or supplying gasoline. The second most common service provided was removing abandoned vehicles from the shoulders. Crash assistance only accounted for 5 to 7 % in each period respectively. Therefore, severity was not an important factor. They also used the XXEXQ network simulation model. The model performs User Equilibrium traffic assignment using the Bureau of Public Roads link functions and generates travel times for individual vehicles and for the entire system. The importance of the XXEXQ model is that it could document the movement of vehicles from the affected road into other roads in the network. Eight scenarios were evaluated for the daytime operation and six scenarios for the 24 hour operation. The benefit-to-cost ratio was estimated at 3:1 before 1996, and an increase of 9:1 was estimated for the 24 hour operation after 1996. The authors also concluded that safety was increased by the 24 hour operation by reducing secondary incidents by 18.5%.

Simulation-based computer models were also used for evaluating the performance of FSP when data prior to the implementation was not available. In 2009, Chou (2009) estimated the benefit-to-cost ratio of the Highway Emergency Local Patrol (HELP) in New York State using the CORSIM microscopic simulation model. Six hundred and ninety three (693) incidents that were assisted by HELP were replicated in CORSIM, both with assistance and without assistance. Each incident was replicated 5 times using different random seeds or input information to ensure proper fit with real data. The only parameter modified in CORSIM was to adjust for rubbernecking. Using conservative assumptions for economic parameters (1 passenger per vehicle, average fuel consumption, etc.) the benefit-to-cost ratio was estimated as 2:1. CORSIM was also used by Heath and Turochy (2008) to evaluate the Alabama Service and Assistance patrol (ASAP). Thirty scenarios were developed and tested using the program database and CORSIM. Results in the form of benefits to cost ratios of vehicular volumes, speeds, delays and emissions were generated. The benefits to cost ratios of the variables using conservative figures were estimated and the B/C ration ranged from 1.7:1 to 23.4:1.

Other methods used include mathematical modeling, deterministic queue modeling, and evaluative surveys. Guin et. al. (2007) used the Traffic Incident Management Handbook provided by the Federal Highway Administration (FHWA, 2000) to develop a mathematical model to represent the motorist assist data generated by the Georgia NaviGAtor program. The model proved to fit the data reasonably well and took into consideration vehicular delay, fuel consumption, secondary crashes and emissions. The NaviGAtor program had a benefit-to-cost ratio of 4.4:1. One drawback from this mathematical model was that it could not be easily transferred to other systems because it was created to fit specifically one set of data. A deterministic queue model was used by Dougald and Demetsky (2008) to measure delays and to estimate the benefit-to-cost ratio of the Northern Virginia Safety Service Patrol (NOVA SSP). Queue models could be used by virtually any agency to model delays. Using conservative figures for estimating fuel consumption and vehicle emissions, the benefit-to-cost ratio for the NOVA SSP was estimated in 5.4:1. The Tennessee Freeway Service Patrol program used surveys to estimate the adequacy of its FSP program (Baird et. al., 2003). Motorists that had been assisted on the road were given a return postage paid comment card to evaluate the services received. Between the years 2001 and 2003, 11,000 cards had been returned and 99% of the evaluations were excellent. The drawback from this evaluation is its subjective nature.

2.2. Review of Secondary Crash Analysis Methodology

In addition to reviewing literature on MA and TR, the literature pertaining to secondary crashes was also reviewed. The use of the term “secondary crash” instead of “secondary accident” was intentional in order to emphasize the potential for reducing such crashes due to improved incident management and traveler information on the primary incident. Even though there is consensus on the importance of incident management and reduction of secondary crashes, the methods for analyzing secondary crashes are not well defined. The development of this research is based upon previous work in the area of crash analysis and safety. In an important paper on the analysis of secondary crashes, (Raub

1997), Raub presents a methodology for the temporal and spatial analysis of incidents on urban arterials in order to identify the secondary crashes. Raub (1997) found that more than 15% of the crashes reported by police may be secondary in nature. He also found that such crashes result from external distractions instead of internal distractions or driver perception error. For his analysis, he assumed crash effect duration of 15 minutes plus the clearance time. He also assumed a distance of effect of less than 1600 meters (1 mile). In other words, if a crash occurred within these temporal and spatial boundaries, then it is considered to be secondary.

More recently, Moore et al. (2004) examined secondary crash rates on Los Angeles freeways using crash records from the California Highway Patrol's First Incident Response Service Tracking system as well as data from loop detectors on Los Angeles freeways. They defined secondary crashes as crashes occurring upstream of the initial incident in either direction within or at the boundary of the queue formed by the initial incident. A static threshold of 3.2 km (2 miles) and 2 hours was used for forming this boundary. Several levels of filters served to eliminate erroneous data. Another example of the use of static threshold is Hirunyanitiwattana and Mattingly (2006); they used a threshold of 3.2 km (2 miles) and 1 hour in the same direction.

Several recent studies have focused on determining the interdependence between road incidents and the secondary incidents that can be caused by them. Khattak et al. (2008) used the incident database provided by the Virginia Transportation Research Council and applied an Ordinary Least Squares regression model to estimate the relation between primary and secondary incidents. The researchers defined a secondary incident as one that occurs in the same direction as the primary incident and within its time duration. The only exception to this definition was that if the primary incident blocked one or more lanes, then the primary incident duration time would be increased by 15 minutes. After applying the models, the researchers concluded that secondary incidents are closely related to longer durations of primary incidents; therefore, transportation agencies should focus their roadway assistance efforts to providing expedited attention to reducing primary incidents durations in order to reduce the possibility of secondary incidents.

Zhan et al. (2008) proposed a different definition to secondary incidents. In their research, they determined that secondary incidents are those that occur within the queue formed by a primary incident. Using a cumulative arrival and departure traffic delay model, the researchers determined the maximum queues and queue dissipation times from a comprehensive database provided by the Florida Department of Transportation. After identifying all pairs of primary and secondary incidents from the database, the researchers used a logistic regression model to estimate the possibility of secondary incidents. Their conclusions where similar to the conclusions of Khattak et al.: secondary incidents are closely related to the durations of primary incidents; therefore, reducing the durations of lane blockage could significantly reduce secondary incidents.

One possible drawback from the research presented in the two previous paragraphs is that the definition used to identify secondary incidents only considered incidents that occurred in the same direction, which left out incidents that could have occurred in the opposite direction due to distractions caused by the primary incident (rubbernecking). Zhang and Khattak (2009) focused on identifying the time gap between a primary incident and its related multiple secondary incidents, with special attention to incidents in the opposite direction to the primary incident. By using built-in statistical models in MATLAB, the authors concluded that 60% of first secondary incidents and 50% of secondary incidents in the opposite direction occur within 20 minutes of the primary incident occurrence.

Some of the earlier studies exemplify the use of static (fixed) thresholds for classifying secondary crashes. Figure 2.2.1 shows a graph of the progression of an incident. The origin represents the onset of the primary incident. The horizontal axis represents time elapsed since the incident occurred. The vertical axis represents the growth of the queue from the location of the incident. The letters A through F, represent 6 crashes that occurred after the onset of the primary incident and downstream from the incident. If a crash falls within the influence of the primary incident, (i.e. the crash happened within the queue of the primary) then the crash is considered to be secondary. The static/fixed thresholds of queue length and time are superimposed on this progression. Progression refers to the growth and decline of the queue length as the incident progresses through the various stages. In general, the various stages of an incident include the onset, the arrival of response teams, the clearance to the shoulder, the completion of clearance, and the normalization of traffic. The progression is also a function of both the demand (traffic) and the supply (road capacity). With the demand changing constantly, it is clear that the assumption of static thresholds would not capture field conditions as well as dynamic thresholds. Some would argue that on the average, the total number of secondary crashes can still be estimated accurately with static thresholds if the area of the static threshold rectangle is the same as the area under the progression curve. This argument requires the assumption that crashes are independent from the location and time of the primary incident. For example, Figure 2.2.1 shows that the same number of crashes (three) is classified as secondary using a static threshold or an actual incident progression curve. However, by definition, secondary crashes differ in cause from primary crashes. Therefore even if the average number of crashes is captured accurately with static thresholds, the crashes themselves are still misclassified. Referring back to the example and looking at the static thresholds, the total number of secondary crashes is estimated correctly even though crash B is a false positive (should have been excluded) and crash E is a false negative (should have been included). The elimination of such type I and type II classification errors is one primary motivation for the development of dynamic thresholds. It is intuitive that crashes that occur near the time of the onset of the primary crash but far away from its location should be not classified as secondary since the queue growth is limited by the speed of the shockwave. However, this can occur if a static threshold is used.

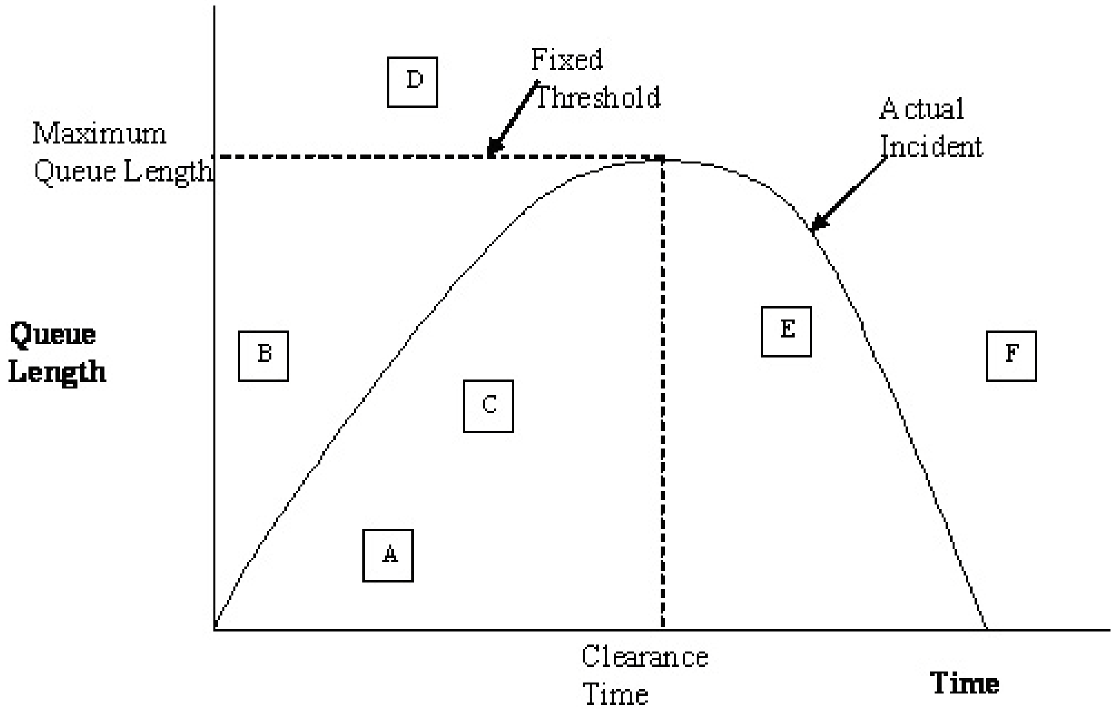


Figure 2.2.1 Comparison between Static and Dynamic Thresholds

There were other articles that relate to secondary crashes but did not address the secondary crash extraction process directly. Karlaftis et al. (1999) examined the primary crash characteristics that influence the likelihood of secondary crash occurrence. They suggested that clearance time, season, type of vehicle involved, and lateral location of the primary crash were the most significant factors. The economic benefit of secondary crash reduction for the Hoosier Helper freeway service patrol program was also presented. There were several articles that addressed the magnitude and impact of incident delays. These include Garib et al. (1997), Giuliano (1989), Skabardonis et al. (1996), Morales (1997), Sullivan (1997), Smith et al. (1987), Lindley (1987), and Lee et al. (2003). Many of these articles tried to estimate the impact of crashes. This project, on the other hand, used the direct derivation of the impacts (queue lengths over time) from intranet traffic reports.

3. MA SAFETY EVALUATION METHODOLOGY

3.1 Safety Data

Safety data collected from the Missouri Uniform Accident Report (MUAR) forms is used in this project. These reports are part of the Statewide Traffic Accident Records System (STARS) that began with support from the National Highway Traffic Safety Administration (NHTSA) (STARS, 2002). The current 2002 revision of the form complies with Federal guidelines. STARS receives recommendations and support from various organizations and agencies including the Automobile Club of Missouri, police and sheriff departments throughout the State, and various Missouri departments such as Health, Revenue, and Transportation. One hundred and one (101) separate fields from approximately 65,000 MUAR reports have been processed with data files ranging in size from 40 MB to 77 MB. A large number of fields are examined in order to maximize existing crash information. Even though there is potential to use many of the fields, many fields are not being filled in by police agencies and thus are not usable. This could be partly due to the type of crash that resulted in the use of only a short form MUAR. This could also be due to the lack of information or the burden of collecting such data. For example, there are several fields pertaining to towing companies, e.g. company, address, zip code, and telephone that are usually not filled in. Such data could have been useful for estimating towing response in absence of FSP involvement.

This study includes data from the following freeways for the years 2000 to 2008.

- I-44
- I-55
- I-64
- I-70
- I-170
- I-255
- I-270

3.2 Identifying Secondary Crashes

Traffic incidents are defined as an unplanned randomly occurring traffic event that adversely affects traffic safety and operations. Thus incidents could be as trivial as vehicle breakdowns, or as severe as multi-vehicle crashes. Secondary crashes are crashes which result from an existing primary incident. Most times these crashes occur at the end of queues that are developed from the primary incident. Quickly opening the highway after an incident reduces the potential for secondary crashes. It is easy then to see the value of analyzing secondary crashes when considering traffic incident management strategies such as MA. On the other hand, the effects of such systems on primary crashes would be much less, because many of these crashes are caused by driver error such as fatigue, intoxication, or aggressive driving. Therefore traditional analysis of primary crashes and crash rates will not reveal the full potential of such systems. One important step in evaluating incident management systems is the identification of secondary crashes. The police crash report contains a field that describes downstream conditions as "accident ahead" or "congestion ahead". The difficulty with the police determining whether the crash is primary or secondary is that they are limited spatially (at one location) and temporally (responding to the current crash). Since the effect of primary crashes can persist long after it has been cleared, it is difficult to determine at the scene of a crash if it is due to recurrent or non-recurrent congestion. The use of the category "accident ahead" for finding secondary crashes would undercount the number of crashes while adding the category "congestion ahead" would severely over-count the number of crashes. Therefore, the crash reports themselves do not contain enough information for classifying secondary crashes.

In order to accomplish the identification of secondary crashes, several other objectives need to be achieved. First, the boundary of the primary incident needs to be specified in order to define the temporal and spatial region of influence of the primary incident. In other words, one needs to determine the length of the queue throughout the duration of the incident. The duration can include the incident normalization period and not just the period up to the incident clearance. In other words, even after the incident has been cleared, it might take a significant length of time before the traffic condition reverts to normal. This boundary of influence is termed the Incident Progression Curve (IPC). Second, once incident progression curves are developed for individual incident, master curves are produced by combining individual curves. The intent is to produce an aggregate measure of secondary crashes by classifying the number of secondary crashes over a significant time period such as a year or multiple years. In other words, these master curves can provide control or information for differences in the severity of crashes and in the level of congestion or more specifically the volume over capacity ratio (v/c).

Traffic management centers and traffic news agencies can provide wide spatial coverage of incidents as well as track the incidents over time. They can use information from aircrafts, elevated traffic cameras, MA, emergency management (fire, police, ambulance, and HAZMAT), and motorist calls. They can also monitor and update this information throughout the course of an incident. Such intranet traffic information can be independent from police information; therefore such information can complement the crash database from the police. Data fusion helps to incorporate all the available information sources including intranet traffic reports and the crash database. By analyzing individual traffic reports in detail, the reporting times of the incident and the dynamic locations of the back of the queue can be found. The difference between the initial and final times gives an estimate of the total duration of the incident, and the distance from the location of the incident to the back of the queue gives an estimate of the length of the roadway that is affected by the incident. A total of 480 incidents were extracted from the traffic reports for freeways I-70 and I-270 in St. Louis, Missouri. These were the incidents that contained some sort of backup or queue information. For these incidents, the extent of traffic information varied from covering the incident progression for the entire duration to reporting the incident with initial back up reports. The intranet traffic reports are used for developing IPCs. Figure 3.2.1 shows the IPC for PDO primary incidents and Figure 3.2.2 shows the IPC for injury and fatal primary incidents. In order to use the IPCs presented in Figures 3.2.1 and 3.2.2, one first identifies the severity of the primary incident and the v/c when the incident occurred. If a potential crash falls within this IPC curve then it is considered to be a secondary crash. In other words, if the crash occurred at a close proximity upstream from the primary incident and at the same time occurred recently after the onset of the primary incident then it is considered to be secondary. Because fatal crashes are rare events, there are not enough reports to generate a separate IPC for fatal incidents. Table 3.2.1 presents relevant the maximum queue length, the time of the maximum queue, and the time to normalization. For example, an injury crash during heavy traffic will have a median maximum queue length of 4.91 miles at 68 minutes and a time to normalization of 127 minutes.

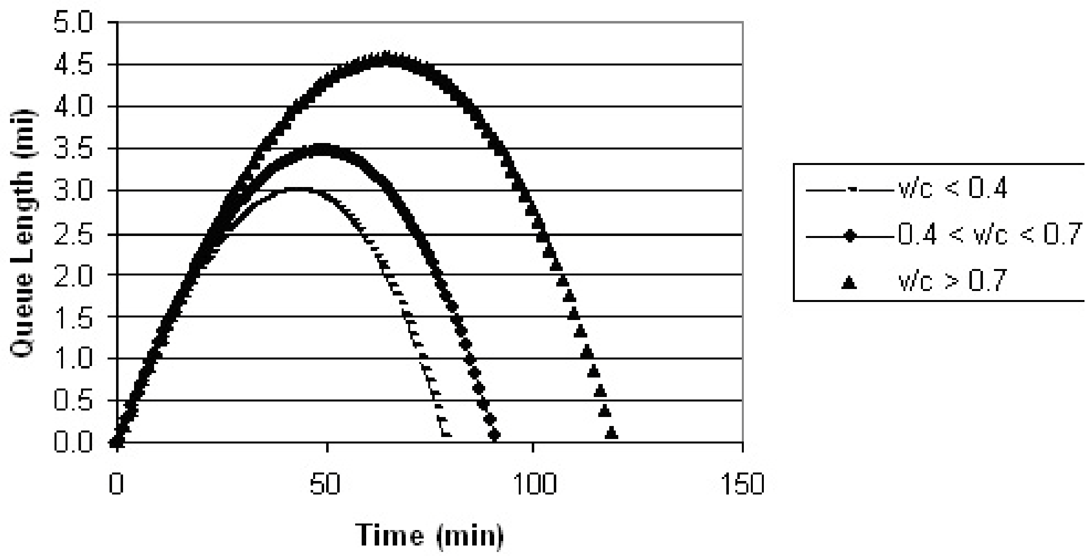


Figure 3.2.1 IPC for PDO crashes.

