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16. ABSTRACT

Knowledge about Intelligent Transportation Systems (ITS) technologies and their impacts is important for understanding and applying them and the realization of their benefits. The ITS Decision website was created to provide ITS information and analysis tools. Phase IV of the research project focuses on the design, updating of information, and tool development for the ITS Decision website. The website provides a comprehensive overview of the deployment of ITS technologies, products and services at local, state, national and international locations where they have been deployed. ITS Decision provides extensive information on project costs and benefits, risks and lessons learned.

This project continued the development of ITS decision making tools namely: the Expert System, Case Based Reasoning and the Cal-ITS Benefit-Cost model. Informational sections of the website (i.e., ITS Architecture and ITS Links) were updated with recent information and data. To facilitate deliberation and dialog regarding ITS, this project also developed a Wikipedia-like web tool that provides information, addresses ITS related comments, and collects feedback from transportation professionals who contribute to the ITS knowledge base. Overall, this project produced a comprehensive, robust, practical and user-friendly website that contains valuable information about ITS as well as decision support and analysis tools.

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ITS Decision: Gateway to Understanding and Applying Intelligent Transportation Systems

Phase IV: Expert System Tool Development, Case-Based Reasoning Tool Expansion, Website Functionality Improvement, and Update of ITS Information Content

Final Research Report

Submitted to:

The Division of Research and Innovation
California Department of Transportation

In Partial Fulfillment of the Requirements for Contract # 65A0289

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ABSTRACT

Knowledge about Intelligent Transportation Systems (ITS) technologies and their impacts is important for understanding and applying them and the realization of their benefits. The ITS Decision website was created to provide ITS information and analysis tools. Phase IV of the research project focuses on the design, updating of information, and tool development for the ITS Decision website. The website provides a comprehensive overview of the deployment of ITS technologies, products and services at local, state, national and international locations where they have been deployed. ITS Decision provides extensive information on project costs and benefits, risks and lessons learned. This project continued the development of ITS decision making tools namely: the Expert System, Case Based Reasoning and the Cal-ITS Benefit-Cost model. Informational sections of the website (i.e., ITS Architecture and ITS Links) were updated with recent information and data. To facilitate deliberation and dialog regarding ITS, this project also developed a Wikipedia-like web tool that provides information, addresses ITS related comments, and collects feedback from transportation professionals who contribute to the ITS knowledge base. Overall, this project produced a comprehensive, robust, practical and user-friendly website that contains valuable information about ITS as well as decision support and analysis tools.

Keywords: *Expert Systems, Cased-based reasoning, Intelligent Transportation Systems, Benefits and Costs.*

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1 INTRODUCTION: UNDERSTANDING AND APPLYING ITS

There is a growing need by transportation planners, engineers, and decision makers, in the State of California, as well as at the national level, to have a reliable, up-to-date one-stop shop to learn about and understand various ITS technologies and how to best implement them. The need exists in particular at Caltrans districts and Headquarters that deal with transportation planning, traffic operations, and mass transit. Transportation system planners and operators need to learn about the state-of-deployment and lessons learned from ITS technology projects, ITS systems, and ITS user services across the U.S., and worldwide. In previous phases, ITS Decision website had paved the way to become this "information gateway," a one-stop shop providing wealth of up-to-date information and deployment lessons learned. Learning from experiences of others regarding ITS implementation prerequisites, deployment requirements, as well as its benefits, costs, roadblocks, and implementation challenges will allow better understanding of, and more efficient implementation of ITS.

The objectives of this project are to develop a comprehensive, robust, practical, integrated and user-friendly Web-based transportation planning/Decision Support tool. The project developed the ITS Decision website and provides a comprehensive overview of the deployment of ITS technologies, products and services at local, state, national, and international locations where they have been deployed. The project has continued the development of two ITS deployment decision-making tools: An Expert System (ES) and Case Based Reasoning (CBR). ITS Decision has incorporated the ES and CBR modules, as well as the Cal-ITS-BC Model as one integrated suite of ITS planning tools. Included in the website is a section on ITS Architecture and Architecture conformity and initial efforts to develop a Wikipedia-like Web tool to collect feedback from transportation professionals who wish to contribute to ITS knowledge base.

ITS Decision has been a collaborative effort of many researchers at Partners for Advanced Transportation Technology (PATH) and California Center of Innovative Transportation (CCIT) under Intelligent Transport Systems (ITS) of University of California, Berkeley, University of North Carolina, Old Dominion University, as well as several research staff at Caltrans Division of Research and Innovation. Initial development began in 1996 and content and design were subsequently revised in response to users' feedback. Former members of the research team have made numerous live group PowerPoint presentations to Caltrans and its partners. Two user surveys and two sets of usability tests have been conducted in real-world settings (at Caltrans Headquarters, District 4 offices, Oakland MTC, and few Bay Area city DOTs to obtain feedback from real-world users to improve ITS Decision as a planning tool.

Caltrans has sponsored development, maintenance and enhancement of the ITS Decision website. The website has been maintained and updated regularly with newly emerged ITS technologies, e.g., Weather Applications, Automatic Vehicle Location, Freight Operations. The website and related ITS articles updated and added resulting in a searchable database with about 600 ITS publications. Over the years, numerous inquiries by transportation practitioners in the public and private sectors about ITS Decision have been received (and responded to). Most of these inquiries came from California and other states but a good number came from outside the U.S. (Europe, South Korea, Singapore, Australia, Egypt, and the UAE). This has been an indication that ITS Decision is a reliable, well-known and used worldwide. Incoming inquiries have also indicated interest not only in acquiring data and general/specialized information about ITS, but more importantly on specific deployment issues. Planners and engineers making inquiries want to use ITS Decision to guide product development as well as commercialization, marketing, and deployment.

This phase of the project deals with further development of analytical tools that include CBR and ES, updating information about ITS available at the ITS Decision website and the creation of a Wiki tool that can enhance deliberation and debate among stakeholders/users.

2 CASE BASED REASONING TOOL

The Case-Based Reasoning (CBR) tool is meant to increase decision-makers' awareness of deployed ITS technologies and provide comparative technical information about these high-impact, feasible and cost-effective technologies. The original version of the CBR tool contained information about three technologies, which include the Automatic Vehicle Location, Employer-based transit pass program, and Freeway Service Patrols. A second phase of the project added five technologies: Advanced Traveler Information Systems, Automatic Weigh Stations, Corridor Signal Coordination, Electronic Toll Collection, and Ramp Metering. This phase of the project enhanced the existing ITS decision website by adding seven high-impact ITS technologies to the current CBR tool; these are: Adaptive Signal Control, Bus Rapid Transit, Car Sharing, Congestion Pricing, Intelligent Parking systems, Road Weather Information Systems, and Work Zone Operations Management. The expansion utilizes the theory and structures already developed for case-based reasoning. A user interested in implementing any of the technology enters parameters of the context and technology, e.g., area density and technology classification. In the Internet-based tool, users enter initial input parameters within the maximum and minimum limits provided, to avoid extreme input values. The tool then presents historical cases where the specific technology has been used. The historical cases are presented in order of their similarity scores, in accordance with their resemblance with the input parameters. Information about the mean and mode of the input parameters is also presented. The user can view attributes of each historical case by clicking on the hyperlink associated with each case. Attributes include qualitative information about the technology as well as the program's performance measures such as costs and benefits, wherein the impacts are further categorized for better evaluation. The presented information about historical cases can help planners and engineers make more informed decisions regarding ITS deployment.

The Case-Based Reasoning (CBR) tool is a computer-based knowledge management tool. It has been applied widely in various domains, including medical diagnosis, airplane production, plant pathology diagnosis, computer aided systematics, and law. It acts as an artificial intelligence agent that uses old cases (in both knowledge-rich situations and knowledge-poor situations) to apply existing information and knowledge to new contexts.

More generally, CBR is one of the decision-making methods used by human beings throughout their daily lives. For example, lawyers rely on other cases for "precedent"; doctors make diagnoses based on the similarity of symptoms to those seen in past patients to aid someone currently in their office and policy analysts generalize study results of the existing policy areas and transfer these estimates to a potential new policy site. CBR is also used every day by transportation planners and public officials who try to make decisions by drawing upon their previous experience or by learning from other communities' experience.

When used to facilitate decision-making processes, a CBR system systematically reviews and synthesizes cases in a database by taking into account the qualitative richness of the content and quantitative information, and provides results that consider similarities with the current case. This methodology has the advantage of retaining the richness of individual cases, interpreting the new case from existing studies, and finding historical cases closest to the new case.

To expand the existing CBR tool on the ITS Decision website, we utilized the structures described in the previous section to develop web-based CBR systems for seven additional ITS technologies:

- Bus Rapid Transit (BRT)
- Congestion Pricing (CP)
- Car Sharing (CS)
- Intelligent Parking Systems (IP)
- Adaptive Signal Control (ASC)
- Work zone Operations Management (WZM)
- Road Weather Information Systems (RWIS)

Visitors to the ITS Decision website can use the newly expanded CBR tool to guide them in deciding where and how to deploy these technologies. For instance, each user considering implementing an Adaptive Signal Control (ASC) is queried regarding the type of the area, the road network, traffic signal strategy and other relevant information. Based on this information, the user is presented with cases that are similar to his/her, along with information on how to make inferences about his/her case from the list of similar cases. At this point he/she can determine if ASC is an idea worth considering further.

The CBR tool can facilitate the deployment of ITS and increase awareness of ITS impacts, as well as provide structured and organized information about relevant historical cases to decision makers and potential implementers.

3 CBR TECHNOLOGY CASES

This chapter consists of seven subsections providing details of individual ITS technologies. Each subsection provides an introduction and a brief summary of the technology and its deployment status at different locations around the world. It also provides a summary of the technology's costs and benefits.

3.1 BUS RAPID TRANSIT

Bus Rapid Transit (BRT) integrates intelligent transportation technologies by providing, signal priority for buses, cleaner and quieter vehicles, electronic fare collection and integration with land use policy to improve mobility in urban environments. BRT operates on exclusive transit paths, High Occupancy Vehicles (HOV) lanes, expressways and ordinary streets. It combines the reliability associated with rail and the convenience and flexibility rendered by cars. For instance, buses that operate on an exclusive right-of-way provide a service similar to that of a metro rail line. Likewise, buses that operate on specific bus lanes or median reservations provide a service similar to that of light rail systems.

In some cities in the United States, bus transit offers a relatively low level of service compared with the automobile, and in some cases it serves people who lack alternatives. This creates an environment that results in reduced investment in buses and relatively low levels of support for bus transit. However, recent innovations, specifically, Bus Rapid Transit has caused a shift in perception, and hence decision-makers recognize that buses can provide high quality service which can attract general public as well as discretionary travelers (those who have alternative travel options). Bus Rapid Transit is considered a more affordable alternative to rail. This alternative helps in improving transit service quality and attracting travelers who would otherwise drive on congested urban corridors. This scheme was initially implemented in developing countries such as Brazil and Columbia during the 1990s, but the concept has become widely accepted by transportation planners and transit advocates throughout the world. This is not a debate between the merits of bus transit versus rail transit. Each mode is appropriate in certain circumstances (see discussion in Litman, 2004).

3.1.1 BRT Cost and Benefits

BRT is beneficial in different deployment contexts. Table 1 summarizes the costs and benefits of BRT deployment in recent times.

3.1.2 BRT Cases and the CBR Tool

If planners from a jurisdiction are considering implementing a Bus Rapid Transit (BRT) program, then they might be interested in knowing about historical cases of bus rapid transit programs implemented in other regions under similar circumstances. The Web-based BRT CBR module offers the desired information. The user has to enter initial information about the BRT program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the BRT program (number of miles, ITS technology, and population density) is shown in Figure 1.

Table 1 Summary of Benefits and Costs of BRT Deployment

Benefits	Costs
i. Reduction in passenger travel time ii. Faster service iii. Improved traveler information iv. Better marketing and improved transit's image v. A practical alternative to highway reconstruction; BRT can help in the effort to promote transit-oriented land development. vi. Because buses travel on urban roadways, infrastructure investments needed to support bus service can be substantially lower than the capital costs required for rail systems. As a result, bus service can be implemented cost-effectively on routes where ridership may not be sufficient or where the capital investment may not be available to implement rail systems. vii. Less traffic congestion viii. Less air pollution (with the use of BRT buses that run on gas)	Facility development costs reflect the time, type, and complexity of construction. Estimated costs can include: i. $272 million per mile for bus tunnels ii. $7.5 million per mile for bus ways iii. $6.6 million per mile for arterial median bus-ways iv. $4.7 million per mile for guided bus operations v. $1 million per mile for mixed traffic or curb bus lanes Operating costs for BRT service are influenced by wage rates (of transit employees) and work rules of employees, fuel and electricity costs, operating speeds and ridership.

(Data Sources: Levinson, H., S. Zimmerman, J. Clinger, J. Gast, Bus Rapid Transit: Synthesis of Case Studies, http://www.worldtransitresearch.info/research/772/, Accessed 5/30/2011.)

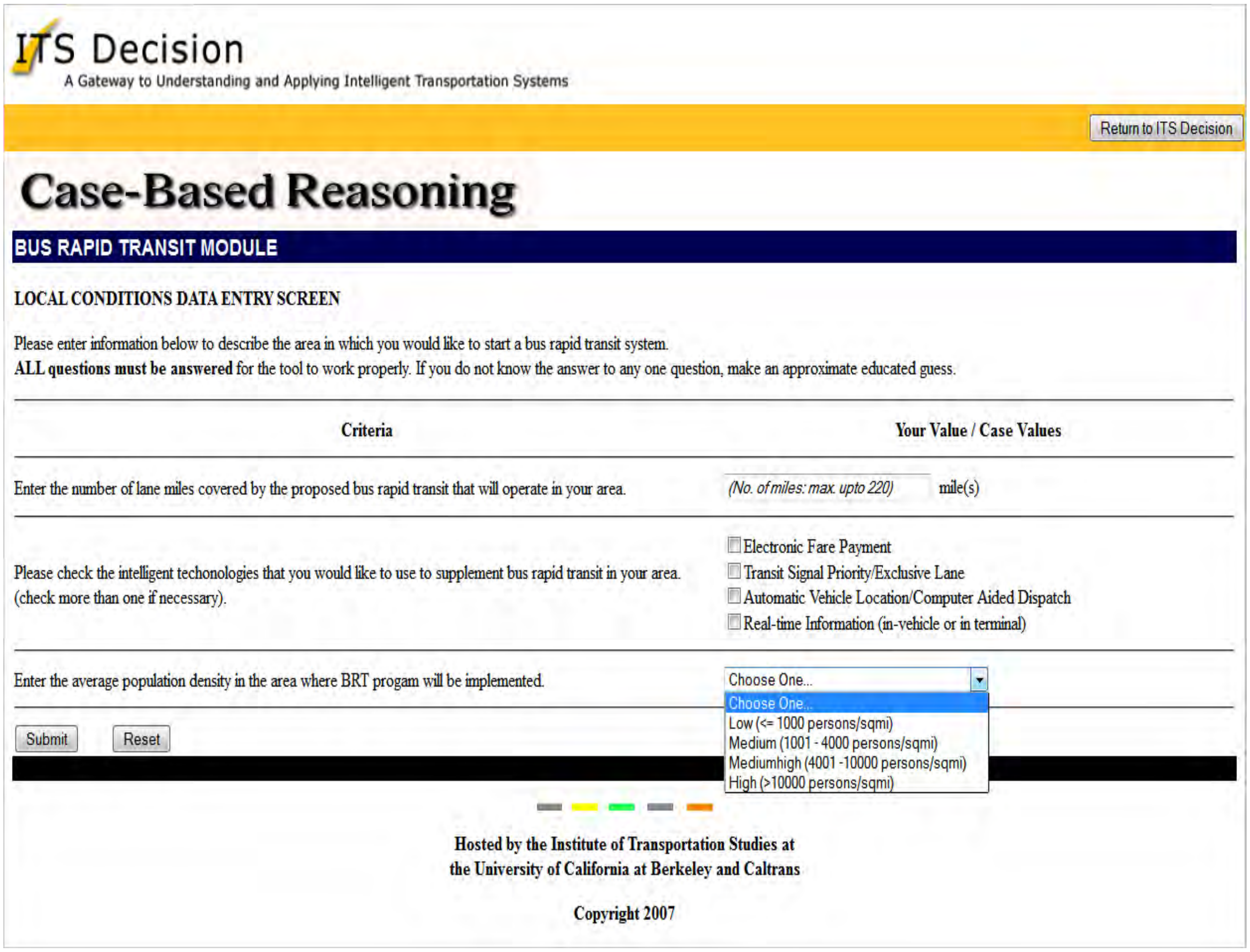

Figure 1 Entry page of BRT CBR Module

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 2) where case studies of BRT programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: number of miles of roadway where BRT provides service (30%), ITS technology used in BRT (45%), and population density (25%).

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Case-Based Reasoning

BUS RAPID TRANSIT MODULE

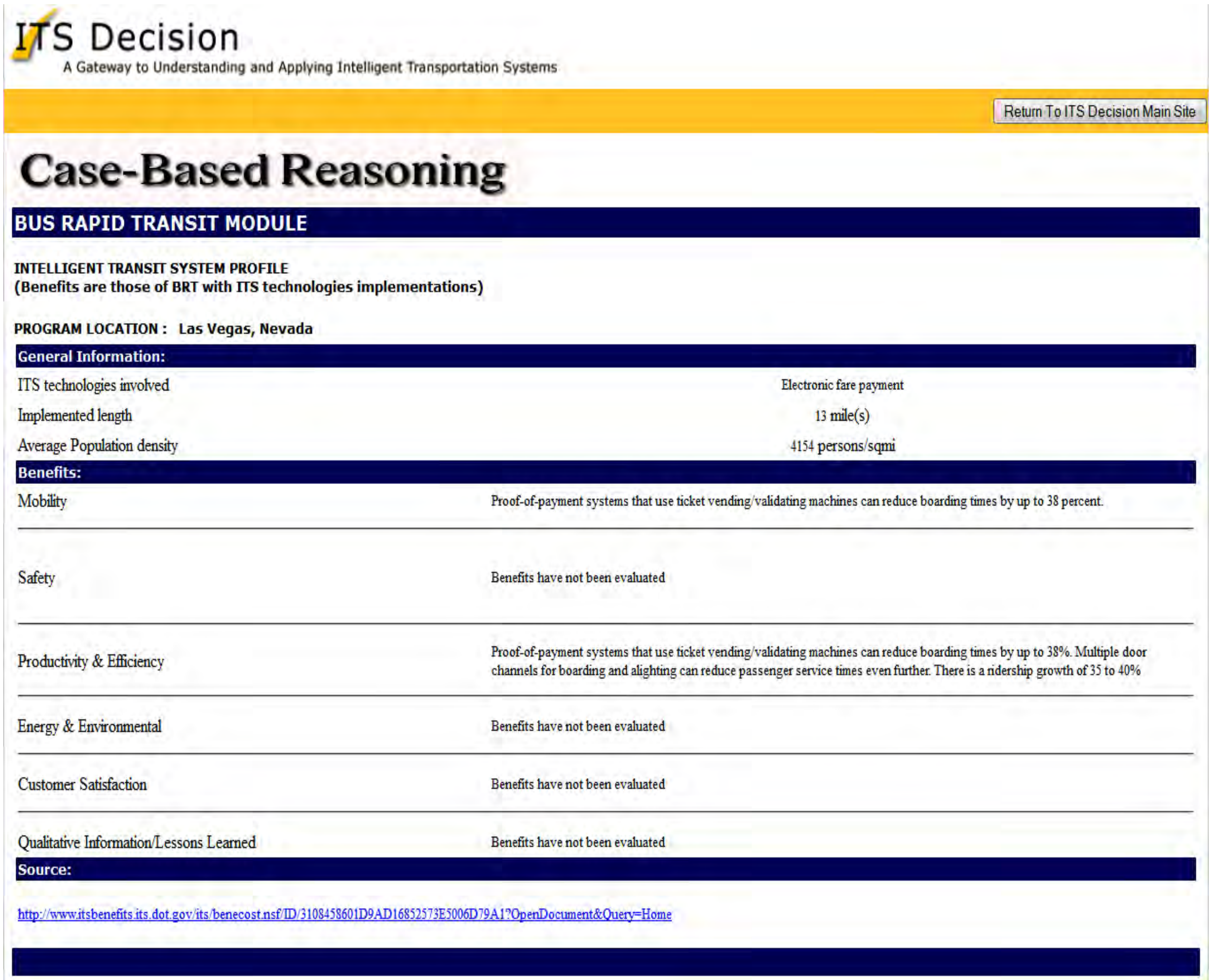
Bus Rapid Transit Program SIMILARITY SCORES
Before implementing your BRT program, you should examine what has been done in these programs:

Run this Tool Again

Location	Similarity Score	ITS Technology (Weight=0.45)	Implemented length (Weight=0.3)	Population Density (Weight=0.25)
Your Input	- NA -	Electronic Fare Payment	22 miles	Low
Mean for Cases	- NA -	- NA -	33 miles	- NA -
Mexico City, Mexico	100	Electronic Fare Payment	30	High
Vancouver, British Columbia	100	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane, Automatic Vehicle Location / Computer-Aided Dispatch	30	High
Oakland, California	100	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane, Real-time Information	30	High
Southampton, United Kingdom	100	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane	30	High
Portland, Oregon, US--Tri-Met	98.8	Electronic Fare Payment, Automatic Vehicle Location / Computer-Aided Dispatch	30	Medium-High
Washington DC, USA	98.8	Electronic Fare Payment	30	Medium-High
Las Vegas, Nevada	98.8	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane	30	Medium-High
Helsinki, Finland	98.8	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane, Automatic Vehicle Location / Computer-Aided Dispatch, Real-time Information	30	Medium-High
Nevada, USA	96.2	Electronic Fare Payment, Automatic Vehicle Location / Computer-Aided Dispatch	30	Low
Europe(England, France)	96.2	Electronic Fare Payment, Transit Signal Priority/Exclusive Lane	30	Low
Seoul, Korea	95.5	Electronic Fare Payment	25.5	High
Boston, US	95.5	Electronic Fare Payment, Real-time Information	25.5	High

Figure 2 Sample cases retrieved and ranked by BRT CBR Module

As shown in (Figure 2), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of BRT deployment. For example, the user clicks on Las Vegas, Nevada link, a new window opens with a case profile sheet (Figure 3) that provides detailed information about the BRT program implemented in Las Vegas, Nevada. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.



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Case-Based Reasoning

BUS RAPID TRANSIT MODULE

INTELLIGENT TRANSIT SYSTEM PROFILE
(Benefits are those of BRT with ITS technologies implementations)

PROGRAM LOCATION : Las Vegas, Nevada

General Information:	
ITS technologies involved	Electronic fare payment
Implemented length	13 mile(s)
Average Population density	4154 persons/sqmi
Benefits:	
Mobility	Proof-of-payment systems that use ticket vending/validating machines can reduce boarding times by up to 38 percent.
Safety	Benefits have not been evaluated
Productivity & Efficiency	Proof-of-payment systems that use ticket vending/validating machines can reduce boarding times by up to 38%. Multiple door channels for boarding and alighting can reduce passenger service times even further. There is a ridership growth of 35 to 40%
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	Benefits have not been evaluated
Qualitative Information/Lessons Learned	Benefits have not been evaluated

Source:

http://www.itsbenefits.its.dot.gov/its/benecost.nsf/ID/3108458601D9AD16852573E5006D79A1?OpenDocument&Query=Home

Figure 3 Detailed case profile page of BRT CBR Module

3.2 CONGESTION PRICING

Congestion pricing program charges the motorists a (nominal) fee referred to as Toll fee for using a particular stretch of roadway facility during high-demand periods. The charge can be for using a principal roadway and/or a bridge facility. Fees are also collected when entering a particular area ("cordon tolls" for access to urban areas). It is a market or demand-based strategy designed to encourage a shift of peak period trips to:

- Off-peak periods,
- Routes away from congested facilities,
- Alternative modes (High Occupancy Vehicles or public transit) during the peak demand periods.

Congestion pricing proposes to internalize the transportation and environmental costs (delay, pollution, accidents) associated with congestion, costs that are largely unaccounted for in the current transportation system. Variable pricing, lane charging (including High Occupancy Toll (HOT) or Fast and Intertwined Regular Lanes (FAIR) lanes, which give toll credits to all highway users based on their usage of regular lanes adjacent to premium-service HOT or Express Toll lanes) and cordon tolls are three main forms of congestion pricing. For example, variable tolls are placed on existing and/or new roadway facilities, bridges, and tunnels. The toll prices vary depending on traffic levels. Lane charging toll facilities collect money electronically via transmitter from drivers in added or converted highway lanes. Lane charging includes High Occupancy Toll (HOT) lane charges and High Occupancy Vehicle (HOV) charges. HOT lanes are sometimes converted from HOV lanes. Cordon tolls charge a fee for entering and driving in a congested, urban area, e.g., a central business district.

3.2.1 Congestion Pricing Cost and Benefits

Congestion Pricing is beneficial in many contexts. Table 2 summarizes the costs and benefits of congestion pricing deployment.

Table 2 Summary of Benefits and Costs of Congestion Pricing Deployment

Benefits	Costs
i. Reduction of peak-period and total congestion ii. Reduction in the need for adding new road capacity to serve the peak period demand iii. Enhancement of transportation choices iv. Safety improvement: Reduced congestion may enhance road safety by reducing congestion related accidents v. Reduced emissions of pollutants and greenhouse gases and reduced energy consumption. Reduced congestion will reduce emissions of hydrocarbons, carbon monoxide, and carbon dioxide and will reduce fuel consumption vi. In the long-run land use patterns could be affected, in ways that are still unclear.	i. Toll collections; infrastructure; staffing and enforcements. ii. Inconvenience to motorists – mainly the time taken to pay the tolls. iii. Financial costs to consumers for paying the toll - this last element is actually not a cost but an economic transfer from the traveler to the toll authority. How this transfer affects the consumer ultimately depends on how much time is saved or wasted per person, the time savings, and how the revenues are used.

(Data Sources: ITS Decision website, and Congestion Pricing: What Is It? by Marika Benko & Lauren Smith, available online web1.ctaa.org)

3.2.2 Congestion Pricing Cases and the CBR Tool

If planners from a jurisdiction are considering implementing a Congestion Pricing (CP) program, then they might be interested in knowing about historical cases of congestion pricing program implemented in other regions under similar circumstances. The desired information is offered by the Web-based CP CBR module. The user has to enter initial information about the CP program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the CP program (number of toll stations, type of congestion pricing, and ADT volume) is shown in Figure 4.

