

Analysis, Modeling and Design for Traffic Incident Management Systems

Research Proposal Submitted to:
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Title

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Principle Invstigators

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Problem Statement

Traffic incidents are non-recurring planned or accidental events that generally cause delay due to congestion as well as safety hazards (FHWA [2000], Kutz [2003], Ozbay and Kachroo [1999]). The planned events can be sports events, concerts, or some road maintenance or reconstruction events. The accidental events include crashes, spills and disabled vehicles.

Due to rapid growth in recent years, the Las Vegas Area is now experiencing considerable congestion even outside the normal peak periods. An estimate of user costs for a one hour closure on I-15 in the peak direction during the afternoon peak hour is approximately \$240,000. This estimate cost does not include the traffic that would be caught in the queue that would propagate nearly 10 miles. The user cost of vehicles trapped at interchanges including cross street traffic is not included, nor the cost of drivers *rubber necking* in the opposite direction. Finally, this user cost does not include the impact of the time needed for traffic stream to recover once the closure is removed. This recovery time will extend beyond the end of the peak period. The total cost could be three-fourths of a million dollars for one hour closure.

Incidents result in reduction in the operational efficiency of the transportation network which lead to costly delays for the travellers, increased risk of secondary incidents, and also safety risks to the incident responders.

Designing an effective incident management system requires the study of static (including geometric) and dynamic local characteristics of traffic, freeway and arterial traffic control architecture, and the structure of various organizations involved. Regional incident management requires the coordination of many agencies and technologies. The report produced by Iteris (ITERIS [2008]) provides the summary of existing institutional relationships which includes operational agreements between various agencies for the Las Vegas area. In order to evaluate the current state of incident management in the area, the document used many publications such as (Meyer-Mohaddes-Associates [2005], NDOT [2005]) and also the following:

- Highway Agreement with RTC, NDOT and NHP number R760-03-016
- RTC Incident Management Guidelines 2007
- Surveys of 1st responder agencies 2007 during development of the Guidelines 07 document.
- FAST Functional Requirements Las Vegas Area Freeway Management System January 1999

- FAST High Level System Design Draft Report May 1999
- FAST Incident Management Strategies Report March 1999
- Las Vegas Valley ITS Strategic Plan High Priority Programs Final Report 1996.

The report clearly shows the responsibilities of various organizations during the process of incident management. The agencies include: (1) Department of Safety - Nevada Highway Patrol (NHP), (2) Las Vegas Metropolitan Police Department (PD), (3) North Las Vegas Police Department (NLVPD), (4) Nevada Department of Transportation District 1, (5) Clark County Environmental/Risk Management, (6) RTC Freeway Arterial Transportation System (FAST), (7) Clark County Office of Emergency Management and Homeland Security, (8) Clark County Fire Department (CCFD), (9) Clark County Maintenance, (10) City of Henderson Police Department (CHPD), (11) Clark County Regional Flood Control District (RFCD), (12) RTC of Southern Nevada, and (13) Citizens Area Transit (CAT).

The Incident Management Strategies Draft Report (1999) shows that incident management is the key reason for the existence of the FAST system. The ITS architecture plan (Meyer-Mohaddes-Associates [2005]) shows the central role of the FAST system in the incident management process. This role is shown in figure 1 taken from the same document.