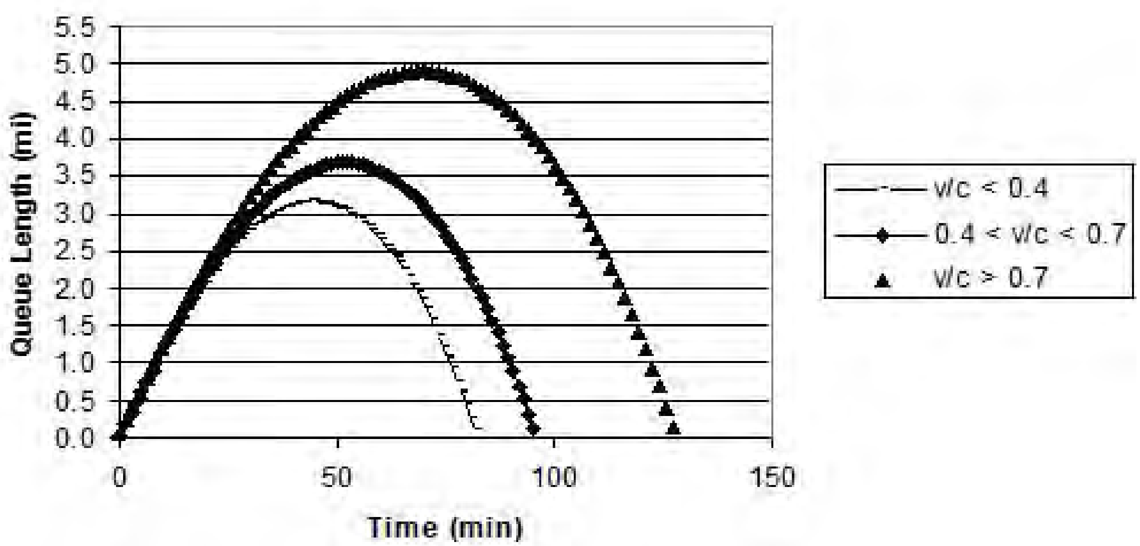


Figure 3.2.2 IPC for Injury and Fatal crashes.

Table 3.2.1 IPC Parameters Based on Severity and v/c Ratio

Description	Criteria	Maximum Queue (km)	Time of Max. Queue (min)	Time to Normal. (min)
Light	PDO, v/c < 0.4	4.86 (3.02 mi)	42	78
Medium	PDO, 0.4 < v/c < 0.7	7.21 (3.48 mi)	48	90
Heavy	PDO, v/c > 0.7	7.35 (4.57 mi)	64	118
Light	INJ, v/c < 0.4	5.09 (3.16 mi)	44	82
Medium	INJ, 0.4 < v/c < 0.7	5.92 (3.68 mi)	51	95
Heavy	INJ, v/c > 0.7	7.90 (4.91 mi)	68	127

In using Figures 3.3.1 and 3.3.2, the v/c ratio is required. This value, however, can require significant labor to derive directly as the crash database will need to be linked with traffic data along with freeway geometric data (lane configuration). Instead, a relationship between the "time of the day" and v/c was developed. In general, non-incident traffic levels are fairly predictable throughout course of the day. For example, Figure 3.2.5 shows volumes on I-64, and it shows v/c ratios corresponding to different time periods. The relationship between v/c and time of the day is as follows:

- v/c>0.7: 4:00-6:00 pm and 7:00-10:00 am
- 0.4<v/c<0.7: 10:00 am-4:00 pm
- v/c<0.4: all other times

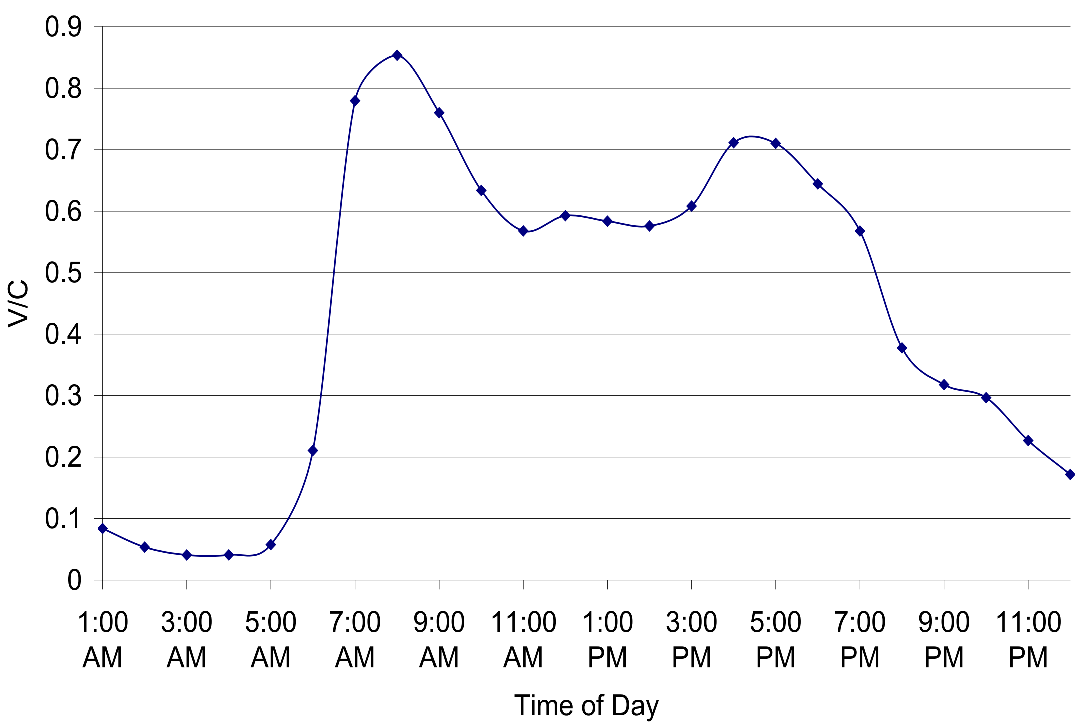


Figure 3.2.5 Typical v/c Throughout a 24 Hour Period

The police crash database is processed and the secondary crashes are classified using the master IPC. In processing the database, a convention for formatting crash reports is developed so that the appropriate information from the crash database is extracted and formatted.

4. MA SAFETY EVALUATION RESULTS

4.1 Comparison between Secondary and Primary Crash Characteristics

Crash reports were examined to determine if there were statistically significant differences between secondary and primary crash severities. A previous study of several arterials and expressways in California showed that secondary crashes represented an increase in collision risk of over 600 percent (Volpe, 1995). Table 4.1.1 presents the severity characteristics of primary and secondary crashes by year in St. Louis. Table 4.1.1 shows the percentage of each crash severity. For example, Row 1 shows that of all secondary crashes in 2000, 1.15% are fatal, 2.20% are disabling injury, 22.93% are minor injury, and 73.72% are PDO, and the percentages add up to 100%. Table 4.1.1 contains data from all freeways in the St. Louis region. These include I-70, I-270, I-44, I-64, I-55, I-170, and I-255. Data from I-64 for the years 2007 and 2008 are not used because of the I-64 reconstruction. The last row contains the average of the all the years from 2000 to 2008.

In comparing the severity of primary and secondary crashes, there is an interesting diverging of the upper and lower ends of the severity. On the one hand, the percentage of fatal crashes is higher for secondary as compared to primary. The percentage of fatal crashes increases 2.46 times by 0.49% (0.337% to 0.80%). On the other hand, the percent of PDO's is higher for secondary as compared to primary. The percentage of disabling injury crashes decreases 1.07 times by 0.15 (2.18% to 2.03%) and the percentage of minor injury crashes decreases 1.11 times by 2.40% (24.29% to 21.89%) while the percentage of PDO crashes increases 1.03 times by 2.05% (73.20% to 75.25%). In other words, for secondary crashes, there are both a higher percentage of the most serious crashes and the least serious crashes. Perhaps, this phenomenon can be explained as follows. The increase in the more severe crashes can be due to the sudden and unexpected encounter of a queue especially if pre-queue speeds are high. While the increase in the least severe crashes can be due to an increase in low speed rear end crashes during more congested conditions. There are, perhaps, also other feasible explanations to the divergent phenomenon. However, in order to examine the phenomenon more closely, there is a need to examine specific crash characteristics in detail which can involve significant labor.

The statistical significance of the difference in crash severity percentage between primary and secondary crashes is examined using the Student T-Test. A one-tailed heteroscedastic T-Test is applied because the variances between the two samples are significantly different. The differences in the average percentage of crashes is significant for fatal ($p=3.95x10^{-05}$), minor injury (0.0004) and PDO (0.0071), and is not significant for disabling injury (0.3788). Typically, p values less than 5% (0.05) or 1% (0.01) are considered to be statistically significant, i.e., the null hypothesis assuming no difference can be rejected. Even though changes in minor injury and PDO are just as statistically significant as the change in fatalities, the magnitude of change in fatalities is much greater by 2.46 times.

In summary, it is important to note the differing severity characteristics between secondary and primary crashes. The most significant is perhaps the fact that fatal crash percentage is much higher for secondary crashes at around a 2.5 times increase. This difference in average crash percentage is found to be statistical significant. These results point to the importance of managing the primary incident quickly and efficiently as to reduce fatal crashes.

Table 4.1.1 Crash Percentage by Severity

	Secondary				Primary			
Year	Fatal	Disabling Injury	Minor Injury	PDO	Fatal	Disabling Injury	Minor Injury	PDO
2000	1.15	2.20	22.93	73.72	0.28	2.21	25.51	72.00
2001	0.62	1.24	23.26	74.88	0.32	2.42	24.61	72.66
2002	1.02	2.54	20.36	76.08	0.38	2.26	24.41	72.95
2003	0.79	2.03	22.94	74.24	0.26	2.25	24.51	72.99
2004	0.48	2.63	20.36	76.53	0.31	2.43	23.85	73.41
2005	0.82	2.11	21.87	75.20	0.31	1.95	25.57	72.16
2006	0.91	2.17	22.37	74.54	0.26	2.02	23.57	74.14
2007	0.75	2.25	22.47	74.53	0.30	2.15	23.23	74.32
2008	0.66	2.51	18.34	78.50	0.34	2.42	24.15	73.09
Weighted Average	0.829	2.026	21.89	75.25	0.337	2.18	24.28	73.20

4.2 Temporal Variation in Number of Crashes

Figure 4.1.1 shows the number of crashes on all St. Louis freeways for this decade (i.e. years 2000-2008). The number of secondary crashes correlates somewhat with the number of all crashes. The correlation coefficient is 0.719. This correlation is intuitive since secondary crashes can result from primary crashes, but secondary crashes can also result from non-crash incidents. The number of annual crashes stabilized around approximately 8,300 from 2000 to 2006 and then dropped to approximately 7,000 in 2007 and 2008. The investigation into the causes for the drop in total number of crashes is outside the scope of this project. However, the following are some possible reasons for explaining the trend of decreased number of crashes. One reason is the concerted efforts of people working in highway safety throughout the State. This can include umbrella organizations such as Missouri Coalition for Roadway Safety, and organizations involved in engineering, enforcement, education, and medical services. This can also include MoDOT efforts in improving engineering such as the installation of rumble strips and median cable barriers. Another reason can be the drop in transportation demand due to various reasons including the downturn in the economy and the rise in gasoline prices. Figure 4.2.2 shows that the annually unadjusted gasoline prices have increased almost two-fold from 2003 to 2008.

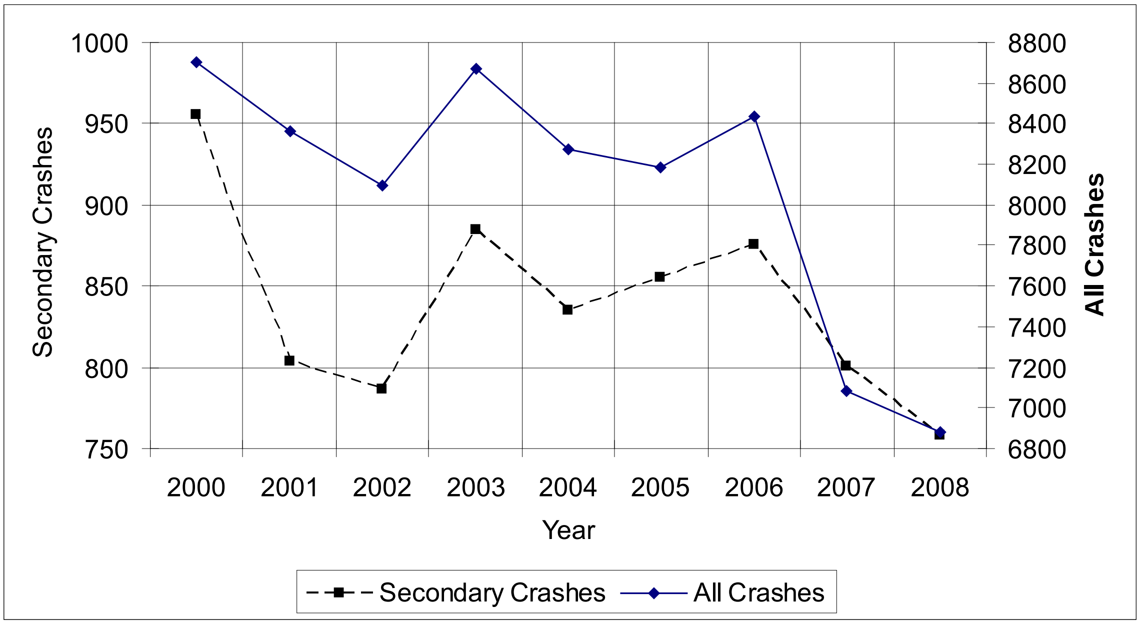


Figure 4.2.1 Number of St. Louis Primary and Secondary Crashes by Year

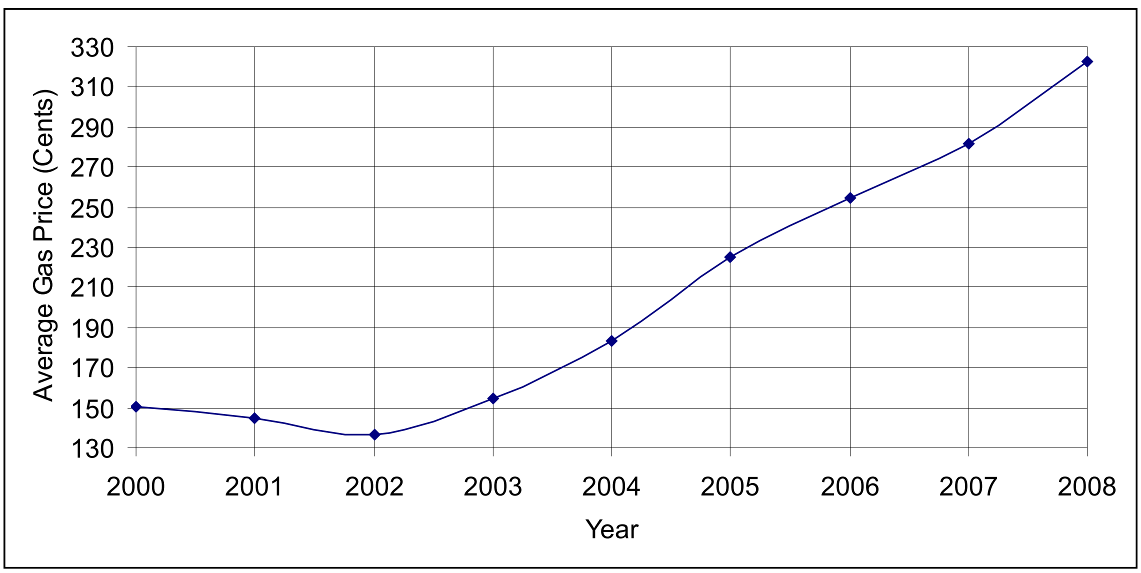


Figure 4.2.2 Annualized Weekly Retail Gas Prices (Energy Information Administration. Official Energy Statistics from the U.S. Government)

4.3 Overview of Cost Benefit Analysis (CBA)

Cost Benefit Analysis (CBA) can be separated into three general steps. First, there is a systematic cataloguing of impacts as benefits and costs. It is typical in performing CBA to consider the costs and benefits of the society as a whole, and the net social benefit is computed by subtracting the net social costs from the net social benefits. Second, there is a valuing in dollars by monetizing impacts and discounting to the net present value (NPV). And third, there is the determining of net benefits relative to the status quo or baseline. CBA is often used to efficiently allocate society's resources. Most of the time, CBA is performed ex ante or while a project is under consideration and before it is started or implemented. Rarely, is a CBA is performed ex post or at the end of the project after all the costs are "sunk". Thus the current ex post analysis of MA is unique and offers valuable results since past data is used instead of future forecasts.

Regarding the valuation of crashes, the non-profit National Safety Council (NSC) explains that the calculable costs of motor vehicle crashes are wage and productivity losses, medical expenses, administrative expenses, motor vehicle damage, and employers' uninsured costs (NSC, 2007). The calculable costs, however, do not include the value of a person's natural desire to live longer or to protect the quality of one's life. This is instead captured in a willingness-to-pay analysis or observing actual market behavior. Miller mentions the following four examples of valuation (Miller, 1993):

- how much of a wage premium people working in risky jobs must be given to compensate them for the additional risks
- consumers' willingness to pay for safety features (safer cars)
- individual behavior with respect to decisions concerning the use of pedestrian tunnels and seat belts
- willingness to invest in specific ways to increase health and safety

There are several organizations that valuate injuries and/or crashes by severity. For example, the National Safety Council values the average comprehensive cost by injury severity as $4,100,000 for death, $208,500 for incapacitating injury, $53,200 for non-incapacitating evident injury, $25,300 for possible injury, and $2,300 for no injury (NSC, 2007). The Missouri High Crash Location (HAL) Manual values fatal crashes at $3,390,000, injury crash at $44,100, and PDO crash at $3,220 (MoDOT, 1999). The AASHTO Redbook values the net perceived user cost of fatal crashes at $3,723,700, all injury crashes at $172,800, and PDO crashes at $200 (AASHTO, 2003). The aforementioned numerical values are very similar even though economists disagree somewhat on the details of valuation methodology.

4.3.1 Discounting

A discount rate is used to translate 2003 dollars to present 2009 values. The discount rate accounts for the change in the value of money over time. In other words, it accounts for the society's perception of what a 2003 dollar is worth in 2009. This perception is important since there is a need to account for lost opportunity costs, i.e. the option to use the funds for something besides what it was used for. For example, financial markets give a positive interest rate on money that is set aside for the future. The Redbook suggests the use of a 3% discount rate when the benefits are in constant, inflation-removed dollar. For the MA safety evaluation, the AASHTO crash severity values are discounted to 2009 dollars as follows:

- $4,446,293 per fatal crash
- $206,332 per injury crash
- $239 per PDO crash

Each severity percentage in Table 1 for secondary crashes is multiplied with the corresponding 2009 injury crash cost results in the proportional value of secondary crashes. Adding all crash severity values will results in the cost per average secondary crash of **$72,350**. In other words, this amount accounts for the fact that 0.829% of all secondary crashes are fatal and they contribute a cost of $30,870; 23.92% are injury crashes and they contribute a cost of $41,329.50 per crash; and 75.25% are PDO crashes and they contribute a cost of $150.50 per crash.

4.3.2 Difference in Secondary Crashes

One major challenge in CBA is to estimate the impact of an alternative. Often times this involves forecasting into the future. The challenge is obvious since forecasting requires making assumptions about the future such as the growth of the population and future travel patterns. For ex post (after the fact) analysis, a comparable challenge presents itself in the form of recreating the past for an alternative that did not exist. The extrapolation from a particular year of analysis to earlier or later years is sometimes known as the annual travel measurement problem (Redbook, 2003, pg. 5-3). The Redbook explains, "Some project benefits are amenable to relatively simple extrapolation because the user benefits are fixed, or trend over time only in response to a particular, predictable variable." For example, when benefits are related to transactions with vehicles, then the number of transactions scales easily with traffic volumes. Even in cases where the underlying relationships are complex, extrapolation can still be performed because there is a stable mathematical relationship between traffic volumes and user benefits.

In this study, assumptions are required for the past in order to estimate the number of secondary crashes that would result if MA did not exist. In order to avoid duplicating previous work, some assumptions are made that are based on the previous MA study. In the previous study, only two principal freeways are examined: I-70 and I-270. Previously, the coverage of MA is not as extensive as it is today. Thus the first assumption is one of geographical homogeneity. Thus the percentage of secondary crashes that are reduced on I-70 and I-270 are assumed to be similar to freeways in the remainder of St. Louis. In other words, the benefits realized on I-70 and I-270 apply similarly to other freeways. This assumption is fairly reasonable since the population of drivers is the same and volume over capacity (v/c) ratios would account for the differences in volume and capacity between I-70/I-270 and the remaining freeways. In addition, the freeways are similarly designed. The second assumption is one of temporal invariance. Thus the types and level of benefits that are achieved by MA in the 1990's are assumed to be similar in the 2000's. The magnitude of the benefits will be scaled according to the actual number of secondary crashes. This again is a reasonable assumption since the fundamental characteristics of the drivers, the MA program, and the regional network have not changed significantly between the two decades. To explain what is meant by fundamental characteristics, the following few examples are presented:

- the retrofitting of the entire population of vehicles to include collision avoidance radar

- the major expansion or reduction of the scope of services of MA
- the implementation of significant geometric design changes

The normal growth in the St. Louis region and the regular economic oscillations that produce increases or decreases in freeway volumes should not theoretically alter the type or the level of benefits achieved by MA. Such changes could affect the overall number of crashes, but the proportion of secondary crashes should remain somewhat proportional to the number of total crashes. Figure 4.2.1 illustrates this empirically with data from St. Louis, as shown previously.