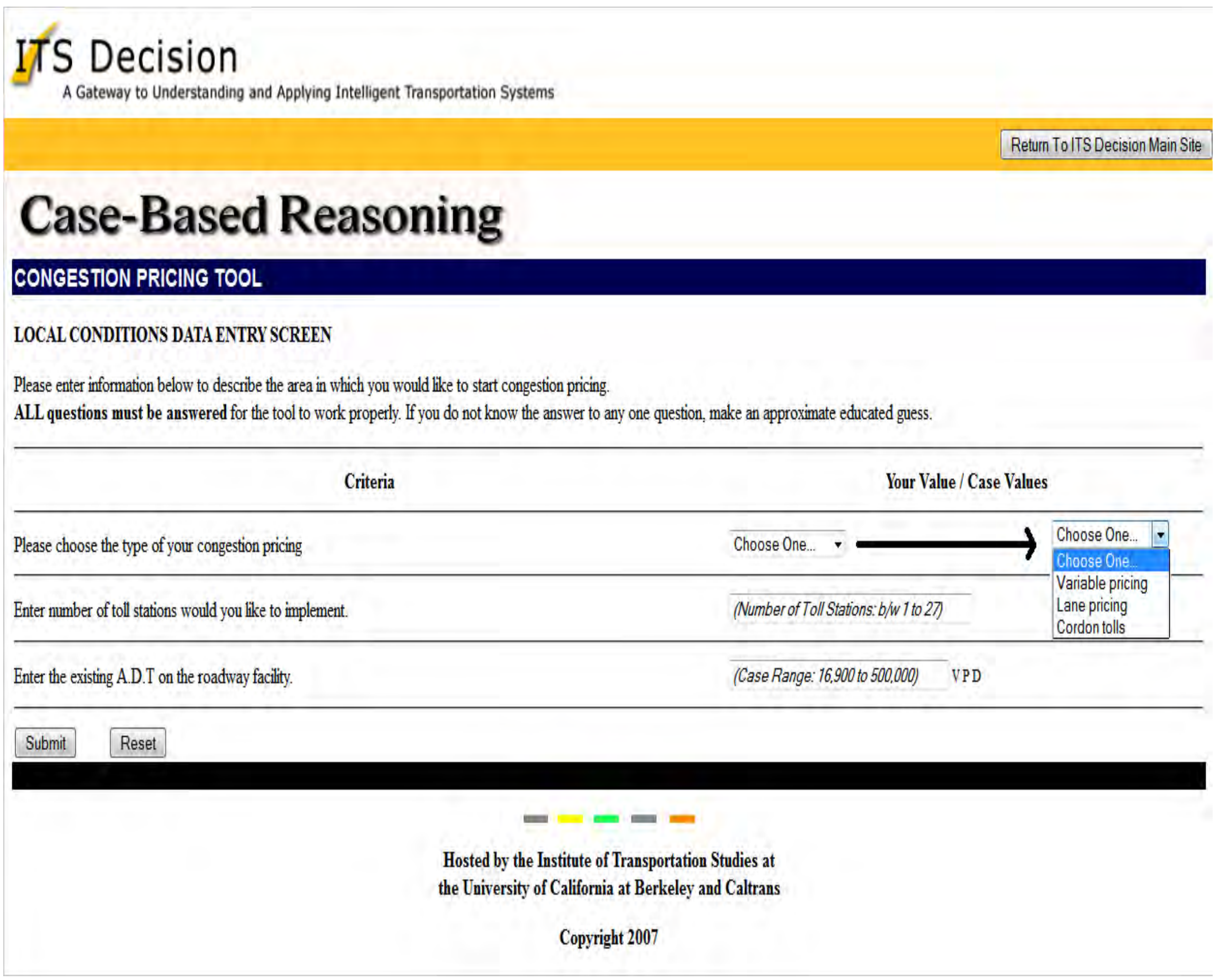
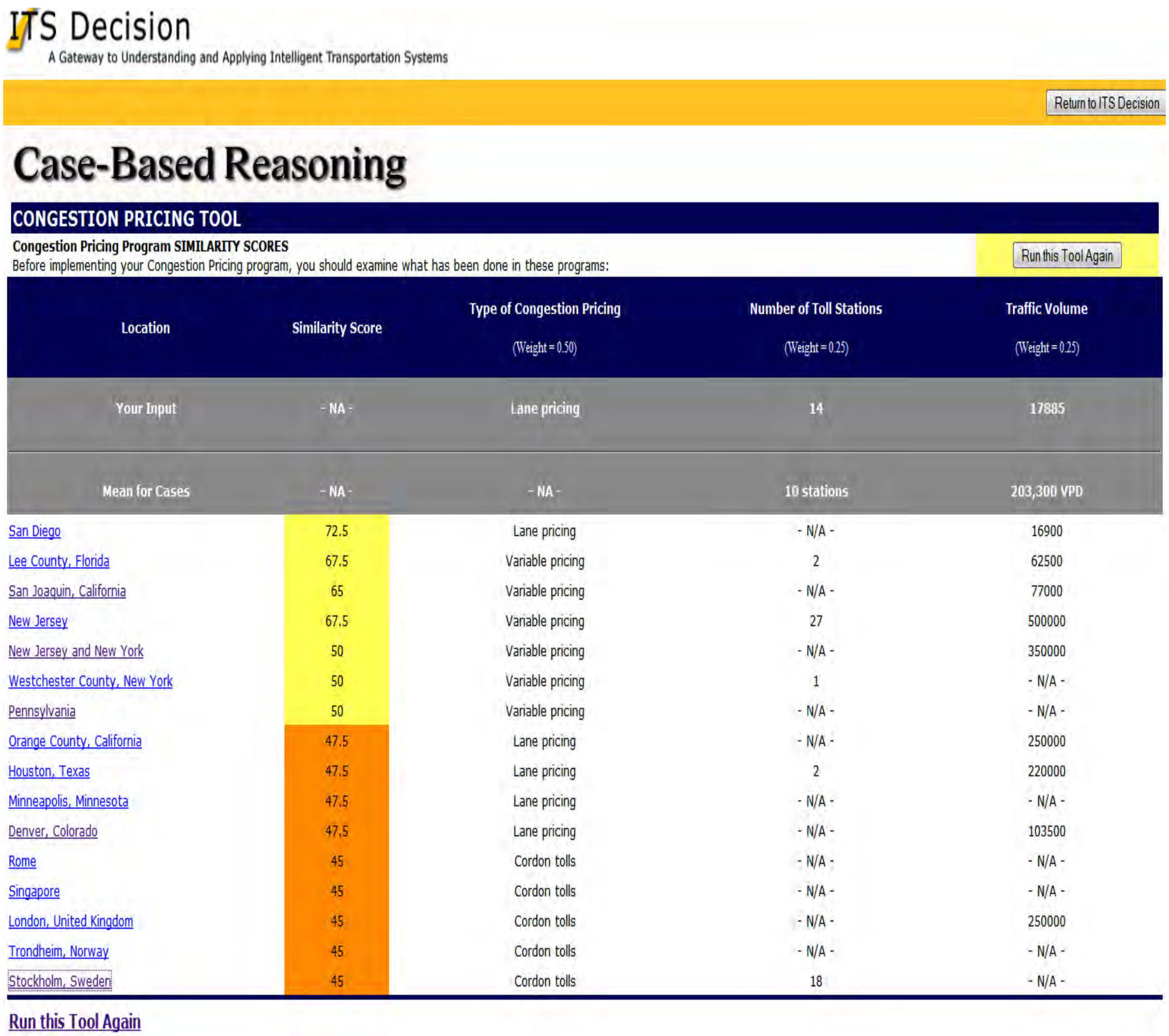


Figure 4 Entry page of Congestion Pricing CBR Tool

Upon entering the input information and clicking submit button, the user is directed to the results page (Figure 5) where case studies of CP programs in similar contexts that have been implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the current case (proposed by the user). The weights for this tool are: number of toll stations (25%), type of congestion pricing (50%), and Average Daily Traffic (ADT) volume (25%).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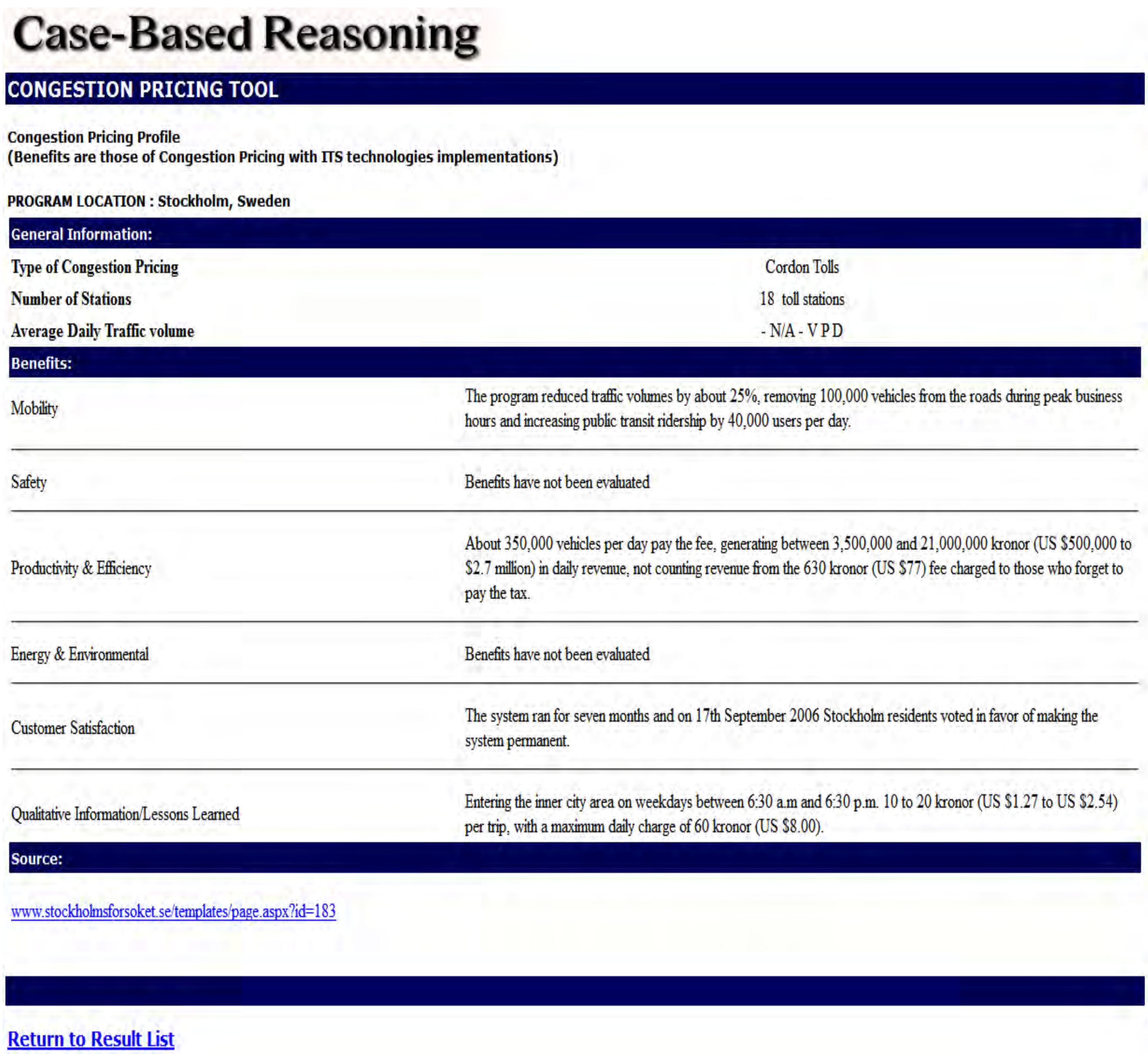
CONGESTION PRICING TOOL
Congestion Pricing Program SIMILARITY SCORES
Before implementing your Congestion Pricing program, you should examine what has been done in these programs:
Run this Tool Again

Location	Similarity Score	Type of Congestion Pricing (Weight = 0.50)	Number of Toll Stations (Weight = 0.25)	Traffic Volume (Weight = 0.25)
Your Input	- NA -	Lane pricing	14	17885
Mean for Cases	- NA -	- NA -	10 stations	203,300 VPD
San Diego	72.5	Lane pricing	- N/A -	16900
Lee County, Florida	67.5	Variable pricing	2	62500
San Joaquin, California	65	Variable pricing	- N/A -	77000
New Jersey	67.5	Variable pricing	27	500000
New Jersey and New York	50	Variable pricing	- N/A -	350000
Westchester County, New York	50	Variable pricing	1	- N/A -
Pennsylvania	50	Variable pricing	- N/A -	- N/A -
Orange County, California	47.5	Lane pricing	- N/A -	250000
Houston, Texas	47.5	Lane pricing	2	220000
Minneapolis, Minnesota	47.5	Lane pricing	- N/A -	- N/A -
Denver, Colorado	47.5	Lane pricing	- N/A -	103500
Rome	45	Cordon tolls	- N/A -	- N/A -
Singapore	45	Cordon tolls	- N/A -	- N/A -
London, United Kingdom	45	Cordon tolls	- N/A -	250000
Trondheim, Norway	45	Cordon tolls	- N/A -	- N/A -
Stockholm, Sweden	45	Cordon tolls	18	- N/A -

Run this Tool Again

Figure 5 Sample cases and ranked by Congestion Pricing CBR Tool

As shown (Figure 5), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of CP deployment. If for example, the user clicks on Stockholm, Sweden link, a new window opens with a case profile sheet (Figure 6) that provides detailed information about the CP program implemented in Stockholm, Sweden. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document, which can be downloaded.



Case-Based Reasoning

CONGESTION PRICING TOOL

Congestion Pricing Profile
(Benefits are those of Congestion Pricing with ITS technologies implementations)

PROGRAM LOCATION : Stockholm, Sweden

General Information:	
Type of Congestion Pricing	Cordon Tolls
Number of Stations	18 toll stations
Average Daily Traffic volume	- N/A - V P D

Benefits:	
Mobility	The program reduced traffic volumes by about 25%, removing 100,000 vehicles from the roads during peak business hours and increasing public transit ridership by 40,000 users per day.
Safety	Benefits have not been evaluated
Productivity & Efficiency	About 350,000 vehicles per day pay the fee, generating between 3,500,000 and 21,000,000 kronor (US $500,000 to $2.7 million) in daily revenue, not counting revenue from the 630 kronor (US $77) fee charged to those who forget to pay the tax.
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	The system ran for seven months and on 17th September 2006 Stockholm residents voted in favor of making the system permanent.
Qualitative Information/Lessons Learned	Entering the inner city area on weekdays between 6:30 a.m and 6:30 p.m. 10 to 20 kronor (US $1.27 to US $2.54) per trip, with a maximum daily charge of 60 kronor (US $8.00).

Source:

www.stockholmsforsoket.se/templates/page.aspx?id=183

Return to Result List

Figure 6 Detailed case profile page of Congestion Pricing CBR Tool

3.3 CAR SHARING

Car Sharing is a system where a fleet of cars (or other vehicles) is jointly owned by the users, which is distinct from car rental or cars in private ownership. Members of a car sharing organization access the vehicles from shared-use lots (e.g., transit station, neighborhoods and employment centers). Fees typically cover maintenance, insurance, registration, fueling, and time of use. Urban car sharing with linkages to transit is a key shared-use vehicle model (Shaheen and Cohen, 2006). However, several new models are being tested, e.g., employer-based car sharing, such as CarLink. Existing car sharing organizations typically provide a choice of vehicle type, rate, and convenience suited to participant needs.

Car Sharing is common in Europe, and this method is expanding and is being implemented in few North American cities. Car share organizations typically charge $1 - $2 per vehicle-hour rent, plus 25 - 40¢ per mile. Some charge a refundable membership deposit of $300 - $500 (which may be refunded partially at the termination of membership). These charges can be used to cover vehicle operating expenses, including fuel and insurance costs. There are often special rates for extended trips and infrequent users. Car sharing is considered a cost effective alternative to owning a vehicle driven less than about 6,000 miles (10,000 km) per year. There are typically 8 to15 members per vehicle. Some small businesses use car-sharing programs (Reutter and Bohler, 2000).

Car Sharing is a middle option between having no vehicle and owning a private automobile. The Table 3 below compares different transportation options. Car sharing offers medium convenience and has low fixed costs and high variable costs. Private vehicle ownership offers the most convenience, has highest fixed costs and lowest variable costs. Conventional vehicle rental businesses are not intended to substitute for private vehicle ownership. They are located at transportation terminals or commercial centers and priced by the day, and so are relatively expensive for individual short trips. They generally have high daily rates but low variable costs. Taxis are relatively convenient and have no fixed charges but the highest variable charges. Public transit has moderate to low convenience (depending on location), and modest to low costs.

3.3.1 Car sharing Costs and Benefits

Car sharing is beneficial in different situations. Table 4 summarizes the costs and benefits of car sharing deployment.

Table 3 Vehicle Use Options Compared

Criteria	Car Sharing	Private Ownership	Conventional Rental	Taxi	Public Transit
Convenience	Medium	High	Varies	High-Medium	Medium-Low
Approx. Fixed Charges	$100 / yr	$2,000 - $4,000/yr	None	None	$600 / yr (max)
Time Charges	$1.50 / hour	None	$20 - $40 / day	None	None
Approx. Mileage Charges	20 – 40 ¢	10 – 15 ¢	5 – 50 ¢	$1.00	21 ¢

Table 4 Summary of Benefits and Costs of Car sharing Deployment

Benefits	Costs
i. More careful consideration of the necessity of car trips, duration and distance of travel, and modal alternatives. ii. Decreased auto use and ownership. iii. Cost savings to individuals and employers iv. Energy and emissions savings. v. Improved mass transportation, when paired with other cost-saving systems like congestion pricing vi. Increased transit ridership vii. Decreased parking demand. viii. Increased cooperation between industry and government	i. Vehicle lease: $300 to 500 per month (almost all car share companies lease; typically no insider deals with car manufacturers) ii. High Insurance ($300K to $1 million single limit); $150 to $250/month per vehicle. iii. Car access and tracking computer costs: [$1200 to $1500 depending on features, GPS plus $30/month for wireless charges (to download reservations, report hours and miles of usage & occasional GPS location query)] iv. Staffing costs: About 4 to 8 on staff per location; includes general manager, one or two salespeople (residential and business), customer service rep, fleet manager and part time "event marketing" people for member recruitment. Vehicle cleaning is outsourced. v. Billing, membership, & admin services handled via Web site at corporate level. vi. Call center rentals: handled nationally; refers problems to local on-call staff member if immediate help is needed; breakdowns handled by contract Tow Company.

(Data Sources: www.carsharing.us)

3.3.2 Car sharing Cases and the CBR Tool

If planners from a jurisdiction are considering implementing a Car Sharing (CS) program, then they might be interested in knowing about historical cases of car sharing programs implemented in other regions under similar circumstances. The desired information is offered by the Web-based CS CBR module. The user has to enter initial information about the CS program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the CS program is the estimated cost of trip, ITS technology (e.g., smart card access and in-vehicle navigation), size of car sharing organization, type of organization, and population density, as shown in Figure 7.

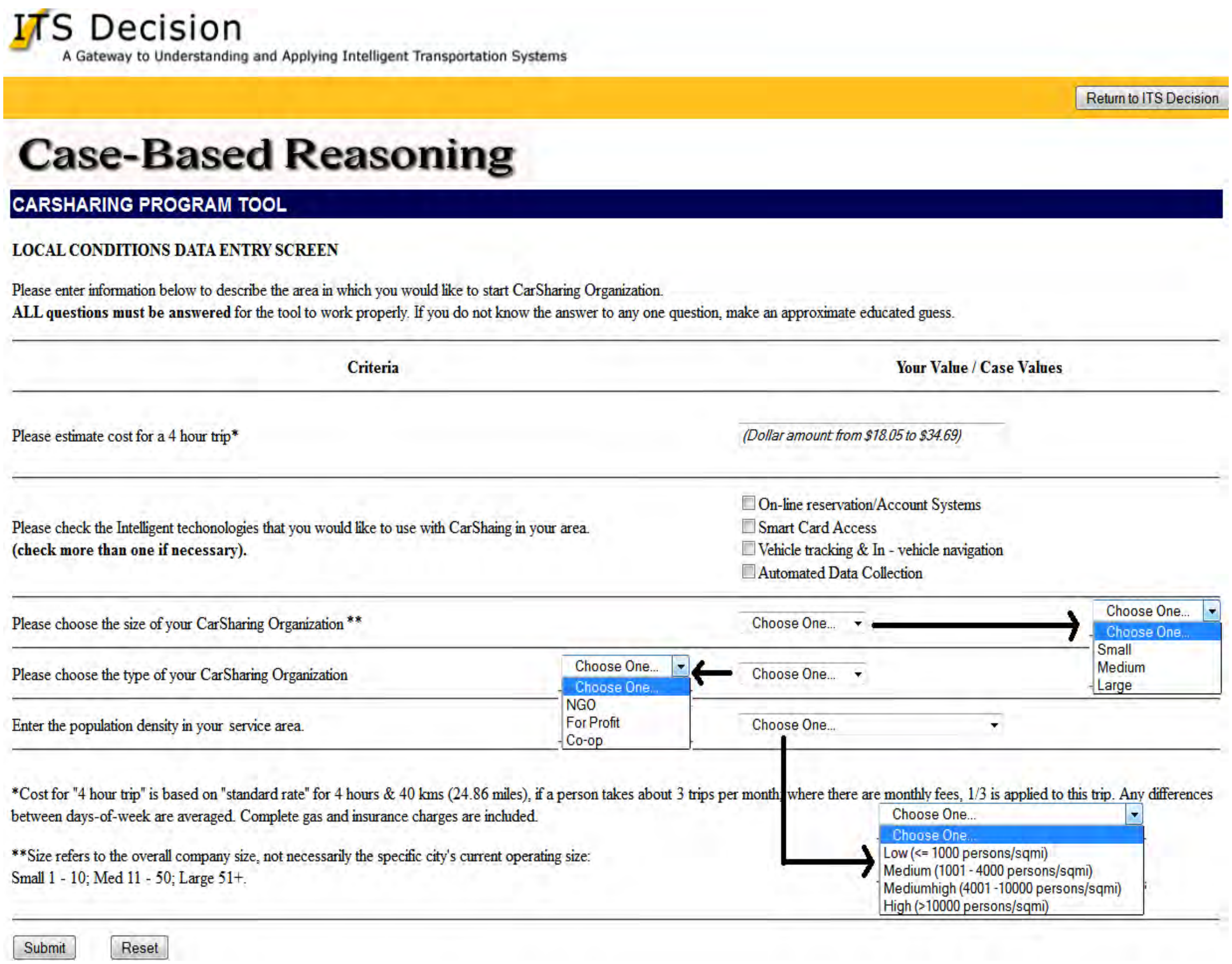


Figure 7 Entry page of Car sharing CBR Tool

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 8) where case studies of CS programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: estimated cost for a "4-hour trip" (20%), ITS technology (30%), size of the organization (15%), type of the organization (15%), and the population density of the area (20%).

Case-Based Reasoning

CAR SHARING TOOL

CarSharing Program SIMILARITY SCORES
Before implementing your Car Sharing program, you should examine what has been done in these programs:

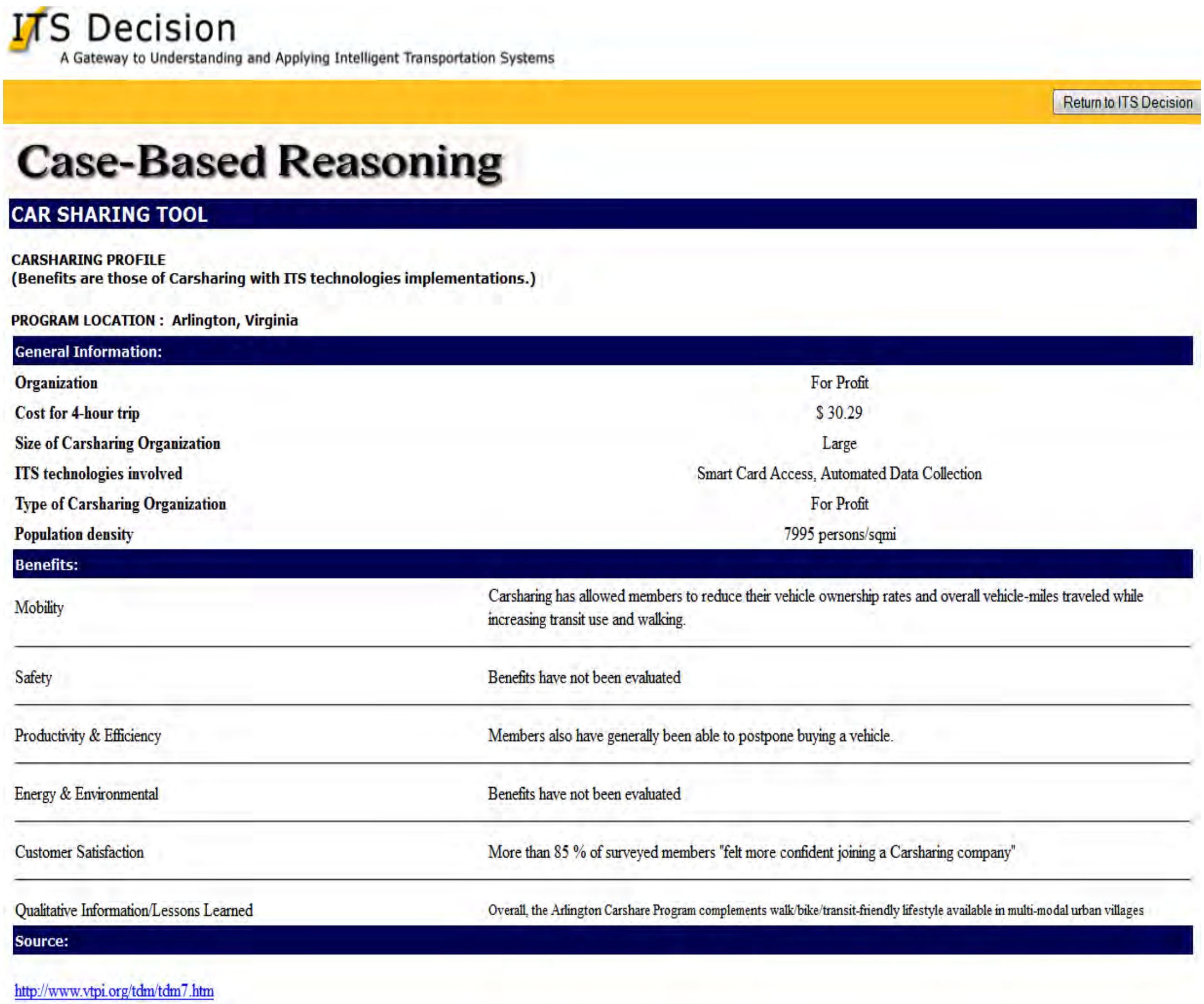
Run this Tool Again

Location	Similarity Score	ITS Technology (Weight = 0.30)	Estimated Cost for "4-hour trip" (Weight = 0.20)	Size of Organization (Weight = 0.15)	Type of Organization (Weight = 0.15)	Population Density (Weight = 0.20)
Your Input	- NA -	On-line reservation/Account Systems, Smart Card Access	$ 21	Small	For Profit	Low
Mean for Cases	- NA -	- NA -	$ 30	- NA -	- NA -	- NA -
Quebec, Canada	92.2	On-line reservation/Account Systems, Smart Card Access	$ 18.05	Large	For Profit	Low
Switzerland	90.2	On-line reservation/Account Systems, Smart Card Access, Vehicle tracking & In-vehicle navigation, Automated Data Collection	$ 30.29	Large	For Profit	Low
Chicago	89	On-line reservation/Account Systems, Smart Card Access, Automated Data Collection	$ 34.69	Large	Non Governmental Organization (NGO)	High
Zwischenwasser, Austria	80.8	On-line reservation/Account Systems, Smart Card Access, Vehicle tracking & In-vehicle navigation, Automated Data Collection	$ 32	Small	For Profit	Low
Bremen, Germany	77	Smart Card Access	$ 30.29	Large	Non Governmental Organization (NGO)	Medium-High
Philadelphia	76	On-line reservation/Account Systems, Automated Data Collection	$ 30.84	Large	Non Governmental Organization (NGO)	High
Odense, Denmark	74.2	Smart Card Access, Vehicle tracking & In-vehicle navigation	$ 30.29	Large	For Profit	Medium
Arlington, Virginia	73.2	Smart Card Access, Automated Data Collection	$ 30.29	Large	For Profit	Medium-High
Langenegg, Austria	71.5	On-line reservation/Account Systems	$ 30.29	Small	Non Governmental Organization (NGO)	Low
San Francisco, California	68.5	Smart Card Access, Automated Data Collection	$ 29.94	Large	Co-op	High
Stockholm, Sweden	64.8	On-line reservation/Account Systems	$ 30.29	Small	For Profit	High
Cleveland, Ohio	63.8	Smart Card Access	$ 32	Small	For Profit	Medium-High
Aalborg, Denmark	48	Vehicle tracking & In-vehicle navigation, Automated Data Collection	$ 30.29	Small	Co-op	Medium

Run this Tool Again

Figure 8 Sample cases retrieved and ranked by Car sharing CBR Tool

As shown in (Figure 8), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of CS deployment. For example, the user clicks on Arlington, Virginia link, a new window opens with a case profile sheet (Figure 9) that provides detailed information about the CS program implemented in Arlington, Virginia. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.


ITS Decision
A Gateway to Understanding and Applying Intelligent Transportation Systems

Return to ITS Decision

Case-Based Reasoning

CAR SHARING TOOL

CARSHARING PROFILE
(Benefits are those of Carsharing with ITS technologies implementations.)

PROGRAM LOCATION : Arlington, Virginia

General Information:	
Organization	For Profit
Cost for 4-hour trip	$ 30.29
Size of Carsharing Organization	Large
ITS technologies involved	Smart Card Access, Automated Data Collection
Type of Carsharing Organization	For Profit
Population density	7995 persons/sqmi
Benefits:	
Mobility	Carsharing has allowed members to reduce their vehicle ownership rates and overall vehicle-miles traveled while increasing transit use and walking.
Safety	Benefits have not been evaluated
Productivity & Efficiency	Members also have generally been able to postpone buying a vehicle.
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	More than 85 % of surveyed members "felt more confident joining a Carsharing company"
Qualitative Information/Lessons Learned	Overall, the Arlington Carshare Program complements walk/bike/transit-friendly lifestyle available in multi-modal urban villages
Source:	

http://www.vtpi.org/tdm/tdm7.htm

Figure 9 Detailed case profile page of Car sharing CBR Tool

3.4 INTELLIGENT PARKING SYSTEMS

Intelligent parking systems include Advanced Parking Systems, Automatic Parking Systems, Electronic and Wireless Payment systems, and Advanced Parking Meters (Figure 10). Advanced Parking Systems integrate electronic systems and parking structures to best utilize the parking lot. The most common advanced parking systems assist drivers in finding parking facilities with available space. They do this by obtaining information about available parking spaces, processing the information and presenting it to drivers via several communication systems. Information may be presented to the motorists via static signs or changeable message signs, mobile phone, Internet, and in-vehicle navigation systems.

Automatic Parking systems automatically park the cars within the parking facility. These systems have been largely implemented in Japan and Vancouver, British Columbia. Their purpose is to reduce the amount of space required for parking. The first installation of this automated parking system modular was in Cesena, Italy.

Figure 10 Example of Automated Parking System (Source: Google images)

Electronic and Wireless Payment systems reduce queuing at the entrance / exit of commercial facilities and largely reduce money handling costs. The wireless transmission of parking fees, sent via mobile phones, is also becoming an alternative to cash payments at parking meters. This Mobile-commerce (m-commerce) application is currently being tested and implemented in different locations around the globe.

Advanced Parking Meters can provide real-time information regarding whether the parking place is occupied and/or if the meter has expired. This information is transmitted by a wireless modem to the main server where parking enforcement staff can observe the parking spaces that are violated. These meters can also verify parking permits for special classes of vehicles, such as disabled people or neighborhood residents. Such meters can reduce parking violations and increase revenues for the city.

3.4.1 Intelligent Parking Systems Costs and Benefits

Intelligent Parking systems are beneficial in a variety of contexts. Table 5 lists some of the costs and benefits of Intelligent Parking deployment.

Table 5 Summary of Benefits and Costs of Intelligent Parking Deployment

Benefits	Costs
i. Reduces time spent searching for a parking place. ii. Reduces congestion iii. Reduces illegal parking iv. Allows better distribution and faster reply to parking demand. v. Allows higher utilization of parking facilities	Costs vary widely depending on the different systems RITA, USDOT shows that in Seattle, WA, an intelligent parking system cost nearly $1.0 million (in 2000).

3.4.2 Intelligent Parking Cases and the CBR Tool

If planners from a jurisdiction are considering implementing an Intelligent Parking (IP) program, then they might be interested in knowing about historical cases of smart parking programs implemented in other regions under similar circumstances. The desired information is offered by the Web-based IP CBR module. The user has to enter initial information about the IP program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the IP program includes the number of parking spaces, ITS technology, type of parking facility, and information dissemination technology, as shown in Figure 11.