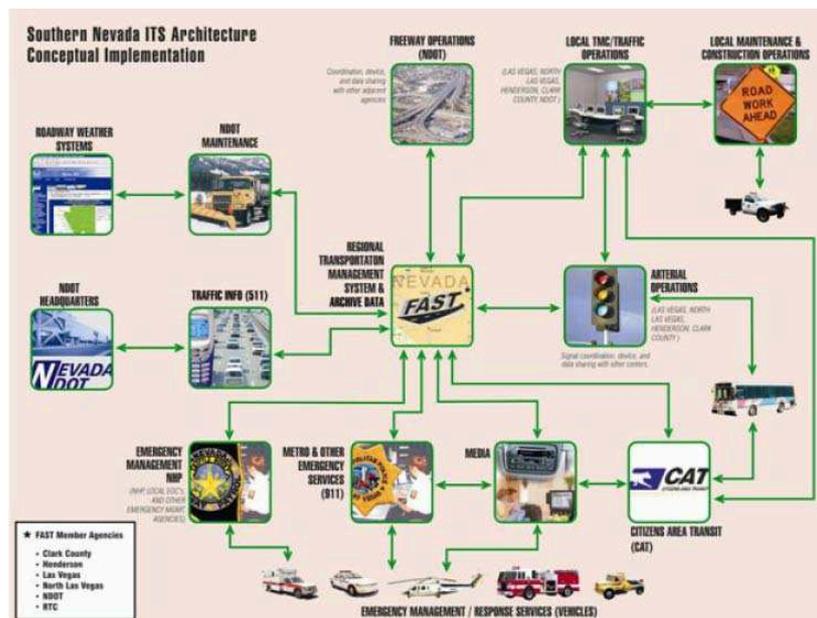


Figure 1: Southern Nevada Conceptual Architecture Implementation Diagram

The Iteris report (ITERIS [2008]) further shows how agencies coordinate the incident management process in this area during the following stages: (1) Incident Detection, (2) Incident Verification, (3) Emergency Response, (4) Site Management, (5) Incident Clearance, and (6) Motorist Information. The report summarizes the future challenges for incident management and lists the following goals:

1. Enhanced coordination, cooperation and communications of responding agencies during traffic incident management.

2. Reduce the Number and Severity Rate of Traffic Incidents on Freeways in the Las Vegas Region; increase safety at the scene.
3. Improve technology and use of technology in traffic incident management and traffic congestion.
4. Improve consistency, accuracy and timeliness of traffic incident management and congestion information to the public
5. Increase funding (grants, etc.) and utilize available resources in the region to facilitate meeting goals and objectives for traffic incident management.

The aim of incident management system is to minimize the total delay experienced by travellers and also to keep the whole operation safe. In order to achieve these two goals, the system should make optimal choices and use optimal designs. For the design of optimal solutions, appropriate mathematical models are needed for various tasks, and then mathematical techniques need to be developed. The mathematical models, their analysis and then optimal solutions can help in a decision support system framework for the overall incident management. As examples of this, we can use graph theoretic methods with real-time traffic information to find out the best alternate route for traffic diversion after an incident. Moreover after an incident occurs, signal timings for signalized intersections or ramp meters might have to be changed to respond to the transient traffic patterns. Since these patterns are non-recurring, the signals would have to be able to respond to real-time traffic demands to bring the traffic to pre-incident level in minimum time possible.

Background Summary

Incident Management is an integral part of freeway and arterial traffic operations. It is designed to alleviate the problems associated with traffic incidents. It generally includes (FHWA [2000]):

- *Incident detection*: This can occur in many ways such as
 - Cell phone calls from motorists
 - Closed circuit TV cameras viewed by operators
 - Automatic Incident Detection Algorithms (AID)
 - Motorist aid telephones or call boxes
 - Police patrols
 - Aerial surveillance
 - Department of transportation or public works crews reporting via two-way radio
 - Traffic reporting services
 - Fleet vehicles (transit and trucking)
 - Roaming service patrols

- *Incident Verification*: Incident Verification involves confirmation that the incident has taken place. This can be accomplished many ways such as:
 - Closed circuit TV cameras viewed by operators
 - Dispatch field units (e.g., police or service patrols) to the incident site
 - Communications with aircraft operated by the police, the media, or an information service provider
 - Combining information from multiple cellular phone calls
- *Motorist Information*: This involves communicating information about the incident to drivers. This is done using technologies such as:
 - Commercial radio broadcasts
 - Highway advisory radio (HAR)
 - Variable message signs (VMS)
 - In-vehicle or personal information or route guidance systems
 - Television traffic reports
 - Internet
- *Response*: This involves dispatching appropriate equipment, personnel, and activating the required communication links.
- *Site Management*: This involves managing resources on site in real-time following proper pre-determined protocols and policies. It usually involves following a formal command system, incident command system (ICS).
- *Traffic Management and Control*: This involves coming up with alternate routes, dispatching personnel for traffic management if necessary and then managing traffic control devices to alleviate congestion.
- *Clearance*: This involves removal of any objects that might impede normal traffic flow at the site.