These assumptions are implemented using a regional factor, F_r that translates the number of secondary crashes into the number of crashes that would have been prevented by the MA program. The following equations explain this process:

$$F_r = \frac{C_{NMA} - C_{MA}}{C_{MA}} \quad (4.3.2.1)$$

Where, F_r is the reduction factor, C_{NMA} is the number of secondary crashes without MA, i.e. non-MA, C_{MA} is the number of secondary crashes with MA. F_r is estimated using I-70 and I-270 data from 1993 to 1996 from the previous study. Since MA started in 1993, 1993 to 1996 represent the years closest to pre-MA conditions. For that period, C_{NMA} is 1,781 and is estimated using regression, C_{MA} is 789 and is based on actual data, and the resulting F_r is 1.259.

$$C_{NMA1} - C_{MA1} = C_{MA1} * F_r \quad (4.3.2.2)$$

Where, C_{NMA1}-C_{MA1} is the reduction in crashes attributable to MA in the 2000s, C_{MA1} is the number of secondary crashes on all St. Louis freeways in the 2000s with MA deployed, and F_r is as previously defined. Table 4.3.2.1 shows the average annual secondary and primary crashes on every freeway in St. Louis. For example, Row 5 shows that there is, on the average, 1.9 fatal, 4.2 disabling injury, 44.1 minor injury, and 127 PDO secondary crashes a year on I-70. The average annual number of secondary crashes, $C_{MA1,}$ is 859.4 for 2000 to 2008 as shown in Table 4.3.2.1. Multiplying by F_r, the number of crashes reduced by MA is calculated as 1,082. Multiplying C_{NMA1}-C_{MA1} by the cost per crash, the total annual net social benefit of $78,264,017 is obtained.

The reported costs for operating MA are $2,015,378 for 2008 ($2,075,839 in 2009 dollars). In performing benefit-cost analysis, the entire social cost must be computed for the entire program. The operating cost does not account for the capital investments related to several categories. These include equipment such as the vehicle and tools that are used by the operators, the equipment that is housed in the MA garage, and other miscellaneous equipment such as computers, radio (communications), and AVL housed in the MA garage. These also include infrastructure such as the building costs and overhead associated with the operation of the building. And costs associated with training the MA operators and staff would need to be accounted. An additional category that is difficult to capture is the synergistic benefit of the MA as part of the Gateway Guide program. MA operators are an integral part of Gateway Guide, and they work closely with the TMC when managing incidents. However, it is unclear how much of the cost borne by Gateway Guide should be attributed to causing MA productivity. If only operating costs is used, then MA would have an average annual safety B/C of around 37.7:1.

The B/C ratio is much higher than other highly effective crash reduction and safety countermeasures. There are two other system-wide freeway safety countermeasures that are in the top nine list of proven safety countermeasures. These are rumble strips and cable median barriers (FHWA, 2009). The following are some examples of results from studies that have estimated B/C for such countermeasures. The B/C for centerline rumble strips for high volume roads (ADT > 4500) is estimated to be 26.42 (Carlson and Miles, 2005). The B/C for median cable barriers is estimated to be between 0.8 to 5.5 depending on the median width (Hammond and Batiste, 2008). The MA B/C ratio of 37.7:1 far exceeds other highly effective safety countermeasures. From an engineering standpoint, MA should be considered one of the most cost effective safety programs in existence in the St. Louis region.

Table 4.3.2.1 Average Annual Crashes on Freeways in St. Louis, 2000-2008

	Secondary					Primary				
Fwy.	Fatal	Disabling Injury	Minor Injury	PDO	Total	Fatal	Disabling Injury	Minor Injury	PDO	Total
I-44	2.0	3.3	24.8	99.0	129.1	7.8	33.7	271.7	918.7	1231.8
I-55	1.2	2.8	16.7	57.4	78.1	5.6	24.6	203.9	586.3	820.3
I-64	0.9	2.3	31.6	102.1	136.9	2.9	19.0	344.9	985.6	1352.3
I-70	1.9	4.2	44.1	127.0	177.2	5.3	34.4	451.2	1241.9	1732.9
I-170	0.4	0.9	13.0	48.2	62.6	2.9	15.3	152.8	484.1	655.1
I-270	0.6	4.9	58.1	212.0	275.6	4.7	52.9	570.2	1784.6	2412.3
Total	7.0	18.4	188.2	645.8	859.4	29.1	179.9	1994.6	6001.1	8204.7

4.3.3 Consistency with Previous Study

In the previous study, a crash reduction benefit of $30,000 per crash was used. For this study, more recent numbers for valuation of crashes from AASHTO discounted to present values and updated percentages of crash severities collected from 2000-2008 are used. The updated values resulted in more than a doubling of the crash reduction benefit to approximately $72,350 per crash. The increase in value of benefit, the greater coverage of MA to include all the freeways in St. Louis, and the inclusion of incident generated secondary crashes results in the significant increase in B/C over the previous study. Thus, this increase is not attributable to a change in methodology even though there is an improvement in the accuracy of extracting secondary crashes from the MUAR reports.

Appendix B presents the annual secondary crash statistics for each freeway in St. Louis and shows the number of incident-caused secondary crashes which are caused by non-crash incidents such as parked motor vehicles, animals, and other non-fixed objects. (E.g. objects from vehicles, fallen tree). In the years 2000 to 2008, such non-crash incident-caused secondary crashes accounted for 33.9% of secondary crashes. In contrast to primary crashes, such incidents are conceivably less burdensome for MA to handle.

5. MA MOBILITY ASSESSMENT METHODOLOGY

Everyday, MA operators patrol St. Louis freeways to assist in clearing the roadways from incidents such as debris on the road, accident, disabled vehicles etc. With a roadway closed, any delay that occurs will increase non-linearly. For example, if a roadway is blocked for a certain period of time then with every minute passing, the delay of the each vehicle waiting is compounded by another minute. So clearing the roadways quickly will reduce the delay significantly. MA operators by patrolling the freeways are able to respond quickly and clear (or assist in clearing) the roadways in a timely manner.

5.1 Data Needs

The amount of delay reduced by this program can be computed by estimating the cumulative delay caused by all of the incidents with and without MA. To compute this, the following data are needed:

a) Incident specific details such as the type of incident, number of vehicles involved, location and time of incident
b) Traffic characteristics at the time of incident such as volume and speed
c) Response and clearance information of MA and non-MA scenario i.e. how fast is the response in both the scenarios and how long it takes to clear the incident.

Using the first two types of data, one can understand how much delay the incident will cause over time and the third helps in understanding how soon the incident can be mitigated.

5.1.1 Incident Data

MA operators keep a detailed paper log of incidents that includes type of incident, location, time and duration of assist. But all this information is not transferred to an electronic format. Only the summary of these incidents, such as the number of incidents per zone in the am and pm are recorded. By not converting this detailed information from paper logs to electronic format, one has to depend on other data sources for a less labor intensive data extraction.

Two other sources that keep an electronic incident log are Traffic.Com and Gateway Guide. These two sources maintain data of incidents in slightly different formats as shown in Table 5.1.1.1 and Figure 5.1.1.1. Although Traffic.com provides Latitude and Longitude of incident location, it does not provide the direction of freeway incidents. So, Gateway Guide, which contains the direction and more detailed information, was chosen for data processing.

```
======================================================= Event 18140 =======
===========================================================================
   Location: I-44 W (MO)  @RP JAMIESON TO I44W            Lat,Lon: 38.602900, -90.311000
   County: LCM

Chronology ---------------------------------------
   Created:              Tue 04/01/2008 07:12    (Confirmed by: caseyj3)
   Lane Blockage:                     ('^'=open; 'X'=closed)
                         04/01 07:28     | ^ | ^ | ^ | ^ |
   Terminated:           Tue 04/01/2008 07:28
   Duration:             0 hr 15 min (Level 1)
   ---
   Estimated Clearance:
   Estimated Duration:    min

Attributes ---------------------------------------
   Event Type:         COLLISION
   Road Type:          ML
   Vehicles involved: 0
   Injuries:           0
   Fatalities:         0
   Source:             R (OPERATOR/CCTV)
   Weather:             (--)
   CCTV1:    (MI044E284.7C)    I-44 AT ARSENAL ST.
   CCTV2:    (MI044E284.0C)    I-44 WEST OF JAMIESON AVE.

Response Plan ------------------------------------
   Time of Day:
   Traffic Impact:

Comments -----------------------------------------
    Date Time     Operator         Comments
    04/01 07:14    (caseyj3)     ==> 6913 on scene

DMS Messages -------------------------------------
   DMS ID     Posted       Removed     Duration Operator  Phase 1              Phase 2

ATIS Messages ------------------------------------
   ---------------------------- Sent: 04/01 07:13    Removed: 04/01 07:28    (caseyj3)
   CRASH PARTLY BLOCKING THE RAMP FROM JAMIESON TO WESTBOUND I-44.
```

Figure 5.1.1.1 Gateway Guide Incident Log

Table 5.1.1.1 Sample Incident Log from Traffic.Com

	Sample Incident 1	Sample Incident 2	Sample Incident 3
Lat	38.634	38.634	38.633
Long	-90.142	-90.142	-90.144
Zone	null	Null	null
Start Date	4/2/2008	4/2/2008	4/2/2008
Start Time	04:09:00	04:09:00	04:09:00
End Date	4/2/2008	4/2/2008	4/2/2008
End Time	06:15:08	06:20:41	06:23:54
Criticality	critical	Critical	critical
Type	ACCIDENT	ACCIDENT	ACCIDENT
Location	I-55/I-70	I-55/I-70	I-55/I-70
Description	approaching I-64 - accident blocking all lanes - ambulance, fire department, police on the scene	approaching I-64 - accident blocking all lanes - ambulance, fire department, police on the scene ALTERNATE: traffic can exit onto I-64 eastbound	at I-64 - accident blocking all lanes - ambulance, fire department, police on the scene ALTERNATE: traffic can exit onto I-64 eastbound

5.1.2 Traffic Flow Data

The traffic flow characteristics such as volume and speed were not available during the previous study. So, the hourly traffic volumes generated by MoDOT for planning purposes was used for estimating the demand on the St. Louis freeway sections. Now, the St. Louis freeway system has an extensive network of detectors from which volume, speed and occupancy data can be extracted at an interval as small as 30 seconds; and this information from the nearest detector can be used for estimating the traffic flow characteristics at the time of incident. In the previous study, due to lack of real time traffic information, the researchers had to depend on capacity reduction factors from other regions to estimate the traffic delay over time.

5.1.3 Response and Clearance Information

MA's average response time of 20 minutes, as reported on MoDOT website, is used for this study. For the non-MA scenario, the response time is assumed to be 35 minutes, which is same as the earlier evaluation. This value was obtained from surveys conducted by J.D. Power and Associates, an independent consumer research firm (Lawlor, 2003). This value represents the lowest average or the best performing private responders. The clearance is assumed to vary from 10 minutes to 20 minutes for both MA and non MA.

5.2 Assessment Methodology

The real time traffic flow data is used for estimating the delays due to incidents. The utilization of this information, as opposed to using historical data or factors from other cities, will help in building a model that is more representative of actual delay. But the real time data provides the information only for “with MA” scenario and does not provide for “without MA” scenario. So this methodology has two steps:

1) Estimate Delay of actual incident (i.e. with MA scenario)
2) Estimate non MA delay based on MA delay

5.2.1 Delay with MA

Gateway Guide’s electronic incident logs were used for extracting the incidents in the year 2008. The incident fields pertaining to location, type and time of the incident were extracted from each of these logs and cross referenced with the 5 minute volume information that was processed from the freeway detector data.

Figure 5.2.1.1 shows an illustration of speed data from multiple detectors. This particular example shows the impact of two incidents which happened on I-270 NB near Page Avenue. The first incident was a collision that was reported at 3:05 pm and subsequently a stolen vehicle car chase that ended near Page Ave at 3:25 pm. The impact of these incidents can be seen on the upstream detectors (i.e. mile markers 15.4, 14.8 and 13.6). This example shows how the detector data can be used for understanding the impacts of incidents.

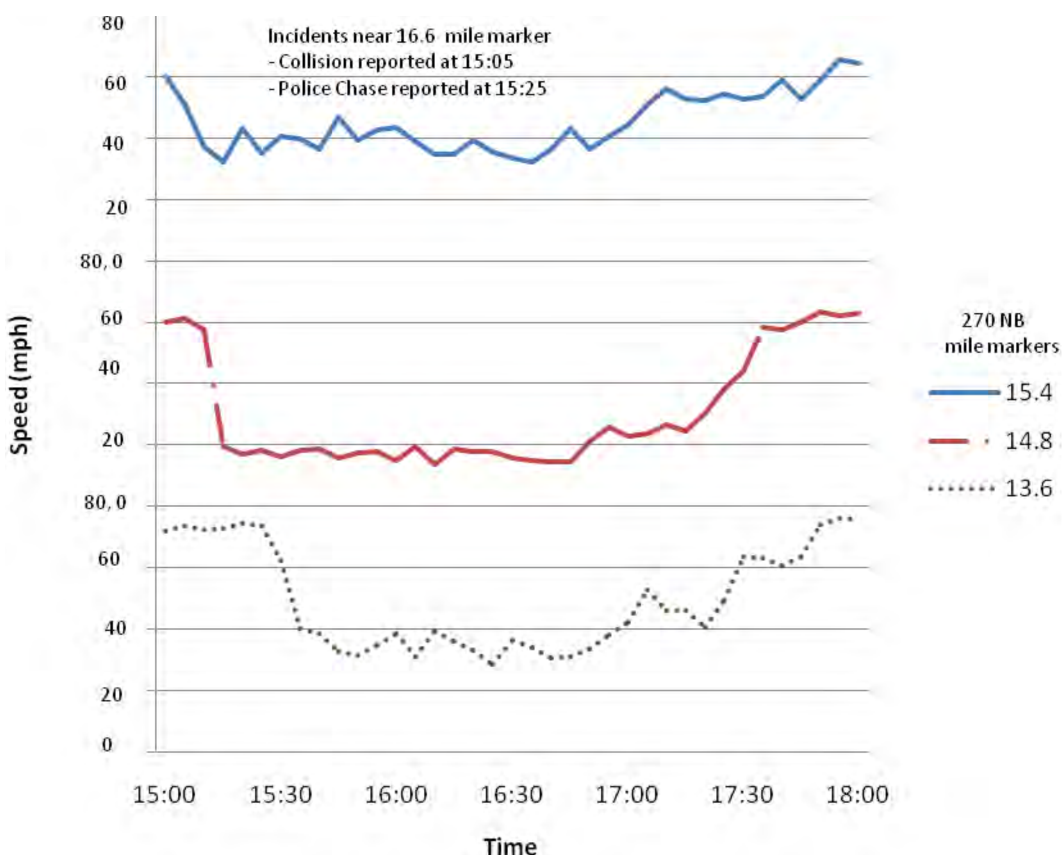
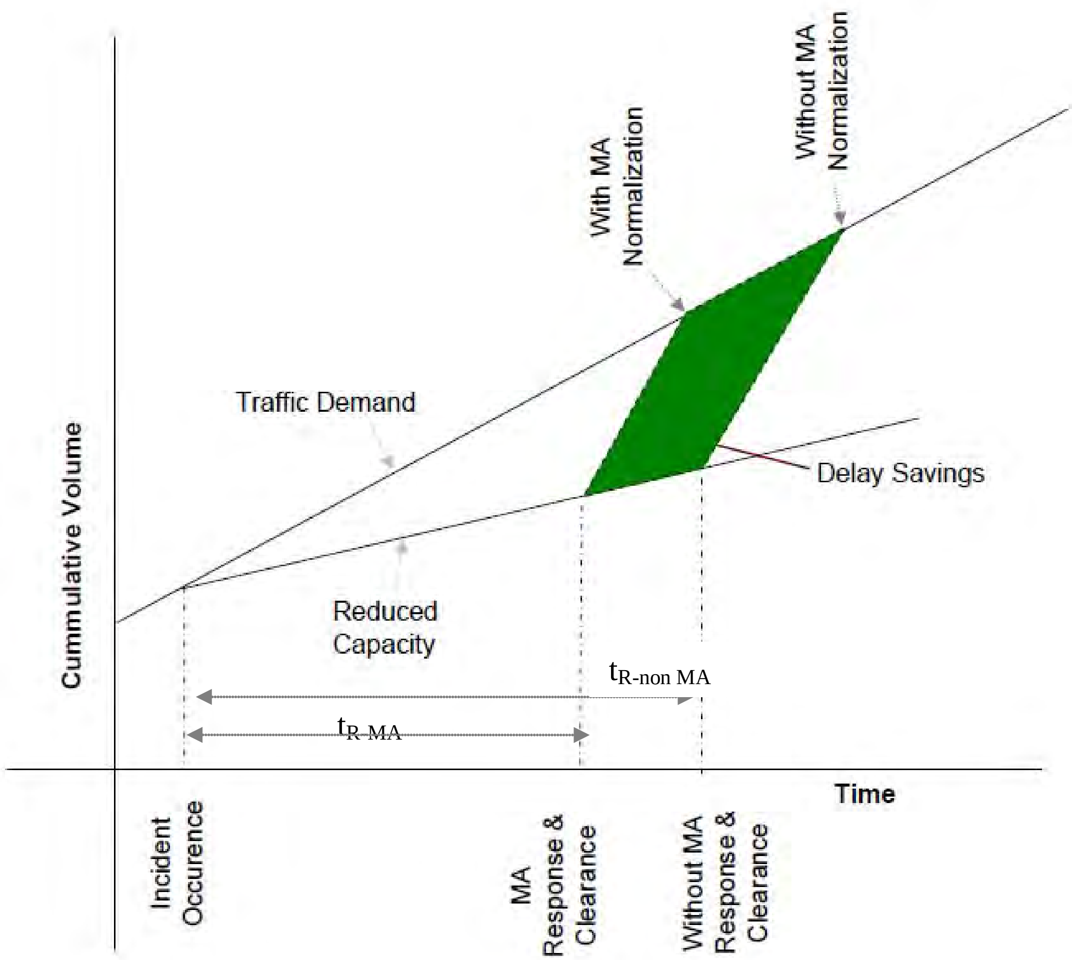


Figure 5.2.1.1 I-270 North Bound Speeds during an Incident

The total delay of the incidents is calculated by estimating the number of vehicles impacted by each incident and multiplying it by the increased travel times due to the incident. This delay then reflects the amount of delay experienced by the users. Using this information, the expected delay without a program like MA will be estimated based on the methodology from the next section.