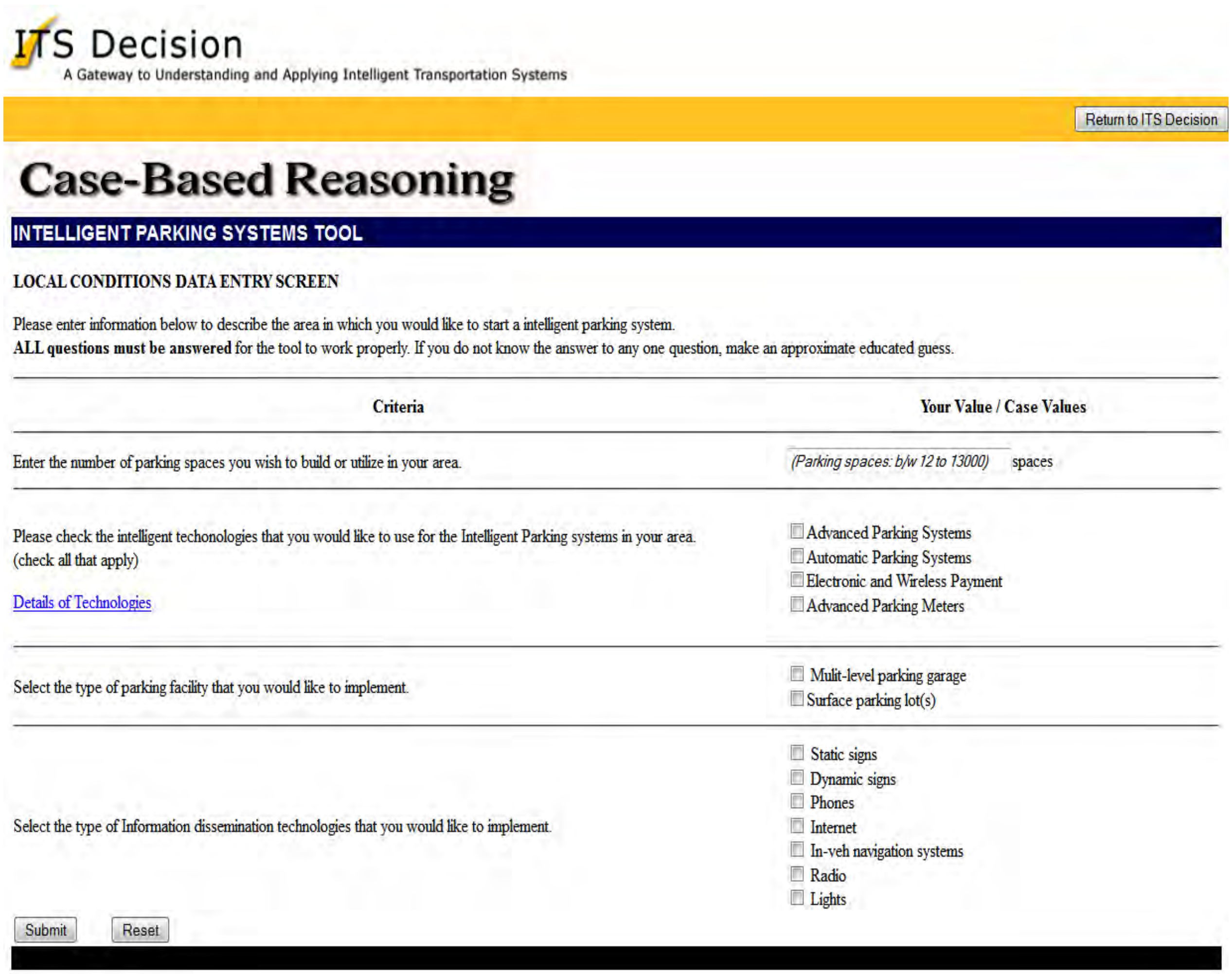


Figure 11 Entry page of Intelligent Parking CBR Tool

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 12) where case studies of IP programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: number of parking spaces (30%), ITS technology (30%), parking facility type (25%), and information dissemination technology (25%).

INTELLIGENT PARKING SYSTEMS TOOL

Intelligent Parking Program SIMILARITY SCORES

Before implementing your intelligent parking program, you should examine what has been done in these programs:

Location	Similarity Score	ITS Technologies (Weight=0.45)	Scale of Parking Lot (Weight=0.3)	Population Density (Weight=0.25)
Your Input	NA	Advanced Parking Systems, Automatic Parking Systems	Medium	High
Mean/Mode for Cases	NA	NA	NA	6631 persons/sqmi
St. Paul, MN, USA	71.2	Advanced Parking Systems	Medium	Medium-High
Koeln, Germany	71.2	Advanced Parking Systems	Medium	Medium-High
Yokohama, Japan	71.2	Advanced Parking Systems	Medium	Medium-High
Minneapolis/St. Paul International Airport	71.2	Advanced Parking Systems	Medium	Medium-High
Toulouse, France	71.2	Advanced Parking Systems	Medium	Medium-High
San Francisco,California	67.3	Advanced Parking Systems, Electronic and Wireless Payment	Large	High
Vancouver, British Columbia	67.3	Automatic Parking Systems	Small	High
Ghent, Belgium	65	Advanced Parking Systems	Medium	Medium
Houston International Airport	65	Advanced Parking Systems, Electronic and Wireless Payment	Medium	Medium
Baltimore, Maryland, USA	61	Advanced Parking Systems	Large	Medium-High
Pittsburgh, PA, USA	61	Advanced Parking Systems	Large	Medium-High
Bristol, UK.	61	Advanced Parking Systems	Small	Medium-High
Vienna, Austria	55	Electronic and Wireless Payment	Medium	High
Frankfurt am Main, Germany	54.8	Advanced Parking Systems	Large	Medium
Toyota, Japan	54.8	Advanced Parking Systems	Large	Medium
New Jersey, USA	54.8	Automatic Parking Systems	Small	Medium
Bar Harbor, Mount Desert Island, Maine (Acadia National Park)	48.6	Advanced Parking Systems, Electronic and Wireless Payment	Small	Low
European cities	48.6	Advanced Parking Systems	Large	Low
Suntec City, Singapore	44.8	Electronic and Wireless Payment	Small	High
Washington, DC	38.6	Electronic and Wireless Payment	Large	Medium-High

Figure 12 Sample cases retrieved and ranked by Intelligent Parking CBR Tool

As shown in (Figure 12), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of IP deployment. For example, the user clicks on Baltimore, Maryland link, a new window opens with a case profile sheet (Figure 13) that provides detailed information about the IP program implemented in Baltimore, Maryland. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.

Case-Based Reasoning

INTELLIGENT PARKING SYSTEMS TOOL

Intelligent Parking Profile
(Benefits are those of Intelligent Parking with ITS technologies implementations)

PROGRAM LOCATION : Baltimore, Maryland

General Information:	
ITS technologies involved	Advanced Parking Systems
Number of parking lots	13000 lots
Facility type	Multi-level Garages
Information dissemination technologies	Static signs, Dynamic signs, Lights

Benefits:	
Mobility	The system made parking easier and faster
Safety	The system reduced illegal parking.
Productivity & Efficiency	Benefits have not been evaluated
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	The initial test period showed that the system increased customer satisfaction and improved traffic flow in the hourly facilities. A customer satisfaction survey indicated that 81% of the BWI travelers felt that parking was easier at BWI compared to other airports and 68% agreed that parking was faster. The system reduced the frustration of drivers leading high level of customer satisfaction. The stakeholders' praise for the system is evident supported by assistant manager of the MDOT and Terminal Services at BWI Airport.
Qualitative Information/Lessons Learned	Some of the lessons learned were that: It is important to involve all stakeholders in a formal and collaborative manner to ensure that the needs of all stakeholders are met. There must be a champion and a formalized stakeholder group. APMS sign structure and locations require continuity of effort. Coordination with the regional ITS architecture helps ensure interoperability and helps leverages resources. System accuracy is a critical factor. It is important to identify the roles and responsibilities of each agency for system operations and maintenance.

Source:

http://www.its.dot.gov/jpodocs/repts_te/14318_files/14318.pdf

Figure 13 Detailed case profile page of Intelligent Parking CBR Tool

3.5 ADAPTIVE SIGNAL CONTROL

Arterial management systems manage traffic along arterial roadways. Traffic signal control systems have progressed substantially and vary in complexity from pre-timed traffic control plans (which use historical data), to adaptive control plans (which use real-time traffic information). These advanced control systems enhance monitoring and control of traffic flow. They help optimize traffic flow based on prevailing conditions and improve the overall traffic operation of the roadway network. The integration of arterial traffic management systems across jurisdictions often can yield significant benefits and improve traffic operations efficiency.

Adaptive Signal Control is the application of traffic control systems that operate in real-time, adjusting signal timing to accommodate changing traffic patterns. Adaptive Signal Control (ASC) systems are currently the most advanced and complex traffic control systems available. These signal control systems use algorithms that perform real-time optimization of traffic signals based on current traffic conditions, and maintain system capacity. They dynamically adjust traffic signal splits, offsets, phase lengths, and phase sequences. The signals can adapt to recurring congestion, non-recurring congestion (incidents), events or traffic demand growth over time, all without needing to be reset. The principal goals of these signal control system include maximizing throughput, reducing vehicle stops and achieving smooth and safe traffic flows. Environmental benefits are also associated by the implementation of these systems. Based on ITS Joint Program office's 2006 National survey, 99 metropolitan areas in the United States have deployed this technology of traffic signal control. Major metropolitan areas of ASC implementation are Detroit, Los Angeles, New York and Washington D.C.; each area has at least 700 signalized intersections coordinated and optimized based on real-time traffic. One of the first and largest ASC deployments was in Oakland County, Michigan, as part of the FAST-TRAC project during 1992; more than 350 intersections were under SCATS adaptive control.

Signal coordination mainly requires that the signals at multiple intersections be timed to meet network wide objectives for traffic flow. Signals that are coordinated are divided into two categories namely, distributed systems and centrally controlled systems. Modern centralized systems have the important features of distributed systems and most of the distributed systems have useful central control features.

3.5.1 Distributed ASC systems

These systems are mainly governed by local intersection controllers. The intersection controller is responsible for the control decisions at the particular intersection. Some of the important characteristics of this system are:

- These systems are very robust and incorporate certain characteristics that are very effective (time base backup)
- Rely on powerful local intersection controllers

- Have the provision to be expanded
- Are not very expensive
- Cannot support and provide real-time surveillance
- Do not provide a platform for centralized adaptive control algorithms. A central processor primarily operates the interface and display functions.

3.5.2 Centralized ASC systems:

In these systems, the central computer makes the control decisions and coordinates the actions of individual standard controllers. Some of the important characteristics of these systems are:

- These systems largely depend on reliable communications networks and central computers.
- Are not easily expandable.
- Are relatively expensive.
- Provide excellent surveillance (mandatory real-time communications)
- Allow centralized optimized control algorithms (central computer calculates the optimization algorithm for entire network of interconnected signals)

The core purpose of implementing these advanced systems is to dramatically improve and increase the benefits associated with signal coordination. Some of the adaptive control technologies implemented on a large scale in different locations are provided in the next section.

3.5.3 **Most commonly used ASC technologies**

Sydney Coordinated Adaptive Traffic System (SCATS) - This is a dynamic signal control system with a decentralized architecture. It updates intersection cycle length using the detectors at the stop line, and allows for phase skipping. The offsets between adjacent intersections are predetermined and adjusted with the cycle time and progression speed factors.

Split Cycle and Offset Optimization Technique (SCOOT) - This is a centralized computerized traffic control system. The system uses detectors to measure traffic flow profiles in real-time and along with predetermined travel times and the degree of saturation (the ratio of flow-to-capacity), predicts queues at intersections. Adjustments of cycle length, phase splits and offsets are made in small steps to operate at a preset degree of saturation. It coordinates the operation of all the traffic signals in an area to give good progression to vehicles through the network.

Real-time Traffic Adaptive Signal Control System (RT-TRACS) - This is a real-time, traffic adaptive signal control system. This system assesses the current status of the network and also has forecasting capabilities, allowing proactive responses. The system effectively manages and responds to rapid variations in traffic conditions.

Automated Traffic Surveillance and Control (ATSAC) - This is an advanced traffic management system including centralized, adaptive traffic signal control. The system includes surveillance via closed circuit television; loop detectors and sensors (in the street detect the passage of vehicles and determine various attributes like vehicle speed), level of congestion, signal optimization software, and real-time remote control of signals. ATSAC is a computer-based traffic signal control system that monitors traffic conditions and system performance, selects appropriate signal timing strategies, and also performs equipment diagnostics and alert functions.

3.5.4 Other ASC technologies

Optimized Policies for Adaptive Control (OPAC) – This signal control strategy helps maximize throughput, adjusts splits, offsets and cycle lengths and maintains the specified phasing scheme. This system uses a local level control at the intersection to determine the phase and a network level of control for network synchronization. This system best works under saturated traffic conditions.

Real-Time Traffic Adaptive Control Logic (RTACL) – This control strategy uses a macroscopic simulator to determine the signal phasing alternatives. It best works at the local level and the controller helps in optimizing the timing based on queues at an intersection.

Real- Time Hierarchical Optimized Distributed Effective System (RHODES) – This is a real-time traffic adaptive signal control system. The system takes input detector data, i.e., real-time measurements of traffic flow and optimally controls the traffic flow through the network. It predicts the impacts of the approaching traffic and plans for signal phases accordingly and adapts to the most recent information.

Other relevant systems are listed below:

- *Traffic Network Study Tool (TRANSYT)*
- *Adaptive Control Software Lite (ACS-Lite)*
- *Intelligent Adaptive Traffic Control system (ITACA)*
- *Adaptive Traffic Control System (ATCS)*
- *Urban Traffic Optimization by Integrated Automation (UTOPIA)*
- *System for Priority and Optimization of Traffic (SPOT)*
- *Universal Traffic Management System (UTMS)*
- *Method for the Optimization of Traffic Signals in Online controlled Networks (MOTION)*
- *Systeme Urbain de Regulation des Feux (SURF – 2000) traffic control system*
- *QuicTrac*
- *TracoNet*

3.5.5 Advantages and Drawbacks of ASC

ASC systems are classified into two different system groups as listed below. In centralized control systems, a single main central computer controls the decision making of all the individual traffic controllers. This is intended to control the operation of systems of signals rather than isolated intersections. In distributed control systems, the system is closed loop wherein the control decisions and timing plans are executed at the intersection controller level. Table 6 below summarizes the merits and demerits the different strategies.

3.5.6 Adaptive Signal Control Systems Costs and Benefits

By assessing the existing state of traffic conditions, traffic engineers can implement the best and most effective traffic signal control system. Adaptive signal control provides significant benefits and improves traffic flows along arterial networks. The major advantages of ASC systems include:

- Reduce congestion
- Travel time reduction
- Average number of stops decrease and mobility increases
- Fuel consumption decreases and lessens impact on the environment
- Motorist frustration and stresses decrease and travel satisfaction increases
- Accidents and aggressive driving during peak hours decrease, improving safety
- Systems reduce operational and maintenance costs associated with signal re-timing
- Overall traffic efficiency for the network improves and average traffic speeds increases.
- Systems have the added advantage to grow in an expanding community.

Table 7 provides an estimate of the typical costs involved in implementing ASC technology.

Table 6 Advantages and Drawbacks Traffic Control strategies

Control Type	Advantages	Disadvantages
Centralized Traffic control systems E.g.: SCOOT & UTMS	i. Ability to manage non-recurring traffic at intersections. ii. Improve mobility and traffic flow conditions during heavy and unpredictable periods. iii. Improve safety. iv. Lesser requirement in periodic maintenance of the system. I.e., no need to retime signals often. v. Provide excellent surveillance response time. vi. They allow centralized control algorithms.	i. System is expensive and requires high capital costs. ii. Depends on reliable central computers and communication networks. iii. Has high maintenance and operational costs. iv. Often not easily expandable.
Distributed Traffic control systems E.g.: OPAC & UTOPIA	i. Very robust. ii. Improved network efficiency. iii. Easily expandable. iv. Reduced Environmental impacts v. Provides the good support for traffic management teams. vi. Often inexpensive and are cost effective for communications infrastructure. vii. Do not provide centralized adaptive control algorithms.	i. Dependent and rely on powerful local intersection controllers. ii. Do not provide real-time surveillance. iii. The central processor is limited primarily to operator and display functions.

Table 7 Typical Costs ($) of Adaptive Signal Control components. (Source: ITS Decision)

ASC System	**Central Hardware** (dollars)	**Central Software** (dollars)	**Local Controllers** (dollars)	**Detectors** (dollars)
SCATS	30,000	40,000 – 70,000	4,000 – 6,000	5,000 – 7,000
SCOOT	30,000	-- N A--	-- N A--	5,000 – 7,000
OPAC	20,000 – 50,000	100,000 – 50,000	4,000 – 6,000	-- N A--
RHODES	50,000	500	-- N A--	-- N A--
ATSAC	40,000 – 50,000	1000 + license	8,000 – 10,000	5,000 – 10,000

Adaptive Signal Control systems are associated with large equipment and implementation costs. However, they have high benefit-cost ratios and generate many benefits as stated above.

Table 8 summarizes the various benefits and costs of Adaptive Signal Control implemented in different locations.

3.5.7 ASC Cases and CBR tool:

If traffic engineers and planners from a jurisdiction are considering implementing Adaptive Signal Control (ASC) program, then they might be interested in knowing about historical cases of adaptive signal control system programs implemented in other regions under similar circumstances. The desired information is offered by the Web-based ADS CBR module. The user has to enter initial information about the ADS program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the ASC program includes the type of area, length of the roadway where ASC is implemented, number of signalized intersections, and signal control strategy, as shown in Figure 14.

Table 8 Summary of Benefits and Costs of A.S.C systems by Location

LOCATION	BENEFITS	COSTS
Los Angeles, California	i. Increase in average vehicle speed by 16%, ii. Reduction in delay time by 44%, iii. Reduction in travel time by 13%, iv. Reduction in number of stops by 41%, v. Reduction in fuel consumption by 13%, vi. Reduction in air emissions by 14%, vii. Benefit/cost ratio was found to be 9.8:1.	--- N/A ---
State of California	i. Reduction in travel time by 11.4%, ii. Reduction in number of stops by 27%, iii. Reduction in fuel use by 7.8%, iv. Decrease in delay by 24.9%, v. Benefit-to-cost ratio was 17:1.	Total cost of $16.1 million, or $1,091 per signal.
Toronto, Canada	i. Reduction in travel time by 8%, ii. Reduction in delay time by 17%, iii. Reduction in number of vehicles. stops by 22%, iv. Reduction in fuel consumption by 6%.	--- N/A ---
Beijing, China	i. Increase in average traveling speed by 19.75%, ii. Decrease in travel time by 13.38%, iii. Decrease in number of stops by 12.42%, iv. Decrease in av. queue lengths by 15.30%.	--- N/A ---
Detroit, Michigan	i. Increase in peak hour speeds by 19%, ii. Reduction in injury accidents by 6%, iii. Reduction in injuries by 27%, iv. Reduction in serious injuries by 100%, v. Reduction in accidents by 89%, vi. Reduction in intersection delay by 30%.	--- N/A ---

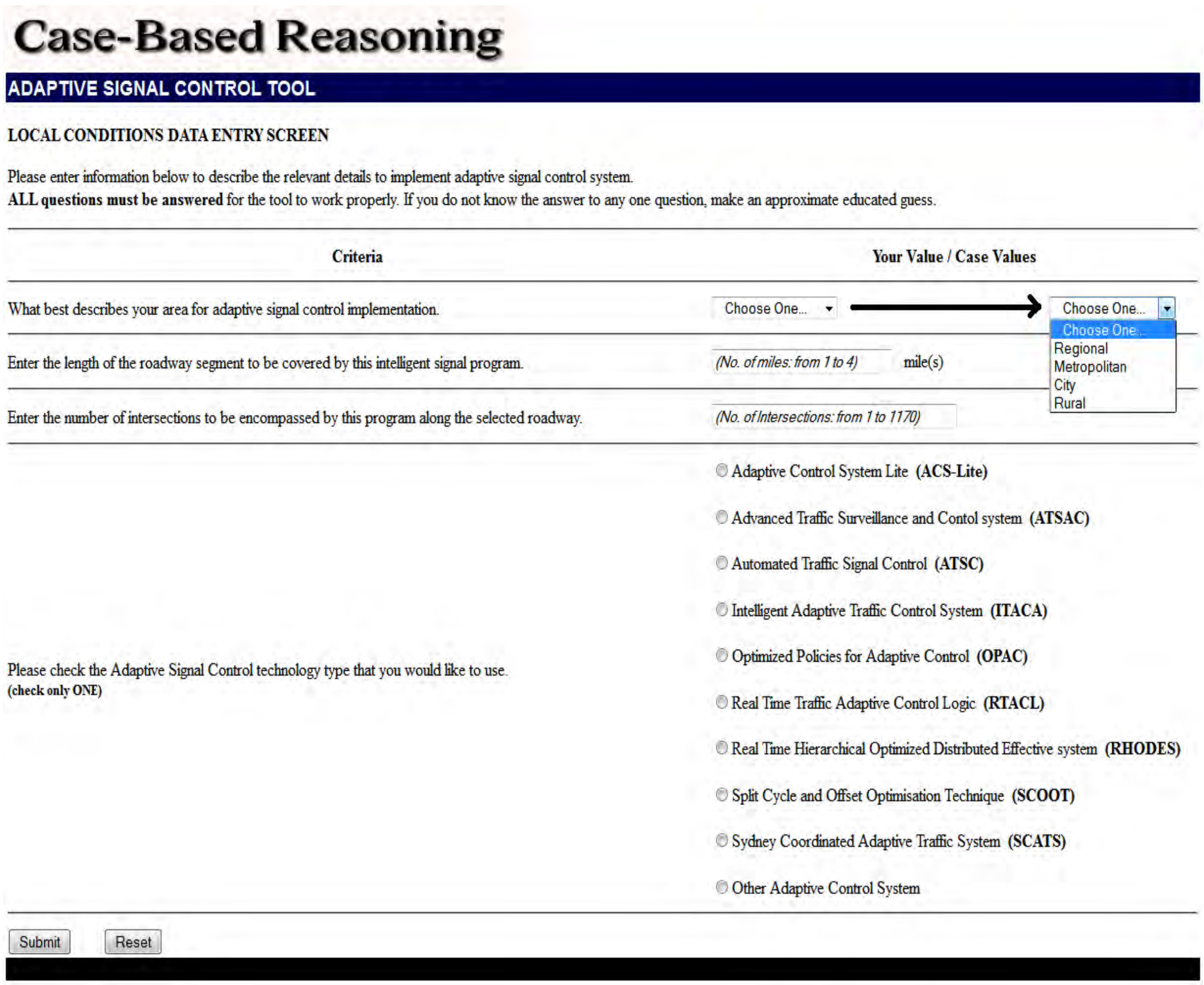


Figure 14 Entry page of Adaptive Signal Control CBR Tool

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 15) where case studies of ASC programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: area type (20%), roadway length (25%), number of intersections (30%) and ASC technology type (25%).

ITS Decision
A Gateway to Understanding and Applying Intelligent Transportation Systems

Return To ITS Decision Main Site

Case-Based Reasoning Tool

ADAPTIVE SIGNAL CONTROL PROGRAM TOOL

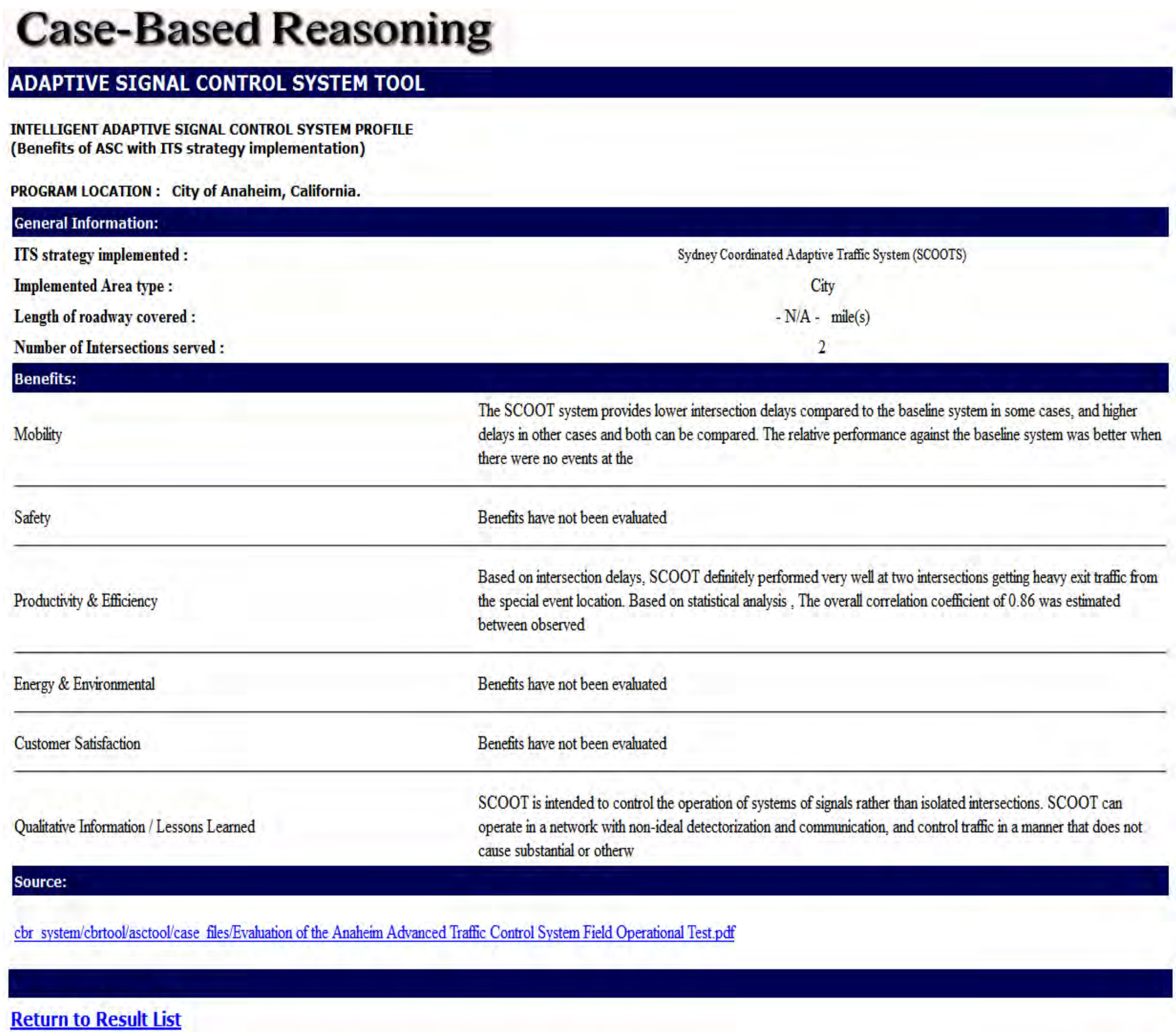
Adaptive Signal Control Program SIMILARITY SCORES
Before implementing your ASC program, you should examine what has been done in these programs:

Run this Tool Again

Location	Similarity Score	Area Description (Weight = 0.20)	Length of Roadway (Weight = 0.25)	Number of Intersections (Weight = 0.30)	Intelligent Signal Control Strategy (Weight = 0.25)
Your Input	- NA -	- N/A -	2 miles	22	Split Cycle and Offset Optimization Tool (SCATS)
Mean for Cases	- NA -	- NA -	1.90 miles	23	- NA -
Burnside road, Gresham, Oregon	93	- N/A -	1.88	11	Split Cycle and Offset Optimization Tool (SCATS)
South Lyon, Oakland County, Michigan	92.5	- N/A -	3.1	6	Split Cycle and Offset Optimization Tool (SCATS)
Rio Branco AV. / Norma Gianotti AV,Sau Paulo, Brazil	70	- N/A -	1.67	10	Sydney Coordinated Adaptive Traffic System (SCOOTS)
Alvarenga St. / Camargo St, Sau Paulo, Brazil	70	- N/A -	1.13	8	Sydney Coordinated Adaptive Traffic System (SCOOTS)
Houston, Texas	68	- N/A -	1.5	8	Adaptive Control Software (ACS-Lite)
Hamilton Road in Gahanna, Ohio	68	- N/A -	1.6	9	Adaptive Control Software (ACS-Lite)
Lins de Vasconcelos AV, Sau Paulo, Brazil	67.5	- N/A -	0.74	10	Intelligent Traffic Adaptive Control Agent (ITACA)
Columbia Pike arterial, Northern Virginia.	65.5	- N/A -	3.4	16	- N/A -
Pinellas County, Florida	64.8	- N/A -	6	17	Real-Time Hierarchical Optimized Distributed and Effective System (RHODES)
Pinellas County, Florida	55.5	- N/A -	10	11	Optimization Policies for Adaptive Control (OPAC)
Munich, Germany	48	- N/A -	- N/A -	25	- N/A -
Anaheim, California	46	- N/A -	- N/A -	20	Sydney Coordinated Adaptive Traffic System (SCOOTS)

Figure 15 Sample cases retrieved and ranked by Adaptive Signal Control CBR Tool

As shown in (Figure 15), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of ASC deployment. For example, the user clicks on Anaheim, California link, a new window opens with a case profile sheet (Figure 16) that provides detailed information about the ASC program implemented in Anaheim, California. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.



Case-Based Reasoning

ADAPTIVE SIGNAL CONTROL SYSTEM TOOL

INTELLIGENT ADAPTIVE SIGNAL CONTROL SYSTEM PROFILE
(Benefits of ASC with ITS strategy implementation)

PROGRAM LOCATION : City of Anaheim, California.

General Information:	
ITS strategy implemented :	Sydney Coordinated Adaptive Traffic System (SCOOTS)
Implemented Area type :	City
Length of roadway covered :	- N/A - mile(s)
Number of Intersections served :	2

Benefits:	
Mobility	The SCOOT system provides lower intersection delays compared to the baseline system in some cases, and higher delays in other cases and both can be compared. The relative performance against the baseline system was better when there were no events at the
Safety	Benefits have not been evaluated
Productivity & Efficiency	Based on intersection delays, SCOOT definitely performed very well at two intersections getting heavy exit traffic from the special event location. Based on statistical analysis , The overall correlation coefficient of 0.86 was estimated between observed
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	Benefits have not been evaluated
Qualitative Information / Lessons Learned	SCOOT is intended to control the operation of systems of signals rather than isolated intersections. SCOOT can operate in a network with non-ideal detectorization and communication, and control traffic in a manner that does not cause substantial or otherw

Source:

cbr_system/cbrtool/asctool/case_files/Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test.pdf

Return to Result List

Figure 16 Detailed case profile page of Adaptive Signal Control CBR Tool

3.6 WORK ZONE OPERATIONS MANAGEMENT

With the United States' roadway system aging, the number and costs of rehabilitation, resurfacing, and reconstruction projects is (are) also increasing. Work zone areas are dynamic and often exhibit constantly changing roadway conditions that are unexpected by most motorists. Hence the frequencies of crashes are typically higher compared to other locations. Work zone management is necessary to ensure safe roadway operations during short term and long-term roadway construction activities. The objectives of work zone management are to provide smooth traffic flow during such activities, to maintain capacity, minimize the unnecessary stops and vehicle delays, reduce impacts on the environment, and most importantly, provide safety for the pedestrians, motorists and work zone crew members. The main attributes involved while developing an effective work zone management plan are duration of activity, type of activity, and time of day of activity. ITS can assist agencies in improving safety and mobility in work zones. They are being extensively implemented in and around work zone areas to provide higher levels of safety and mobility. Work zone ITS provide distributed warnings, advisory, and other important information based on the current traffic flow conditions in the work zone region. The systems employed in work zones are classified into two major categories namely, real-time information systems and individual warning systems.