The different stages of incident management process and how those effect the traffic flow are shown in figure 2. The figure shows how using a good incident management plan reduces the total delay for travellers when the time taken for incident detection, response, clearance, and recovery are all reduced, and also when traffic diversion is used.

Proposed Research

Objective

The major aim of this project is to develop mathematical models, perform analysis, develop simulations, and then apply those to assist decision support system for incident management

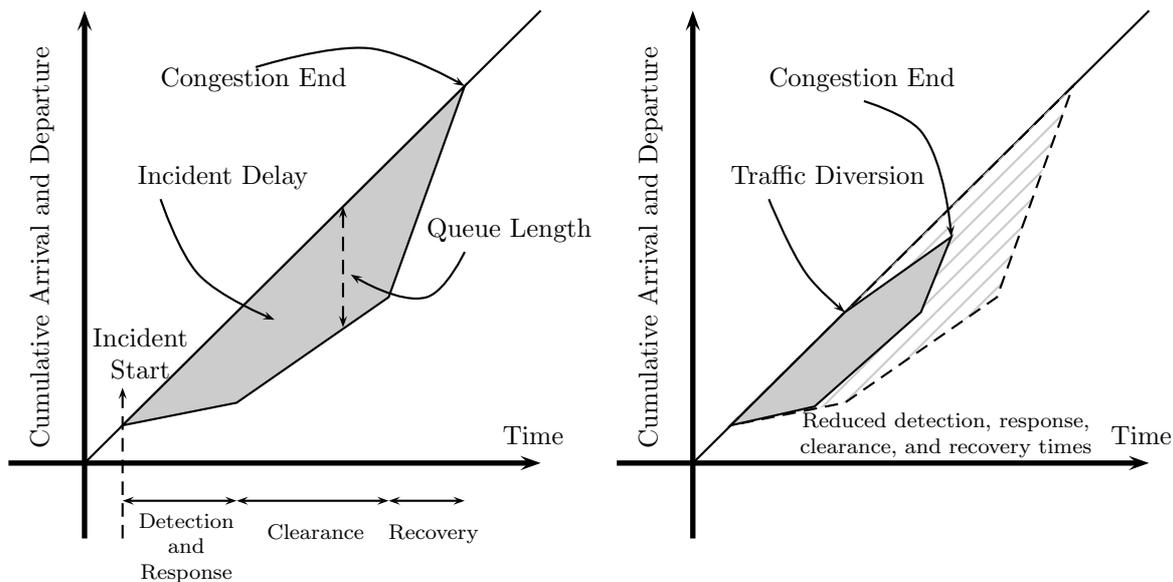


Figure 2: Traffic Impact of an Incident without and with Incident Management

in the Las Vegas area. In order to implement the system the project will get a handle on the local state of the art on Incident Management; will study alternate designs for incident management and then design a system that focuses on the details of field implementations and operations. This system will involve the collaboration with various agencies in Clark County such as RTC of Southern Nevada, Nevada DOT and Nevada Highway Patrol through FAST, and their consultant ITERIS. Additional collaboration will occur with local agency first responders and the private towing industry.

Research Proposed

Tasks related to the research include the following:

1. Identify the ITS infrastructure availability for detecting the location of incidents and re-routing traffic
2. Evaluate public communications and education regarding incidents
3. Determine the availability of ITS elements for communicating to the public those locations where incident are more likely to occur
4. Obtain a system level mathematical model for the purposes of incident management; analyze the model; validate the model with data; develop a simulation model. Perform studies with this simulation model.

The proposed tasks will be performed with close coordination with ITERIS.