5.2.2 Delay without MA

The delay in non-MA scenario is estimated as a factor of MA scenario. Figure 5.2.2.2 shows a cumulative volume and time diagram. The diagram shows that after the incident occurrence, the capacity is reduced, thus delay is accumulated since the arriving traffic can not be serviced. But if the clearance occurs sooner, then there is a delay reduction or savings. The total delay of an incident, like the one shown in Figure 5.2.2.2 can be computed as follows



λ = Traffic Demand
μ_R = Reduced Capacity

For an incident, the delays with and without MA can be represented as follows

$$\text{Total Delay with MA, } TD_{MA} = 0.5^* (t_{R\text{-}MA}{}^{2})^*(\lambda\text{-}\mu_R) \quad (5.2.1.2)$$
$$\text{Total Delay without MA, } TD_{non\ MA} = 0.5^* (t_{R\text{-}non\ MA}{}^{2})^*(\lambda\text{-}\mu_R) \quad (5.2.1.3)$$

From equations 5.2.1.2 and 5.2.1.3, the today delay without MA can be calculated as

$$TD_{non\ MA=}\ TD_{MA} * [t_{R\text{-}non\ MA}{}^{2} / t_{R\text{-}MA}{}^{2}] \quad (5.2.1.4)$$

Incident duration consists of response time and clearance time. The response times of MA and non-MA are assumed as 20 minutes and 35 minutes, and the clearance time is assumed to vary from 10 to 20 minutes for both the scenarios. Applying this information to equation 5.2.1.4 gives the following range of total delays

$$\begin{aligned} TD_{non\ MA} &= TD_{MA} * [(35+\text{clearance time})^2 / (20+\text{clearance time})^2] \\ &= TD_{MA} * [(35+10)/(20+10)]^2 \text{ to } TD_{MA} * [(35+20)/(20+20)]^2 \\ &= 2.25\ TD_{MA} \text{ to } 1.89\ TD_{MA} \qquad (5.2.1.5) \end{aligned}$$

Therefore the delay savings with a MA program would be 1.25 to 0.89 times of total delay with MA program.

6. MA MOBILITY ASSESSMENT RESULTS

In the year 2008, there were about 6,000 incidents that were recorded in the Gateway Guide Incident logs. Table 6.1 shows the number of each type of incident for each freeway in St. Louis. These incidents did not include those that were coded as Roadwork, Utility and Arterial Incidents.

Table 6.1 Year 2008 Freeway Incident Logs from Gateway Guide

	COLLISION	STALL	OTHER	FIRE	DEBRIS	Total
I-70	1017	440	233	27	7	1724
I-270	798	459	175	32	10	1474
I-44	492	550	176	13	10	1241
I-55	338	141	93	14	4	590
I-64	196	102	52	10	4	364
I-170	150	67	37	7	3	264
I-255	25	10	8	1	0	44
Total	3016	1769	774	104	38	5701

About 83% of these consisted of either Collision or Stall. From this dataset, 14 weekdays were sampled in the month of April for the interstate I-270 for a detailed investigation of the incident delays. I-270 data was chosen for three reasons:

a) It has one of the highest incident rates
b) It has most of the detectors working in year 2008
c) The cost of data processing was shared with another MoDOT project.

The total delay on I-270 from the 14 weekdays was estimated as 782 vehicle hours. This value was extrapolated to 250 working days as follows

Total Delay on Interstate 270 = 250*782 /14 = 13,964 vehicle hours

Most of the above data was observed from Collision incidents. Assuming if the I-270 data is representative of the region, then the total yearly delay can roughly be estimated as follows:

Approximate delay = (3059/798)*13964 = 53,528 vehicle hours

Without MA the delay would be 2.25 times to 1.89 times of MA delay. So the delay savings ranges from 66,910 vehicle hours to 47,640 vehicle hours. When translated to monetary value using a value of $23.82/hr, the savings is around $ 1.59 Million to $ 1.13 Million. Adding the mobility benefit to the safety benefit, the total annual benefit of $79,394 is obtained. The total mobility and safety B/C is **38.25:1**.

7. CONCLUSION

After a detailed analysis of St. Louis crash records for the years 2000 to 2008, the results show that the Motorist Assist Program (MA) in St. Louis provides tremendous safety and mobility benefits to the region. The benefit-cost ratio (B/C) is estimated to be 38.25:1. This reflects the reduction of secondary crashes using actual average annual secondary cashes of 859 for 2000 to 2008. The crash reduction factor of 1.259 was estimated using data from 1987 to 1990 and 1993 to 1996 which are the years immediately proceeding and following the implementation of MA. The B/C also reflects a $1.13 million savings in mobility benefits or reduced delay.

An interesting by product of the study is the discovery that secondary crash characteristics are on the average more severe than primary. The percentage of fatal crashes is 0.829% for secondary while it is 0.337% for primary. But the percentage of PDO crashes is 75.25% for secondary while it is 73.20% for primary. Since fatal crashes are the costliest crashes, overall secondary crashes are costlier than primary crashes. Secondary crashes tend to be more severe with regards to more fatal crash occurrences while having a slightly higher PDO crash occurrences and less injury crash (minor and major) occurrences.

The estimated per crash cost for secondary crashes was found to be $72,350 in 2009 dollars. National accepted values for the valuation of fatal, injury, and PDO crashes from the AASHTO Redbook were used. Due to the lack of previous knowledge, one could only speculate as to why there are both more fatal and PDO secondary crashes as compared with primary. Perhaps, one reason why there are more fatal crashes is because of the sudden encounter with the back of an unexpected queue at high speed and low volume conditions. Another reason could be there are more PDOs because of a higher incidence of low severity rear end crashes in high volume stop-and-go traffic caused by a primary incident. Even though the exact cause of the difference cannot be pinpointed at this point, the difference is clearly evident in the data, found to be statistically significant, and is based on approximately 65,000 crashes of which there are around 7,500 secondary crashes. The data set is large and is from almost all the freeways in the St. Louis region and from almost a full decade. There is every reason to believe that the difference is systematic and not random.

There is certainly other methodology that could have been used for evaluating MA. The literature review describes other methodology such as the use of micro-simulation and mathematical modeling. Each methodology has its plusses and minuses and practical constraints. The strength of a study based on actual crash reports is that no assumptions are made in terms of driver car-following behavior such as in simulation or shock wave speeds such as in mathematical modeling. One weakness is that it is difficult to explain the reasons why the numbers are such without using other variables to control for other factors. And unlike simulation, no sensitivity analysis can be easily performed. The University of Missouri is interested in continuing to analyze the causes for the difference between primary and secondary crash characteristics as the results will help to advance and improve incident management. The transportation engineering community has only recently begun to focus on the study of the nature of secondary crashes due to the availability of more detailed forms of safety data and the ability of performing data fusion with other data sources such as traffic data, incident reports, and media reports. The hope is that such investigations will reveal practical strategies to mitigate further the effects of primary incidents.

APPENDIX A. ANNUAL PRIMARY AND SECONDARY CRASHES IN ST. LOUIS

The following figures show the annual primary (vertical scale on the right) and secondary (vertical scale on the left) crashes. The figures from each freeway look very different by visual inspection, but the correlation of the primary to the secondary crash is visually obvious. No analysis was conducted to explain the differing curves from each freeway.

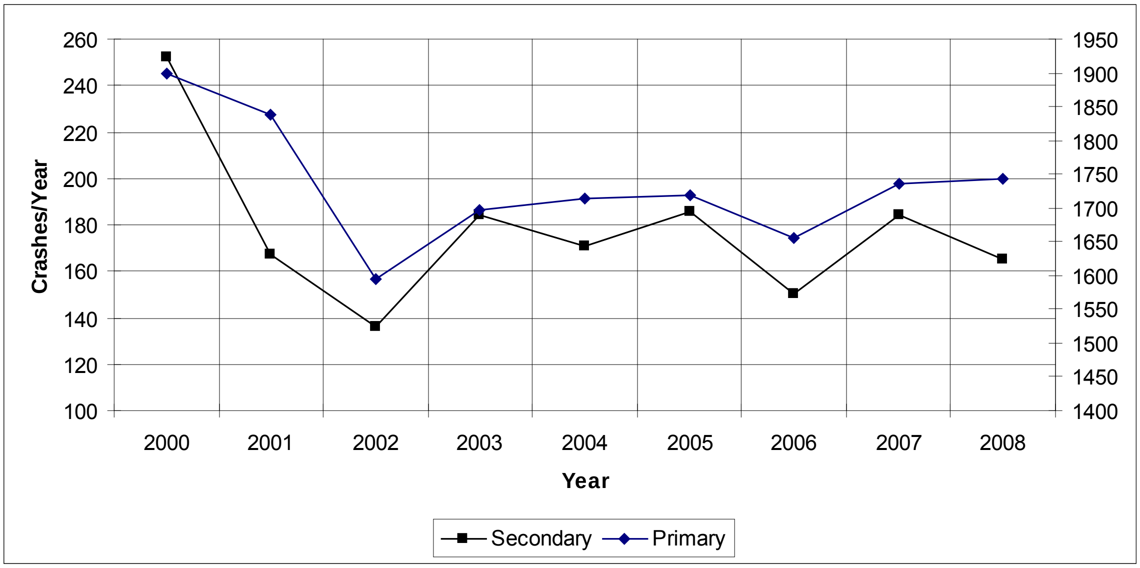


Figure A1. I-70

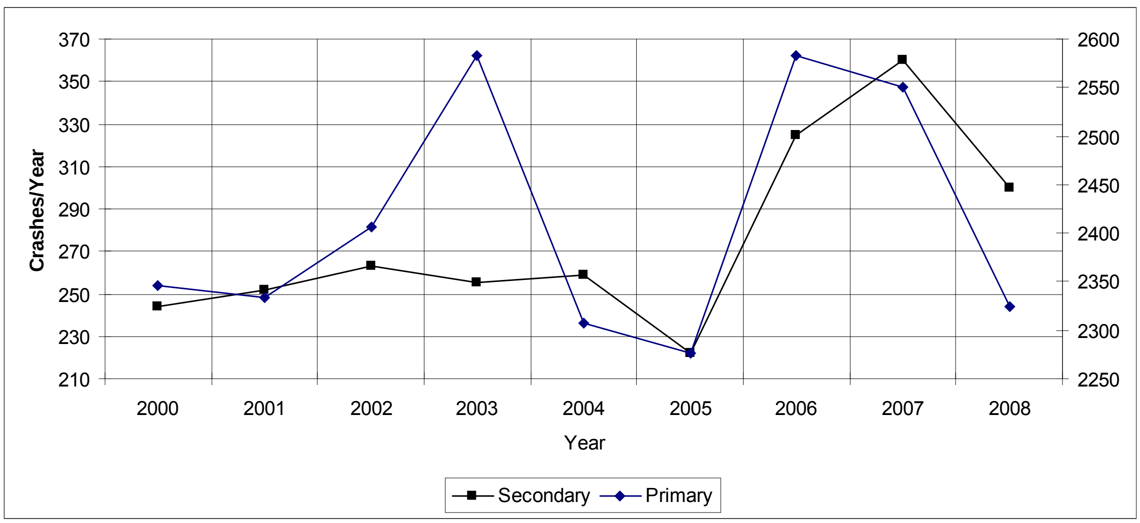


Figure A2. I-270

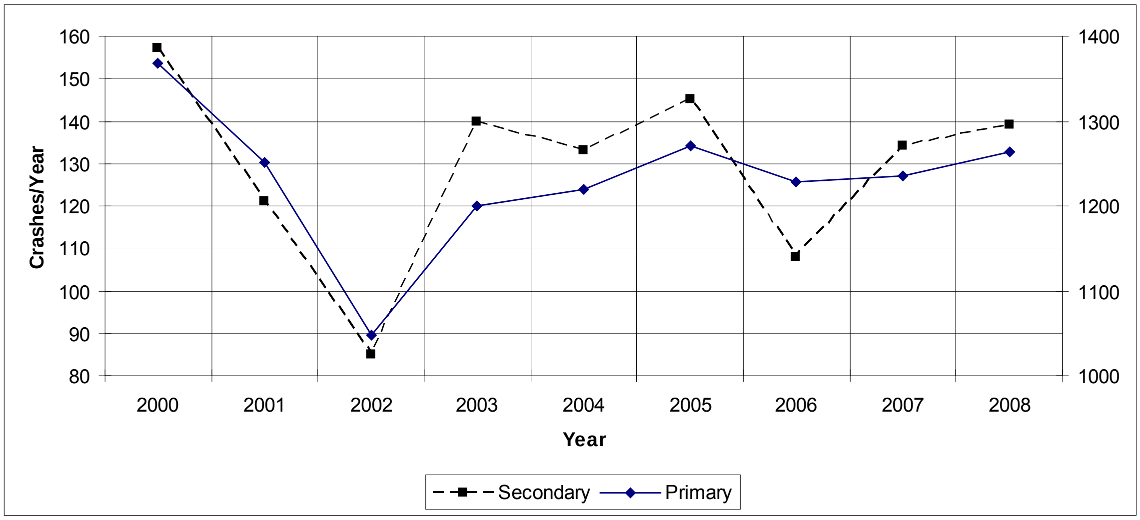


Figure A3. I-44

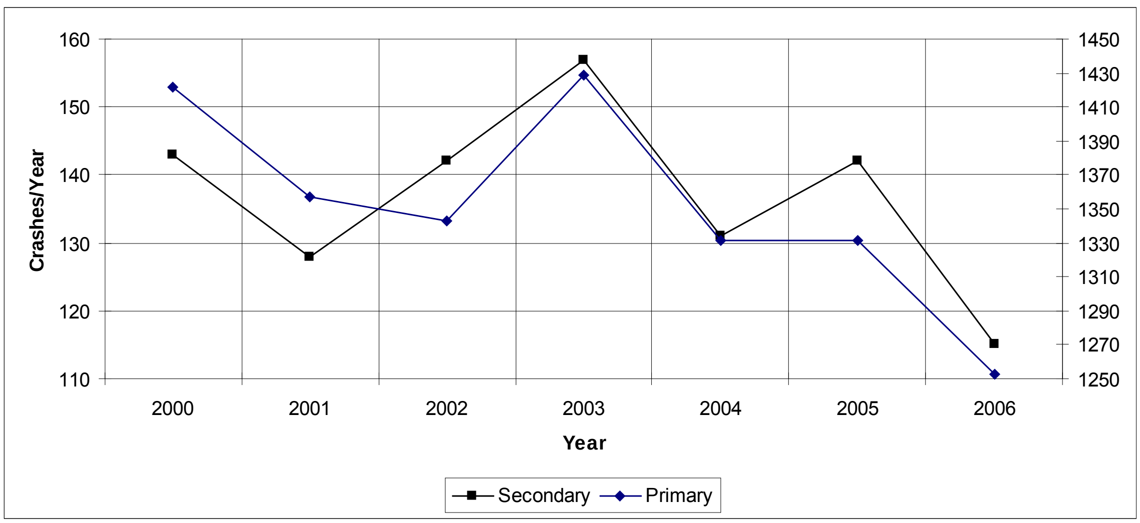


Figure A4. I-64

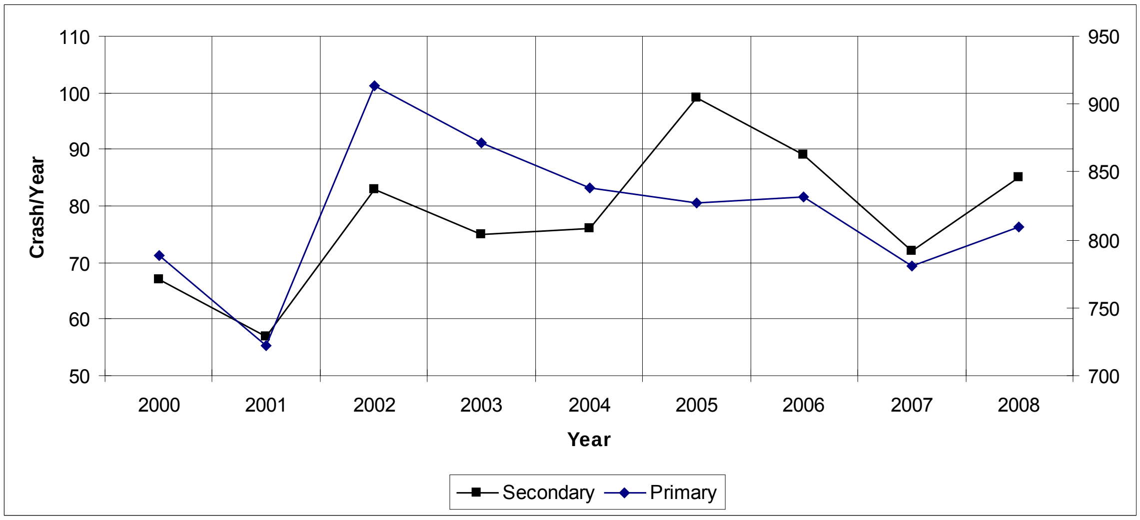


Figure A5. I-55

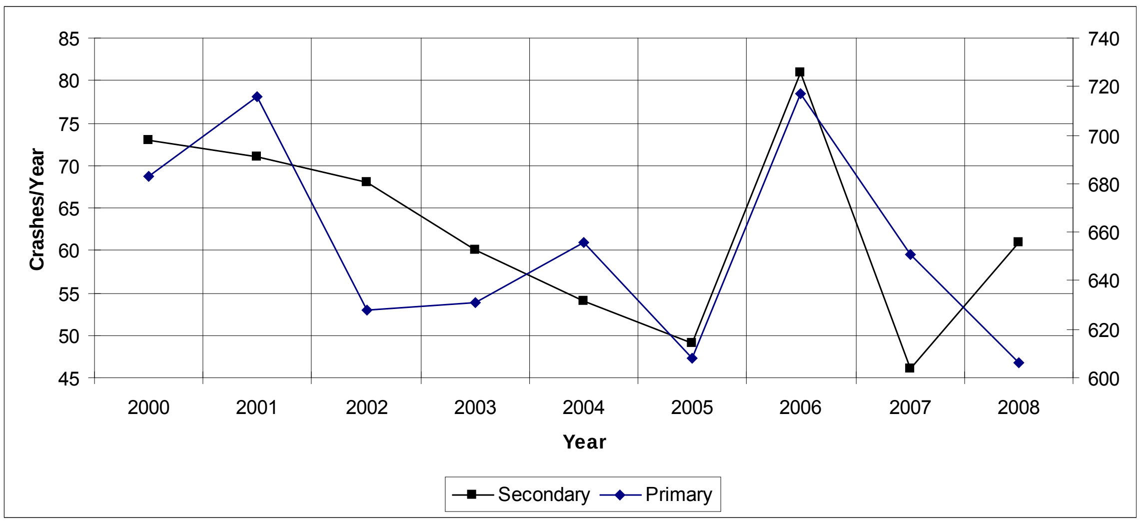


Figure A6. I-170

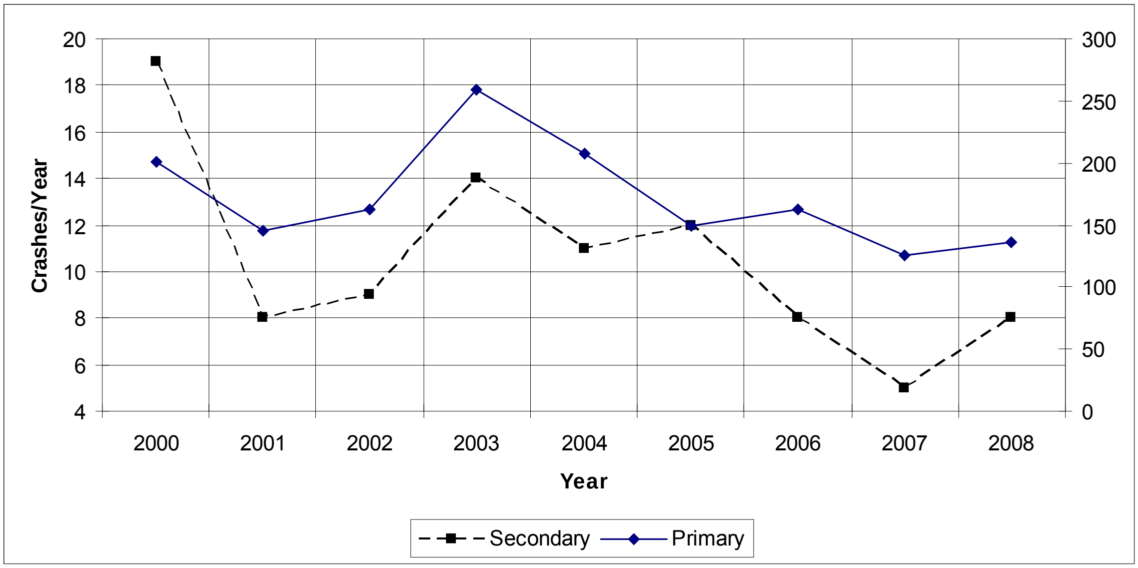


Figure A7. I-255

APPENDIX B. SECONDARY CRASHES BY SEVERITY IN ST. LOUIS

The following tables present the annual secondary crash statistics for each freeway in St. Louis. Incident-caused secondary crashes are ones caused by non-crash incidents such as parked motor vehicles, animals, and other non-fixed objects. (E.g. objects from vehicles, fallen tree). The sum of the fatal, disabling injury, minor injury, and PDO columns should equal the number of non-redundant secondary crashes.