Real-time Info systems: These systems provide road users and travelers, information about current traffic conditions continuously along a particular roadway facility where the work zone is active (i.e. on a real-time basis). These systems have shown to be effective when the traffic flow is heavy. They have high capital costs but the quality of information communicated is usually very accurate and highly beneficial to various users. Some of the important benefits derived include predicting the queue formations, providing information on congestion conditions in the work zone area and along the approaching roadways, providing alternate and detour information, providing lane operating instructions, and providing hazardous situation information. Common examples of such technologies are: *SWZ, ATIS, WZSAS, ADAPTIR, TIPS, CHIPS, RTTCS, RTWS, INTELLIZONE, CALM, DELMTCS, WIZARD, RTCMSC, DLMS,* Smart Drum, Queue detection systems and Autoroutes-traffic. They are discussed in more detail in the next section.

Individual Warning systems: These systems are appropriate for low traffic conditions. They are typically implemented at places where real-time systems are not critically needed. These systems are cost effective and relatively flexible. They can also be referred to as 'low cost technology' systems. Some of the benefits include helping to reduce speeds of vehicles near and within work zones, and effectively managing all types of traffic flows and conditions. Examples of these systems include: Drone Radar, SpeedGuard, Safe T-spins, Speed detection and monitoring displays, Speed Advisory system, Automated Flagger assistance device, Truck mounted crash attenuators, Robot sign barrels, over-height detector, intrusion alarms, portable signal systems and Portable Changeable Message Signs.

Other relevant systems: Apart from the above two categories of modern systems, other technologies are also used to improve the overall conditions in and around work zones. These include In-vehicle navigation systems, HAR, Wizard CB Alert system, temporary traffic control methods like police enforcement, rumble strips, fluorescent-orange static warning sign boards, fluorescent and/or yellow-green vests, reflective construction vehicle magnetic strips, warning and speed limit information sign boards, flagger control, traffic channelizing devices, traffic control signs, flashing paddles, lighting devices, illuminated arrow panels, vehicle mounted flashers and beacons are all considered under this category.

Various ITS technologies implemented to achieve and overcome traffic flow and safety problems in work zone areas are listed out below:

Advanced Traveler Information Systems (ATIS) - Many innovative technologies have been developed to make work zone areas safer and traffic operations efficient using ATIS. The main functions of these intelligent systems are to provide travel information to travelers to enhance their decisions in choosing routes, lane closures, reduce speeds, etc. These systems can provide real-time work zone information which is communicated to the drivers through various information disseminating devices.

Automated Work Zone Information Systems (AWIS) – These technologies are part of the ATIS, and provide motorists with useful real-time traffic information as they approach and/or travel through the work zone. They provide travelers advanced warnings of slow and congested traffic conditions. It helps increase the safety of both construction crews and motorists. Traffic information provided to the travelers helps increase the efficiency of the overall traffic system in work zone areas.

Smart Work Zone Systems (SMZ) – These ITS technologies aim to improve mobility and safety of motorists by providing real-time traffic and road conditions. They advise drivers of expected delays ahead provide alternate route options. They significantly help reduce of traffic demands in these critical areas. Information of the current conditions is sometimes posted on the Internet, which helps in pre-trip planning.

Advanced Speed Information Systems (ASIS) – These systems are among the newer technologies being developed. ASIS provide real-time information on speeds to motorists at various locations upstream of the work zone. It helps reduce the speeds of approaching vehicles. It also helps improve safety conditions upstream of work zones.

Automated Information Management Systems (AIMS) – These systems provides motorists with information about travel times, speed limits within work zones, and alternate routes which help in efficiently managing the work zone traffic conditions. They help reduce driver's frustration and increase driver's awareness.

Dynamic Lane Merge Systems (DLMS) – This technology monitors the traffic flow in work zones and regulates merging of traffic close to lane closures. These systems help alleviate the congestion and reduce crash rates upstream of the work zone area.

Work Zone Speed Advisory Systems (WZSAS) – These are traveler information systems which provide real-time speed advisory information to travelers within the construction zone. They also encourage drivers use alternate routes if needed.

IntelliZone – This is a portable and flexible system which provides advanced warning to the slow moving traffic entering the work zone area and helps streamline approaching traffic. It also provides speed advisory warnings.

Real-time Traffic Control Systems (RTTCS) – These systems help in traffic monitoring and management and provide information on traffic speed and congestion to the travelers. They help enhance the safety in work zone areas. These systems are suitable for large stationary work zones where there are frequent roadway alignment changes.

Real-time CMS Control (RTCMSC) - This is an en-route traveler information system which provides real-time information to drivers to advise them of a work zone ahead and encourages them to use alternate routes during congestion hours.

Real-time Work Zone Systems (RTWS) - These systems monitor the work zone traffic conditions; provide real-time delay and speed information, and recommend alternate routes during congestion periods, thus improving safety and mobility throughout the work zone area.

Automated Data Acquisition and Processing of Traffic Information in Real-time (ADAPTIR) – This system is an automated, portable traffic control system which provides drivers with real-time information about the work zone traffic conditions. This system provides warning to drivers about the delays and slower desired speeds within a work zone. It also provides travelers with information on detours and alternate routes.

Computerized Highway Information Processing Systems (CHIPS) – These are real-time information systems which provide motorists with information about the expected conditions in a work zone. They also help improve highway safety and reduce work zone accidents.

Travel Time Prediction Systems (TIPS) – These are portable, automated, real-time systems used in predicting and displaying the travel time to motorists approaching and traveling within a work zone.

Construction Area Late Merge system (CALM) – This is a dynamic merge system. It operates as an early merge system during low traffic volume and late merge system during heavy traffic conditions.

Dynamic Early lane Merge Traffic Control System (DELMTCS) – This system improves the traffic flow by encouraging motorists to merge early in the traffic stream. It improves safety by reducing last minute dangerous driving maneuvers.

Work Zone Alert and Information Radio (WIZARD) – This is a portable device which provides advanced warning to drivers of commercial vehicles regarding traffic conditions and incidents on the roadway. This system provides speed advisory messages and helps in improving safety by minimizing incidents and improves traffic flow by encouraging drivers to take alternate routes.

Smart Drum – This warning system alerts the approaching drivers of the slow moving traffic and congested conditions ahead. They help in reducing the speed differential problems around work zones and thus improve safety.

Speed Guard – This is a portable speed reporting system which informs drivers of their speeds within the work zone, thus alerting them to slow down if they are violating the speed limits. These systems are intended to help slow speeding vehicles and increase speed limit compliance.

Safety Warning System – This is a semi portable alert system which alerts motorists of upcoming road and traffic conditions. They provide advanced warning to motorists and help in reducing the speeds of vehicles approaching the construction area.

Wizard CB Alert System – This system uses CB channel radio to broadcast alerts and warning messages to truck drivers. This system alerts them of a work zone ahead and helps traffic merge safely and efficiently before reaching the work zone. It helps drivers reduce their approaching speed to the work zone and hence potentially improves safety.

Drone Radar – This system is intended to reduce speeds in work zones and to reduce speed variance in work zones. It helps in enforcing speed limits in construction areas.

Variable Speed Limit System (VSL) – This system assists in managing speed of approaching traffic and traffic flow through the work zone based on the current traffic, roadway and construction conditions by displaying speed limits to the travelers.

Motorist Awareness System or Maintenance of Traffic System (MAS or MOT) – This is a work zone traffic control system developed by Florida DOT. It regulates traffic in work zones and also serves as a warning device. It alerts travelers of the work zone activities ahead and helps reduce speeds through work zones.

Portable Changeable Message Signs (PCMS) – This ITS element is used for dissemination of advanced warnings and driver information.

Full Road Closure Procedure - This method of traffic management in work zone areas is the most efficient arrangement from a construction prospective as it isolates the complete construction area. This method is least desirable to implement because closing a major roadway even for short periods, can lead to major inconveniences and various other transportation and traffic flow distribution problems. To implement this technique, there must be alternate routes that have sufficient capacity to accommodate the additional traffic volumes generated by the closure.

3.6.1 Work Zone Operation Management Systems Costs and Benefits

The implementation of smart systems at work zones provides effective management of traffic. Various benefits associated with these systems are:

- Reduces Delays and Number of stops, thus improving congestion.
- Minimizes traffic backups and ensures efficient traffic flows
- Improves Quality of driving
- Reduction of speed violations
- Provides real-time information and avoids impatient driving
- Provides alternate route information and improves traffic flow
- Reduces Travel time and better traveling speed, thus improves mobility.
- Faster Incident response and clearance time reduction.
- Improves roadway capacity and traffic throughput in work zones.
- Reduces operational costs and traffic maintenance personnel cost.
- Reduces emission and fuel consumption.
- Reduces hazardous driving conditions and last minute maneuvers.
- Helps motorists in pre-trip planning.
- Provides cooperation among transportation departments, other public work agencies and the traveling public.

Table 9 summarizes the typical benefits and costs of work zone traffic management systems in selected cases.

Table 9 Summary of Benefits and Costs by use of ITS in Work zones by Location

LOCATION	BENEFITS	COSTS
Detroit, Michigan (DLM)	i. Lower average number of stops. ii. Reduced travel time reduced from 96 s/veh to 69 s/veh for every 10,000 ft. iii. Increased average travel speed increased from 40 to 46 mph. iv. Reduction in aggressive driving and during the afternoon peak period. v. Less disruption to traffic flow and less queuing.	Cost for deployment of the DLM system was $120,000. The total project cost was $46 million. The system was cost-effective.
Racine county, Wisconsin (TIPS)	i. Alternative route selection rates were between 7% and 10% of the freeway traffic. ii. Safety improved and injury crash frequency was lower after TIPS began operation.	Cost of lease for TIPS was $179,000
Springfield, Illinois (RTTCS)	i. No significant traffic backups reported. Minimized the delay conditions in the work zone. ii. Helped travelers in pre-trip planning. iii. No additional staff or personnel were required as system updated automatically. iv. Speed reduction and a significant downward trend in the number of violations indicating safety improved	Cost of lease for RTTCS was $785,000 which represented approx. 2% of the total reconstruction budget.

Table 10 Summary of Benefits and Costs by use of ITS in Work zones by Location

(continued)

LOCATION	BENEFITS	COSTS
Albuquerque, New Mexico (AWIS)	i. The average time for responding to and clearing an incident dropped from 45 to 25 min in the work zone area. ii. The average clearance time reduced by 44%. iii. Survey respondents (60%) indicated that the information displayed was accurate and timely. It helped travelers in pre-trip planning. iv. There was a crash reduction of 32% and there were many fewer secondary incidents in the work zone. v. System automatically updated message boards based on real-time traffic without human intervention.	The Smart Work Zone system was purchased for $1.5 million.
West Memphis, Arkansas (CHIPS)	i. Information enabled drivers to choose alternate routes in case of queues ahead and the length of queues as they approached the work zone. ii. Enhanced congestion management. iii. Improved public relations. iv. Reduction in rear-end collisions.	The cost of lease for C.H.I.P.S is estimated at $495,000. The total project was estimated to be a $13.8 million project.

3.6.2 WZM Cases and CBR tool

If traffic engineers & planners from a jurisdiction are considering implementing a Work Zone Management (WZM) systems program to improve the safety & traffic flow at work zones, then they might be interested in knowing about historical cases of WZM programs implemented in other regions under similar circumstances. The desired information is offered by the Web-based WZM CBR module. The user has to enter initial information about the WZM program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the WZM program includes the type of work zone activity, duration of activity, type of roadway facility, length of work zone, number of lanes closed, ADT volume and ITS technology. A sample screen is shown in Figure 17.

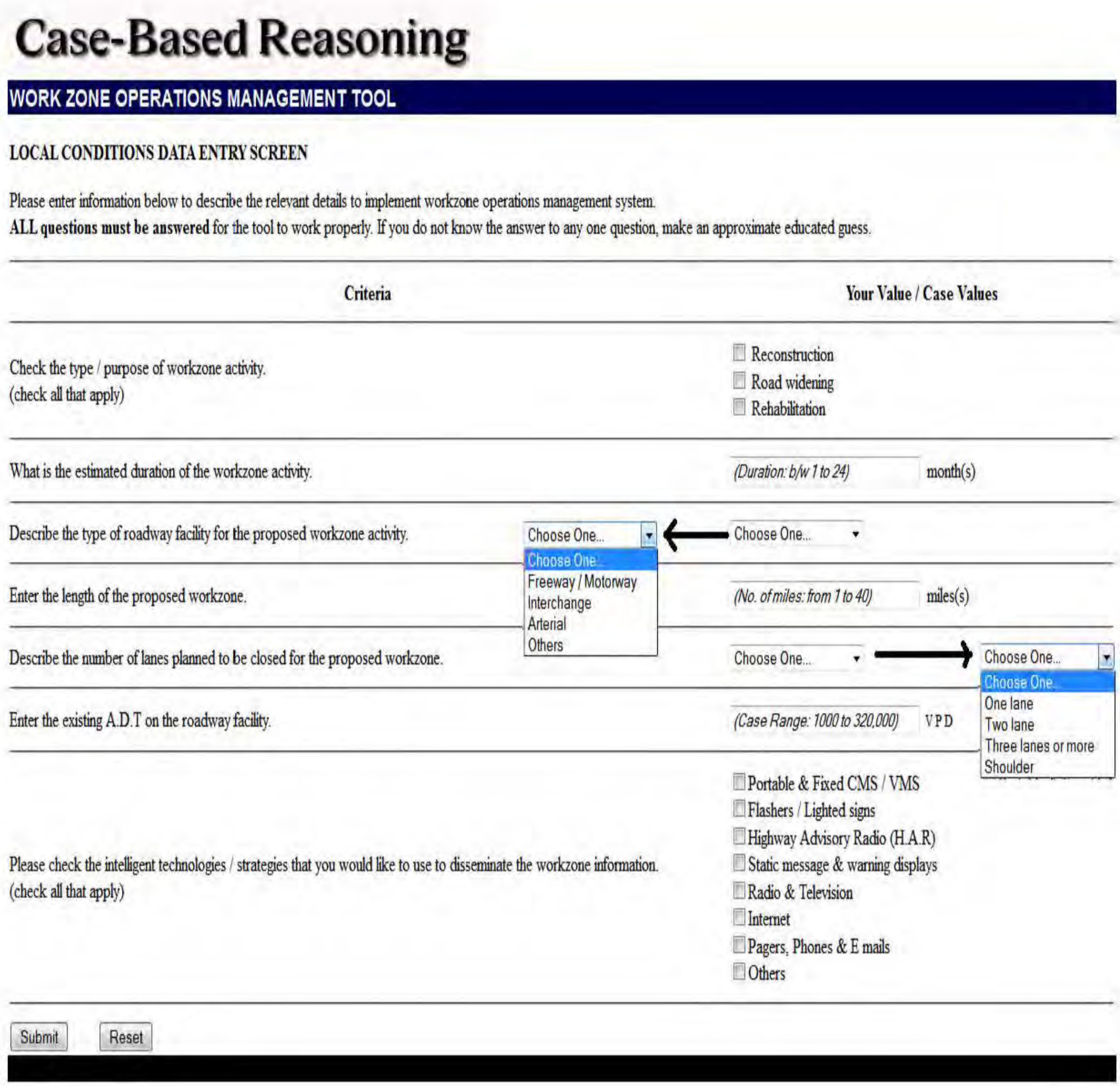


Figure 17 Entry page of Work zone Operations Management CBR Tool

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 18) where case studies of WZM programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: activity type (15%), work zone duration (15%), facility type (10%), work zone length (15%), number of lanes closed (15%), traffic volume (10%) and technologies implemented (20%).

Case-Based Reasoning

WORKZONE OPERATIONS MANAGEMENT TOOL

Workzone Operations Management Program SIMILARITY SCORES
Before implementing your W.O.M program, you should examine what has been done in these programs:

Run this Tool Again

Location	Similarity Score	Activity Type (Weight = 0.15)	Duration (Weight = 0.15)	Facility Type (Weight = 0.10)	Length of Workzone (Weight = 0.15)	Lane Closure (Weight = 0.15)	Traffic volume (Weight = 0.10)	Intelligent Technologies (Weight = 0.20)
Your Input	- NA -	ROAD WIDENING	12 months	Freeway	25 miles	1	14785 vpd	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Highway Advisory Radio system
Mean for cases	- NA -	- NA -	17 months	- NA -	7.8 miles	1 lane	44,000 vpd	- NA -
Atlanta, Georgia	68	ROAD WIDENING	- N/A -	Freeway	23	1	- N/A -	Portable & Fixed CMS / VMS, Highway Advisory Radio system, Static message & warning displays, Others
Little Rock to Benton, Arkansas	57	ROAD WIDENING	- N/A -	Freeway	17	- N/A -	63000	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Highway Advisory Radio system, Static message & warning displays
Baker County, Florida	54	RECONSTRUCTION	22	Freeway	20	1	- N/A -	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Static message & warning displays
Lansing, Michigan	50	REHABILITATION	4	Freeway	18	1	41500	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Static message & warning displays, Pagers, Phones & E mails
Lonoke County, Arkansas	49	REHABILITATION	18	Freeway	6.3	1	36350	Portable & Fixed CMS / VMS, Highway Advisory Radio system, Static message & warning displays, Pagers, Phones & E mails
Greenwood, Nebraska	47	RECONSTRUCTION	1	Freeway	2.7	1	38000	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Highway Advisory Radio system, Static message & warning displays, Others
Copenhagen, Denmark	47	ROAD WIDENING	12	Freeway	- N/A -	- N/A -	- N/A -	Portable & Fixed CMS / VMS, Static message & warning displays
Albuquerque, New Mexico	46	RECONSTRUCTION, REHABILITATION	24	Interchange	- N/A -	2	300000	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Highway Advisory Radio system, Static message & warning displays, Radio & Television, Pagers, Phones & E mails, Others
North Carolina	42	REHABILITATION	17	Freeway	19	1	38000	Portable & Fixed CMS / VMS, Static message & warning displays
Dan Ryan, Chicago	41	RECONSTRUCTION, REHABILITATION	24	Interchange	9	3	320000	Portable & Fixed CMS / VMS, Flashers / Lighted signs, Static message & warning displays, Others

Figure 18 Cases retrieved and ranked by Work zone Operations Management CBR Tool

As shown in (Figure 18), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of WZM deployment. For example, the user clicks on Lansing, Michigan link, a new window opens with a case profile sheet (Figure 19) that provides detailed information about the WZM program implemented in Lansing, Michigan. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.

Case-Based Reasoning

WORKZONE OPERATIONS MANAGEMENT TOOL

WORKZONE OPERATIONS MANAGEMENT PROFILE
(Benefits of W.O.M with ITS technology implementation)

PROGRAM LOCATION : Lansing, Michigan

General Information:	
Type of Activity	Rehabilitation project
Duration	4 months
Type of Roadway Facility	Interstate 96
Length of Workzone	18 miles
Lanes Closed	1
Average Daily Traffic volume	41500 VPD
Information Dissemination Technologies	Variable Message Signs (VMS); Trailer-mounted solar power source and signs; Pager system; Regulatory signs;
Benefits:	
Mobility	There were positive effects on (increased) average speeds and (decreased) travel time through the VSL deployment area. Motorists seemed to respond better to the lighted VMS displays than to standard static speed limit signs mounted on trailers. There was some evidence that motorists gave more credibility to the lighted, VMS-active speed limit signs than static ones.
Safety	A review of the crashes in the area showed that most were rear-end collisions, most occurred in the non-VSL direction, and none appeared to be directly associated with the deployment of the system.
Productivity & Efficiency	The percentage of vehicles exceeding certain thresholds (e.g., 60 mph) did, however, decrease when the system was in operation. The presence of enforcement personnel in the deployment area appeared to have no significant effect.
Energy & Environmental	Benefits have not been evaluated
Customer Satisfaction	Motorists responses to the VSL were more consistent during non-peak periods, especially at night.
Qualitative Information/Lessons Learned	Motorist speeds (and congestion) can vary both by day of the week and longitudinally through the workzone. Static speed limits cannot effectively account for the speed variations, but the VSL display can change with changing conditions and present more credible limits to the motorists. The VSL system is responsive when ambient traffic conditions vary longitudinally throughout the zone. VSL systems will have different applicability in different types of work zone situations. VSL systems will have potentially more utility in longer and "simpler" work zones (e.g., long zones with short work

Figure 19 Detailed case profile page of Work zone Operations Management CBR Tool

3.7 *ROAD WEATHER INFORMATION SYSTEMS*

Adverse weather conditions are known to disrupt the normal operational conditions and increase the number of traffic incidents/accidents. Weather is a critical factor that should be addressed with caution. Weather related driving risks could be reduced by better engineering and maintenance of transportation infrastructure, driver education, roadside warnings, better law enforcement, and timely road surface treatment strategies.

Road Weather Information Systems (RWIS) can be defined as a collection and combination of technologies that are used in the decision making for managing labor, equipment and materials as cost-effectively as possible, while providing effective information to travelers during the course of an adverse weather event. RWIS encompass various levels of sophistication from utilizing a particular technology to a statewide network of weather prediction and pavement temperature detection stations. These decision-making technologies use historical data and real-time road weather and information to improve the efficiency of highway maintenance operations and to disseminate real-time weather and traffic information to travelers to avoid traffic related problems.

The three main elements of RWIS are environmental sensor system technologies, weather forecast systems, and information dissemination and display methods. These are discussed below:

Environmental sensing stations (ESS) are the most critical component of the RWIS as these systems collect weather data and are equipped with meteorological stations and sensors. The following types of weather data are commonly collected by these technologies: air temperature, amount and type of precipitation, visibility, dew point, relative humidity and wind speed and direction; surface data (including pavement temperature, subsurface temperature, surface condition (dry, wet, frozen)), amount of deicing chemical on the roadway, and freezing temperature of the road surface. Data are collected by equipment such as pavement sensors, atmospheric sensors, active and passive sensors, and anemometers that are placed alongside the roadway or within the pavement. Recently, cameras have also been installed to collect real-time images during adverse weather. Environmental data are also collected using vehicle-based sensors. Remote Processing Units (RPUs) are also located along the roadway equipped with sensors. However, these RPUs have limited capacity for processing. Therefore, data are typically transmitted to a central server, where it can be processed and used.

The central server is typically located in a highway maintenance facility and provides support for communications, collection, archiving and distribution of information. Raw data are used directly or in coordination with a service provider to prepare reports or forecasts used to predict site-specific weather and pavement conditions. The system automatically controls and posts the relevant information through various technologies to traveling motorists and to trip planners. The data from the ESS and reports of current and future conditions are compiled and also disseminated to maintenance personnel. Maintenance personnel use this information to monitor and plan various operations such as scheduling personnel, timing of operations, selecting roadway surface control materials, and deploying equipment cost-effectively.

Several information dissemination methods are currently in use within transportation agencies in the US and they include the Internet, Intranet, satellites, and dial-up connections. Additionally, the information can be disseminated to the traveling public through various means including the Internet, television broadcast, radio stations, kiosks, other information display terminals, information centers, and truck stops. This provides travelers with effective real-time information and forecasts on roadway conditions. Latest RWIS technologies are capable of automatically producing variable speed limits and warning information that are posted on the display boards that can help make traffic flow smooth and safer. They also have the ability to produce alerts when required.

A single ESS can provide real-time weather information for a local area as well as for a larger geographic area. The area covered by a regional ESS site is largely influenced by various factors including topography, climate, time and intensity of weather events, and location of adverse weather conditions. These systems have equipment to monitor weather and to provide forecasts that represent a larger area which at times can be an isolated area where no other means of weather & road observations are possible. The ESS weather data density also offers back up to national weather system and help improve the forecasting techniques.

Further information about road weather information systems is available at the following link: www.ops.fhwa.dot.gov/publications/ess05/index.htm.

3.7.1 Road Weather Information Systems Costs and Benefits

Various ITS technologies can be deployed to improve mobility and safety in a region during adverse weather conditions. The benefits include:

- Lower labor and reduced equipment use which cut costs and improves productivity
- Lower material costs and cost effective allocation of resources.
- Lesser environmental impacts.
- Improved mobility and Level of Service (LOS).
- Increased average vehicle speeds and improved mobility during adverse weather conditions.
- Improved safety (fewer crashes, fatalites and less property damages).
- Reduced traffic violations.
- Prompts drivers to slow down and drive at uniform and safe speeds.
- Travel behavior adjusts based on the information provided on the sign boards.
- Helps in pre trip planning

- ESS data can be used to develop road weather products and weather forecast models.

- State climatologists can use these data for long term records and climatological analyses.
- Local, state and federal agencies can use these data to manage emergencies and related response actions and strategies.
- RWIS ESS data can also be used to improve rail, pipeline and marineline operations.

To maximize the benefits, proper planning among different agencies is needed. Table 10 summarizes sample benefits and costs associated with road weather information systems at a few locations in the US and abroad.

Table 11 Summary of Benefits and Costs Road Weather Information Systems

LOCATION	BENEFITS	COSTS
Kotka & Hamina, Finland	i. Survey of drivers (by Pilli-Sihvola, Toivonen, and Kantonen, 1993) reported that the messages influenced their behavior. It showed that 91% of drivers recalled the posted speed limits and 95% of drivers indicated that VMS messages were according to prevailing road condition were useful. ii. It was estimated that the VMS helped reduce the average vehicle speed by 0.4% (from 1.8%to 1.4%) and reduce annual crash rate by 8% (from 33% to 25%). iii. Overall, it was projected to yield a benefit-to-cost ratio ranging from 0.6:1 to 1.6:1 depending on the influence of the system on vehicle speeds and crash rate.	System investment was estimated roughly at $1.3 million and annual operation and maintenance costs approximately $56,000.

Table 12 Summary of Benefits and Costs Road Weather Information Systems

(continued)

LOCATION	BENEFITS	COSTS
Spokane, Washington	i. Survey (Fred and Chris, 2006) indicated that the weather information website made them better prepared to travel and most of them agreed the information helped them avoid travel delays. ii. Speeds reduced when warnings were given during hazardous conditions.	The total cost of the project was evaluated at $446,807.
State of Montana	i. The 511 guidelines were very helpful for pre-trip planning. ii. "just-in-time" anti-icing treatments, weather forecasts and other maintenance procedure are helped save resources and lives. iii. Travelers were quite satisfied with the accuracy, availability, usefulness, and ease of understanding of the GYRTWIS 511-telephone service.	Costs evaluated were - Implementation costs of $188,000 and maintenance & operation costs of $195,950.
City of Sapporo, Japan	i. After the implementation the system, there were no injuries observed. ii. The new information system implemented accurately determines and predicts snowfall. iii. It also provides current weather and snowfall conditions on display. iv. High standards of snow removal helped the city to function normally during the heavy snowfalls.	Estimated costs were approx. $130 million for snow & ice control strategies.

3.7.2 RWIS Cases and CBR tool:

If planners from a jurisdiction are considering implementing a Road Weather Information (RWIS) program, then they might be interested in knowing about historical cases of RWIS programs implemented in other regions under similar circumstances. The desired information is offered by the Web-based RWIS CBR module. The user has to enter initial information about the

RWIS program to be implemented; and then is presented with list of cases based on similarity scores. The user can make inferences based on the historical deployments/cases presented that are most similar to the one contemplated. The user is subsequently presented with detailed information and performance measures for every historical case. The initial information required for the RWIS program includes type of area, type of facility, type of weather conditions, data collection technologies, communication systems and information dissemination strategies, as shown in Figure 20.

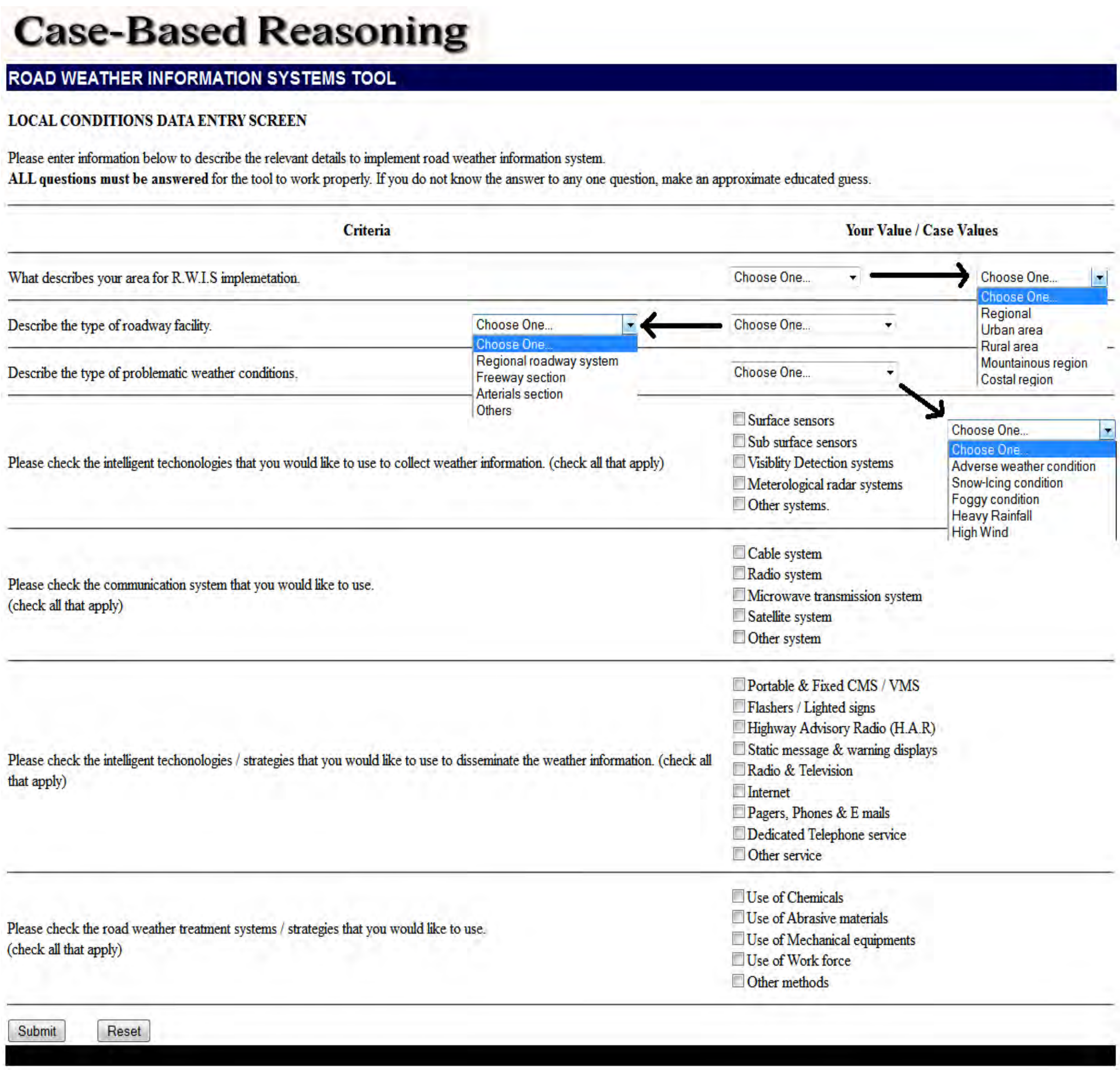


Figure 20 Entry page of Road Weather Information Systems CBR Tool

Upon entering the input information and on clicking submit button, the user is directed to the results page (Figure 21) where case studies of RWIS programs in similar contexts implemented earlier are presented. The historical cases are color-coded in order of similarity. Each historical case's similarity score is calculated based on a set of weights and the differences in attributes between this historical case and the proposed case of the user. The weights for this tool are: area type (10%), type of facility (10%), type of weather (20%), data collection technologies (15%), communication modes (10%), information dissemination strategies (20%) and treatment methods (15%).