ITS Infrastructure for Detection, Information Dissemination and Traffic Control

ITS infrastructure needed for incident management includes sensors for monitoring, computers and processors, as well as traffic controllers and communication systems. The sensors for traffic detection can include the following (FHWA [2000]):

- Inductive Loop Detectors
- Magnetometer Detectors
- Microwave Radar
- Infrared Detector
- Ultrasonic Detector
- Video-Image Detectors
- CCTV
- Vehicle Probes
- AVI and AVL systems

Incident detection algorithms are used for automatic detection of algorithms. Information about the incident is communicated to the motorists using the following methods.

- Variable Message Signs (VMS)
- Highway Advisory Radio (HAR)
- Automated HAR (AHAR)
- Wireless Phone Hotlines
- Commercial Radio

Pretrip information is provided by the following means.

- Kiosks
- Television
- Pagers
- PDAs
- Internet

Traffic control elements that are related to incident management include the following.

- Traffic Signal Timing Adjustments

- Ramp Control
- Traffic Diversion

Other technologies beneficial to incident management include

- Computer Aided Dispatch
- Traffic Signal Preemption for Emergency Vehicles
- Mayday Systems

Mathematical Models, Analysis, and Design

Kachroo has performed research on many elements of mathematical theory of traffic dynamics and control for more than a decade. This has resulted in dozens of research papers (Kachroo et al. [1996, 1998b], Ozbay and Kachroo [1998a,b], Wu et al. [1998], Kachroo et al. [1998a], Ball et al. [1999b,a], Ozbay et al. [2002, 2004], Kachroo and Ozbay [2005, 2006], Kachroo et al. [2008b]) and many books (Ozbay and Kachroo [1999], Kachroo and Ozbay [1999, 2003], Kachroo et al. [2008a]). The mathematical models of traffic that are used for traffic control are taken to be based on macroscopic traffic behavior. Hence our work will be based on macroscopic traffic dynamic modeling for traffic diversion, ramp metering, and speed control. For signalized intersection, queuing models are appropriate for control designs. For simulation purposes macroscopic or microscopic models can be used to test design and alternatives. Mathematical models of specific locations at Las Vegas will be carried out in detail in this research, so that we can design controllers and then test using simulations. For purposes of finding alternate routes in a network graph theoretic techniques will be built to solve network related optimization problems. We can also design stochastic methods to analyze the *safety condition* of a location. This can be done using a Bayesian approach (Pourret et al. [2008]). This will be a completely new technique that the P.I.s will build during this project. It will use all the static and dynamic features of a location, and then using a Bayesian network approach evaluate the total probability of accidents at a site. In summary, the following specific tasks will be performed:

1. Mathematical Model of Incident Locations at Las Vegas
2. Analysis of those Models
3. Network Analysis and Dynamic Alternate Route Generators Designed
4. Traffic Control Designs for those locations
5. Simulations for the Control Designs
6. Design of Bayesian Safety Analyzer (BSA)
7. Software Development for BSA

The macroscopic mathematical models are based on the conservation law (see figure 3)

$$\frac{\partial}{\partial t}\rho(t, x) + \frac{\partial}{\partial x}[\rho(t, x)v(t, x)] = 0 \quad (1)$$

combined with a fundamental relationship between traffic density and traffic speed, such as the Greenshield's law

$$v(\rho) = v_f(1 - \frac{\rho}{\rho_m}) \quad (2)$$

Here ρ is the traffic density, v is the traffic speed, ρ_m the traffic jam density, and v_f the traffic free flow speed.

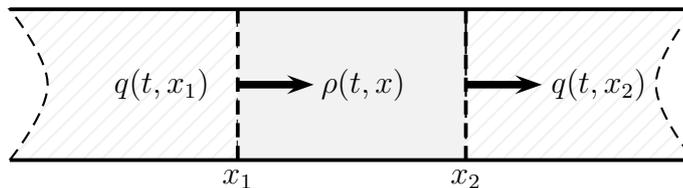


Figure 3: Conservation Law

This relationship is shown in figure 4. Using these relationships on networks we can design feedback based optimal traffic diversion strategies, and ramp metering techniques.

The details of these design techniques are shown in (Ozbay and Kachroo [1999], Kachroo and Ozbay [1999, 2003], Kachroo et al. [2008a]).