Table B1. I-70

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	77	3	7	67	175	252
2001	66	2	3	42	120	167
2002	58	1	3	32	100	136
2003	82	3	6	52	123	184
2004	64	2	2	38	129	171
2005	64	1	2	43	140	186
2006	53	1	3	37	109	150
2007	47	0	8	50	126	184
2008	45	4	4	36	121	165
Totals	556	17	38	397	1143	1595
Average	61.78	1.89	4.22	44.11	127	177.22
Std. Dev.	12.55	1.27	2.22	10.77	21.31	32.58

Table B2. I-270

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	96	1	2	57	184	244
2001	86	0	2	58	192	252
2002	70	0	4	46	213	263
2003	83	0	2	58	195	255
2004	93	0	11	44	204	259
2005	76	1	5	44	172	222
2006	86	2	5	75	243	325
2007	60	1	7	75	277	360
2008	70	0	6	66	228	300
Totals	720	5	44	523	1908	2480
Average	80.00	0.56	4.89	58.11	212.00	275.56
Std. Dev.	11.84	0.73	2.93	12.14	32.75	43.94

Table B3. I-44

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	77	3	4	29	121	157
2001	67	0	4	28	89	121
2002	54	4	5	16	60	85
2003	71	4	3	30	103	140
2004	67	1	3	27	102	133
2005	72	0	1	28	116	145
2006	41	2	4	16	86	108
2007	55	4	2	33	95	134
2008	55	0	4	16	119	139
Totals	559	18	30	223	891	1162
Average	62.11	2.00	3.33	24.78	99.00	129.11
Std. Dev.	11.50	1.80	1.22	6.80	19.38	21.63

Table B4. I-64*

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	39	1	4	28	110	143
2001	36	2	1	28	97	128
2002	37	1	3	40	98	142
2003	33	0	3	34	120	157
2004	27	0	2	29	100	131
2005	18	1	2	35	104	142
2006	29	1	1	27	86	115
Totals	219	6	16	221	715	958
Average	31.29	0.86	2.29	31.57	102.14	136.86
Std. Dev.	7.27	0.69	1.11	4.86	10.75	13.46

*Starting in the third quarter in 2007, the I-64 re-construction had a significant effect on traffic volumes. Thus the data from 2007 and 2008 are not included, as they do not represent normal conditions.

Table B5. I-55

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	31	1	2	17	47	67
2001	37	1	0	13	43	57
2002	46	2	5	16	60	83
2003	32	0	1	16	58	75
2004	40	1	1	17	57	76
2005	46	2	7	22	68	99
2006	35	2	4	25	58	89
2007	26	1	0	14	57	72
2008	34	1	5	10	69	85
Totals	327	11	25	150	517	703
Average	36.33	1.22	2.78	16.67	57.44	78.11
Std. Dev.	6.73	0.67	2.54	4.53	8.44	12.48

Table B6. I-170

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	19	2	2	20	49	73
2001	20	0	0	16	55	71
2002	16	0	0	10	58	68
2003	16	0	3	11	46	60
2004	19	0	1	13	40	54
2005	11	2	0	14	33	49
2006	24	0	1	15	65	81
2007	7	0	1	8	37	46
2008	17	0	0	10	51	61
Totals	149	4	8	117	434	563
Average	16.56	0.44	0.89	13.00	48.22	62.56
Std. Dev.	5.03	0.88	1.05	3.71	10.38	11.67

Table B7. I-255

Year	Incident Caused Secondary Crashes	Fatal	Disabling Injury	Minor Injury	PDO	Non-redundant Secondary Crashes
2000	16	0	0	1	18	19
2001	3	0	0	2	6	8
2002	5	0	0	0	9	9
2003	5	0	0	2	12	14
2004	5	0	2	2	7	11
2005	6	0	1	1	10	12
2006	4	0	1	1	6	8
2007	3	0	0	0	5	5
2008	3	0	0	1	7	8
Totals	50	0	4	10	80	94
Average	5.56	0.00	0.44	1.11	8.89	10.44
Std. Dev.	4.07	0.00	0.73	0.78	4.08	4.16

REFERENCES

AASHTO. (2003). *User Benefit Analysis for Highways (The Redbook)*. American Association of State Highway and Transportation Officials. Washington, D.C.

Adams, K., Knoop, V. L., Hoogendoorn, S. P., Stoop, J. A. A. M., and Loon, A. v. (2008). Safety Impacts of Incident Management at Incident Sites. In *proceedings of the TRB 2009 Annual Meeting*, Washington, D.C.

Baird, M., Cove, L., Horne, F., and Jacobs, B. (2003). Development of Tennessee's Freeway Service Patrol (HELP) Program. *Transportation Research Record: Journal of the Transportation Research Board*, 1856(-1), 87-95.

Carlson, P.J. and Miles, J.D. (2005) *Research Recommendations for Uniform Rumble Strip Applications in Texas*. Project Summary Report 0-4472-5. Texas Transportation Institute.

Chou, C., and Miller-Hooks, E. (2008). Benefit-cost analysis of freeway service patrol programs: methodology and case study. *Presentation at the 88th Annual Meeting of the Transportation Research Board*, Maryland, 20.

Donnell, E., Patten, M., and Mason, J. (1999). Evaluating a Roadside Assistance Program: Penn-Lincoln Parkway Service Patrol. *Transportation Research Record: Journal of the Transportation Research Board*, 1683(-1), 143-149.

Dougald, L., and Demetsky, M. (2008). Assessing Return on Investment of Freeway Safety Service Patrol Programs. *Transportation Research Record: Journal of the Transportation Research Board*, 2047(-1), 19-27.

FHWA (2000) *Traffic Incident Management Handbook.* Federal Highway Administration. Prepared by PB Farradyne. November.

Guin, A., Porter, C., Smith, B., and Holmes, C. (2007). Benefits Analysis for Incident Management Program Integrated with Intelligent Transportation Systems Operations: Case Study. *Transportation Research Record: Journal of the Transportation Research Board*, 2000(-1), 78-87.

Hammond, P. and Batiste, J.R. (2008) *Cable Median Barrier: Reassessment and Recommendations Update*. Washington State Department of Transportation.

Heath, A. J., and Turochy, R. E. (2008). Development of a range-based method to estimate mobility benefits of freeway service patrols and its application in Alabama. *Presentation at the 88th Annual Meeting of the Transportation Research Board*, Washington, D.C.

Hirunyanitiwattana, W., and Mattingly, S.P. (2006). “Identifying Secondary Crash Characteristics for the California Highway System.” Proceedings of the Annual Meeting of the Transportation Research Board, Washington, D.C., January 22-26.

Khattak, A., Rouphail, N., Monast, K., and Havel, J. (2004). Method for Priority-Ranking and Expanding Freeway Service Patrols. *Transportation Research Record: Journal of the Transportation Research Board*, 1867(-1), 1-10.

Khattak, A., Wang, X., and Zhang, H. (2008). Are Incident Durations and Secondary Incidents Interdependent? *Presented at the 2009 Transportation Research Board Annual Meeting*, Washington, D.C.

Latoski, S. P., and Pal, R. (1999). Cost-Effectiveness Evaluation of Hoosier Helper Freeway Service Patrol. *Journal of Transportation Engineering*, 125(5), 429.

Lawlor, D. (2003) Survey of Emergency Roadside Service Providers. J.D. Power and Associates. Troy, Michigan.

Lindley, J.A. (2008) *Guidance Memorandum on Consideration and Implementation of Proven Safety Countermeasures*. U.S. Department of Transportation. Federal Highway Administration. Safety Program. Washington, D.C.

Mauch, M., Ahn, S., Chung, K., and Skabardonis, A. (2005). *Baseline Evaluation of the Freeway Service Patrol (FSP) I-710 Big-Rig Demonstration Program*. WORKING PAPER, University of California at Berkeley, Berkeley, 45.

Miller, T.R. (1993) Cost and Functional Consequences of US Roadway Crashes. *Accident Analysis and Prevention*, 25, no. 5, 593-607.

MoDOT. (1999) *Manual on Identification, Analysis and Correlations of High-Crash Locations: the HAL Manual*. Missouri Department of Transportation. 3rd Edition. Jefferson City, Missouri.

Moore, J.E., Giuliano, G., Cho, S.. (2004) "Secondary Accident Rates on Los Angeles Freeways." Journal of Transportation Engineering Vol. 130, No. 3, American Society of Civil Engineers, Reston, VA., 280-285.

Morris, M. and Lee. W.,(1994). "Survey of Efforts to Evaluate Freeway Service Patrols". Transportation Research Record, 1446, 77-85.

Nee, J., and Hallenbeck, M. E. (2001). *Evaluation of the service patrol program in the Puget Sound Region*. Washington State Transportation Center (TRAC) University of Washington, Seattle.

NSC (2007) *Estimating the Costs of Unintentional Injuries*. National Safety Council. Itasca, Illinois.

Pal, R., Latoski, S., and Sinha, K. (1998). Investigation of Freeway Incident Characteristics and Their Influence in Planning an Incident Management Program. *Transportation Research Record: Journal of the Transportation Research Board*, 1634(-1), 46-55.

Raub, R.A. (1997) "Secondary Crashes: An important component of Roadway Incident Management." Transportation Quarterly. Vol. 51, No. 3, 93-104.

Singh, H. N. (2006). *A Benefit-Cost Analysis of a State Freeway Service Patrol: A Florida Case Study*. Thesis, University of South Florida.

Skabardonis, A., Petty, K., and Varaiya, P. (1999). Los Angeles I-10 Field Experiment: Incident Patterns. *Transportation Research Record: Journal of the Transportation Research Board*, 1683(-1), 22-30.

STARS. (2002). *Missouri Uniform Accident Report Preparation Manual. Statewide Traffic Accident Records System*. The Missouri Traffic Records Committee.

UMC (2003) Evaluation of the Motorist Assist Component of Gateway Guide in St. Louis, Missouri. Statewide Evaluation of Intelligent Transportation Systems in Missouri. Interim Report. Department of Civil and Environmental Engineering. Columbia, Missouri.

Volpe (1995) Intelligent Transportation Systems Impact Assessment Framework: Final Report, Volpe National Transportation Systems Center, September 1995.

Yang, S. (2006). *Integrated Management of Emergency Vehicle Fleet*. Dissertation. University of Maryland.

Zhan, C., Gan, A., and Hadi, M. (2008). Identifying Secondary Crashes and Their Contributing Factors. *Presentation at the 88th Annual Meeting of the Transportation Research Board*, Washington, D.C.

Zhan, C., Shen, L., Hadi, M., and Gan, A. (2008). “Understanding the Characteristics of Secondary Crashes on Freeways.” Proceedings of the Annual Meeting of the Transportation, Washington, D.C., January 13-17.

Zhang, H. and Khattak, A. (2009). “ What is the Role of multiple Secondary Incidents in Traffic Operations?” *Presentation at the 89th Annual Meeting of the Transportation Research Board*, Washington, D.C.

Missouri Department of Transportation
Organizational Results
P. O. Box 270
Jefferson City, MO 65102

573.526.4324
1 888 ASK MODOT
innovation@modot.mo.gov

ATTACHMENT B

Houston TranStar 2013 Annual Report

The Houston TranStar Consortium is a Partnership of Four Government Agencies Responsible for Providing Transportation Management and Emergency Management Services To the Greater Houston Region

INTRODUCTION

This document is the 17th annual report for the Houston TranStar Transportation Management and Emergency Operations Center. This annual report provides a review of the performance of the center and summarizes the estimated return on investment as quantified by the estimated benefit/cost ratio. It also includes conservative estimates of the impact of center operation on regional mobility (travel time, speed and delay), customer satisfaction, and energy and environmental benefits.

Houston TranStar is a formal partnership among the principal transportation and emergency management agencies in Harris County, including:

- Texas Department of Transportation (TxDOT);
- Metropolitan Transit Authority of Harris County (METRO);
- Harris County, including:
  - Traffic & Transportation Group,
  - Harris County Toll Road Authority, and
  - Office of Homeland Security & Emergency Management; and
- The City of Houston.

Established in 1993, Houston TranStar provides for multi-agency operations and management of the region's transportation system and has evolved into a primary resource from which multiple state, county and local agencies respond to incidents and emergencies in Harris County and beyond. It is the mission of Houston TranStar and its partner agencies to provide highly effective transportation and emergency management services through the combined use of the partners' collective resources to maximize safety and mobility to the public.

Houston TranStar plays a pivotal role in the travel of people and goods in the greater Houston region, with an estimated savings to motorists of nearly $3.9 billion in reduced travel time costs over the 17 years of Center operation from 1997 to 2013.

In 2013, the reduction of travel time attributable to Houston TranStar operation was estimated to be over 15.6 million vehicle-hours. This level of delay savings has a corresponding value of over $340 million in road user cost savings and an additional $99 million (or more than 29 million gallons) in reduced fuel consumption. The total estimated benefits of Center operation in 2013 were over $438 million. Comparing the annualized TranStar operating cost estimate of $30.1 million to the estimated annual benefit of $438.9 million yields an estimated benefit/cost ratio for Houston TranStar center operation of 14.6 for 2013.

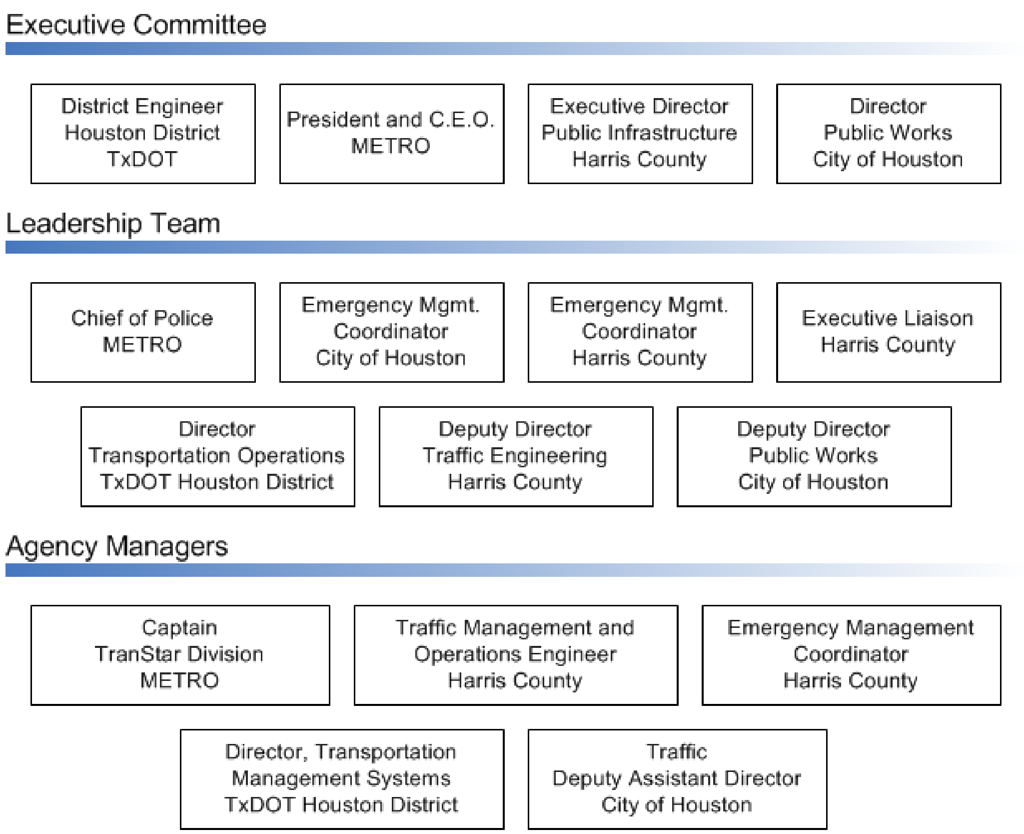
On the Cover: Downtown Houston Skyline as seen over Interstate 45
Attribution: Greater Houston Convention and Visitors Bureau

TRANSTAR OPERATIONS FRAMEWORK

Houston TranStar is staffed by employees from each of the four member agencies which support the three levels of management in operating the programs housed in the Center. Operation of the Center is coordinated by a management staff that is responsible for operating and maintaining Houston TranStar facilities, coordinating multi-agency activities, coordinating budget preparation, hosting workshops and meetings, conducting facility tours, and managing public information activities. The three-tiered management structure and functions of the three committees are:

- Executive Committee – includes agency- or division-level executive administrators; the committee sets policy and manages fiscal and staffing matters;
- Leadership Team Committee – includes administrators of the transportation and emergency management groups; the team administers implementation of various projects and activities and reviews funding commitments; and
- Agency Managers Committee – includes managers of the transportation and emergency management groups; the agency managers are responsible for daily operations.

Houston TranStar Organizational Chart



TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

In 2013, the TranStar Partner Agencies continued ongoing, 24-7, transportation system operations and emergency planning and response. Significant agency activities at the center in 2013 are highlighted in the following sections of this report. Some of these highlights and significant accomplishments of TranStar and the partner agencies included:

- HCOHSEM activated the EOC (Emergency Operations Center) twice in January in response to severe weather potential (on 5th and 8th), moving to Level 3 - Increased Readiness on January 8th.
- HCOHSEM activated EOC January 15 in support of a natural gas pipeline leak in Pasadena.
- In the first quarter of 2013, TxDOT continued its implementation of Bluetooth travel time monitoring, CCTV and Vehicle Detection on: US 90 from IH 610 East Loop to the Harris/Liberty County Line; US 290 from Mueschke Rd to just past SH 6 in Hempstead; and on SH 6 from US 290 in Hempstead to two miles north of US 290 in Hempstead.
- In January, the segment on US 90 from IH 610 East Loop to east of the Sam Houston Tollway was integrated into the TranStar speed map. CCTV images were also integrated into TranStar.
- In February, HCOHSEM activated to support the City of Houston and first response agencies during NBA All-Star weekend. The EOC was staffed for 82 hours during that period.
- METRO PD consoles were upgraded with TranStar Computers to enhance Watch Command Officers operations.
- In February, TxDOT converted travel time monitoring on IH 45 from 61st Street in Galveston to Fuqua Street from the AVI, toll-tag based system to the Bluetooth-based AWAM system.
- In March, Houston TranStar hosted a group from Beijing, China with the HCOHSEM and a visit and webinar with New York University's Polytechnic Department.
- In March, METRO Hosted visitors from the Dallas Area Rapid Transit (DART).
- In March, work on Radio Tower building was completed.
- TxDOT Installed and integrated cameras on FM 2920 from IH 45 west to Tomball in March.
- In April, TranStar released a Public Service Announcement to all the television stations. Subject: Preventing teen distracted driving through peer action.
- HCOHSEM Activated the EOC on April 15 for local monitoring of Boston Marathon bombing.
- HCOHSEM Activated the EOC on April 27 for monitoring of a local flooding event.
- The TranStar METRO PD WCO/Dispatch console expansion was completed in April.
- In June, Houston TranStar hosted groups from the US State Department – Azerbaijan delegation – and the Nigerian Petroleum Corporation.
- In July, Harris County began building a lab to test various configurations and protocols necessary to integrate Harris County Traffic IP video cameras to the TranStar Video System.
- Harris County Judge Ed Emmett hosted more than 150 elected officials, EMCs and other response partners on July 8 for a 2013 Hurricane Season briefing at Reliant Center. Attendees received detailed information on evacuation and recovery planning from state agencies and private sector partners. HCOHSEM participated in this meeting as well.
- HCOHSEM hosted a Regional Joint Information Center exercise on July 24, the largest since Hurricane Ike in 2008. More than 100 individuals representing 50 agencies and jurisdictions

operated six JICs around the region and in Arlington, Texas. The exercise was a successful test of internal and external communications systems.