Case-Based Reasoning

ROAD WEATHER INFORMATION SYSTEM TOOL

Road Weather Information Program SIMILARITY SCORES

Before implementing your RWIS program, you should examine what has been done in these programs:

Run this Tool Again

Location	Similarity Score	Area Description (Weight = 0.10)	Facilty Type (Weight = 0.10)	Weather Condition (Weight = 0.20)	Collection Technology (Weight = 0.15)	Communication Technology (Weight = 0.10)	Dissemination Technology (Weight = 0.20)	Treatment method (Weight = 0.15)
Your Input	- NA -	Urban area	Freeway	Snow-Icing conditions	Surface sensors, Sub surface sensors	Cable system, Radio system	PCMS, Flashers, Highway Advisory Radio	Use of Chemicals, Use of Abrasive materials
Mean for Cases	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -	- NA -
Spokane, Washington	86.3	Mountainous region	Freeway	Snow-Icing conditions	Surface sensors, Sub surface sensors, Visiblity Detection systems	Cable system	Flashers, Highway Advisory Radio, Internet, Dedicated Telephone service	Use of Chemicals, Use of Abrasive materials, Other methods
Idaho	83.3	Regional	Regional roadway system	Adverse weather conditions	Surface sensors, Sub surface sensors	- N/A -	PCMS, Highway Advisory Radio, Internet, Dedicated Telephone service	Use of Chemicals, Use of Abrasive materials
Bradley & Mc Minn Counties, Tennessee	78.5	Rural area	Freeway	Foggy conditions	Surface sensors, Sub surface sensors, Other systems	Cable system, Microwave transmission system	PCMS, Flashers, Highway Advisory Radio, Dedicated Telephone service, Other service	Other methods
Big Savage Mountain, West Virginia	76	Rural area	Freeway	Foggy conditions	Surface sensors, Visiblity Detection systems	Cable system, Radio system	PCMS, Flashers, Highway Advisory Radio, Static message & warning displays, Internet	- N/A -
Minneapolis, Minnesota	75.7	Urban area	Freeway	Snow-Icing conditions	Surface sensors, Sub surface sensors, Visiblity Detection systems	- N/A -	Flashers, Static message & warning displays	Use of Chemicals, Use of Abrasive materials, Use of Mechanical equipments
San Joaquin County, California	71.8	Rural area	Freeway	High Winds	Surface sensors, Sub surface sensors, Other systems	Cable system	PCMS, Flashers, Other service	- N/A -
Finland	71.7	Costal region	Freeway	Snow-Icing conditions	Surface sensors, Sub surface sensors	Cable system	PCMS, Static message & warning displays, Other service	Use of Chemicals
Nevada	71.3	Mountainous region	Freeway	High Winds	Surface sensors, Sub surface sensors	Radio system	PCMS, Highway Advisory Radio, Static message & warning displays, Internet, Dedicated Telephone service	- N/A -
Mecklenburg County, North Carolina	70.2	Rural area	Freeway	Heavy Rainfall	Surface sensors, Sub surface sensors, Visiblity Detection systems	Cable system, Radio system	PCMS	- N/A -
Utah	68.3	Regional	Regional roadway system	Adverse weather conditions	Surface sensors, Sub surface sensors	- N/A -	PCMS, Highway Advisory Radio, Radio & Television, Pagers, Phones & E mails, Dedicated Telephone service, Other service	- N/A -

Figure 21 Cases retrieved and ranked by Road Weather Information Systems CBR Tool

As shown in (Figure 21), each historical case in the results page is provided with a hyperlink. The hyperlink directs the user to a case profile page that offers more detailed information about each historical case of RWIS deployment. For example, the user clicks on San Joaquin County, California link, a new window opens with a case profile sheet (Figure 22) that provides detailed information about the RWIS program implemented in San Joaquin County, California. Benefits obtained are categorized into mobility, safety, productivity and efficiency, energy and environmental, customer satisfaction, qualitative information and lessons learned. The user is also provided with a source link which will direct them to the original research document that forms the basis of the case, which can be downloaded.

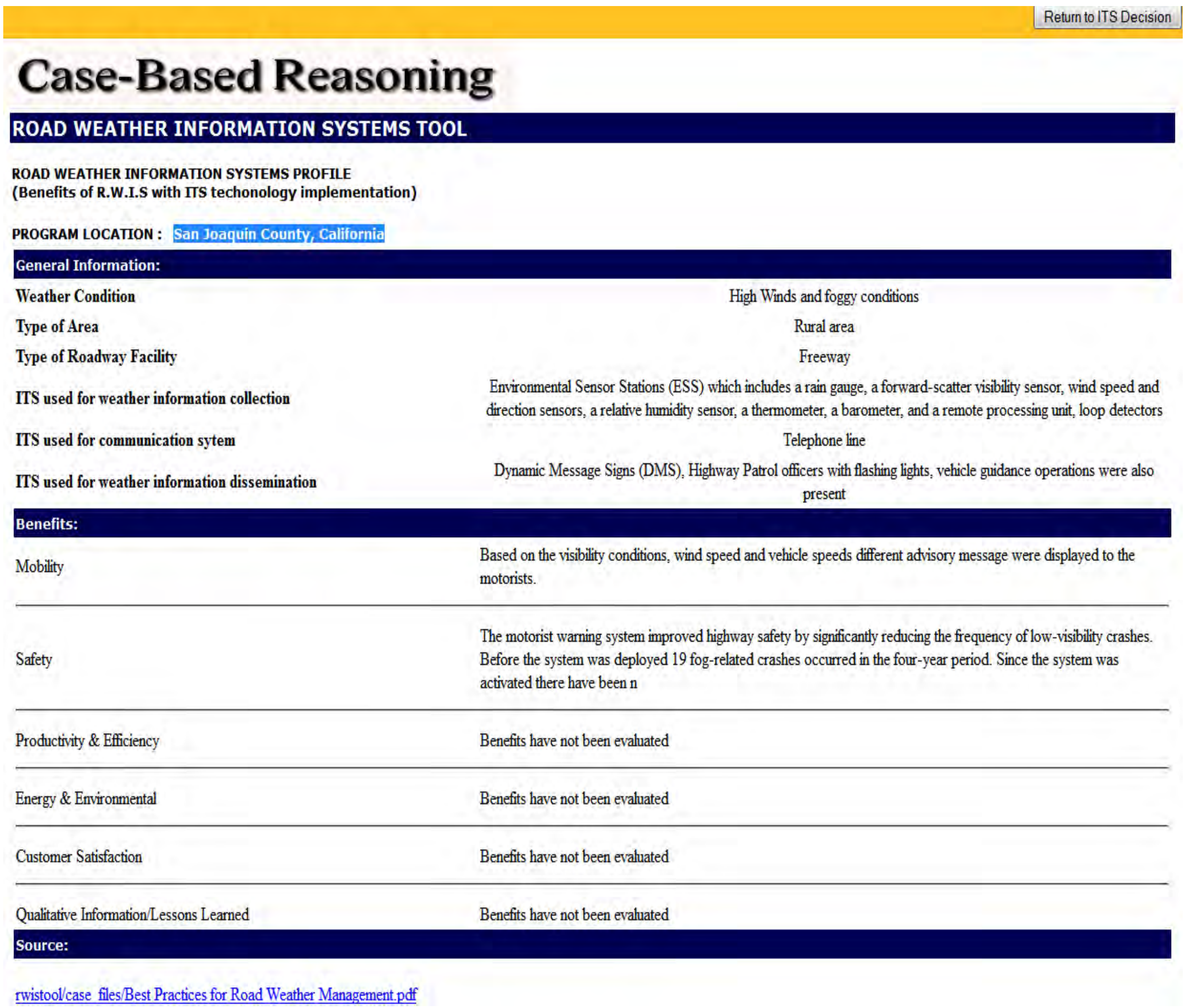


Figure 22 Detailed case profile page of Road Weather Information Systems CBR Tool

4 CONCLUSION: CASE-BASED REASONING

This research has successfully used the theory and structures developed for case-based reasoning to develop an additional set of CBR modules (models 8 to 15 below). The following CBR modules have been developed and are available online.

1. Adaptive Signal Control (ASC)
2. Advanced Traveler Information Systems (ATIS)
3. Automatic Vehicle Location (AVL)
4. Automatic Weigh Stations (AWS)
5. Bus Rapid Transit (BRT)
6. Car sharing (CS)
7. Congestion Pricing (CP)
8. Corridor Signal Coordination (CSC)
9. Electronic Toll Collection (ETC)
10. Employer-based transit pass program (TDM)
11. Freeway Service Patrol (FSP)
12. Intelligent Parking systems (IP)
13. Ramp Metering (RM)
14. Road Weather Information Systems (RWIS)
15. Work Zone Operations Management (WZM)

These tools demonstrate the value of structuring data to create information comparisons to help potential ITS implementers make deployment decisions. To enhance decision-making process, the CBR tool offers a user-friendly interface that connects potential ITS decision makers with the ITS historical cases contained in a database. The system involves a set of CBR algorithms to read user input, to match and rank historical cases based on pre-defined weights, and to display matching results and detailed information of each historical case. The matching results and case profiles are then provided to the user in a structured, user friendly format to help make informed decisions regarding ITS deployment.

In the future, we intend to maintain and update the CBR tool and expand CBR to other ITS technologies. In the next phase of the project, we plan to continue to monitor the development and deployment of these technologies and to integrate new case studies, as they become available. We are also considering additional input and output criteria, where appropriate. Note that the difficulty in adding more matching criteria to the existing technologies is that the inputs must be available for all historical cases. That is, to add additional matching criteria, all (or a majority of) cases in the case-base should have that kind of information available. Practically, this requires contacting the authors and or implementing agencies directly to get certain information (rather than relying on available documents).

We recommend refining the tool and adding modeling tools to fully support a decision maker's cognitive process and help them make informed decisions. The refinements can include (and are discussed in a previous project report in more detail) 1) allowing user assignment of weights, 2) Offering more detailed and consistent data on costs and benefits, 3) providing project cost and benefit forecasts for the implementation site, and 4) providing graphic summary of matching results.

Overall, the proposed future improvements are intended to develop an enhanced decision-making tool for ITS deployment, which offers more user interaction, better data on costs and benefits of historical cases, a new forecast/transfer function of costs and benefits, and high-quality graphic outputs.

5 EXPERT SYSTEMS

An expert system (ES) is an intelligent computer program that uses the knowledge and inference procedures of human experts to solve difficult problems. In other words, an ES tries to mimic a human expert: it extracts expert rules from observed systems to develop knowledge bases; it then makes decisions by inferring results from the knowledge base and rules, based on the information of a particular problem.

The information-intensive nature of Intelligent Transportation Systems (ITS), which typically involves large-scale collection, processing, dissemination, and application of information, imposes challenges for ITS deployment. Therefore, one distinguishing feature of ITS is that it relies heavily on engineering experience and judgment, or expert knowledge, to diagnose and solve transportation-related problems, such as congestion and safety. As more technologies are being deployed to solve transportation issues, decision-makers rely more heavily on interdisciplinary experts. However, the number of available experts is limited, and hiring domain experts is expensive. It is logical, therefore, to apply ES to test the feasibility of using specific ITS technologies to solve transportation-related problems. The ITS Decision Website is valuable in this sense because it can display and store expert knowledge for solving various transportation problems – resulting in the knowledge-based ES. The ES modules are the second step in the entire ITS Decision process. Therefore, the ES modules perform a relatively high level, yet still reliable, analysis on a given problem and provide recommendations about specific ITS technology feasibility.

5.1 OVERVIEW OF EXPERT SYSTEMS (ES)

Figure 23 depicts a typical layout of an ES, which typically includes an expert knowledge base, an inference engine, and a user interface. The knowledge base contains expert knowledge (facts or rules) obtained from various means: published papers/reports, expert interviews, etc. The reference engine operates on rules, i.e., a set of "if-then-else" routines, and an user's input regarding background and information about his/her specific problem to provide answers by applying proper rules. The output of the ES module is a score (or several scores), ranging from 1 – 5, which indicates whether a given ITS technology is feasible to solve a specific transportation problem. Usually, "1" means the technology is least feasible and 5 means definitely feasible.

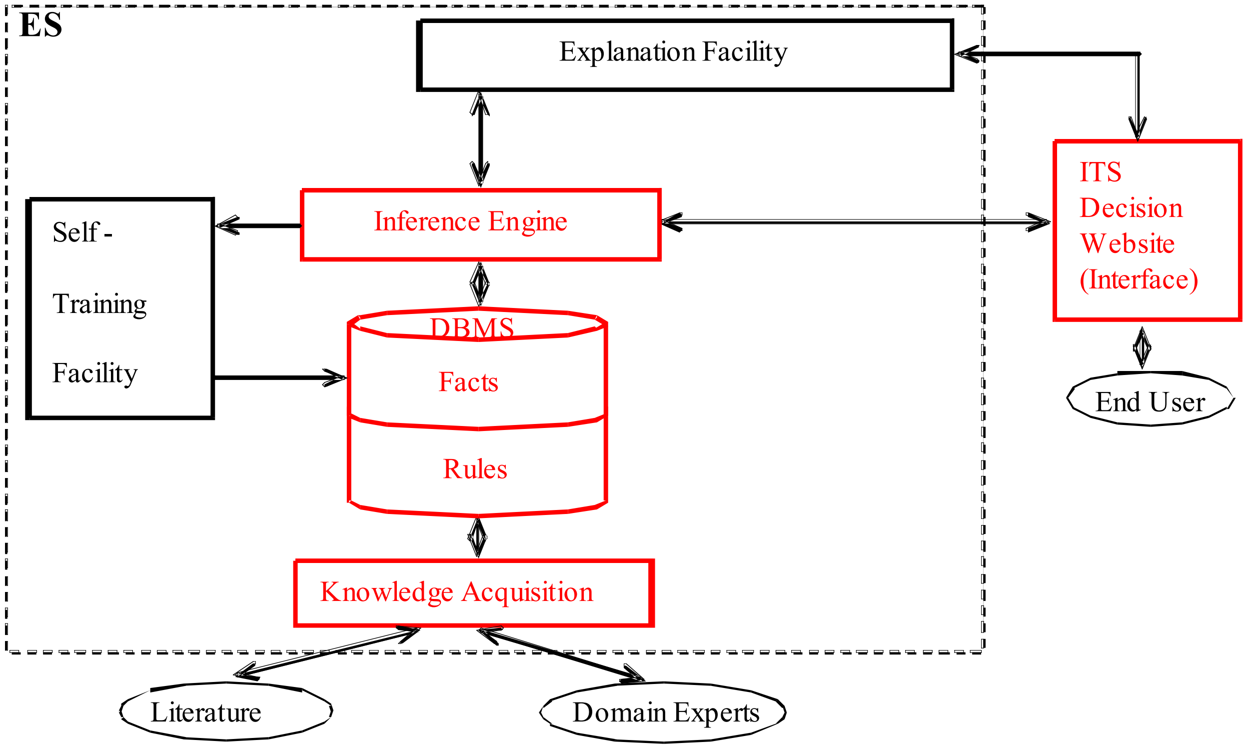


Figure 23 Layout of the ES Engine

Since the developed ES module needs to be integrated into the ITSD website, a web interface for the ES module is needed. To have a clean design for the web interface of the ES module, the MVC (Model-View-Controller) design scheme was adopted[1]. As depicted in Figure 24, the MVC design pattern is usually three-tier architecture with the User and Expert System on the front and back ends, respectively, and the Application Layer functions as an intermediate layer. In this structure, application flow is mediated by a central Controller (servlet). The Controller delegates requests - in our case, users requests - to an appropriate Model. The Model represents the business model that will pass Users' requests to the Expert Systems and manipulate and integrate appropriate responses. The final results are usually forwarded back through the Controller to an appropriate View. The View is normally a JSP that will deal with displaying results in desirable formats to Users.

Therefore, the ES module, including the knowledge base and the reasoning tool, resides as a back-end engine in the entire MVC structure. It takes the user's inputs (passed via the controller), performs the expert reasoning (via accessing the knowledge base), and sends the expert reasoning results back to the user (again via the controller model). Hence, the MVC design pattern provides a loose coupling between the View and Model (including the ES tool), which can make the ES module significantly easier to create and maintain.

[1] http://msdn2.microsoft.com/en-us/library/ms978748.aspx

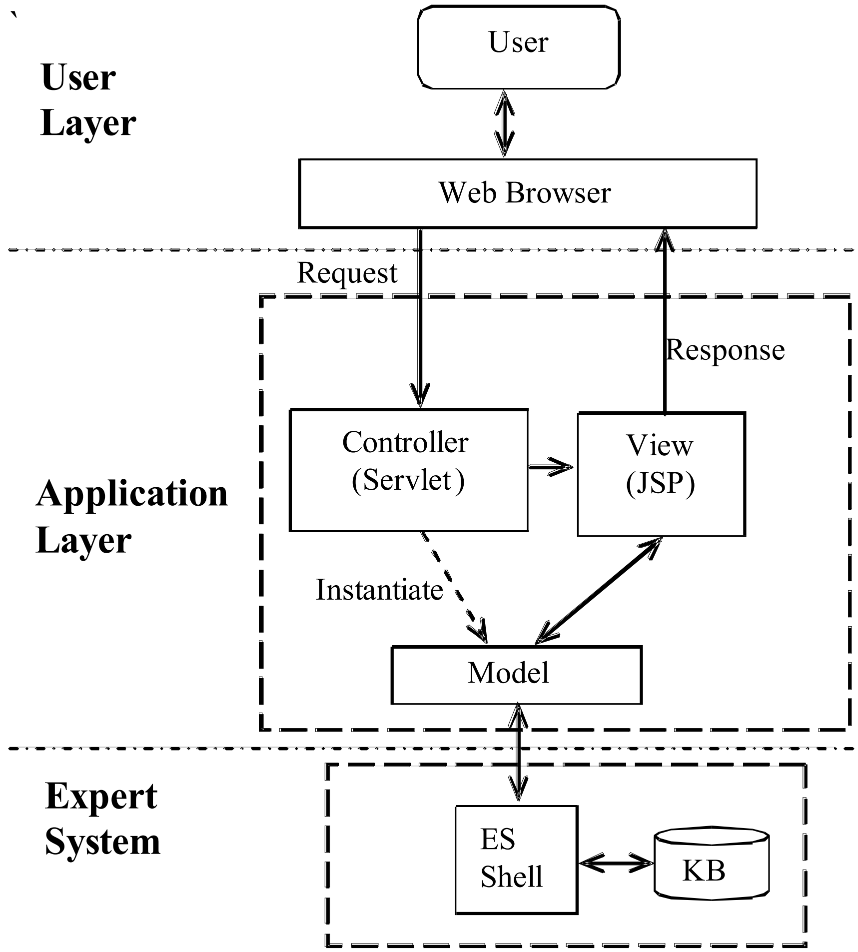


Figure 24 Overview ES Design Using MVC Scheme

In general, the J2EE (Java 2 Platform, Enterprise Edition2) may be used to implement the MVC scheme shown in Figure 24. However, J2EE is mainly used to handle very large and complex web-based applications. For this reason, it contains various Java Beans to handle different business. Nevertheless, our web-based ES is expected to be a small to medium application, and using J2EE may be "overkill". In the actual implementation, therefore, we developed servlets for the Controller and JSPs for the Viewer. It turns out that such a design scheme is more efficient and effective in developing the ES module.

In Sections 5.2 – 5.5 below, we illustrate, using the ramp metering installation application as an example, how knowledge based was created, how the reasoning engine was constructed, and how the user interface was developed. Due to space consideration, we omit the details here for other applications which are similar to the ramp metering application presented here.

[2] http://java.sun.com/j2ee/overview.html

5.2 CONSTRUCTION OF THE KNOWLEDGE BASE

The core of an ES Module is the pre-coded *knowledge*. Knowledge can be categorized into two types: facts (e.g. the maximum metering rate for single-lane-one-car-per-green is 900 vehicles per hour) and rules (i.e. if a certain condition is satisfied, then an action should be taken). Both facts and rules need to be digitized using appropriate knowledge representation methods, resulting in the so-called "knowledge base." In this project, knowledge was obtained mainly through literature review; in certain cases, expert interview was also conducted to obtain additional knowledge or validate knowledge from literature review.

5.2.1 Literature Review

In the literature review phase, published papers from ITS related journals and conferences were reviewed, as well as technical reports and guidelines from different agencies, for the subject ITS technologies. The result is a preliminary knowledge base for each technology. For example, for the ramp metering installation application, we group the knowledge into three categories, denoted as Technical Analysis and Institutional Analysis. The Technical Analysis in particular contains six rules: congestion rule, crash rule, metering method rule, flow control rule, storage rule, and geometric layout rule. Figures 25 to 30 show flow charts of these six rules.

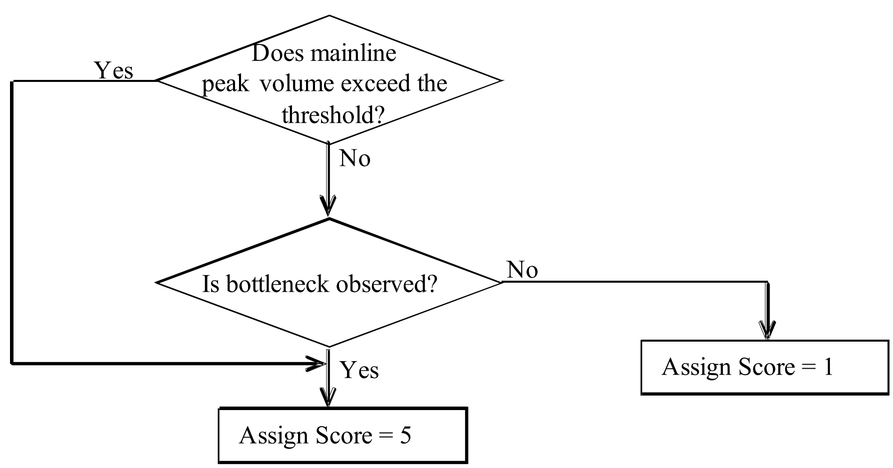


Figure 25 Procedure for congestion rule

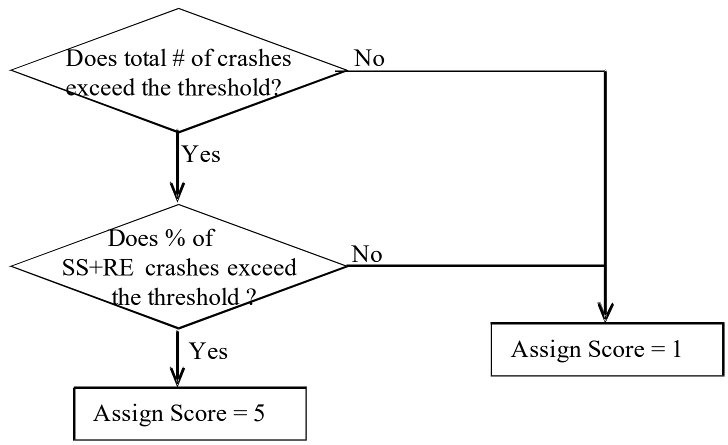


Figure 26 Procedure for crash data rule (SS: side swipe; RE: rear crash)

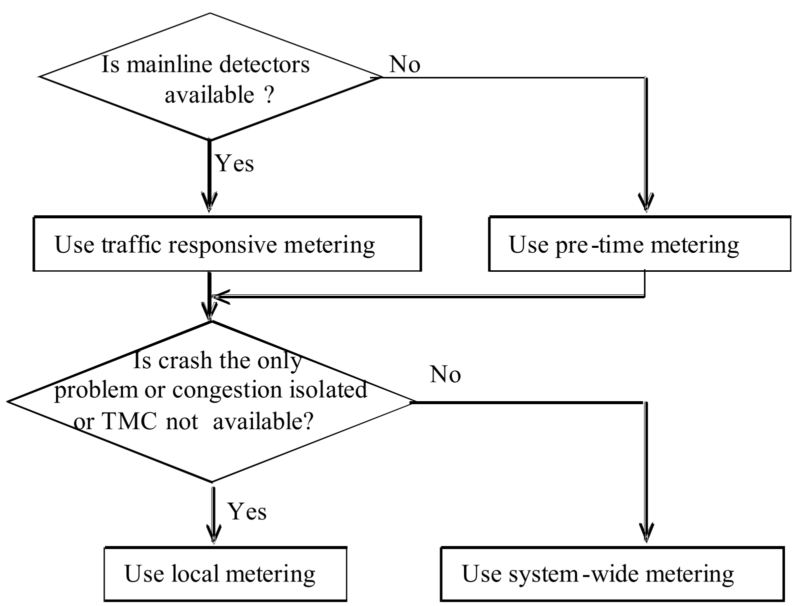


Figure 27 Procedure for metering method rule

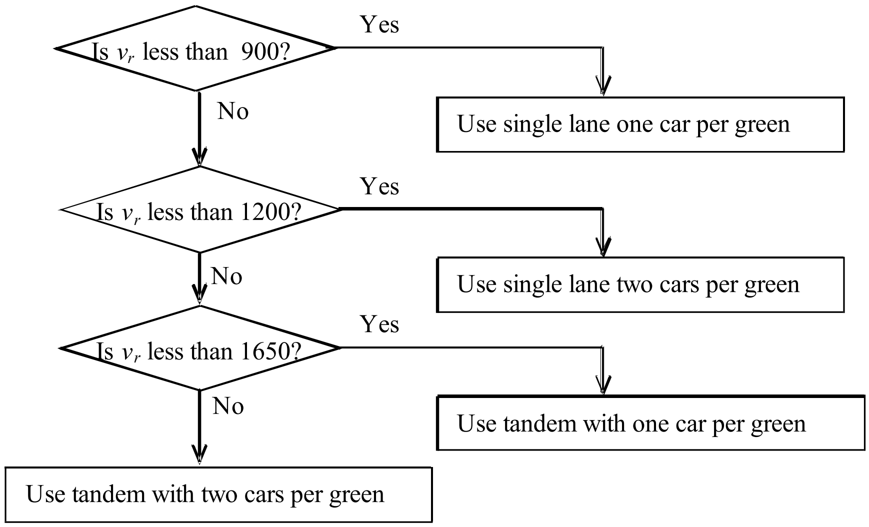


Figure 28 Procedure for flow control rule (vr: ramp volume)

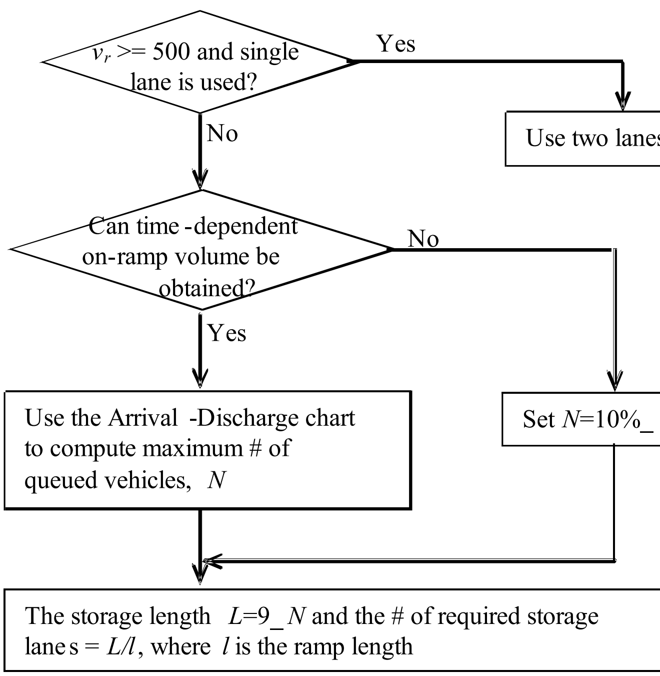


Figure 29 Procedure for storage rule

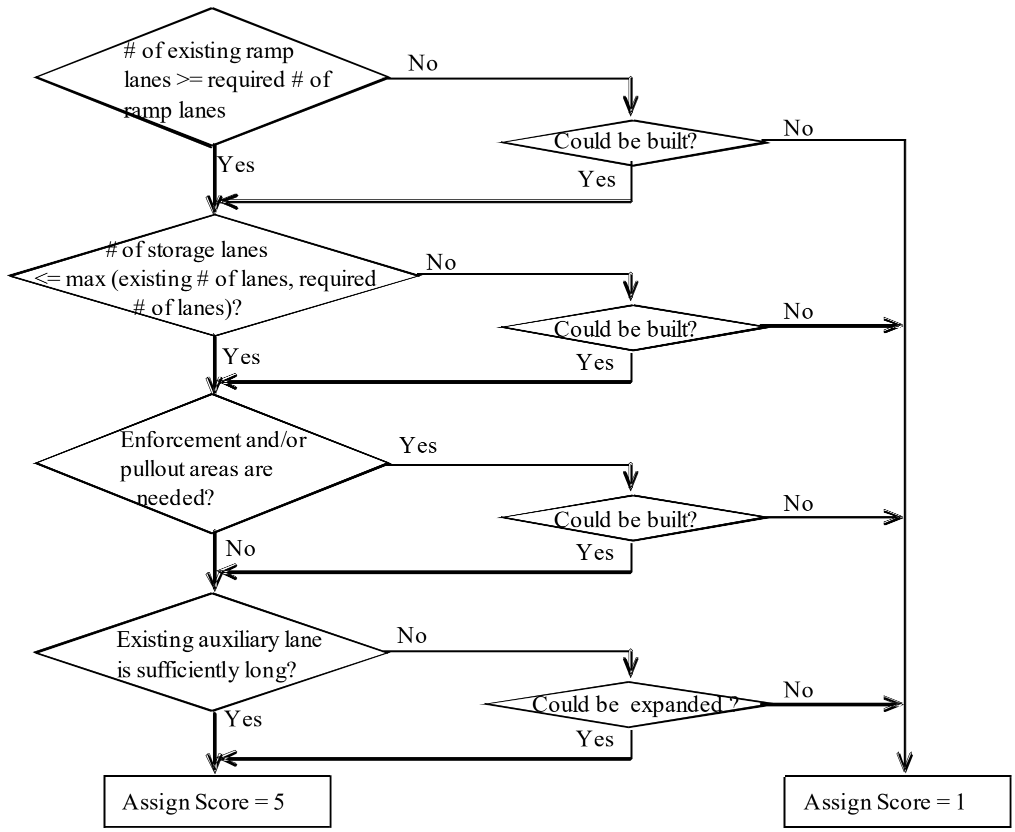


Figure 30 Procedure for geometric rule

Knowledge obtained from literature review constructs the mainly body of the knowledge base, which may be enhanced by expert interview in certain cases (especially for ramp metering, freeway service patrol, electronic toll collection, and weigh-in-motion in this project).