Anticipated Benefits

Having an incident management system that can minimize the temporal, special, human, and financial costs to the system has great benefits to all the stake holders involved. There are benefits especially to highway travelers in terms of lives saved, number of injuries reduced, travel time delay reduced and vehicle operating cost saved. There are also benefits to the involved agencies in terms of roadway better efficiency and effectiveness. The agencies that will be benefited include Nevada Highway Patrol, NDOT, RTC and numerous local government offices. This is urgent because of the unsafe conditions incidents create that can lead to secondary crashes which will likely cause more fatalities and/or injuries.

Implementation Plan

Most of the preliminary tasks include identifying the ITS infrastructure availability in Southern Nevada and their usefulness. These will be documented properly and presented in the

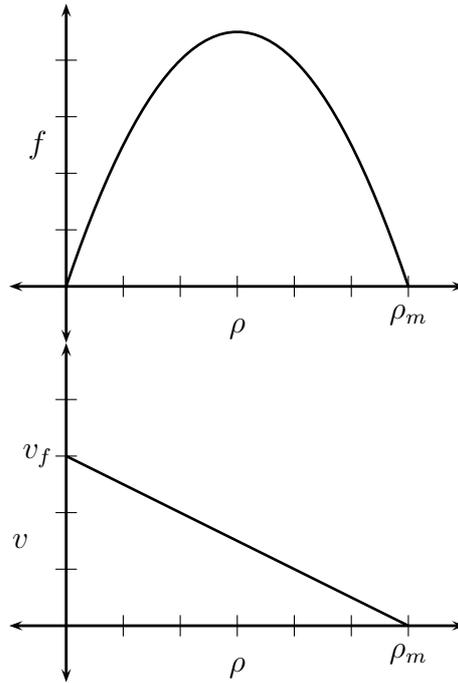


Figure 4: Fundamental Diagram using Greenshield Model

final report. Mathematical models will be developed and validated using local data to make sure that they are adaptable to local data. All these steps will be followed per schedule and will be reported to NDOT on timely basis.

Duration/Schedule

The anticipated duration for this project is 18 months, starting October 1, 2008 and ending on March 31, 2010. Tentative schedule of completion of major tasks are shown in table 1.

Facilities

The research will be carried out at the Transportation Research Center (TRC) at UNLV. TRC lab has most of the required hardware, software, and computer resources required for the successful completion of the project. UNLV library has access to most of the leading of the journal publications and a huge inventory of text books. TRC lab is equipped with simulation software packages, such as, CORSIM, Transyt-7F, and HCS. TRC lab also has hardware materials required for successful completion of the project. The lab has also obtained ITS related hardware and software to enhance its capabilities in that area. The following lists show the hardware and software in the lab.

Table 1: Project Schedule

Tasks	Month																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Literature Review	X	X	X	X	X	X	X	X	X	X	X	X							
Identify ITS Infrastructure	X	X	X	X															
Evaluate Communications	X	X	X	X															
ITS for Communications	X	X	X	X															
Analyze Model					X	X	X												
Validate Model								X	X	X									
Simulate Model											X	X	X	X					
Study with Simulations													X	X	X	X			
Draft Final Report																		X	
Final Report																			X

Hardware

- Short range and long range communication systems
- Vehicle and pedestrian detection and counting systems
- Embedded system development boards for ITS
- Laboratory kits for transportronics
- Complete control design development platform from National Instruments for Advanced Controller Design
- Hardware for Mobile Data Collection

Software

- Software for data analysis and simulation
- Software for GIS and mapping
- Software for animation and graphics
- PCs for data collection, analysis and
- PCs for hardware development, and web and data services

NDOT Involvement (Other Divisions)

Active involvement from NDOT staff would enable the researchers to complete the project successfully. It is anticipated that key NDOT representatives will serve on the Technical Advisory Committee (or Panel) for the project. Interaction with the Las Vegas Traffic Incident

Management (TIM) Coalition group is essential during the project. Since this project involves interacting with various agencies other than NDOT, such as, RTC of Southern Nevada, FAST, Cities of Henderson, Las Vegas, and North Las Vegas, Nevada Highway Patrol, Las Vegas Metropolitan Police Department, North Las Vegas Police Department, and Henderson Police Department, NDOT's support in coordinating with these agencies will be the key to the success of the project. Suggestions and advice from NDOT staff during the duration of the project is essential in delivering a quality product that would be of value to NDOT.