- In July, final closeout for City of Houston WiMAX Project took place.
- In July the Advance Funding Agreement for $1 million was signed between TxDOT and Harris County, funding the HCSO MAP for an additional year.
- In August, two Houston TranStar Web videos were published to the website and YouTube page. One describes TranStar's innovative approach to emergency management and transportation management, and the other portrays TranStar's information-sharing for transportation management.
- In August, members of HCOHSEM staff participated in a Radiological Tabletop response exercise conducted by Harris County Public Health & Environmental Services (HCPHES).
- Also in August, TxDOT implemented Ferry Travel Time traveler information from Seawall Blvd. to Bolivar Peninsula using Wi-Fi technology from TTI.
- In September, the ITS Technology and Applications class of Texas Southern University visited Houston TranStar.
- In September and October, Harris County completed fiber communications installations at Kuykendahl Road and Louetta Road as part of the Changeable Lane Assignment Sign project.
- In October, a group of guests from the Netherlands visited the facility to examine the ITS system.
- HCOHSEM activated on October 3 to monitor Tropical Storm Karen. Karen ultimately dissipated in the Gulf of Mexico, with minor coastal flooding in Brazoria County.
- TranStar made necessary cable runs to facilitate a move in November of the police dispatch consoles to the rear of the floor. This move was determined necessary to meet the DPS CJIS (Criminal Justice Information Security) compliance requirements.
- In November, about 50 members of the Leadership Group from the City of Missouri City visited Houston TranStar to learn more about center operations.
- The National Industrial Transportation League visited Houston TranStar on November 17 as part of a national convention.
- Houston TranStar was selected as a site for one of the vehicles from the City of Houston's electric car fleet. Charging stations were installed for the vehicle.
- HCOHSEM staff participated in the HC Public Health & Environmental Services RADD SNS exercise on November 1 & 2. This multi-location exercise tested the ability of state and local health officials to distribute medication in the event of a medical emergency.
- TxDOT, in conjunction with the City of Houston, installed travel time monitoring equipment on Hempstead Road. Speeds were integrated into the US 290 speed map.
- In December, HCOHSEM monitored extremely cold weather December 5-6.
- TxDOT Installed Bluetooth readers on NASA Road One. The speeds on the roadway were integrated into the Speed Map.

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

- TxDOT opened Grand Parkway (SH 99) Segment E on December 21, 2013. No tolls were charged until February 1, 2014. CCTV, speed and volume sensors were placed on the facility and integrated into TranStar systems.
- There were more than 1,330 visitors to the center in 2013, including local, state, and national public officials and individuals, and overseas visitors from China, Singapore, Mexico, and the Netherlands, among others.

The following sections summarize each partner agency's activity during 2013. This includes various measures of performance of the center and programs operated from Houston TranStar.

Texas Department of Transportation

The Texas Department of Transportation (TxDOT) is responsible for traffic management of freeways and state-maintained arterial highways in the region. TxDOT's Computerized Traffic Management System (CTMS) has been in continuous deployment on Houston area freeways since the late 1980s. The total extent of the regional system is about 890 directional miles, including 801 directional freeway miles and 89 miles on HOV and Managed Lanes. Also not separately monitored are the non-barrier-separated HOV "diamond lanes" on US-59 (Southwest) and IH-10 (Katy Freeway) as these are currently included with mainlane monitoring. TxDOT also has continuous travel time monitoring in-place on 197 miles between The Woodlands and Interstate 20 in Dallas for traveler information and hurricane evacuation route monitoring.

Total TxDOT ITS field equipment deployed as of the end of 2013 included:

- Closed Circuit Television; 717 freeway CCTV cameras and 71 regional hurricane evacuation cameras (on rural and/or remote routes);
- Dynamic Message Signs – 224 total permanent DMS;
- Radar-based Vehicle Volume and Speed Detection – 161 total detectors;
  - 28 locations on evacuation routes (primarily on rural and/or remote highway routes);
  - 133 locations on freeway facilities in the urban area, including 30 on the IH-10 Managed Lanes operated in coordination with HCTRA;
- Flow Signals in Operation – 80 active in 2013 total on six facilities (IH-45 North, IH-45 Gulf, US-59 Southwest; US-290 Northwest, and IH-610 West Loop); and
- Travel Time Monitoring System – 1322 directional miles of coverage (AVI+AWAM).

Major components of the CTMS include CCTV, DMS, freeway entrance ramp flow signals, travel time monitoring using the Automatic Vehicle Identification (AVI) system and AWAM (Anonymous Wireless Address Matching) system, and related communications and central facility computer systems.

TranStar's traveler information systems are the cornerstone of the partner agencies' traffic management function and its ability to respond to and manage incidents. Monitoring systems at Houston TranStar provide extensive information of value to motorists as well as to traffic management operators at Houston TranStar. TxDOT operates and maintains this system for the TranStar consortium. Information is provided to motorists by three primary means: DMS, the Internet (by both desktop and mobile Internet formats), and the local media. The 224 permanent roadside DMSs provide information on traffic incidents and planned construction, giving location, travel direction, and nature of the incident or activity. The system is also used to display current travel times; weather alerts; and Amber (missing child), Silver (missing elderly or disabled persons), and Blue (law enforcement-related) Alerts.

There were more than 206,000 operator activated messages and over 2.45 million automated messages displayed on DMSs in 2013. The total number of operator-activated and automated messages increased 13% over 2012 levels, while the total number of state-mandated Amber, Silver, and Blue Alert messages increased more than 44% over 2012 levels, mostly because of an increase in Silver Alert messages in 2013. There were 50% more incident-related messages in 2013 as compared to 2012.

DMS message categories which changed significantly in 2013 (over 2012 levels) were:

- Incidents – up 50%;
- Road closures – down 24%;
- Safety campaigns – down 60%;
- Weather events – down 99%;
- Ozone alerts – down 46%;
- Informational messages – down 98%;
- Traveler information for special events – down 10%; and
- Traffic control information for special events – down 7%.

The types of DMS messages posted in 2013, and the corresponding estimated number of messages posted included:

- Operator Activated (206,600 total);
  - 95,000 operator activated messages for incidents;
  - 51,500 operator activated messages for road closures or construction;
  - 400 operator activated messages for weather-related events;
  - 29,300 operator activated messages for public service messages, including,
    - 28,600 for safety campaigns;
    - 700 for other informational messages;
  - 17,000 operator-activated messages for Special Events;
  - 9,580 Amber, Silver, and Blue Alert messages;
    - 1,610 for Statewide Amber Alerts;
    - 770 for Local Amber Alerts;
    - 7,070 for Silver Alerts;
    - 130 for Blue Alerts.

- Automated Messages:
  - 2,456,000 Freeway travel time messages
  - 3,800 Ferry travel time messages

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

Some of the significant activities of TxDOT at TranStar in 2013 included:

- In January, TxDOT continued its implementation of Low Cost ITS of Bluetooth, CCTV and Vehicle Detection on: US 90 from IH 610 East Loop to the Harris/Liberty County Line; US 290 from Mueschke Rd to just past SH 6 in Hempstead; and SH 6 from US 290 in Hempstead to 2 miles north of US 290 in Hempstead. A segment of US 90 was integrated into the TranStar Speed map from IH 610 East Loop just past the BW8/Sam Houston Tollway. Camera images have also been placed on the map.
- In February, TxDOT converted travel time monitoring on IH 45 from 61st Street to Fuqua to Bluetooth Speed Readers.
- In March, work on the new Radio Tower building was completed and TxDOT installed and integrated cameras on FM 2920 from IH 45 west to Tomball.
- Conducted several public information campaigns, including the "Talk, Text, Crash" Safety Message and Work Zone Safety Week Campaigns in April.
- In July, an Advance Funding Agreement for $1 million was signed between TxDOT and Harris County, funding the HCSO MAP for one more year.
- In August, TxDOT implemented Ferry Travel Times from Seawall Blvd. to Bolivar Peninsula using Wi-Fi address readers.
- In November, Hempstead Road was outfitted with AWAM sensors and placed on the US 290 speed map
- In December, TxDOT installed Bluetooth readers on NASA Road One and placed the roadway on Speed Map. That same month, TxDOT let a project to extend ITS on US 59/ IH 69 from SH 6 to SH 99 in Fort Bend County.
- SH 99 Segment E opened on December 21, 2013. No tolls were charged until February 1, 2014.

City of Houston

The City of Houston Traffic Operations Branch, located at Houston TranStar, directs the design and installation of new traffic signals, operates and manages the city's signal system, and over sees operations and development of the traffic signal communications infrastructure. Traffic congestion is a major issue for Houstonians, making signal timing optimization an excellent investment with significant benefits for our city's future traffic operations. Houston has more than 2,450 signalized intersections maintained and operated by the city.

The Public Works and Engineering Department's Traffic Signal Performance Improvement Program (TSPIP) is a coordinated effort to ensure the city's traffic signals are using the most up-to-date traffic data, while taking advantage of the most recent technologies to produce new customized signal timings. TSPIP'S revolving program is scheduled to revisit each major corridor every four years for retiming. The central approach of TSPIP is to provide an optimized level of traffic signal operation on the city's most heavily-traveled corridors and throughout some of its most heavily-populated employment areas.

In addition to providing the program management for TSPIP, the Traffic Operations Branch is responsible for developing signal optimization plans for the selected zones. The Traffic Operations Branch's role in this process consists of field data collection, timing plan design, and signal timing implementation. Approximately 800 traffic signals are evaluated and optimized each year. In TSPIP 2013-2014, signal performance improvements continued in the following areas: North West Area – 130 Traffic Signals; North Central Area - 310 Traffic Signals; North East Area – 270 Traffic Signals; Clear Lake Area – 55 Traffic Signals; and Uptown District & Surrounding Area – 70 Traffic Signals.

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

Metropolitan Transit Authority of Harris County

The Metropolitan Transit Authority of Harris County provides bus and light rail transit services as its core function but is also involved in other transportation and law enforcement functions. METRO is an active partner in the operation of Houston TranStar, and by using Houston TranStar's collection of ITS technologies, METRO provides improved service to the Authority's patrons. METRO programs operated from Houston TranStar include METRO bus and METRORail dispatch, METRO Police Communication Section operations, traffic signalization systems, HOV management systems, SAFEClear and incident management programs. METRO activity highlights for 2013 include:

- The METRO Motorist Assistance Program (MAP) consists of civilian staff members who continued to provide METRO MAP services in close coordination with the SAFEClear program. Both METRO MAP and SAFEClear on the HOV lanes are coordinated through Houston TranStar in partnership with the Houston Police Department and the SAFEClear Management team. In 2013, METRO's MAP personnel assisted 3,211 motorists on regional freeways.
- METRO began implementation of High Occupancy Toll (HOT) Lanes in the Houston region in 2012. These lanes allow single occupant vehicles to pay a toll to ride the HOV Lane during designated times. The IH 45 South (Gulf Freeway), US 59 Southwest, and IH 45 North Freeway HOT Lanes opened in 2012. HOT Lanes opening in 2013 included the US 290 (Northwest Freeway) and US 59 (Eastex Freeway) corridors. Included in these deployments is the Automated Reversible Gate Operation (ARGO) System, which enables remote opening, reversal and closure of the regions HOV/HOT Lane facilities. The ARGO system is operated from METRO consoles within TranStar.

Harris County Traffic Management

The Harris County Public Infrastructure Department's Traffic Maintenance Group (TMG) is responsible for the operation and maintenance of the County's traffic signal infrastructure, which includes the fiber optic interconnect communications network. Major initiatives during 2013 included:

- In January, staff built a fiber path from the Crosby-Lynchburg switch to CE King Satellite building to build a redundant path for the 10 GigE backbone.
- Also in January, worked with ITC to develop network growth plans in order to build resiliency into the systems backbone, to develop near/long term vision of the LTE build-out requiring fiber work, and assisted with integration efforts of LTE circuits from Baytown to TranStar.
- In June, county staff replaced a failed Network Time Protocol Server; repaired eight cameras and three fiber cuts; handled video issues at Washburn Tunnel; programmed IP encoders for deployment into CMAQ-1 corridors; finalized new communications maintenance contract documents. In addition, staff installed fiber to support Constable operations; worked on DMS signs on BW-8 East; repaired one switch failure on BW-8; and worked on integrating switch at DPS in support of ITC/Dowley Securities requirements.
- In July, repaired damaged fiber trunk cable in two areas, replaced older switches in both Clay Hub and Klein Church Hub in preparation for ATM to IP transition, and began building a lab to test various configurations and protocols necessary to integrate HC Traffic IP video cameras to the TranStar Video System.
- In August, staff moved fiber at Kuykendahl Road @ Louetta Road as part of the CLAS Project; worked to build a circuit from TranStar to the East Toll Plaza for the Precinct 8 Constable's

office; and replaced transceivers with Ethernet switches for 20 DMS signs on Beltway 8 East in order to improve the communications path between the DMS subsystem and the DMS controller.

Harris County Office of Homeland Security and Emergency Management (HCOHSEM)

With almost 4.2 million residents, Harris County is the most populous county in the State of Texas and the third most populous county in the United States. Harris County consists of 34 cities, including Houston, the nation's fourth-largest city, but nearly 1.6 million people live in unincorporated Harris County and rely on the county to be the primary provider of basic government services.

County Judge Ed Emmett
Director

While the proximity to the Gulf of Mexico makes Harris County vulnerable to hurricanes, it has seen its share of other incidents. The Harris County Office of Homeland Security & Emergency Management (HCOHSEM) is ready to activate its Emergency Operations Center (EOC) for any natural or man-made disaster. In the past, the EOC has activated for emergencies that have included weather events, health related events, hazardous materials, industrial accidents and wildfires. HCOHSEM serves as a liaison to local, county, state, federal and military agencies and departments. In total, HCOHSEM activated the EOC 14 times in 2013.

Hurricane Season

The Texas Gulf Coast was again spared in 2013 from any significant hurricane activity. The 2013 season had 14 named storms and only two hurricanes. HCOHSEM monitored storms all season, keeping a close eye on Tropical Storms Ingrid and Karen which could have moved into the Texas coast.

Homeland Security

The HCOHSEM collaborates with local, state and federal partners to prevent, protect against, respond to and recover from natural and man-made disasters, health emergencies and terrorism. Partner agencies include the Harris County Sheriff's Office, Harris County Fire Marshal's Office, Federal Bureau of Investigation, U.S. Department of Homeland Security, U.S. Coast Guard, Federal Communications Commission, State of Texas, the local Fusion Center, and countless first responder organizations as well as other local, state, national and international partners. Harris County Sheriff's Office (HCSO) HCSO has seven officers assigned to HCOHSEM.

Some of their duties include:

- Working directly with Incident Command during activations.
- Staffing and providing security for Houston TranStar during dignitary visits and Emergency Operations Center activations.
- Participating in all drills/exercises in which the HCSO or Harris County, in general, is a stakeholder.
- Coordinating planning and response activities with state and federal military forces.
- Transporting assessment teams and/or conducting damage assessments post events.
- Maintaining and updating all plans that would involve a Homeland Security Bureau response, such as deployment of the Strategic National Stockpile.

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

- Reviewing and updating, as needed, all annexes that are assigned to the Sheriff's Office in the Harris County Emergency Management Plan.
- Conducting public awareness activities/education for residents and business groups.

Emergency Operations Center (EOC)

HCOHSEM activates its Emergency Operations Center (EOC) for a wide range of emergencies or special events. The EOC is where emergency partners coordinate response efforts, make decisions, locate and deploy resources, and gather and disseminate information. In 2013, HCOHSEM activated its EOC 14 times. The EOC is equipped with state-of-the-art technology to assist in information gathering, assessment and public notification. It is also connected to the State's WebEOC network that enables emergency personnel to electronically share real-time information during an incident and helps manage resources. Construction is under way at Houston TranStar to expand HCOHSEM facilities to include a new and larger EOC. The construction began in 2012 and continued through 2013.

On-Call

The On-Call program provides response partners with 24-hour access to a trained staff member for the reporting of significant events and after-hour resource requests. The calls range from severe weather inquiries to assistance requests for high impact chemical spills. In 2013, On-call received 2,532 documented notifications requiring more than 734 hours of staff time.

Industry

HCOHSEM's Operations team was involved with various industrial and hazardous material emergencies during the year. This includes supporting the Harris County Hazmat team with on-scene safety, emergency communications to community leaders and serving as liaison with partner agencies. In general, the department assists the Texas Division of Emergency Management, State Operations Center, U.S. Department of Homeland Security and the National Response Center to gather information on industrial incidents.

HCOHSEM's new technology systems allows for training and emergency response, while also making inventory control of cache items automated. All of these enhanced capabilities benefit the entire region because they allow HCOHSEM to be more productive, efficient, and responsive to all needs. The following are a few 2013 incidents that HCOHSEM monitored and supported in coordination with HCFMO:

- Skid fire at a major pipeline facility
- Trimethylacetyl chloride release at a chemical facility
- Explosion at a gas facility

- Acetylene cylinder fire
- Compressor shutdown at Houston Ship Channel
- Liquid propane tanker truck accident
- Scrap metal facility fire
- Boron trifluoride leak.

Transportation Assistance Registry (TAR)

HCOHSEM plays a critical role in serving people with functional access needs (formerly special needs) before and during emergencies. Every year, designated planners update the transportation registry list for Harris County and participate in several projects aimed at helping residents requiring evacuation assistance. Individuals who need evacuation assistance can dial 2-1-1 and provide their contact information and any medical needs that may require special transportation.

Training & Exercises

Training and exercises are essential components to HCOHSEM's comprehensive approach to preparedness for homeland security and emergency management. Training and exercises provide a practical evaluation of the capabilities of local governments and their partners. HCOHSEM, in collaboration with federal, state and regional partners, conducts and participates in training and exercise events that strengthen the ability of the local emergency management community and build strong relationships.

In 2013, HCOHSEM hosted six exercises and participated in an additional 28 partner exercises throughout the region. The office hosted several state and federal courses, including a Public Officials Workshop and a Threat and Risk Assessment course. Key events included:

- Regional Joint Information Center (JIC) Functional Exercise - In 2013, HCOHSEM hosted the Regional JIC functional exercise. Close to 100 federal, state and local public information professionals, representing more than 50 organizations, participated in this exercise that tested and evaluated public information during a disaster.

- Rail Hazardous Materials Virtual Tabletop Exercise - HCOHSEM and several other county departments participated in a Federal Emergency Management Agency (FEMA) virtual tabletop exercise to test response capabilities for a chemical release from a train derailment. This unique tabletop provided the opportunity to coordinate face-to face with other local response organizations and correspond virtually with nine other communities. This was accomplished via conference calls and through video teleconferencing technology.

- County Staging Area – POD Training and Drill - HCOHSEM and the Harris County Community Services Department held a POD drill focused on the testing of communications equipment and standard operating guidelines between the CSA and the Harris County EOC. This two-day event was a result of lessons learned from Hurricane Ike, as well as our 2012 full-scale hurricane exercise.

- Other partner exercises included:
    - United States Coast Guard SecureEx Functional Exercise
    - Regional Allocation Distribution and Dispensing Strategic National Stockpile Full-Scale Exercise

- Texas Medical Center Weapons of Mass Destruction (WMD) Tabletop Exercise
- Various LEPC and industrial exercises

Public Information Office & Public Education

A strong public outreach program is a key part of HCOHSEM's mission to encourage personal disaster preparedness. Each year, HCOHSEM works closely with private sector partners, faith-based organizations, school districts and other groups to promote an all-hazards approach to disaster preparedness. Highlights from HCOHSEM's outreach program in 2013 included:

- National Weather Service Hurricane Workshop - The largest and best attended hurricane preparedness event each year is the National Weather Service's Hurricane Workshop that is held at the George R. Brown Convention Center. In 2013, more than 3,500 residents from Harris and surrounding counties discussed hurricane preparedness with elected officials, local television meteorologists and other experts.