5.2.2 Expert Interview

Expert interview is to obtain additional knowledge from domain experts who have the most up-to-date and case-specific knowledge. For some of the selected applications, we identified a group of domain experts and solicited their views of the technology. The experts we selected include Caltrans engineers, New York State Department of Transportation (NYSDOT) managers and engineers, regional transportation planning agencies staff, academic professionals, and private sector technology suppliers. The following list summarizes the questions that we used to interview domain experts for ramp metering installation. The list includes general questions and specific technical questions on the six rules developed from literature review.

General Questions

1) Before a meter can be installed at a freeway entrance, what are the procedures and/or studies that need to be performed?
2) Are the studies standard procedures in Caltrans or your District? Is there any guideline currently available--besides the Ramp Meter Design Manual?
3) If there are guidelines, what are they? Are they easy to use?
4) If no guidelines exist, how are the studies are performed?
5) What is Ramp Meter Development Plan (RMDP)? How is RMDP developed?

Technical Questions

1). Congestion Rule
    - Is the rule reasonable? (If not, how to conduct the congestion analysis?)
    - What are the thresholds of mainline volume?
2). Crash Rule
    - Is the rule reasonable? (If not, how to conduct the crash analysis?)
    - What are the thresholds of total # of crashes and # of RE + SS?
3). Metering Method Rule
    - Is the rule reasonable (if not, how to determine the metering method?)
4). Flow Control Rule
    - Is the rule reasonable (if not, how to determine the flow control method?)
    - Are the threshold values reasonable? (If not, what should they be?)
    - Are there any other types of flow control methods, e.g. 3 cars per green?
5). Storage Rule
    - Is the rule reasonable (if not, how to determine the required storage?)
    - Are the threshold values reasonable? (If not, what should they be?)
6). Geometric Layout Rule
    - Is the rule reasonable? (If not, how to conduct the analysis?)
    - Are the threshold values reasonable? (If not, what should they be?)
    - Is length of the ramp a concern?

Knowledge obtained from both the literature review and expert review was synthesized into a knowledge base. For the ramp metering example, the finalized knowledge base contains 16 facts and 29 rules.

5.3 DEVELOPMENT OF THE REASONING ENGINE

The reasoning engine generates results based on the knowledge and user input. The project team first used the JESS ES shell to implement the reasoning engine for the ramp metering installation application, due to its relatively complex knowledge and rules. For this, we just need to construct rules according to the JESS' format and trigger its own reasoning engine. This has shown to be fairly efficient to develop the reasoning engine for the ES module, although the downside is that the JESS ES shell is not very user friendly and is a large program by itself (therefore there are certain overheads to load and run it). For the other seven applications, the reasoning engines were implemented using Java codes and JSP scripts by imbedding the knowledge base and rules directly in the program. The advantage of this is that the resulting program for each ES application is much smaller compared to the entire JESS ES shell (but larger than the codes that the team needs to develop if JESS is used) and more efficient to run. Also by developing our own engine, our ES modules will NOT depend on a third-party program. That dependency sometimes might be a problem if licensing is an issue. The downside, however, is that we had to develop our own specialized ES engine using Java and JSP for each of the seven applications, which increased the team's work load.

In retrospect, based on the team's experience of using both standard ES engines (e.g., the JESS ES shell) and developing specialized engines for specific ITS applications, it seems that there needs to be a balance between performances and work load. In particular, if the ES module is very complicated, using a third-party standard ES engine may be a good choice. On the other hand, however, if the ES module is relatively straightforward, developing specified engine without using any third-party program seems to be a better choice.

In terms of actual implementation of the reasoning engine, a two-phase approach was used. A standalone ES prototype was developed in the first phase, starting with a preliminary constructed knowledge base, a reference engine, and a roughly designed user interface, without being integrated into the web interface. The system was then evaluated by the team for improvements. In the second phase, the finalized knowledge base, reference engine, and interface were integrated into a web-based ES system. The ES Module then functions as a back-end service and the interface was embedded in the website (i.e. the front-end). This way, interactions with users are handled by the web interface, and any request regarding "intelligent decisions" is forwarded to the ES.

5.4 USER INTERFACE

The user interface of an ES collects inputs from users and passes the expert reasoning results back to the users. Therefore it is an important component in the ES module. As aforementioned, we designed web interfaces for the ES module on ITS Decision. They were divided into three parts for the technical, institutional, and economic analysis respectively. Since this project does not focus on the economic analysis, this part of the web interface is currently only a place-holder.

Figures 31 – 33 depict the web-interfaces for the Technical and Institutional Analyses of the ramp metering installation application.

Figure 31 Web-Interface for Ramp Metering Installation ES (Technical Analysis)

B. INSTITUTIONAL ANALYSIS

In the following, we are trying to gather information from you in order to conduct the institutional analysis of the feasibility of installing ramp metering at a specific on-ramp. For each of the questions, please provide a score with 1 for absolutely no or unsure and 5 for absolutely yes or sure. You may skip certain questions by clicking the "Skip" button; however, this will reduce the relevance of the results the expert system produces for the institutional analysis.

1. Public Relations Questions: Skip
Have you conducted PR required for marketing, outreach, education, and feedback? 3

2. Performance Monitoring Questions: Skip
Have you determined performance measures to be used? 3
Have you identified data required for performance monitoring? 3
Can you collect data required for PeMs? 3
Can you run analysis to measure performance? 3

3. Operating Procedure Question: Skip
Have you determined adequate operating procedures? 3

4. Inter-Jurisdiction Questions: Skip
Have you determined which jurisdictions are impacted and how? 3
Have you determined the type and level of inter-agency coordination required for O&M? 3
Have you determined the type and level of inter-agency coordination required for enforcement (CHP, etc.)? 3

5. Staffing Questions: Skip
Have you determined the specific staff functions and required skills? 3
Have you determined the adequate # of staffers needed? 3
Can you hire and train staff? 3
Can you retain sufficient # of staff with adequate skills? 3

6. Agency Commitment Questions: Skip
Can you secure required technical means, tools, & resources from your agency for initial planning? 3
Can you secure required technical means, tools, & resources from your agency for engineering design? 3
Can you secure required technical means, tools, & resources from your agency for field construction ? 3
Can you secure required technical means, tools, & resources from your agency for O&M (project life time or at least 5 years)? 3

Figure 32 Web-Interface for Ramp Metering Installation ES (Institutional Analysis, Part I)

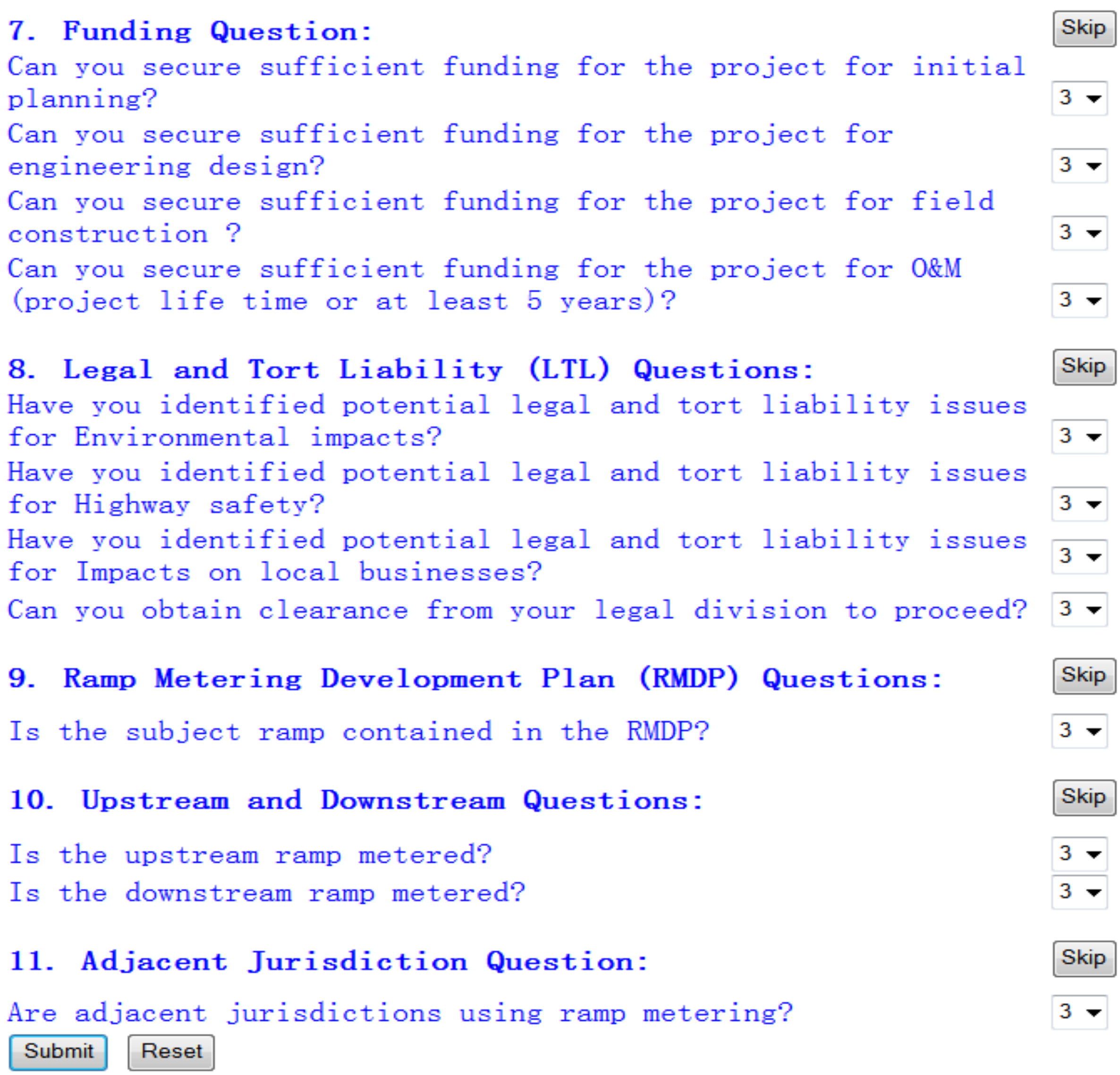


Figure 33 Web-Interface for Ramp Metering Installation ES (Institutional Analysis, Part II)

For the inputs shown above, the ES module produces a score of 2.5 for the Technical Analysis and 3.0 for the Institutional Analysis. This indicates that from purely a technical point of view, the recommendation of installing ramp metering is mild (2.5 out of 5); from institutional perspective, the recommendation of installing ramp metering is a bit higher (i.e., 3.1 out of 5).

The output of the reasoning results for ramp metering installation based on the input in Figures 32-33 is shown in Figure 34.

ES Reasoning Results:

Traffic responsive metering is recommended
System-wide metering is recommended
Use single lane with one car per green
Required length of the acceleration lane: **900.00 feet**
Required number of ramp lanes (metering): **2**
Required number of ramp lanes (storage): **3**
Required number of ramp lanes (overall): **3**
Congestion Analysis Score: **1.0**
Crash Analysis Score: **5.0**
Geometric Analysis Score: **1.0**
Overall Technical Analysis Score: 2.5

Score of Public Relations Rule (PRR): **3.0**
Score of Performance Monitoring Rule (PMR): **3.0**
Score of Operating Procedure Rule (OPR): **3.0**
Score of Inter-Jurisdiction Rule (IJR): **3.0**
Score of Staffing Rule (SR): **3.0**
Score of Agency Commitment Rule (ACR): **3.0**
Score of Funding Rule(FR): **3.0**
Score of Legal and Tort Liability Rule (LTLR): **3.0**
Score of Ramp Metering Development Plan Rule (RMDPR): **3.0**
Score of Upstream and Downstream Rule (UDR): **3.0**
Score of Adjacent Jurisdiction Rule (AJR): **3.0**
The Score for Institutional Analysis is: 3.0

Final Confidence for Institutional Analysis is: 100.0%

The Economic Analysis is skipped.

Back to expert reasoning system

Figure 34 Results of Ramp Metering Installation ES

5.5 *SUMMARY OF THE ES TOOL*

The project has successfully used the theory and structures developed for expert systems (ES). The ITS technologies for which ES has been developed (available online) include:

1. Advanced Traveler Information System (ATIS)
2. Congestion Pricing (CP)
3. Electronic Toll Collection (ETC)
4. Employer-Based Transit Pass (EBTP) Program
5. Freeway Service Patrol (FSP)
6. Ramp Metering Installation Assessment
7. Transit Automatic Vehicle Location (AVL)
8. Weigh-In-Motion (WIM) Station.

These ES tools continue to demonstrate the value of using expert system reasoning tools to guide users for implementing ITS technologies. To enhance decision-making, the ES tool offers a user-friendly web interface that facilitates user's input and ease of accessing and understanding the ES output. The ES modules involves a set of expert knowledge bases constructed via literature review and in some cases expert interviews, inference engineers that take user input and operate on proper rules in the knowledge to produce appropriate decisions, and a web-interface for gather users' input and disseminate ES results. The final recommendations from the ES can provide guidance to users on whether a particular ITS technology is feasible for solving the specific problem.

In the future we plan to maintain and enhance the current eight ES modules and expand ES to other ITS technologies. In the next phase of the project, we will continue to monitor these technologies and to integrate new ITS technologies as they become available. We will also consider using multiple output formats including tabular and graphical forms to display the final ES results, where appropriate.

6 ITS DECISION: WEBSITE ENHANCEMENTS

Several enhancements were made to the ITS Decision website, based detailed input and comments received from users, which included Caltrans staff. They are discussed briefly below.

6.1 UPDATING CONTENT OF ITS DECISION WEBSITE: THIS TASK WAS INTENDED TO UPDATE INFORMATION CONTENT OF THE WEBSITE AND FINALIZE AS AN ITS INFORMATION GATEWAY FOR ALL ITS TECHNOLOGIES.

As we are aware, intelligent transportation systems are rapidly evolving engineering sciences developed to improve transportation. Currently, relevant information of individual ITS technology were updated on the new website and it meets user needs for an ITS Gateway. Applicable data and information on new ITS technologies and implementations are documented on the website and information is presented in an easy to follow format. A new section was created under ITS Links on the new and updated ITS Decision website titled "ITS Friday Headlines". It lists all the relevant ITS projects and programs that are implemented in United States and across the world. Figure 35 shows a refined and an orderly arrangement of all the documented cases.

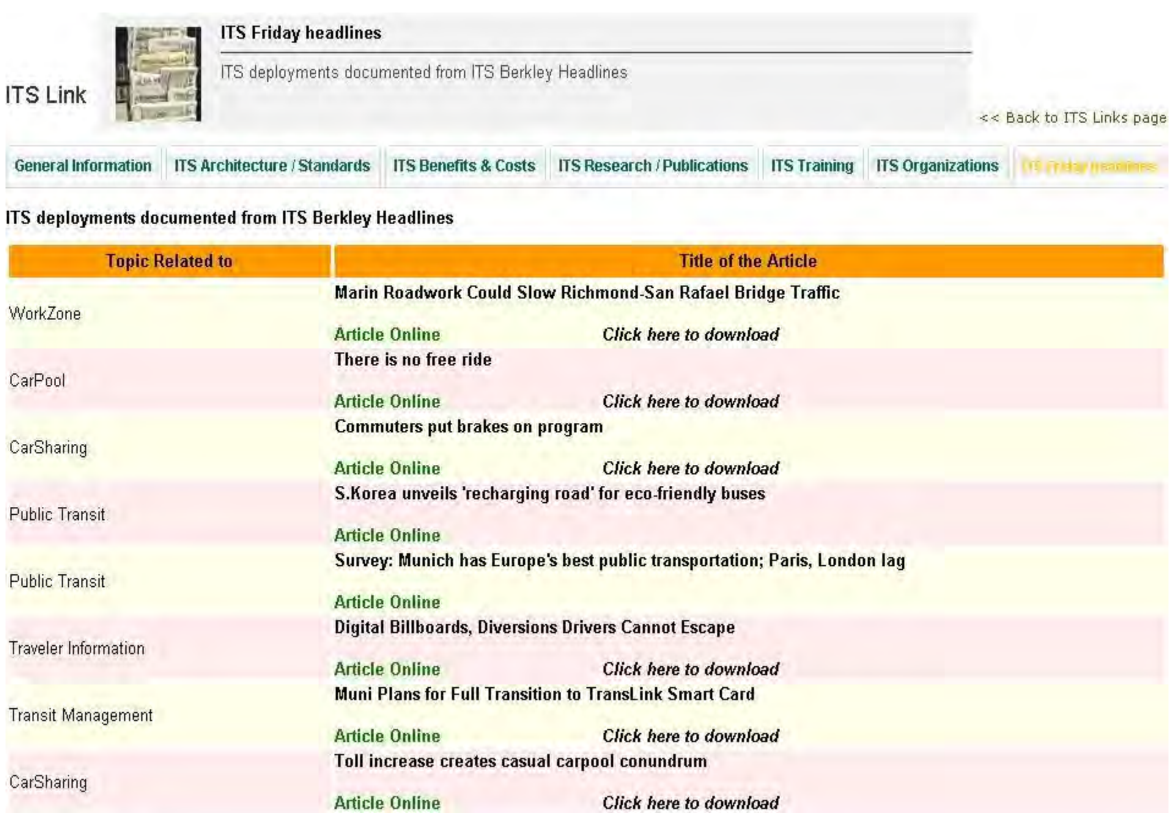


Figure 35 Listing of ITS cases related to ITS Friday Headlines

The “ITS Friday Headlines” section provides only selected pieces of information that are related to the deployment and application of ITS technologies. The links listed for individual cases on the website will direct the user to the original location of the news article. Another link is provided for the complete article to be downloaded (if desired by the user) in an Adobe (.pdf) file format.

The ITS reports and articles section of the ITSD website was updated with recent ITS records that were documented for the various decision making tools. Currently the searchable database for this section was been revised and updated to provide (limited) information on recent developments and articles (Figure 36).

Overall, the accessibility of the website was improved substantially. Links were established to other relevant University of California websites. The new website is now available and it was error checked to ensure that all the links were working properly.

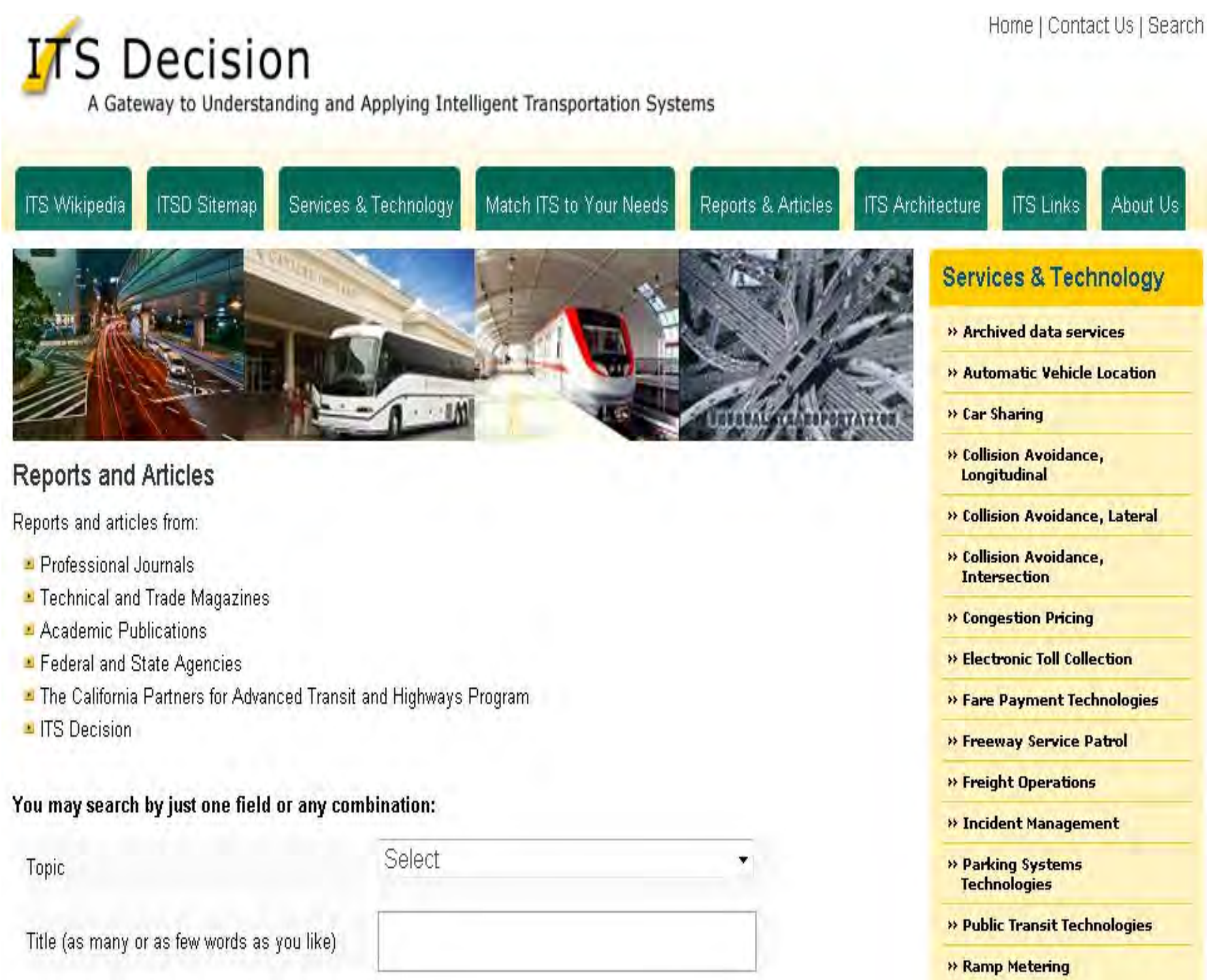


Figure 36 Revised webpage of the ITS Reports and Articles

6.2 DEVELOPMENT OF ITS WIKI TOOL: DEVELOP AN INTERACTIVE WEB-BASED ITS WIKI-LIKE INFORMATION SHARING FORUM

To facilitate communication and deliberation among stakeholders, a knowledge transfer forum was developed where transportation professionals can post comments and remarks pertaining to specific ITS technology. Information and ITS project experiences are exchanged among various registered users of the community. The objective of the Wiki Forum is to create a professional social network for development and deployment of ITS projects (Figure 37).

The stakeholders (ITS decision makers, corporate community, experienced professionals and Caltrans field engineers) can post questions, receive solutions, add comments, provide reviews, upload and download files and provide informative links to users and discuss the merits or impacts of new ITS projects. This is a knowledge transfer domain where registered members can review the website, provide new information or sources of new information, and provide expertise including advice on expanding the functions included in the site.

The web administrator is intended to provide services in maintaining the web consistency; he or she will validate the input information and deal with all forum and user management issues. Accuracy and efficiency will be maintained to present information that will reflect only the contributor's view. The administrator will manage user accounts, create and delete irrelevant topics, delete spam messages, etc. The administrator will also be responsible for database management and security.

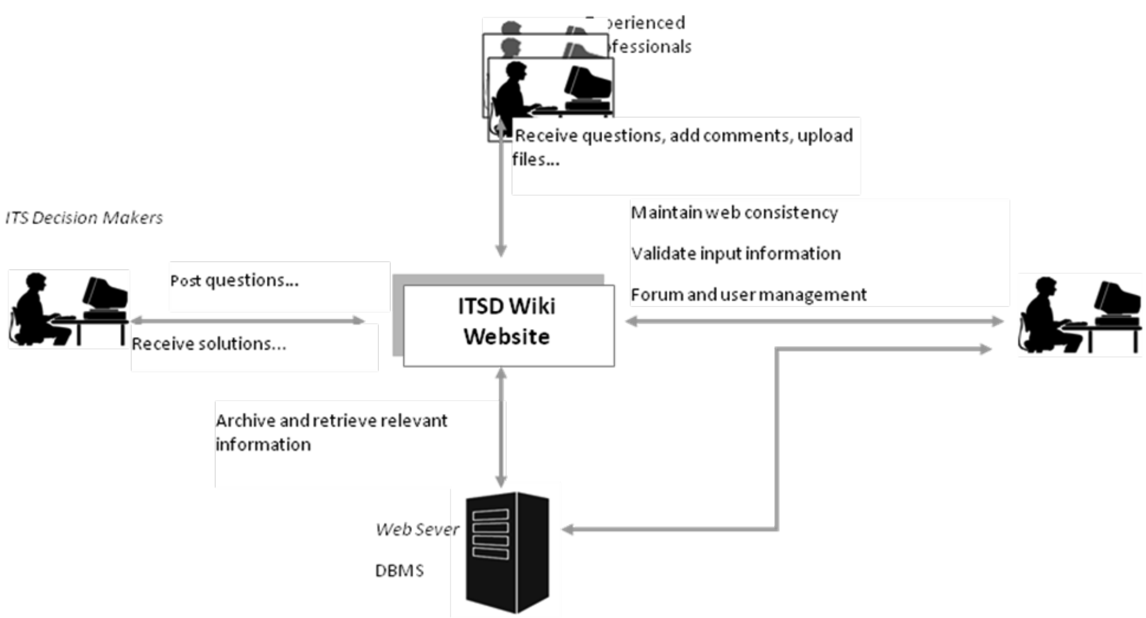


Figure 37 Structure of ITSD Wiki Forum

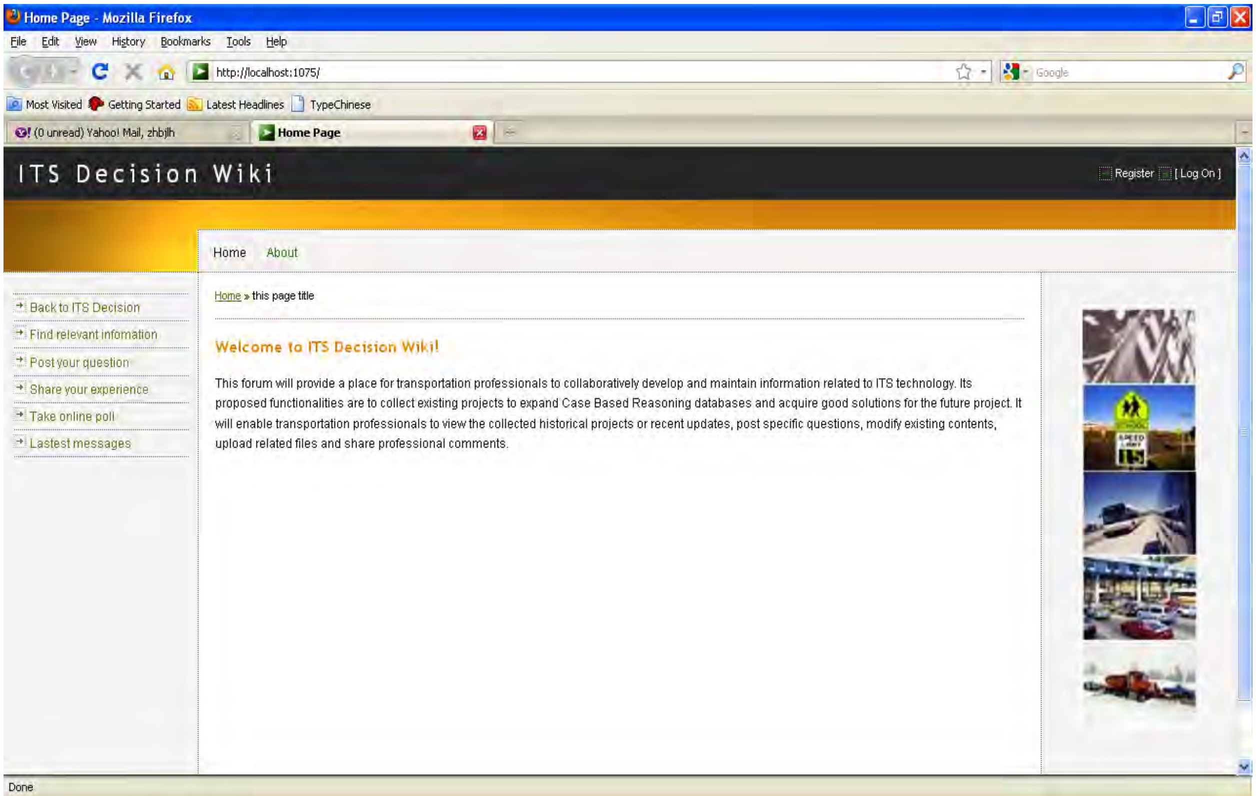


Figure 38 Master page / Home page of ITSD Wiki Forum

Currently, a basic structure for the ITS Wikipedia Forum has been developed and it is functional on the new ITSD website (Figure 38). Presently, only authorized users can access this site and provide their expertise. This developing Wiki Forum is simple and the standalone version is developed using ASP.NET MVC2.0 providing expandable user functions and controls for the future. Future work on ITS Wiki will include:

- A mailing system for the stakeholders/members
- Increasing the database size
- Providing more efficient administration and user access
- Authorization of users at different levels
- Management of messages and exchange of information.

6.3 *ENHANCING THE ITS DECISIONS WEBSITE: THE TASKS WERE TO ENHANCE THE FUNCTIONALITY, NAVIGABILITY, AND USER INTERFACE OF THE WEBSITE.*

A new website was developed for ITS Decision with a completely new design and user interface (Figure 39 shows the home page for ITSD). The site structure was modified substantially to enhance the overall user navigability and functionality. The content was revised and new sections were added to the redesigned website, based on input from Caltrans staff and engineers, who used the website. The new topics were added in respective sections of the website. Overall, the new website design is more attention-getting, provides information in simple and easy to understand format with reduced clicks, and only selected information has been added to each ITS section on the website. The pages for ITS links and analysis tools were updated as shown in Figures 40, 41, and 42 respectively.