Short Bio of Key Personnel

Pushkin Kachroo, Ph.D., P.E.

Pushkin Kachroo is the co-director of the Transportation Research Center and the University Transportation Center at UNLV. He is also a Professor in the Department of Electrical and Computer Engineering at UNLV. He received his Ph.D. from University of California at Berkeley in Mechanical Engineering 1993, his M.S. from Rice University in Mechanical Engineering in 1990, and his Bachelors' degree in Civil Engineering from Indian Institute of Technology, Bombay in 1998. He also has an additional M.S. and Ph.D, both in Mathematics that he received in 2004 and 2007 respectively from Virginia Tech. He obtained the P.E. license in Electrical Engineering from the State of Ohio in 1995. He was an Associate Professor in the Bradley Department of Electrical & Computer Engineering at Virginia Tech until 2007. He was a research engineer in the Robotics R&D Laboratory of the Lincoln Electric Co. from 1992 to 1994, after which he was a research scientist at the Center for Transportation Research at Virginia Tech for about three years. He has written six books (Feedback Control Theory for Dynamic Traffic Assignment, Springer-Verlag, 1999, Incident Management in Intelligent Transportation Systems, Artech House, 1999, Feedback Control Theory for Ramp Metering in Intelligent Transportation Systems, Kluwer, 2003, Mobile Robotic Car Design, McGraw Hill, 2004, Practical & Experimental Robotics, 2007, and Pedestrian Dynamics: Feedback Control of Crowd Evacuation, 2008), three edited volumes and overall about eighty publications including journal papers. He has been the chairman of ITS and Mobile Robotics sessions of SPIE conference multiple times. His research interests are in theory and applications of traffic and vehicle control, transportation systems and traffic dynamics. He received the award of "The Most Outstanding New Professor" from the College of Engineering at Virginia tech. in 2001, and Dean's Teaching Award in 2005.

Vinod Vasudevan, P.E.

Mr. Vinod Vasudevan is an Associate Research Engineer at the Transportation Research Center at the University of Nevada, Las Vegas (UNLV). He earned his Masters degree in Transportation Engineering from UNLV in the year 2003. Mr. Vasudevan is enrolled for his Ph.D. program and expects to complete it by Fall 2008. His areas of interests include traffic engineering, transportation planning, traffic safety, and, transportation financing. He is a registered Professional Engineer (Civil) in Nevada. Mr. Vasudevan currently serves as Vice-President of Nevada Chapter of Institute of Transportation Engineers (ITE). Mr. Vasudevan

has served as member of technical committees and reviewer for organizations such as the Transportation Research Board and the Institute of Transportation Engineers.

Rita Brohman

Ms. Rita Brohman is a Senior Project Manager with ITERIS, Inc. Ms. Brohman has more over 20 years of comprehensive experience in project and program management, public outreach, transportation planning, executive training and business management. She has dedicated the past 15 years to managing Intelligent Transportation Systems (ITS) projects and developing various elements of training in the area of ITS Architecture, maintenance and systems management for ITS. Ms. Brohman is a long-standing member of the National ITS Architecture Team providing ongoing Architecture development to the FHWA for the National ITS Architecture. Much of her overall career focus has been in program implementation management, outreach to the public while building stakeholder consensus and coordination, communications, technical and systems analysis, ITS evaluation and presenting project results. She has a demonstrated acute ability in presenting complicated ITS Architecture, legislative, engineering and other transportation issues in an understandable format to professionals and the public at all levels of involvement. In 1997, Mrs. Brohman was an Outstanding Young American award recipient, honoring exceptional individuals achievements.