- Medical Community Preparedness Events - In 2013, HCOHSEM worked with the medical community to participate in health and safety fairs at several major hospitals. In May 2013, HCOHSEM joined the annual Texas Children's Hospital Bridge Event which draws more than 1,000 employees of the Texas Medical Center as well as patients and their families. Similarly, HCOHSEM participated in events at Lyndon B. Johnson and Ben Taub hospitals at the invitation of Harris Health Systems.

- Homeowners Associations - One of HCOHSEM goals for 2013 was to engage community and homeowner associations as a means of improving our preparedness culture. The Greater Houston Neighborhood Association's annual seminar and trade show last February served as the kick-off for that effort. Hundreds of homeowners from all parts of the county gathered to hear an address by Harris County Judge Ed Emmett and learn more about improving disaster preparedness in their neighborhoods. This event led to nearly a dozen events at homeowner association meetings throughout the year.

- Industry - In 2013, HCOHSEM collaborated in more than 20 presentations at safety meetings for companies such as Baker Hughes, Chevron, ExxonMobil, BP and Schlumberger.

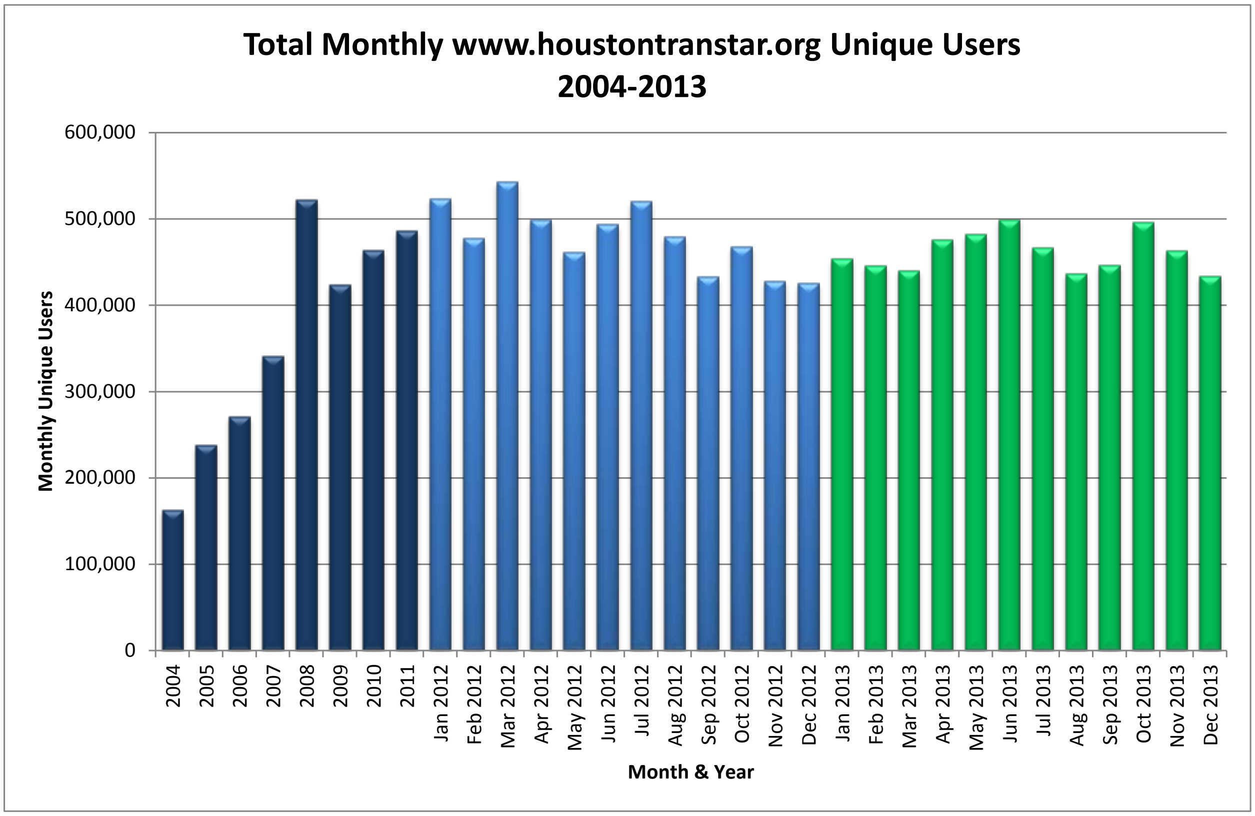
- EOC Tours - In 2013, more than 900 visitors toured the Harris County EOC and TranStar, including almost 100 dignitaries from Azerbaijan, China, Ghana, Japan, Mexico, the Netherlands, Nigeria and Singapore.

TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES

One of the most visible products of Houston TranStar center operation is traveler information. Local Internet and media outlets use the TranStar CCTV feeds, Internet-based incident reporting capabilities, and travel time reporting systems in their daily traffic reporting functions. In addition, traffic service organizations are housed on the operations floor of Houston TranStar.

Operational highlights for the TranStar Website in 2013 included:

- Average unique monthly users held relatively steady, with 461,500 users, a -3.7% change over 2012, but a 35% increase over in the five years since 2007.



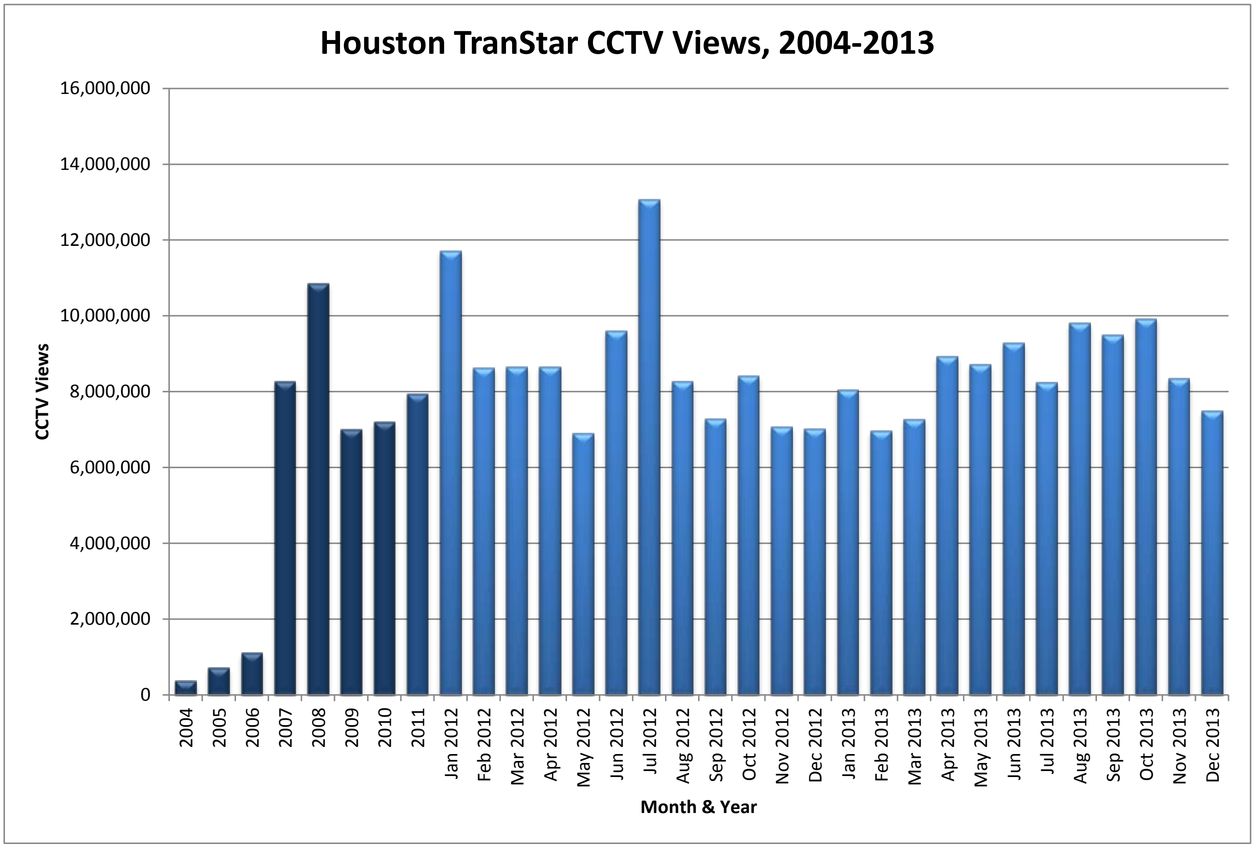
- Monthly Webpage accesses in 2013 ranged from 8.8 to 11.7 million, with a monthly average of about 9.82 million accesses. Total Webpage accesses for the year were more than 117.8 million, down slightly from 119.4 million in 2012.

- Route builder information was accessed 2.1 million times in 2013.

- Views of CCTV images remained steady at 102.5 million in 2012 as compared to 105.2 million in 2012. Cameras showing moving snapshots showing motion remain most popular.

- Traffic alert subscribers increased from an average monthly subscriber base of 10,200 in 2013, about 4.5% higher than in 2012. A periodic effort to clean the subscriber database to eliminate those no longer reaching their email address ensures active subscriptions.

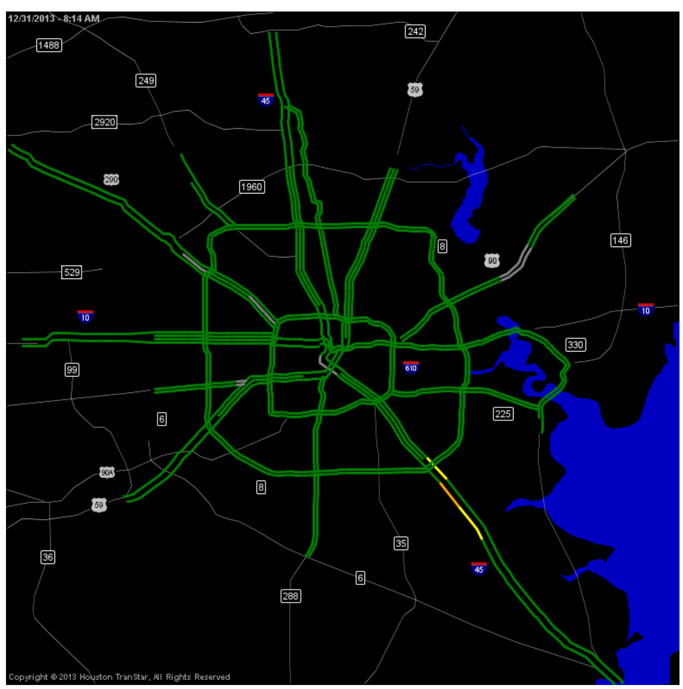
TRAVELER INFORMATION PROVIDED BY HOUSTON TRANSTAR AGENCIES



- Construction information data accesses increased in 2013 to 410,000 million accesses as opposed to 326,000 in 2012, a 25% increase.

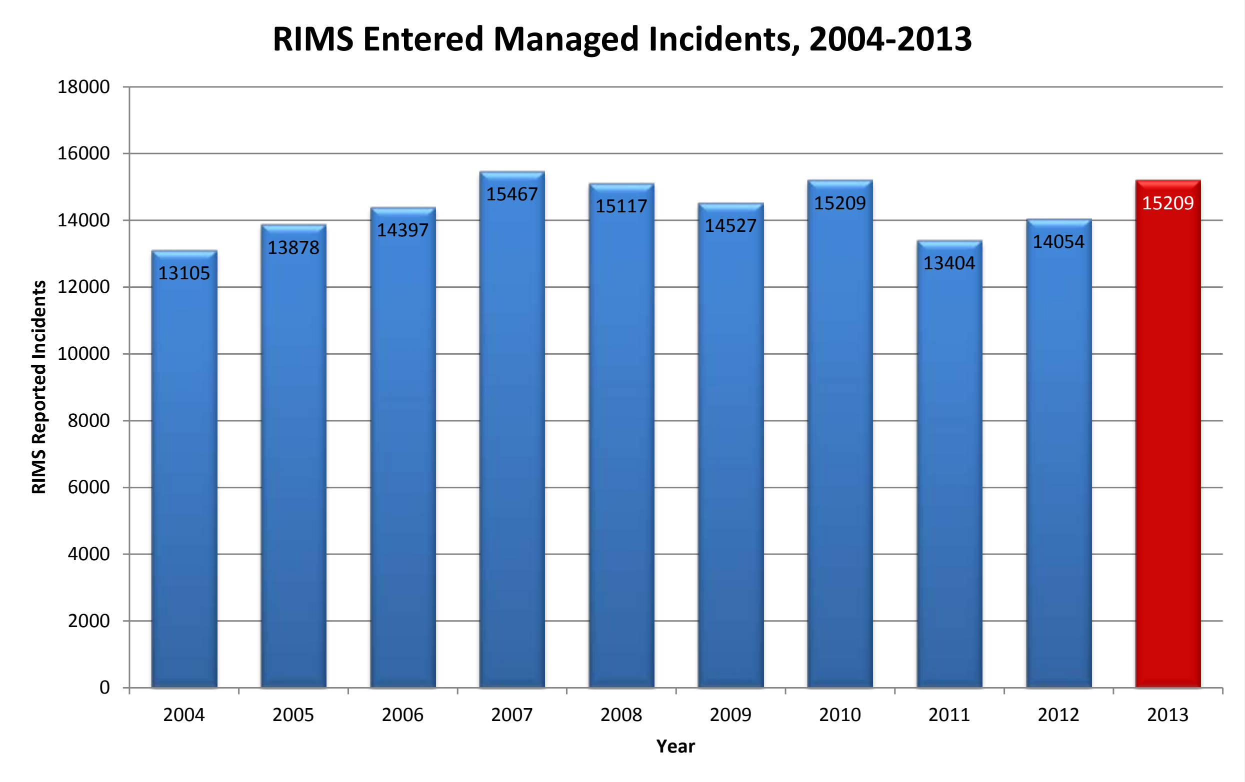
- DMS information viewed decreased by 17% from 2012 to 2013, with more than 7.6 million views.

- Speed map coverage at the end of 2013 totaled approximately 890 directional miles of travel on area freeways, tollways, and managed lanes.



INCIDENT MANAGEMENT

Detection, response, and clearing of freeway incidents are important functions of Houston TranStar, and the Houston TranStar agencies play a major role in incident response management and information dissemination. A majority of incidents are entered into the Regional Incident Management System (RIMS) operations database by agency personnel. In 2013 there were 15,209 incidents recorded by Houston TranStar operators, largely by TxDOT personnel. This is an increase of about 8.2% when compared to total incidents entered into RIMS in 2012.



Some of the incident related performance measures determined for 2013 included:

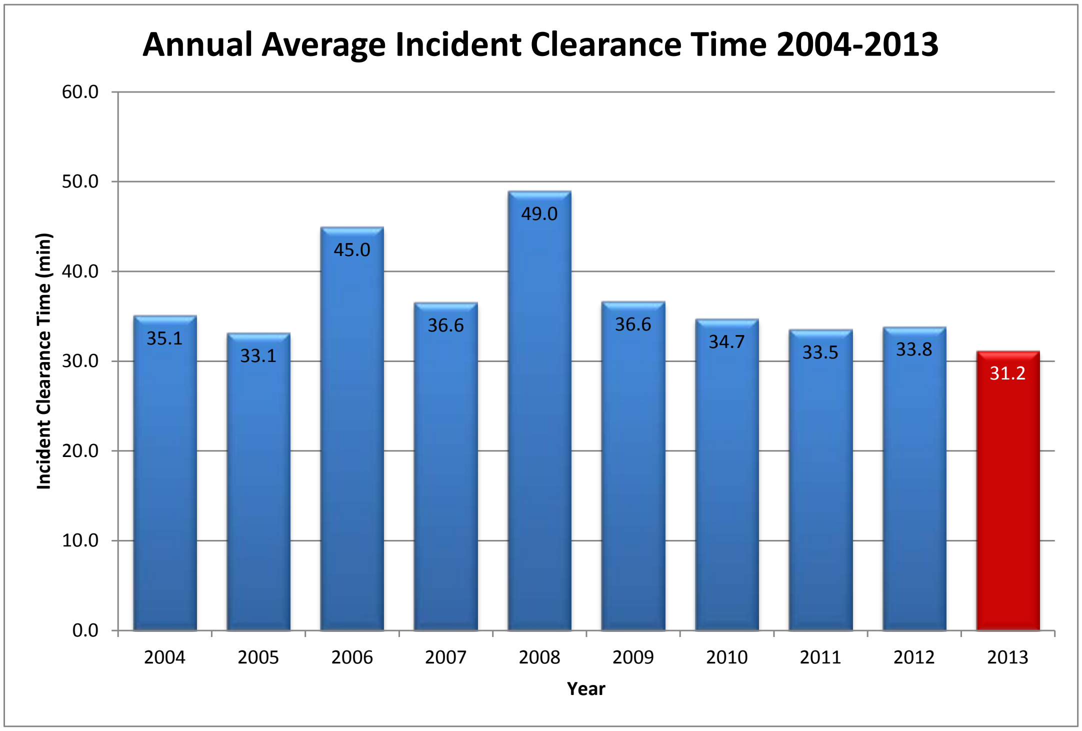
- There were 7,902 incident-hours managed from the Center in 2013 (as compared to over 7,927 in 2012), a decrease of about 0.3%.
- The average incident clearance time in 2013 was 31.2 minutes, which was about 8% lower than in 2012.

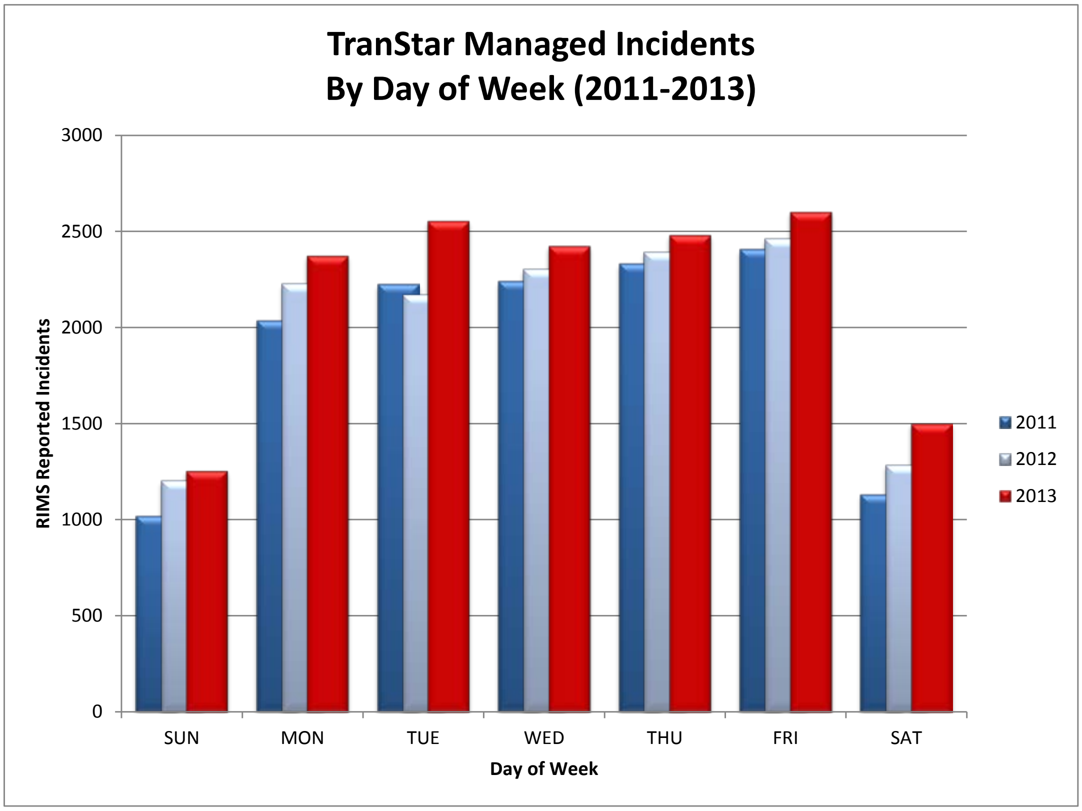
The top ten incident locations managed and/or monitored from TranStar in 2013 included:

- WEST SAM HOUSTON TOLLWAY Northbound at SOUTH SAM PLAZA
- EAST SAM HOUSTON TOLLWAY Northbound at SHIP CHANNEL/TOLL BRIDGE
- WEST SAM HOUSTON TOLLWAY Southbound at CENTRAL PLAZA
- WEST SAM HOUSTON TOLLWAY Southbound at SOUTH SAM PLAZA
- NORTH SAM HOUSTON TOLLWAY Westbound at NORTH SAM PLAZA
- WEST SAM HOUSTON TOLLWAY Northbound at CENTRAL PLAZA
- NORTH SAM HOUSTON TOLLWAY Eastbound at NORTH SAM PLAZA
- IH-45 GULF Northbound at US-59 EASTEX
- IH-45 GULF Northbound at I-610 SOUTH LOOP
- IH-610 WEST LOOP Northbound at US-59 SOUTHWEST

INCIDENT MANAGEMENT

RIMS incident locations and status are automatically provided on the traffic Website. Operators develop and activate DMS messages providing information on the incident (e.g., traffic direction, location, type incident, lanes blocked) to motorists at the roadside.