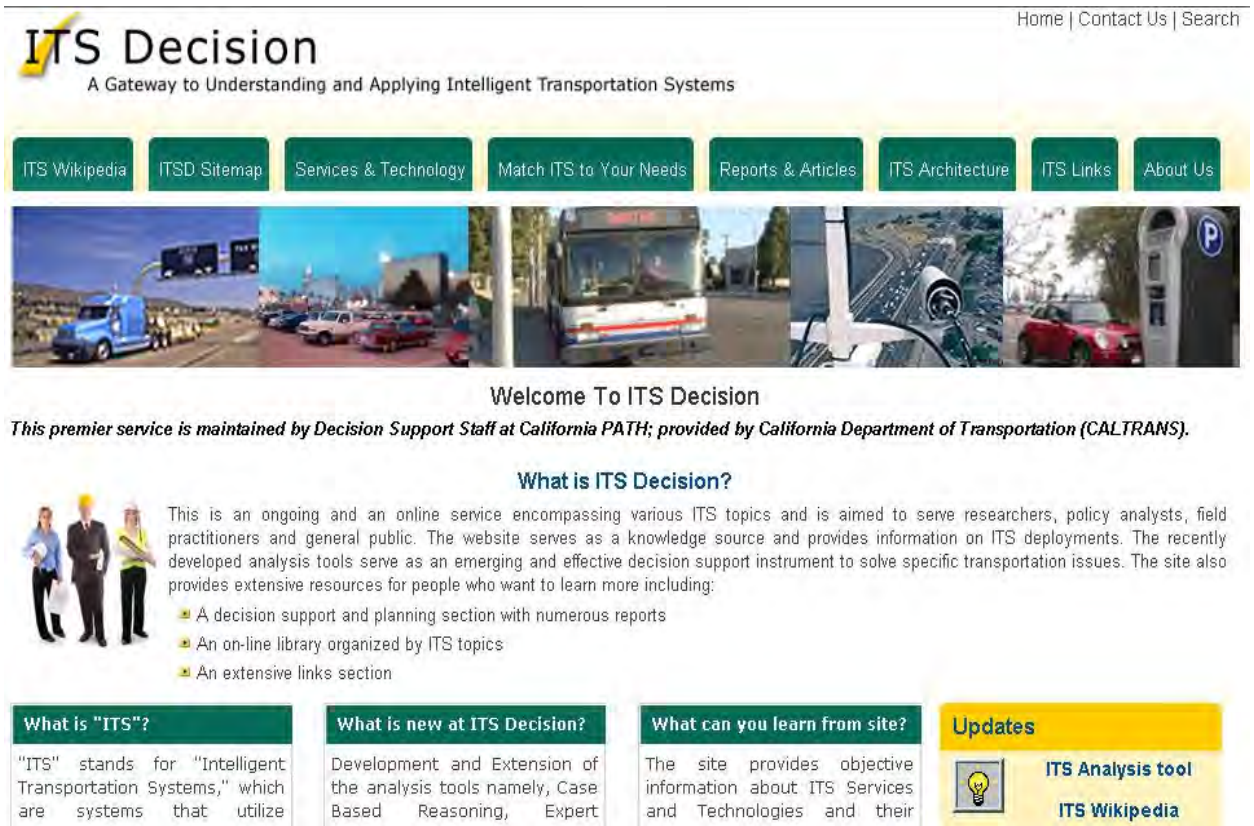


Figure 39 Revised ITS Decision home page

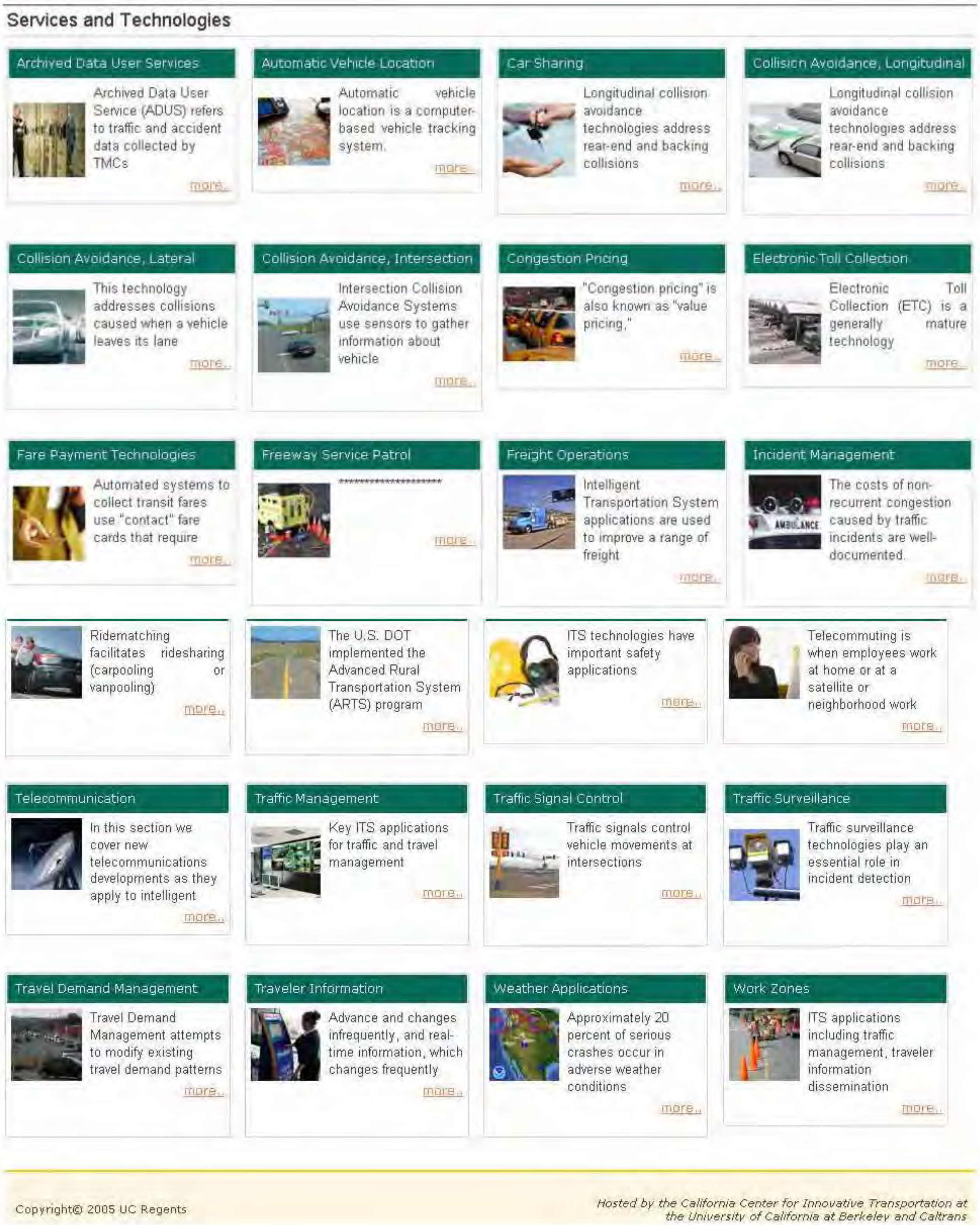


Figure 40 Revised ITS Decision Service and Technology page

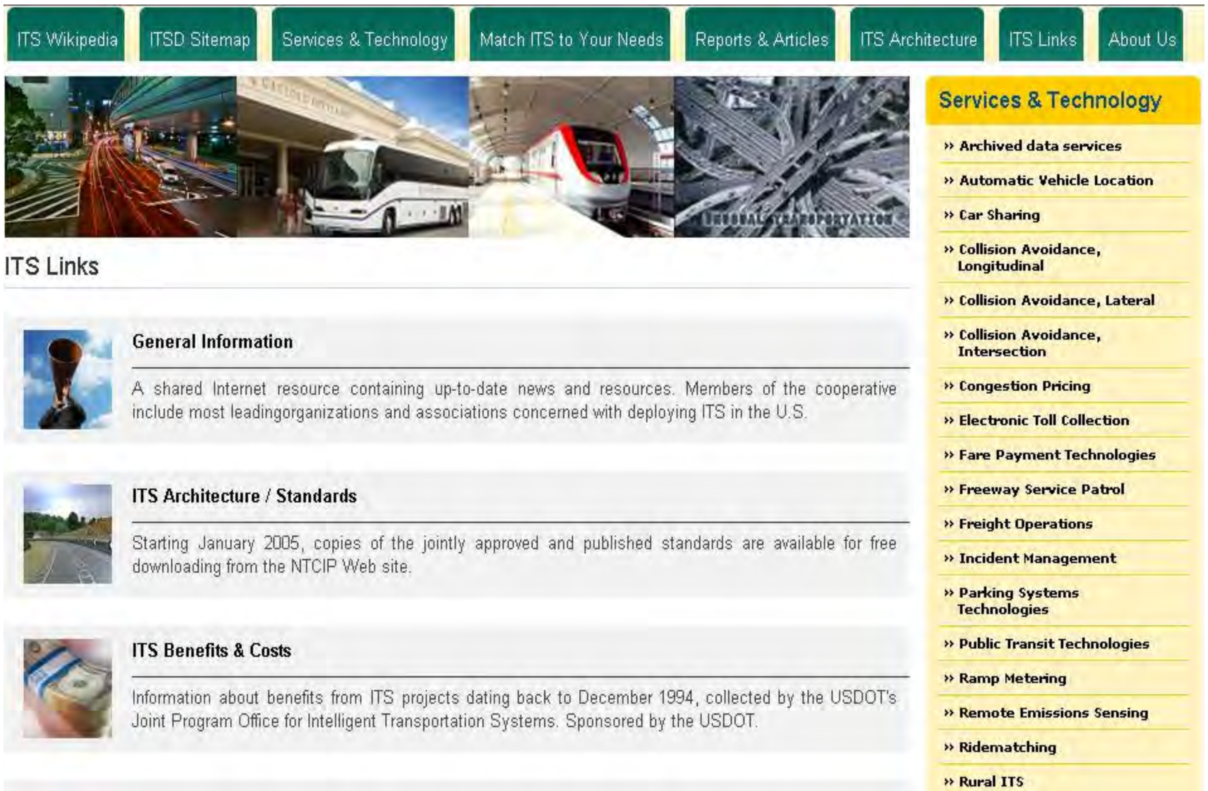


Figure 41 Revised ITS Links section

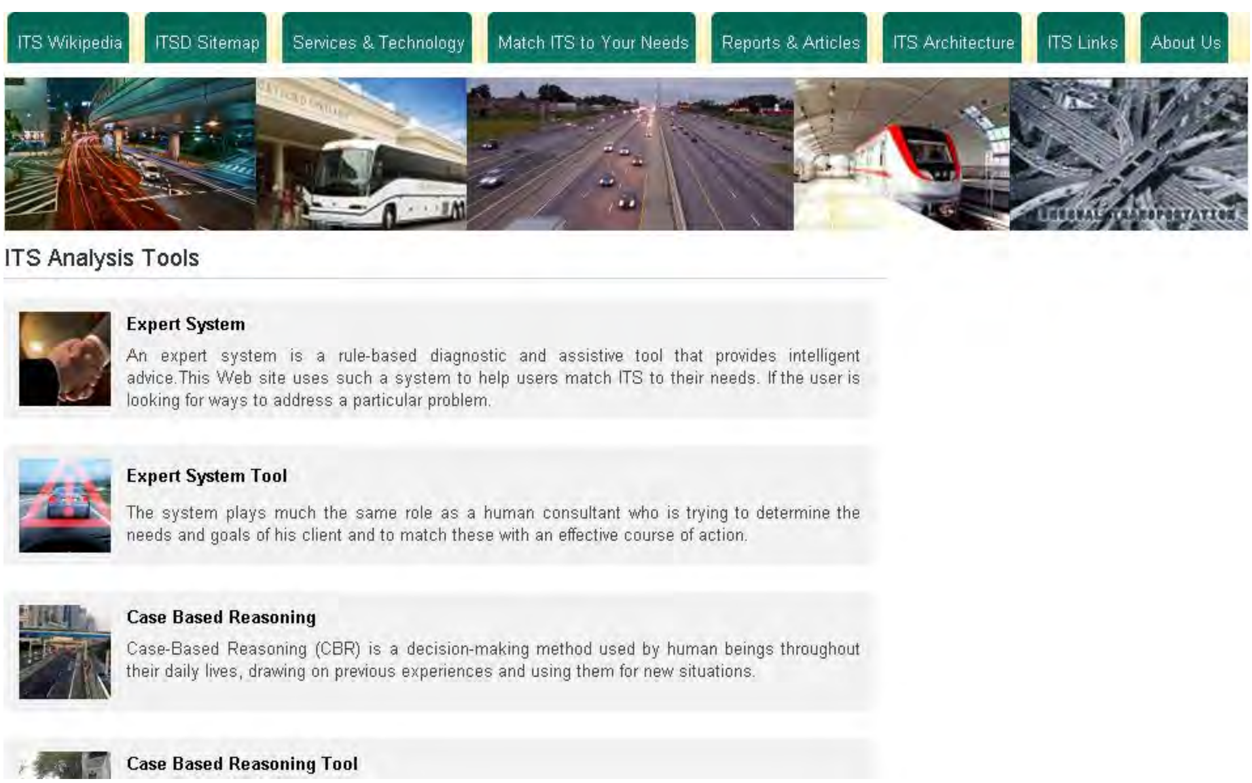


Figure 42 Revised ITS Analysis Tools section

6.4 *LINKING MODELS AND FINAL PRESENTATION: THIS TASK WAS INTENDED TO CREATE AN INTERFACE TO LINK ITS DECISION WITH CALTRANS DOTP'S CAL-BC-ITS MODEL, AND TO DO A FINAL PROJECT PRESENTATION.*

The newly developed Life-Cycle/Benefit-Cost Analysis Model (Cal-BC-ITS) has been linked to the new website (Figure 43). This model helps professionals in preparing economic analysis for a transportation project. The Cal-BC-ITS helps to determine the costs and benefits of implementing a particular ITS technology. Users can use this B/C model in conjunction with the other planning analysis practices as the last step in ITS decision making process.

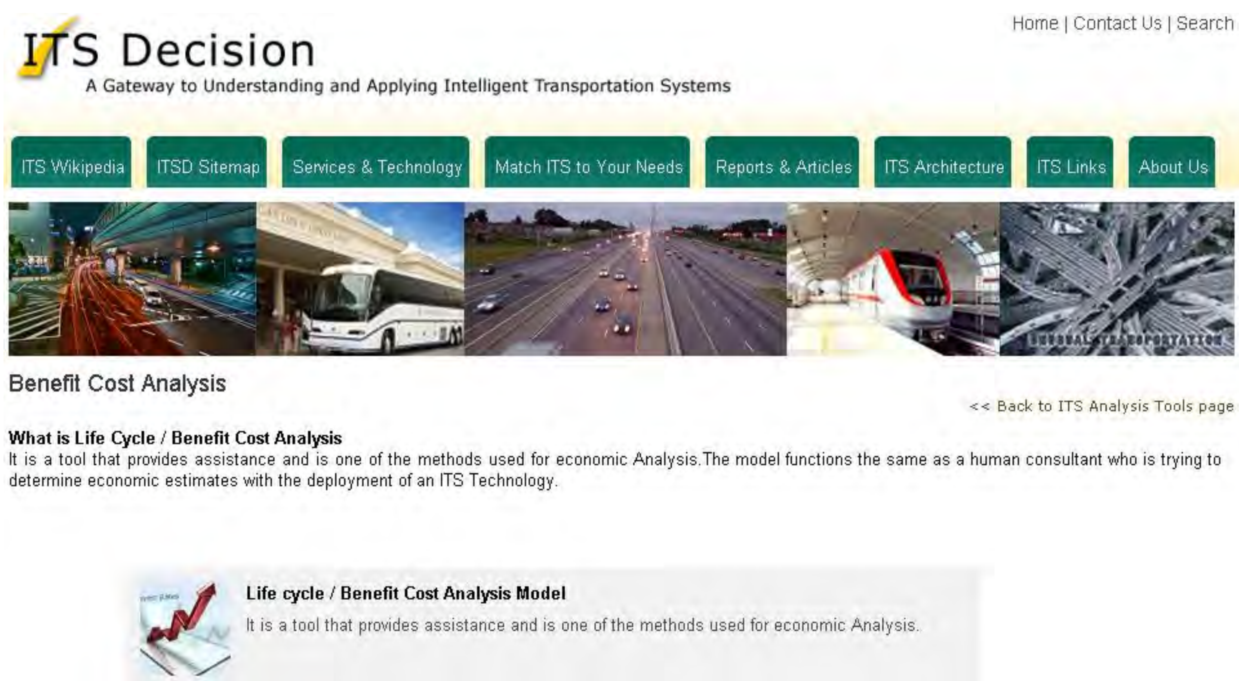


Figure 43 Revised ITS Benefit-Cost Analysis tool page

Finally, Appendix 1 provides a presentation made to Caltrans staff summarizing the project results.

7 CONCLUSIONS: ITS DECISION ENHANCEMENTS

The work on this project has produced a system contained in the ITS Decision website that informs users about ITS technologies and guides them in deciding where and how to deploy intelligent transportation systems technologies. The project facilitates the use of ITS by directing users towards relevant information and case studies and also by providing intelligent expert advice for implementation. It provides awareness of ITS deployments and ITS impacts from around the world. The ITS Decision website is developed as a guide to product development as well as commercialization, marketing and deployment.

The project has successfully achieved the following:

1. Creation of an ITS gateway, complete with an ITS knowledge base and ITS solutions database with links to important federal and state ITS websites.
2. Availability of an Expert System (ES) with 8 working ITS modules
3. Availability of a Case-Based Reasoning (CBR) tool with 15 working ITS modules
4. An interface to the Cal-BC-ITS analysis tool
5. An ITS Wiki Forum for deliberation and debate by stakeholders.

Overall, a properly designed and well maintained ITS Decision website provides users with up-to-date and easily accessible ITS information, deployment data, services and technologies. The end result of this project is to allow Caltrans engineers and deployment staff to easily access ITS related information from the ITS Decision website and apply the developed analysis tools to make better decisions.

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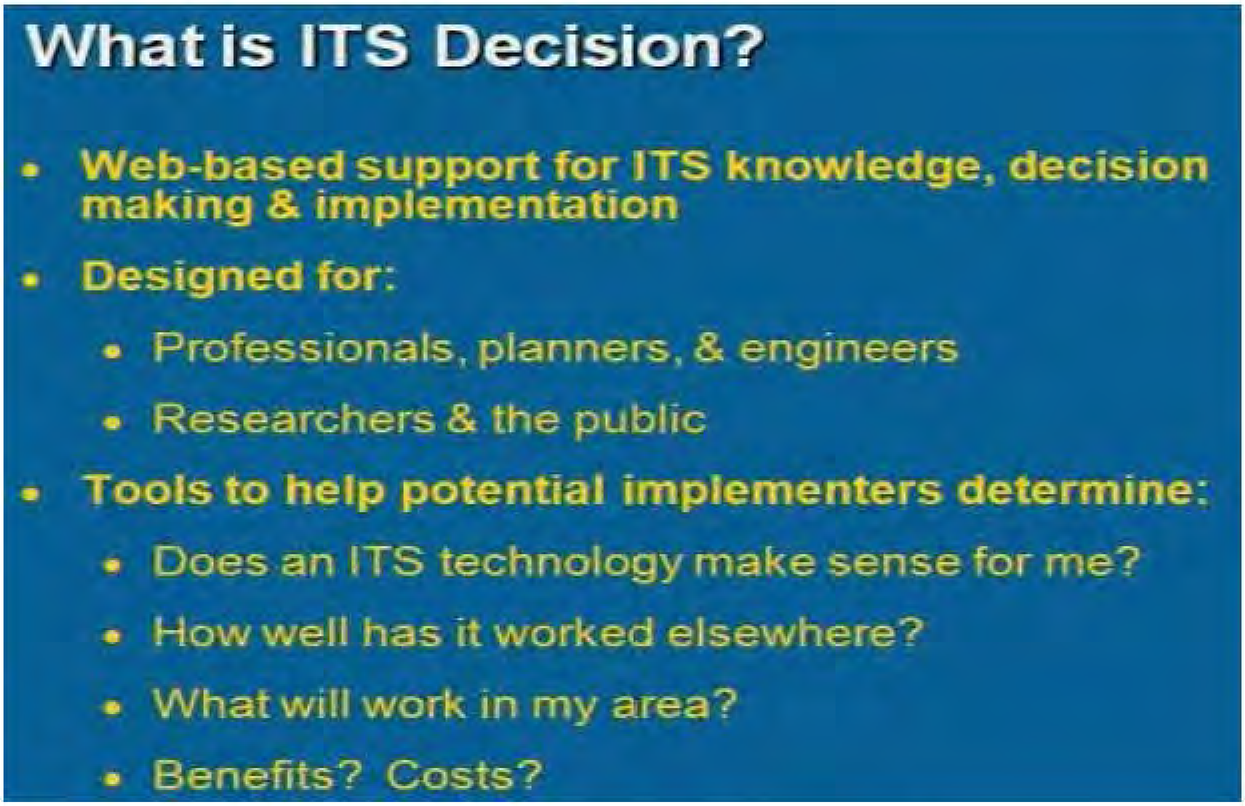
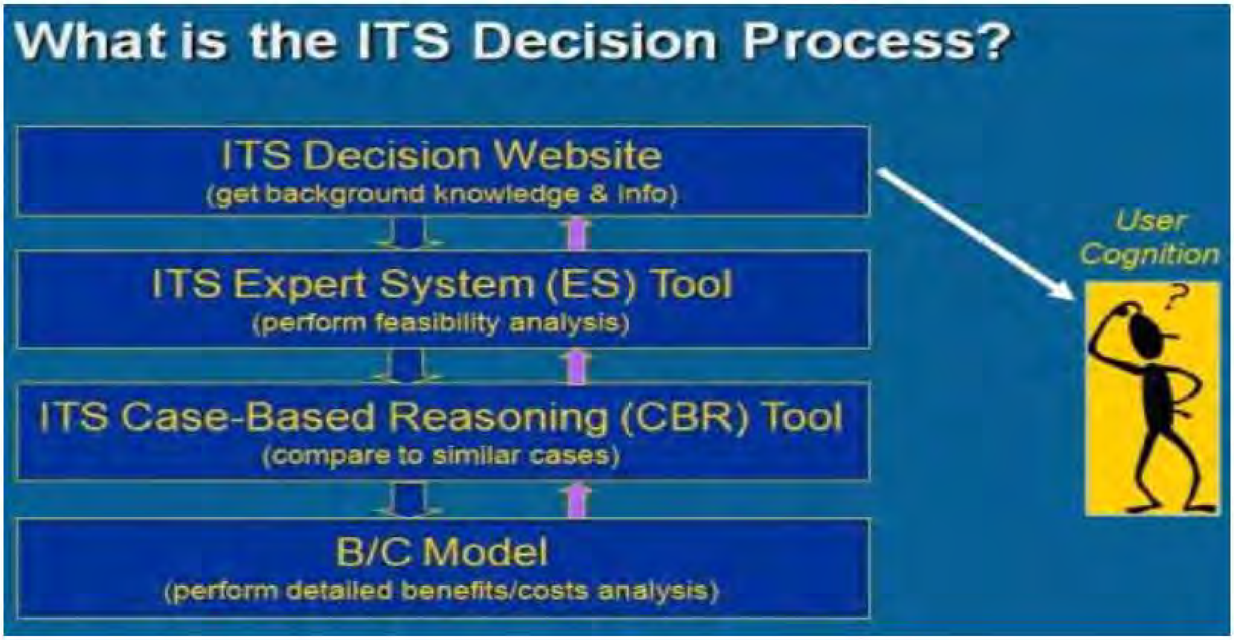
8 APPENDIX A: FINAL PROJECT PRESENTATION




What is the ITS Decision Process?
ITS Decision Website
(get background knowledge & info)
ITS Expert System (ES) Tool
(perform feasibility analysis)
ITS Case-Based Reasoning (CBR) Tool
(compare to similar cases)
B/C Model
(perform detailed benefits/costs analysis)
User Cognition


Existing ITS Decision Website
ITS Decision
Services & Technologies
Match ITS to Your Needs
Reports & Articles
ITS Architecture
Links
About Us
Site Map
Welcome to the ITS Decision Website.
What can you learn from this website?
What is new at ITS Decision?
Archived Data
Carsharing
Congestion Pricing
Electronic Toll Collection
Fare Payment Technologies
Freeway Service Patrol
Freight Operations
Incident Management
Intelligent Vehicles
Parking Systems Technologies
Public Transit Technologies
Ramp Metering
Remote Emissions Sensing
Ridematching
Rural ITS
Safety
Telecommunications
Telecommuting
Traffic Management
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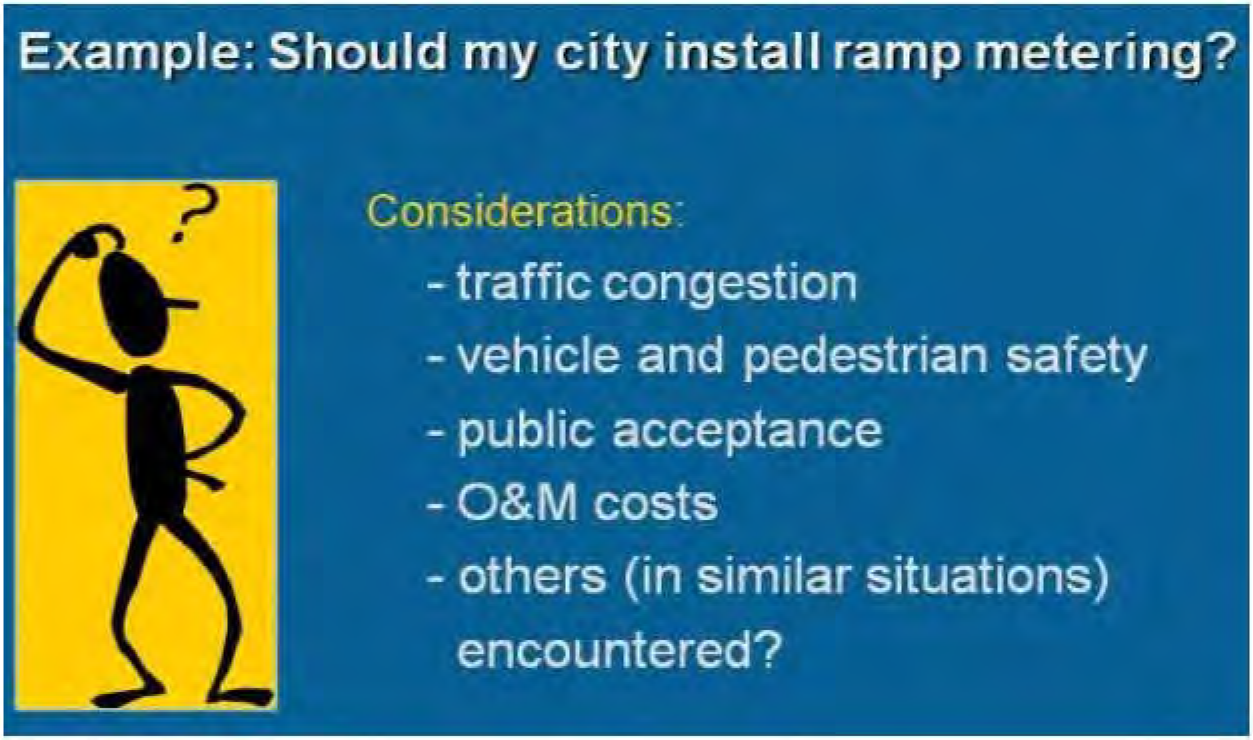
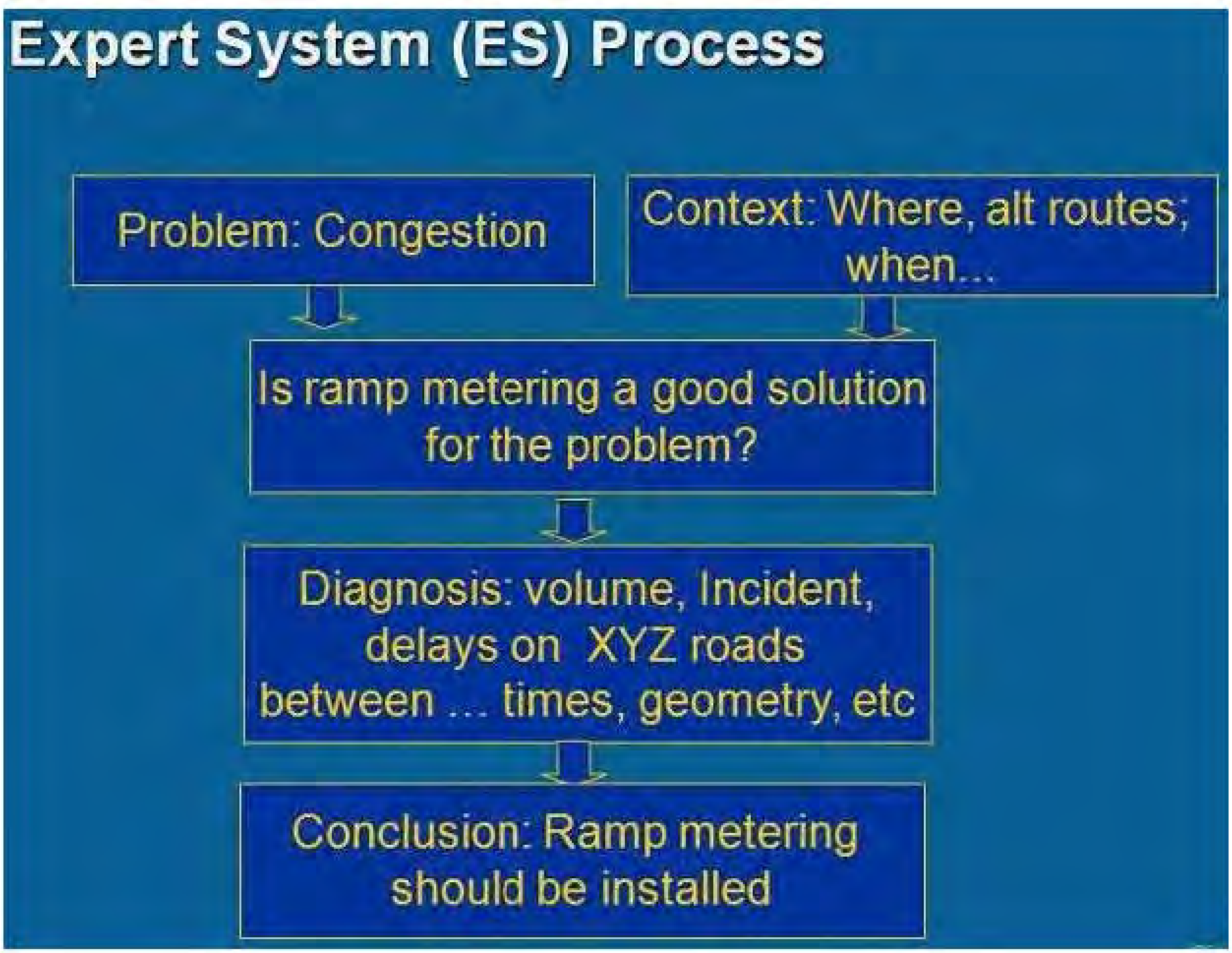
New ITS Decision Website
What we have done:
• Revised frame structure, view, pictures, fonts and styles
• Updated Links & Architecture sections
• Improved site navigation
• Reduced clicks
• Simplified design, appropriately formatted
• Expanded CBR Tool (from 8 to 16 modules)
• Added ES Tool (8 modules)
• Added Wiki Expert Forum.