Erin Breen

Erin Breen has been the director of the Transportation Research Center's Safe Community Partnership for the past 12 years. Although her background is in special education, Ms. Breen made the transition from classroom education to community education, much to the benefit of the residents of Clark County.

During her tenure, Ms. Breen has directed successful campaigns educating literally every facet of the population in the county. Successful campaigns in pedestrian safety, impaired driving alternatives, teen driver education, seat belt and child safety seat education and many more have made Clark County streets safer for all who use them.

Ms. Breen joins the team to assure the community will receive the education messages developed through this project. Outreach will be conducted through mixed media messages along with neighborhood meetings to introduce each area to the information. Partner agencies and programs of the partnership will be utilized to help deliver the education along with public service campaigns developed and distributed to all local media outlets.

Ms. Breen has been invited to present on a variety of safety topics at conferences across Nevada and the U.S., and enjoys developing new marketing campaigns. Ms. Breen has received numerous awards for her work including the Allstate Foundation National Safety Partner award and the National Highway Traffic Safety Administration (NHTSA) National Safety Advocate award.

Budget

The budget for the proposed program is shown in figure 5. As discussed in the previous sections, this proposed project would be funded partially from UNLV University Transportation Center and NDOT. Figure 6 and figure 7 shows that divisions of the funding based on two sources (NDOT and UTC). NDOT portion is amount the project team requesting for funding from the NDOT. The details of this NDOT portion are summarized as follows:

Budget Summary

During the 2009-2011 year of the project the Personnel Salary and Wages budget includes support for efforts of the following individuals: 0.33 Full Time Equivalent months (FTE) effort by the Principal Investigator (Kachroo) during the academic year/summer, 1.30 Full Time Equivalent months (FTE) effort by the Co-Principal Investigator (Vasudevan) during the academic year/summer, 0.30 FTE by Research Engineer (Peck), 0.30 FTE by outreach program manager (Breen), 0.30 FTE effort by Grants Coordinator (DuBois), one Graduate student providing 9.00 FTE effort, and an undergraduate student providing 9.00 FTE effort directed towards the project. These may possibly be as an overload or extra contractual compensation. All personnel costs are based on the projected salaries for the 2008-2009 at UNLV, and with an increase for the fiscal year (2009-2010) at UNLV (note that the UNLV fiscal year is from July 1 of one year to June 30 of the next year). These add up to \$48,416. Health insurance, fringe and retirement benefits are also included per existing UNLV policies and they total \$6,683. The total budget for personnel is \$55,100. This does not include funds budgeted for efforts contracted to non-UNLV employees.

The travel budget estimates driving and airfare expenses required for the program. Project Investigators and/or students may travel to Reno to showcase the product, to provide updates, or to meet with project partners. The estimated cost for travel is \$1,000.

Operating expenses include research supplies, printing, photocopying, mailing/postage which is estimated for a total of \$200, computing resources for specific needs is estimated as \$600. The budget also includes \$200 for telecommunications such as telephone and fax. The total of the operating expense budget is \$1000.

This project requires a graduate student's and an undergraduate student's effort for data collection and data analysis. Full time graduate students are allowed work only 50%FTE. Therefore, 9.00 FTE is the maximum effort for a graduate student per year. Graduate tuition and fees are included in the budget at a rate of \$222 per credit for 3 credits and a fee of \$337 per student per semester. This amounts to \$4,296. The undergraduate students are paid \$12.00 and hour and the project requires 9.00 FTE of an undergraduate student. The project team will have a sub contractor, ITERIS (\$20,000), which is a private consultant company who is expert in the area of Intelligent Transportation Systems related studies and incident detection systems. The Total Direct Costs amount to \$81,396 and the Modified Total Direct Costs amount to \$77,100.

The facilities and administrative (F&A) costs are calculated at 23 percent of the modified total direct costs. This is per existing NDOT's policy and its existing agreement with UNLV. This amounts to \$17,733. UNLV's standard F&A cost is charged at a rate of 43 percent. The total budget request to NDOT is \$99,128 for the Federal Fiscal Year 2009-11.

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