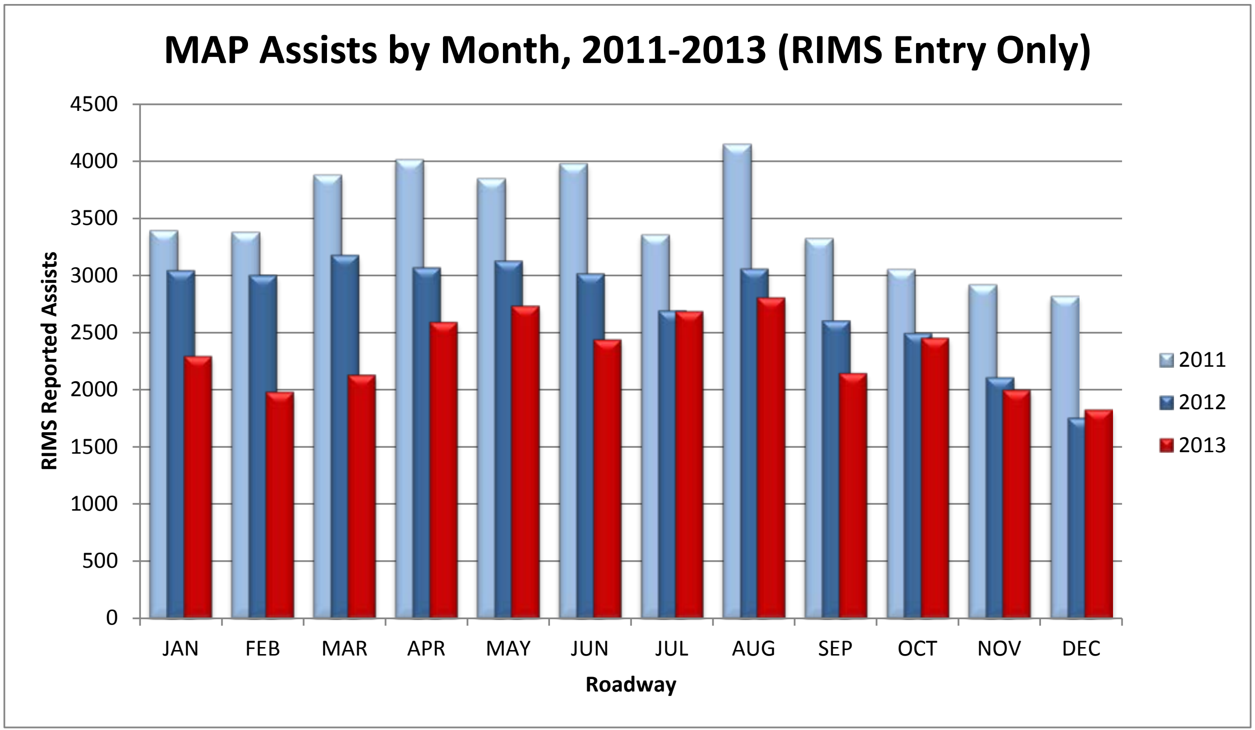
INCIDENT MANAGEMENT

Motorist Assistance Program (MAP)

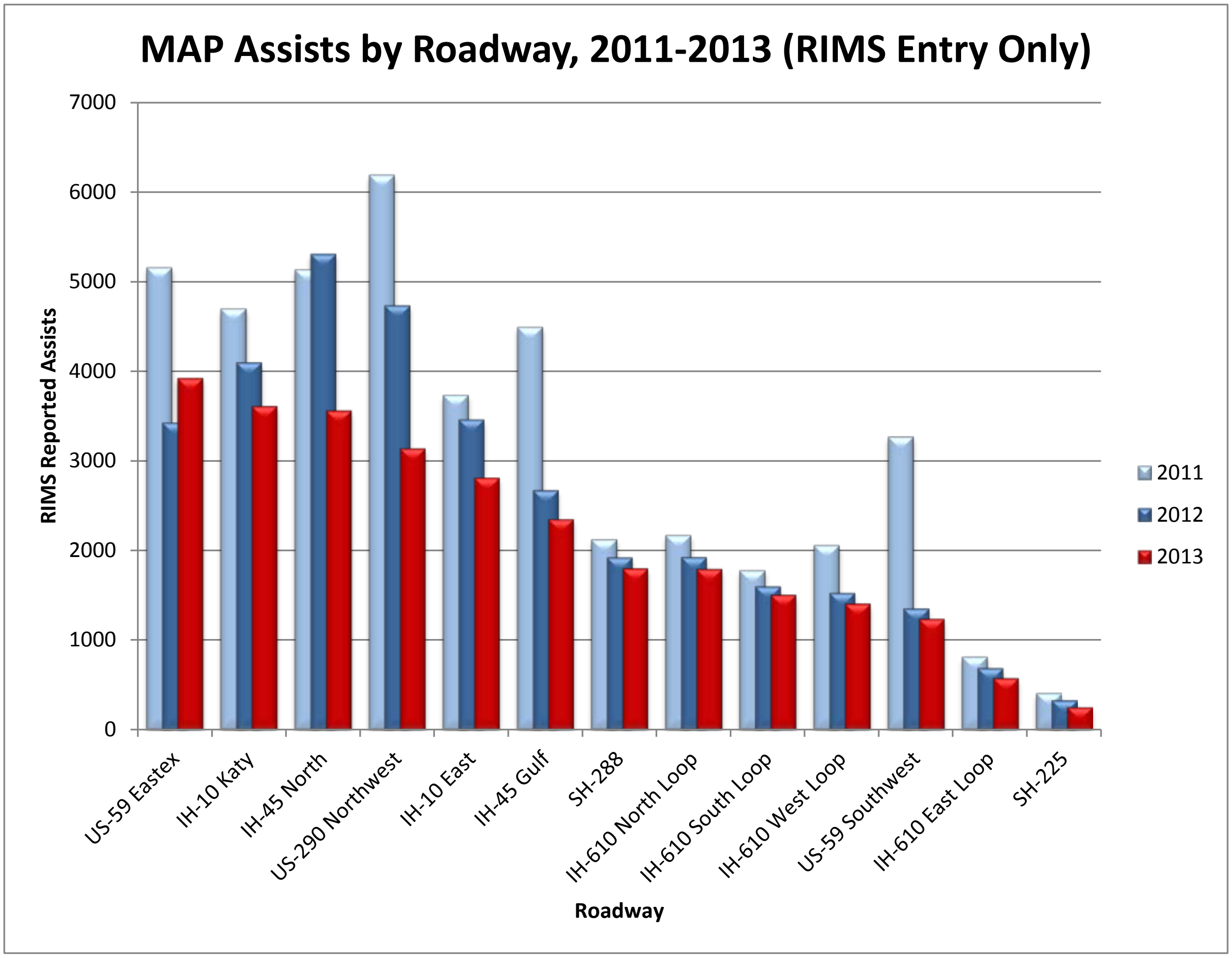
The Motorist Assistance Program (MAP) continues to be one of the most visible services operated by the Houston TranStar agency partnership.

MAP started in 1986 with two vans operating eight hours per day. The program has expanded significantly since, operating 16 hours per day on all major freeways, Monday through Friday. The program was expanded in 2005 to include the participation of METRO Police in addition to Harris County Deputies. In 2008, METRO replaced METRO Police with METRO civilian staff members to participate in MAP activity.

There were 28,124 RIMS-reported assists handled by MAP in 2013, a decrease of about 15% from 2012. The decrease was likely due to staffing reductions in the program. The RIMS-reported MAP assists are for Harris County Deputy MAP activity only. METRO reported an additional 3,211 assists, but those are not currently entered into RIMS, the TranStar Incident Database. TxDOT operators provide dispatch service to the MAP program.



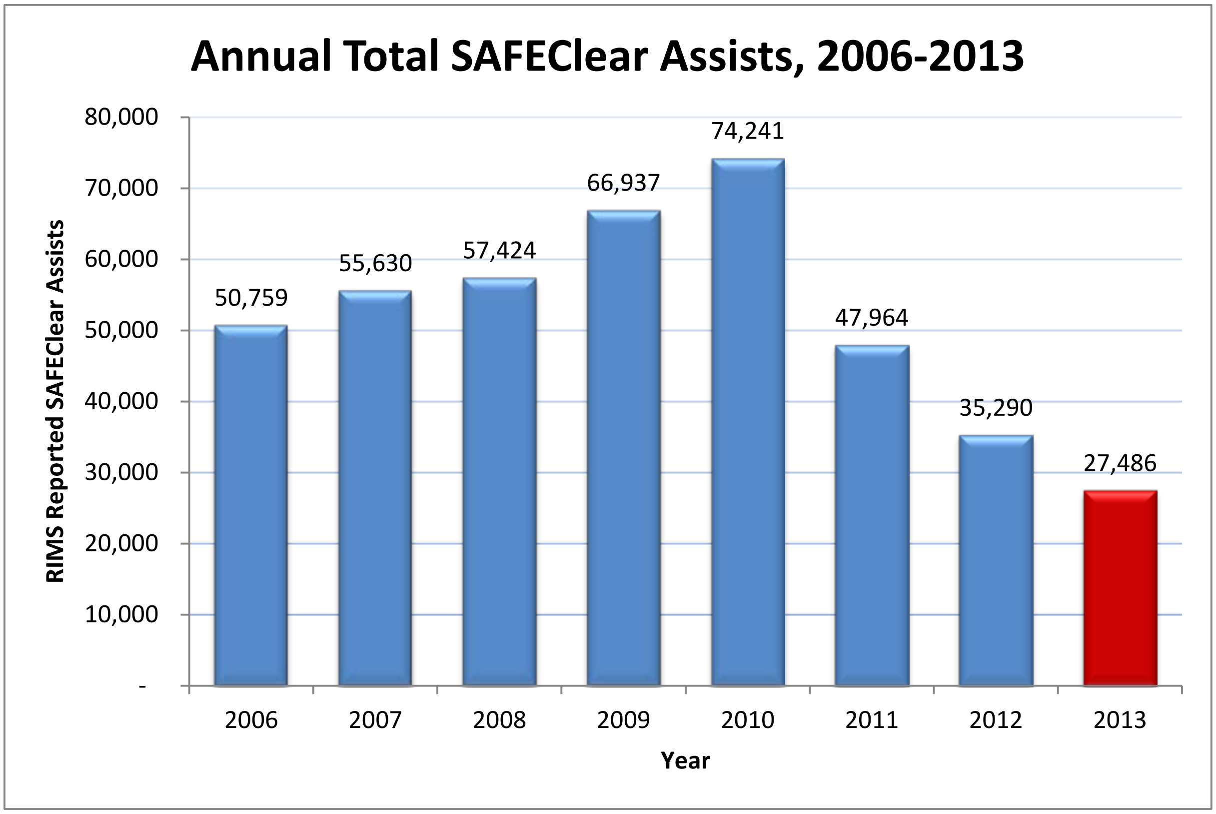
INCIDENT MANAGEMENT



INCIDENT MANAGEMENT

SAFEClear

SAFEClear, the City of Houston's rapid clearance program, was instituted in 2005. SAFEClear is intended to bring quick response to disabled vehicles to reduce the occurrence of secondary crashes in the freeway queue. There were 27,486 RIMS reported SAFEClear assists in 2013; a decrease of 22% from 2012 levels. In 2013, the average time from tow authorization to clearance was 48.4 minutes.



BENEFITS

This report develops estimates of those benefits which are quantifiable, such as the cost of motorist delay savings (in time and dollars), fuel savings (in gallons and dollars), and emissions reductions (in tons of emissions). However, determining the benefits of Houston TranStar is treated conservatively because many benefits are not easily quantifiable and some are intangible.

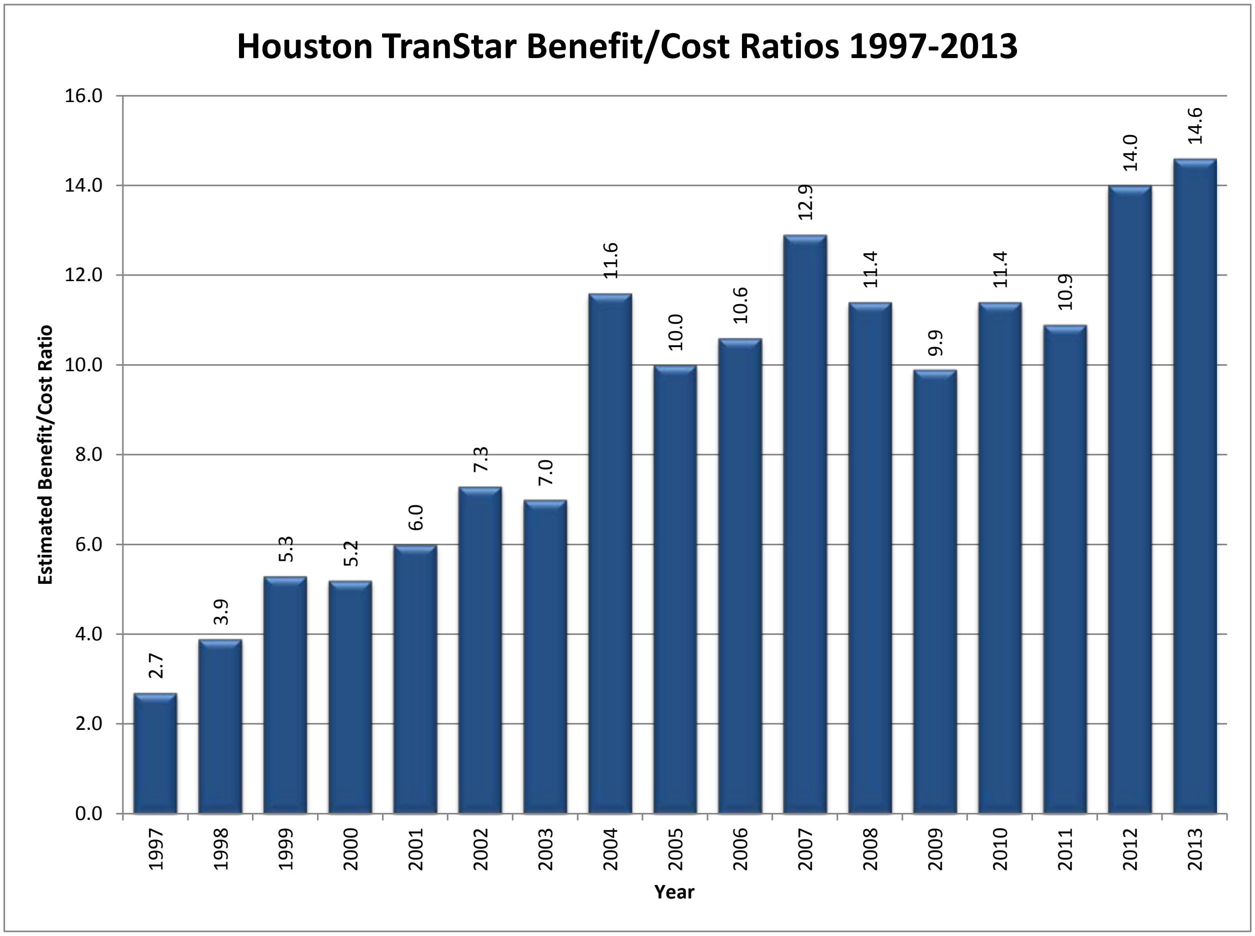
For the past 17 years, this report has used an approach which estimates the operational benefits in terms of freeway motorist delay savings. Traffic delays on the freeway mainlane system were estimated using the TxDOT travel time monitoring system and traffic volumes from the TxDOT annual volume-roadway inventory files and from HCTRA on the toll road system. The procedure for evaluation uses national benchmarks and experience to establish Houston TranStar quantitative goals for expected benefits. The expertise of Houston TranStar staff is relied upon to estimate performance of the transportation systems in terms of percent attainment of the goals.

The estimated costs of congestion in the Houston TranStar monitored region were calculated to be just under $863 million in 2013. Annual benefits in the reduction of travel time were estimated to be more than 15.6 million vehicle-hours with an estimated monetary benefit of over $340 million. The saving in travel time is equivalent to reducing fuel consumption more than 29.2 million gallons, which results in an additional savings of about $98.9 million. Thus, the total 2013 motorists' savings was in excess of $438 million. Since 1997 (when benefits were first estimated), Houston TranStar has saved Houston area motorists over $3.9 billion in reduced traveler delay and fuel costs.

An estimated reduction in the amount of fuel consumed would also result in a reduction of mobile source exhaust emissions. Based on USDOT Bureau of Transportation Statistics, the reduction of 29.25 million gallons of fuel is equivalent to an estimated reduction of 632 tons of hydrocarbons; 4,085 tons of carbon monoxide; 258,570 tons of carbon dioxide, and 919 tons of nitrogen oxides.

A benefit/cost analysis for 2013 was performed, comparing the benefits discussed previously to the annual costs of Houston TranStar. Annual costs include annualized capital costs, annual operational costs of the Houston TranStar systems, and the annual cost of operation and maintenance of the field installations. The annualized cost estimate of $30.14 million is divided into the annual benefit estimate of $438.9 million, yielding a 2013 estimated benefit/cost ratio of 14.6. Since 2004, the benefit/cost ratio of Houston TranStar has ranged from 10.0 to 14.6.

BENEFITS



Several factors enter into this calculation when comparing 2013 to previous years:

- The motorist value of time increased from $21.42 per vehicle-hour in 2012 to $21.75 in 2013.
- The annual average cost of fuel in the Houston area decreased 3.4% in 2013 as compared to 2012, from $3.50/gal in 2012 to $3.38/gal in 2013.
- The largest factor in the increased B/C ratio in 2013 was the significant increase in congestion in the Houston region as the economy gained strength and population growth accelerated. As congestion increases, the benefits of quick incident clearance and traveler information become realized as traffic operations becomes critical to keep traffic moving as smoothly as possible.

ACRONYMS

TxDOT	Texas Department of Transportation
METRO	Metropolitan Transit Authority of Harris County
HCTRA	Harris County Toll Road Authority
RIMS	Regional Incident Management System
TEEX	Texas Engineering Extension Service
PIO	Public Information Officer
FEMA	Federal Emergency Management Agency
CTMS	Computerized Traffic Management System
CCTV	Closed Circuit Television
DMS	Dynamic Message Sign
HAR	Highway Advisory Radio
AVI	Automatic Vehicle Identification
HOV	High Occupancy Vehicle
MAP	Motorist Assistance Program
PEAT	Patron Emergency Assist Team
TSTOP	Traffic Signal Optimization Program
HCPID	Harris County Public Infrastructure Department
HCOHSEM	Harris County Office of Homeland Security and Emergency Management
EOC	Emergency Operations Center
CERT	Citizens Emergency Response Team
RWIS	Roadway Weather Information System
USDOT	United States Department of Transportation