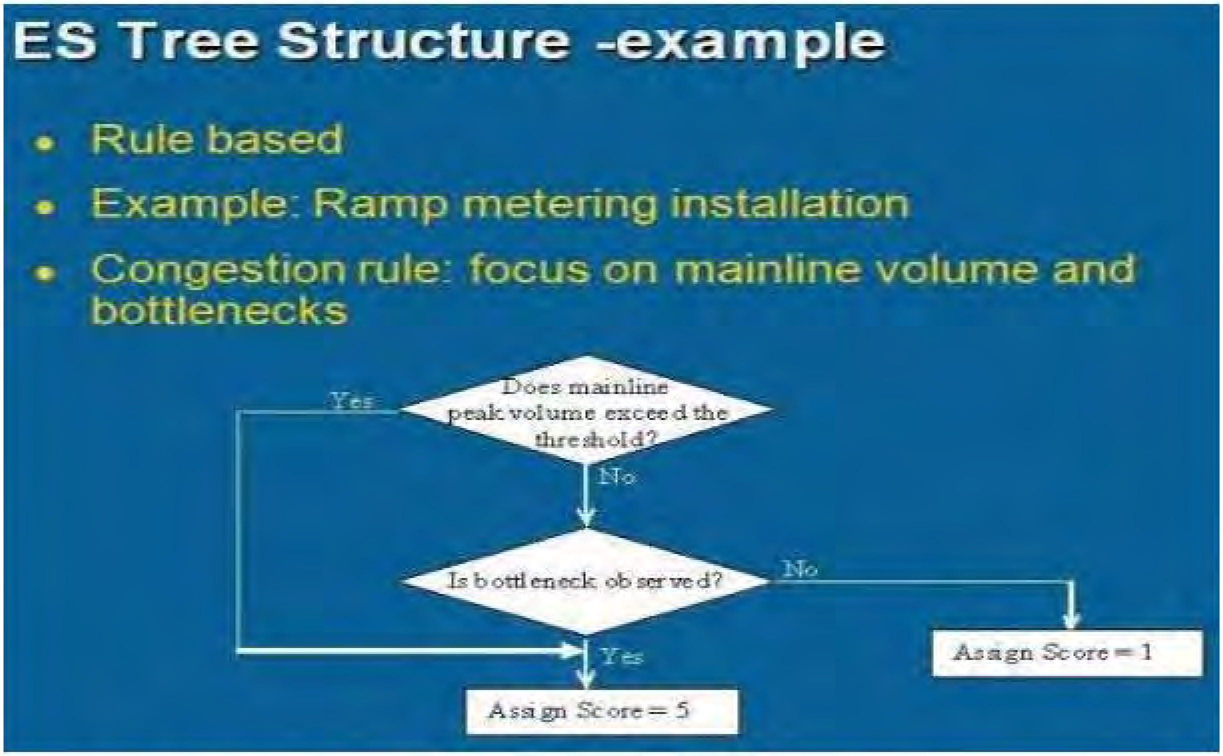

Sample Improvements
• Left side space wasted (gray area)
• Redesign vertical bar: Take off or add pictures related to Specific tool and or technology
• Beautification: Color & less wastage of space
• Horizontal navigation bar problems should be addressed, e.g., add buttons
• More spacing between lines for better reading
• Black bars (lines, bands) and unnecessary items to be removed
• Bugs and missing links to be removed
• Better introduce the ITS Decision concept and improve navigability
ITS Decision
ITS Decision

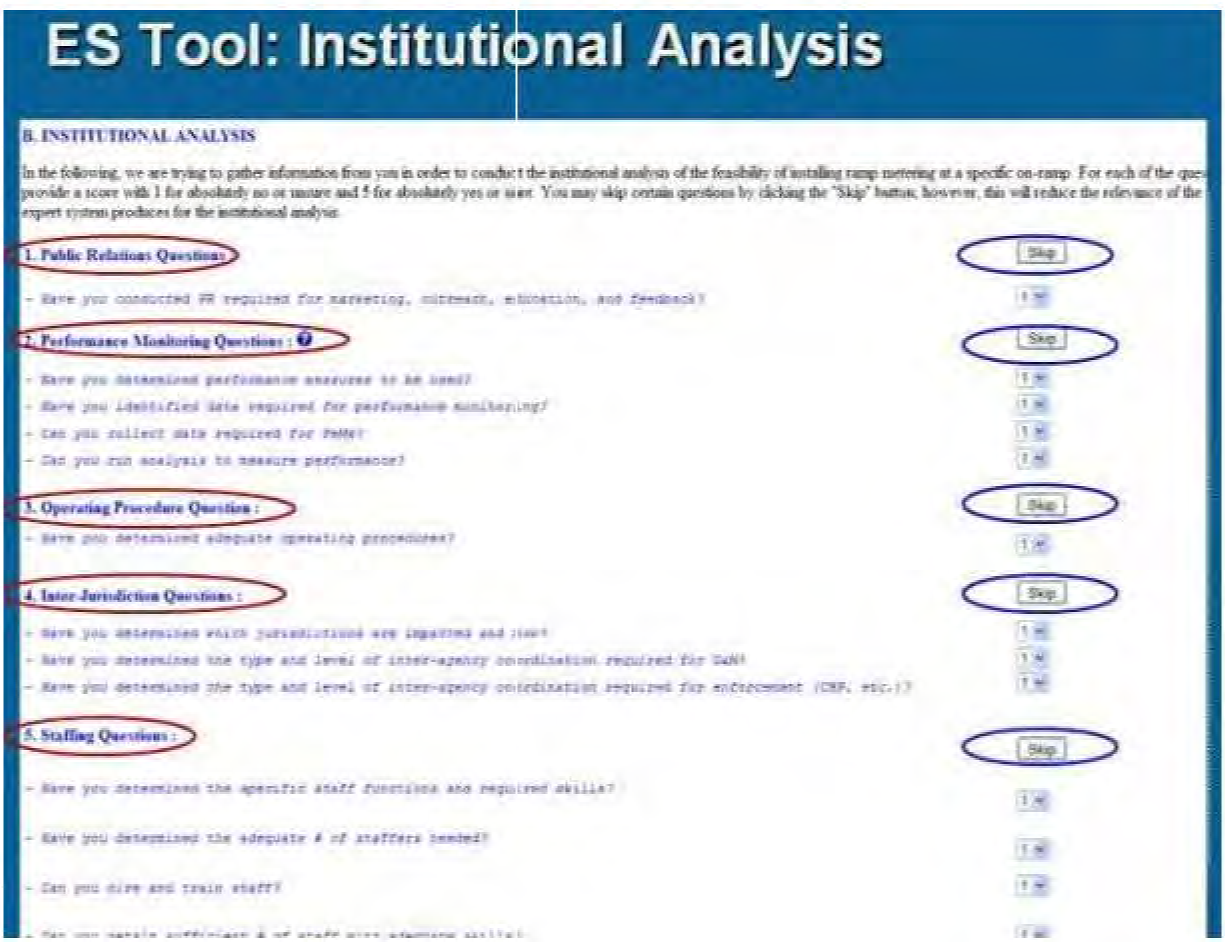
Expert System (ES) Tool

- Tool provides expert diagnosis of feasibility of an ITS technology to a particular problem
- Preliminary, high level assessment only
- Both **technical** and **institutional** analyses covered


Example: Should my city install ramp metering?
?
Considerations:
- traffic congestion
- vehicle and pedestrian safety
- public acceptance
- O&M costs
- others (in similar situations) encountered?


Expert System (ES) Process
Problem: Congestion
Context: Where, alt routes; when...
Is ramp metering a good solution for the problem?
Diagnosis: volume, Incident, delays on XYZ roads between ... times, geometry, etc
Conclusion: Ramp metering should be installed


ES Tree Structure -example
Rule based
Example: Ramp metering installation
Congestion rule: focus on mainline volume and bottlenecks
Does mainline peak volume exceed the threshold?
Yes
No
Is bottleneck observed?
No
Yes
Assign Score = 1
Assign Score = 5


ES Tool: Institutional Analysis
B. INSTITUTIONAL ANALYSIS
In the following, we are trying to gather information from you in order to conduct the institutional analysis of the feasibility of installing ramp metering at a specific on-ramp. For each of the ques
provide a score with 1 for absolutely no or unsure and 5 for absolutely yes or sure. You may skip certain questions by clicking the "Skip" button; however, this will reduce the relevance of the
expert system produces for the institutional analysis.
1. Public Relations Questions:
Skip
- Have you conducted PR required for marketing, outreach, education, and feedback?
2. Performance Monitoring Questions :
Skip
- Have you determined performance measures to be used?
- Have you identified data required for performance monitoring?
- Can you collect data required for PeMs?
- Can you run analysis to measure performance?
3. Operating Procedure Question :
Skip
- Have you determined adequate operating procedures?
4. Inter-Jurisdiction Questions :
Skip
- Have you determined which jurisdictions are impacted and how?
- Have you determined the type and level of inter-agency coordination required for O&M?
- Have you determined the type and level of inter-agency coordination required for enforcement (CHP, etc.)?
5. Staffing Questions :
Skip
- Have you determined the specific staff functions and required skills?
- Have you determined the adequate # of staffers needed?
- Can you hire and train staff?

Current Progress

- Currently, eight modules are online
  - 1. Automatic Vehicle Location (AVL) for Transit Vehicles
  - 2. Freeway Service Patrol (FSP).
  - 3. Ramp Metering Installation (RMI).
  - 4. Electronic Toll Collection (ETC).
  - 5. Employer-Based Transit Pass Program (EBTP).
  - 6. Advanced Traveler Information Systems (ATIS).
  - 7. Corridor Signal Coordination (CSC) or Congestion Pricing.
  - 8. Weigh-in-Motion Systems (WIM) or Intelligent Parking Systems.
- Testing is underway
- Further improvements are still needed
  - Add the help option for each question
  - Keep consistent design/format
  - Improve the output format
  - Better output page (will improve appearance and esthetics)

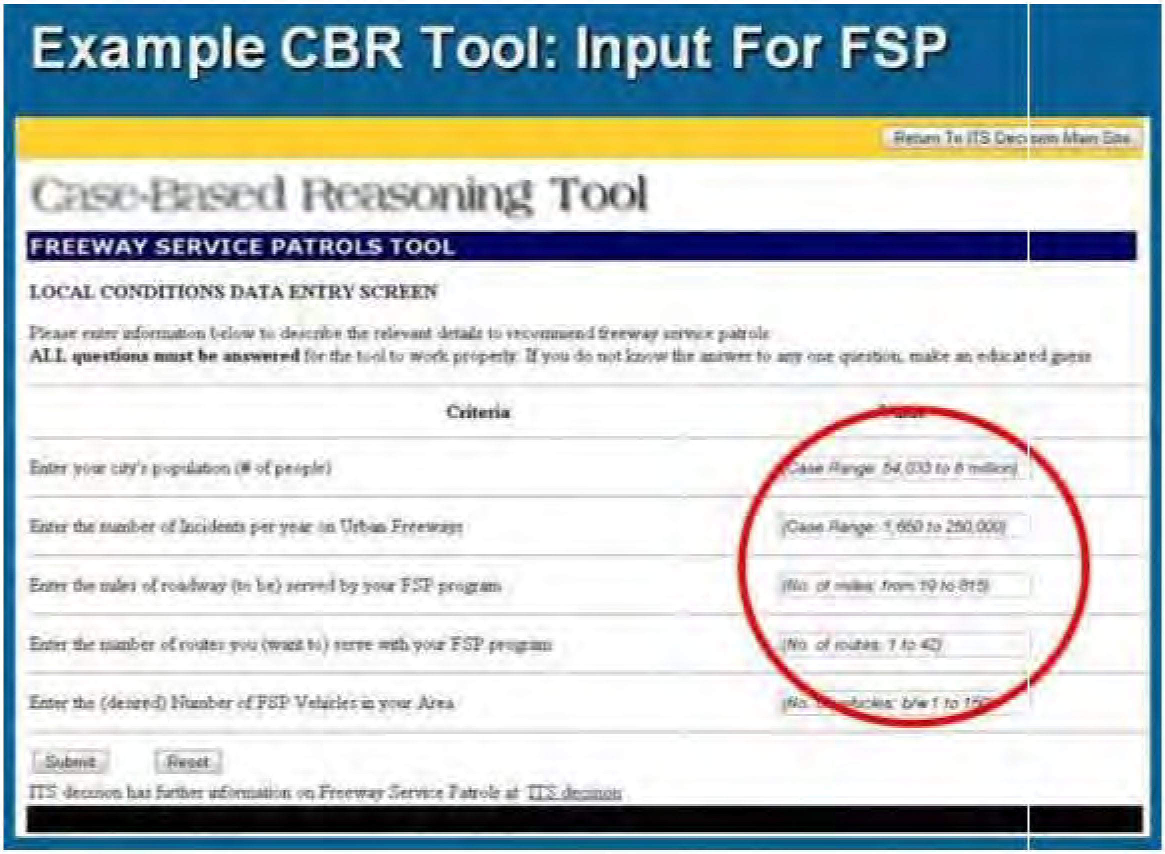
Case-Based Reasoning Tool

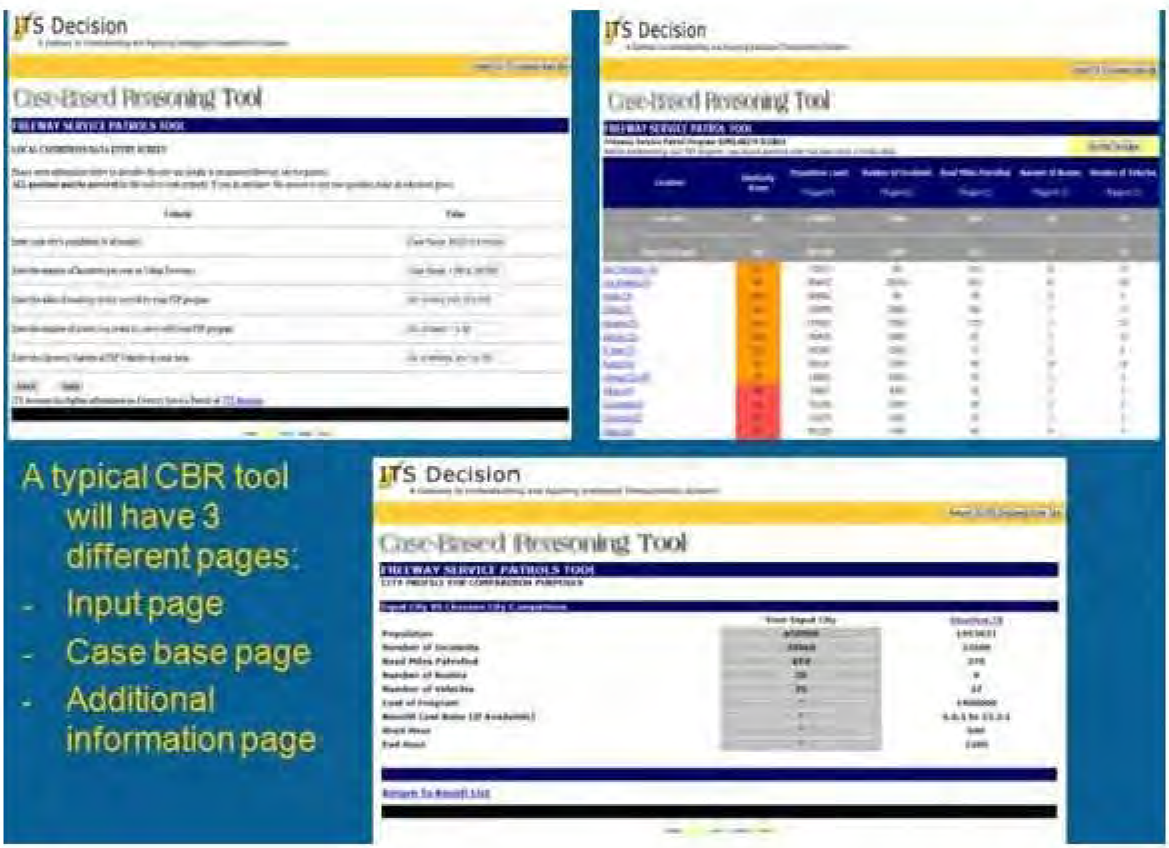
- Answer to "Who else has tried it?"
- Focuses on similarities (but also know the differences)
- Qualitative and quantitative information combined
- User may not be familiar with the context
- CBR: Are there similar cases?
- What have others done in similar situations?
- Quantitative + Qualitative information
- Currently have 15 technologies

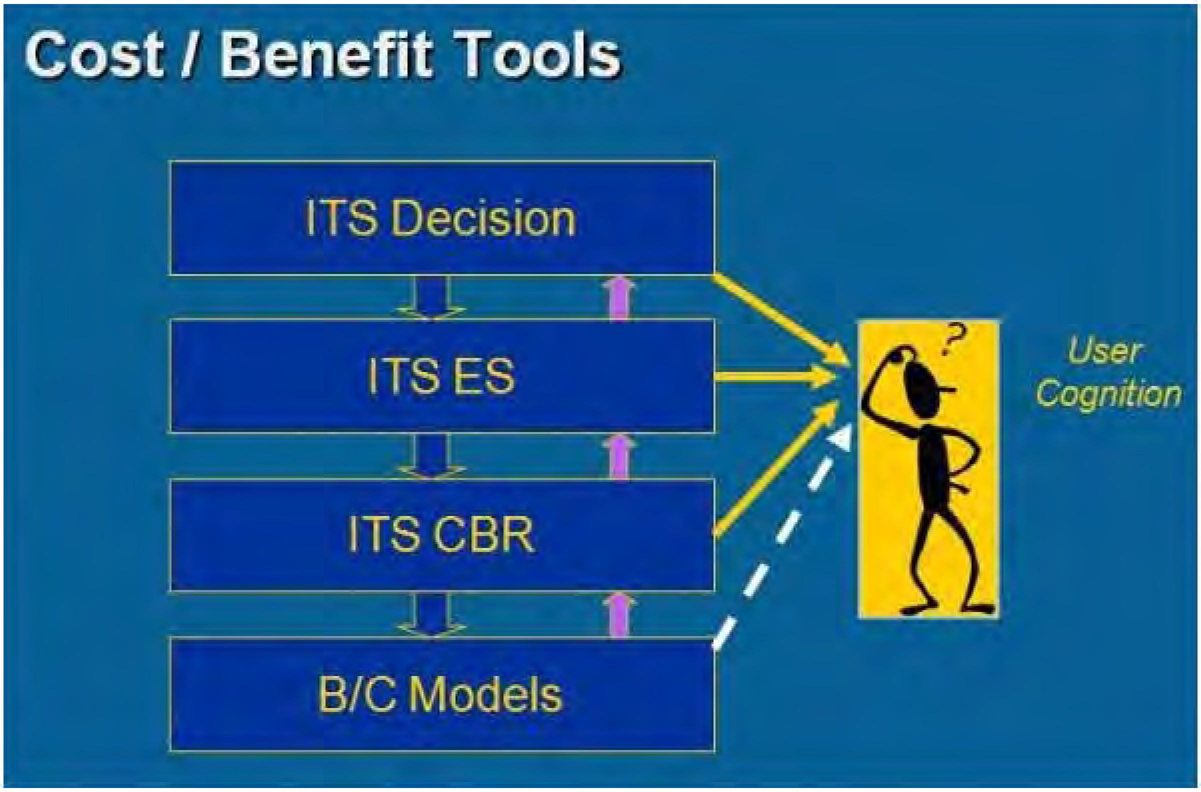
1. Employer-Based Transit Pass Program (EBTP)	9. Arterial Management Systems -Adaptive Signal Control (ASC)
2. Automatic Vehicle Location (AVL)	10. Workzone Operations Management (WOM)
3. Freeway Service Patrol (FSP)	11. Road Weather Information Systems (RWIS)
4. Ramp Metering (RM)	12. Car Sharing (CS)
5. Advanced Traveler Information Systems (ATIS)	13. Automatic Transit Fare Payment (ATFP) (or BRT systems)
6. Electronic Toll Collection (ETC)	14. Congestion Pricing (CP)
7. Corridor Signal Coordination (CSC)	15. Intelligent Parking Systems (IPS)
8. Weigh-in-Motion Systems (WIM)	

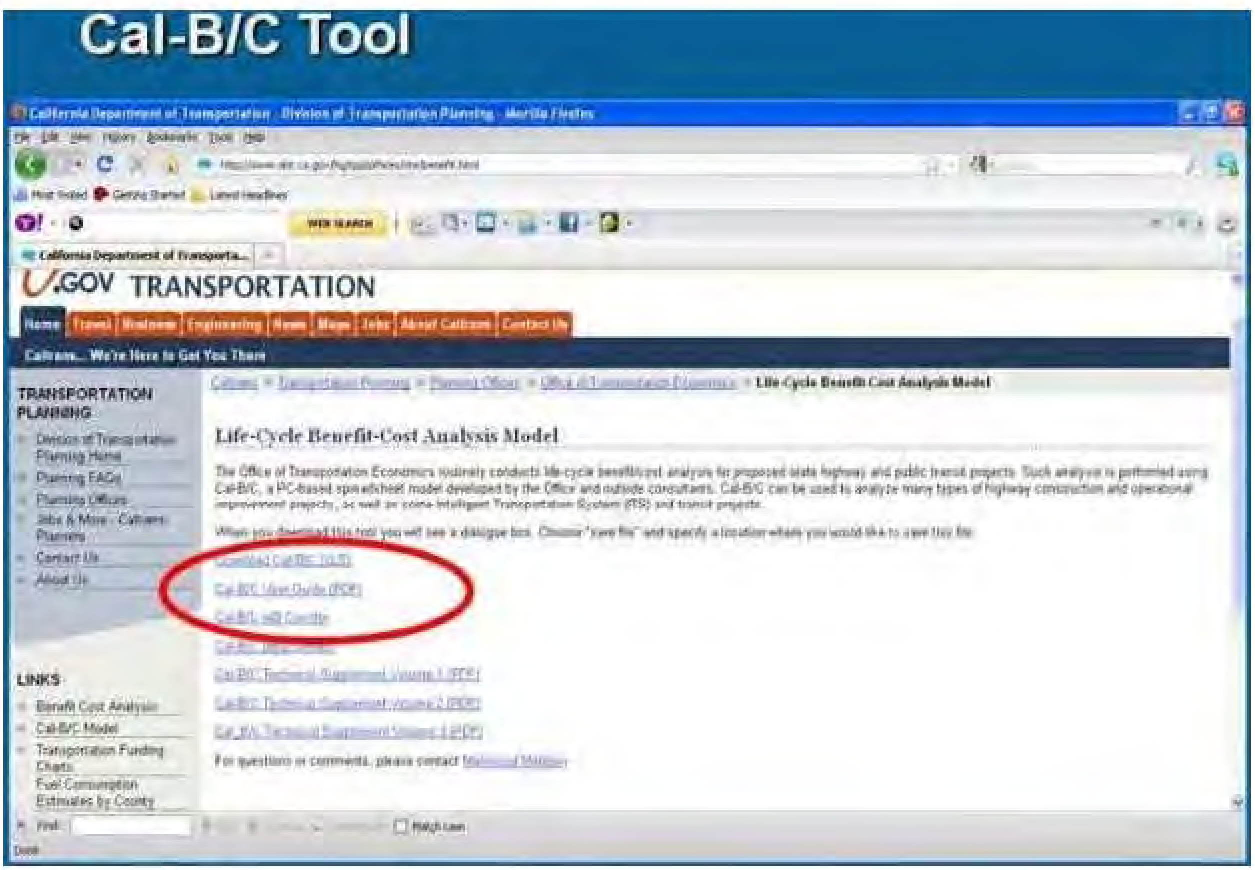

Example:
Should my agency implement or expand/contract freeway service patrols?
Need to weigh:
• how many travelers might use it?
• costs of administering program
• benefits of program & techs
• what operational problems have others (in similar situations) encountered?

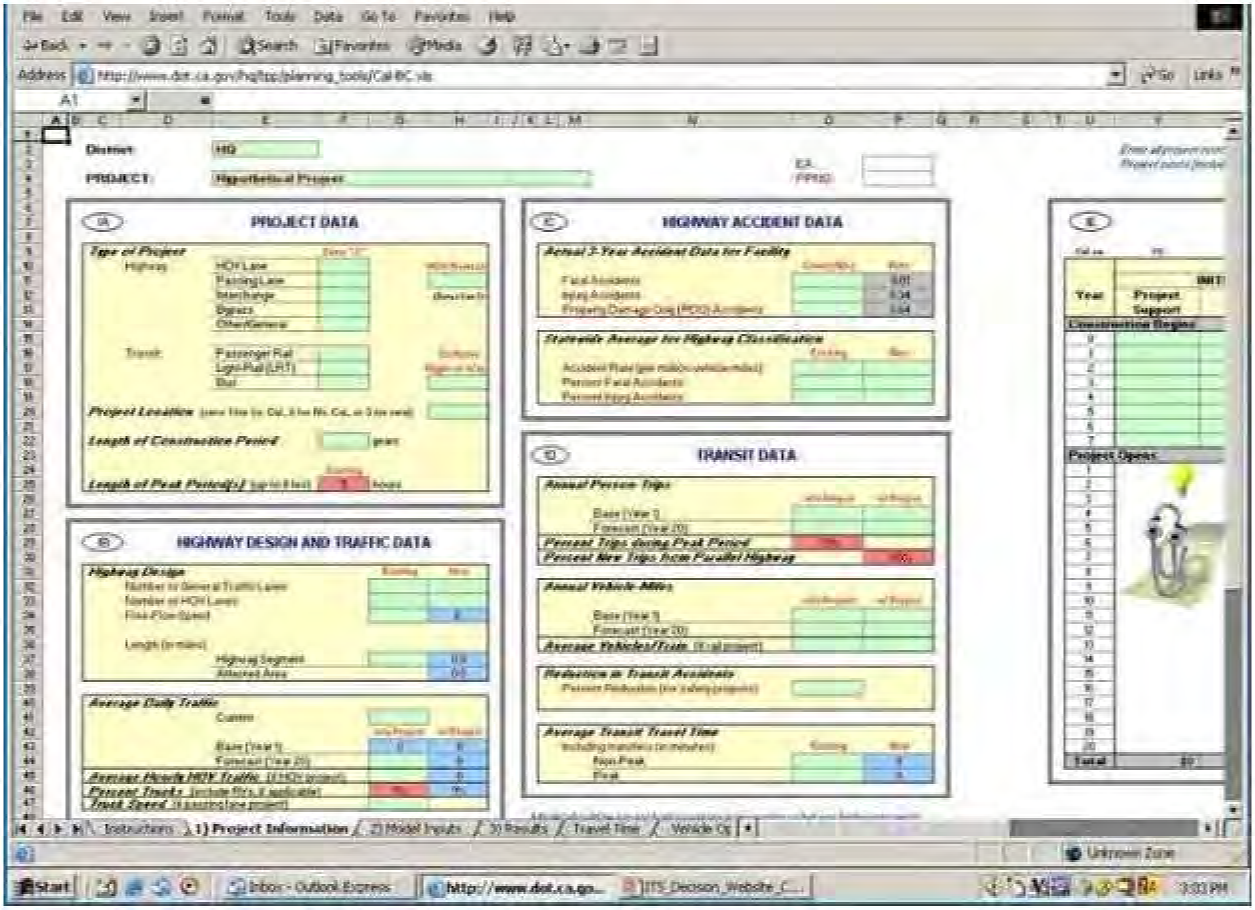

Do Research
• Attend Conference:
-hear about other implementations
-talk to those who already run FSP programs
• Read documents:
-study results of other projects
-review cost/benefit analyses


Example CBR Tool: Input For FSP
Return To ITS Decision Main Site
Case-Based Reasoning Tool
FREEWAY SERVICE PATROLS TOOL
LOCAL CONDITIONS DATA ENTRY SCREEN
Please enter information below to describe the relevant details to recommend freeway service patrols
ALL questions must be answered for the tool to work properly. If you do not know the answer to any one question, make an educated guess
Criteria
Enter your city's population (# of people)
(Case Range: 54,033 to 8 million)
Enter the number of Incidents per year on Urban Freeways
(Case Range: 1,650 to 250,000)
Enter the miles of roadway (to be) served by your FSP program
(No. of miles: from 10 to 815)
Enter the number of routes you (want to) serve with your FSP program
(No. of routes: 1 to 42)
Enter the (desired) Number of FSP Vehicles in your Area
Submit
Reset
ITS decision has further information on Freeway Service Patrols at ITS decision


ITS Decision
Case-Based Reasoning Tool
FREEWAY SERVICE PATROLS TOOL
A typical CBR tool will have 3 different pages:
- Input page
- Case base page
- Additional information page


Cost / Benefit Tools
ITS Decision
ITS ES
ITS CBR
B/C Models
User Cognition
?


Cal-B/C Tool
.GOV TRANSPORTATION
Caltrans... We're Here to Get You There
TRANSPORTATION PLANNING
Life-Cycle Benefit-Cost Analysis Model
Contact Us
About Us
LINKS
Benefit Cost Analysis
Cal-B/C Model
Transportation Funding Charts
Fuel Consumption Estimates by County
For questions or comments, please contact




ITSD Wiki Design
• Master page
– Layout of the wiki webpage
• User account management page
– Contains user profile, authorizations and security & users database
• Message/Information management
– Exchange information between registered users
– posts, reply, edit, delete functions, etc.
– Code for security message database
• Mailing system
– Mailing list, groups
• Administrator
– Manage account-promote, downgrade, block, delete users, etc.
– Manage messages-create/delete topics, spam messages etc.
– Maintain database and wiki


What Next?
• Finalize project, based on input
• Further develop Expert System and Case-Based Reasoning tools
- Benefits transfer
- Other high-impact ITS technologies
• Incorporate transportation models
• Explore opportunities for collaboration tools (wiki)…