Using Reidentification to Evaluate the SCOUT Traffic Management System (TMS)

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ABSTRACT

The Kansas City SCOUT Traffic Management System (TMS) is a cooperative effort funded by the State Departments of Transportation of Kansas and Missouri and involving the DOTs, local and state law enforcement, Mid-America Regional Council (MARC—KC MPO), local municipalities and townships, and others. The system integrates dynamic message signs, video surveillance, traffic detection, computer networking and analysis, and a Traffic Operations Center.

In the evaluation of SCOUT, incident-related delay was chosen to be the primary measure of effectiveness, because that is where the greatest benefits of the system are expected to occur. To measure this delay, an approach was developed that utilizes video observation and post-processing to obtain travel times throughout the peak periods. The travel times were obtained by employing characteristic-based reidentification, aided by a custom computer application developed at The University of Kansas, ReID. Using ReID, temporal profiles across the peak periods can be generated of the average travel time for each corridor under study. Profiles are generated for baseline (i.e., non-incident) conditions and for each period during which an incident occurred on the study segment while it was under observation. The baseline profile is subtracted from the incident profiles to obtain the delay caused by the incident. Comparing the delay caused by incidents before the implementation of SCOUT with those after the implementation of SCOUT will show any improvements caused by the SCOUT system. Data was collected over a total of approximately seven months during 2002 and 2003.

Key words: evaluation—delay—incident—ITS
INTRODUCTION

Evaluation of Intelligent Transportation Systems (ITS) is a critical issue to sustained progress, providing decision makers the evidence of benefit they need to justify system updates, upgrades, and expansions. Complex ITS deployments, such as urban Traffic Management Systems (TMS) require that significant resources be devoted to evaluation if the evaluation is to be thorough and defensible. While some aspects of ITS evaluation are straightforward (e.g., changes in speeds, throughput, or travel times), others are more difficult to quantify, such as public acceptance, safety benefits, and other benefits related to incidents. Sometimes, the needed historical data does not exist, or the amount of data needed makes the data collection prohibitive.

BACKGROUND

The first phase of deployment of the Kansas City SCOUT Traffic Management System (TMS) is scheduled to be completed in late 2003. Phase I of the deployment includes four primary corridors, the southern leg of I-435, I-35, and I-70 east of the CBD. The system comprises 45 variable message signs (VMS), 75 video surveillance cameras and 1200 inductive loops, all of which are connected to a Traffic Operations Center (TOC) via a region-wide fiber-optic network. SCOUT is jointly funded by the State Departments of Transportation of Kansas and Missouri. In 2001, the DOTs asked the University of Missouri and The University of Kansas to work cooperatively to evaluate SCOUT Phase I.

Between the early stages of planning the system and the beginning of the deployment, various factors led to the postponement of the implementation of ramp metering until a later phase. When ramp metering was deleted from the initial deployment, the focus of the system shifted from recurring congestion to incident-related congestion. While the system could still provide some benefits related to recurring congestion, the greatest benefits are likely to be incident-related. The system is expected to improve incident detection and reduce response times. The VMS can be used to inform drivers, reducing flow to the bottleneck by allowing drivers to choose alternate routes and reducing secondary accidents by warning drivers of the congestion ahead.

APPROACH

The incident-orientation factored heavily in the planning of the evaluation. Many of the measures of effectiveness commonly used in evaluations of other TMS are much less relevant because they pertain specifically to recurring congestion, such as travel time reliability or spot speed characteristics. Measures of effectiveness that relate most directly to incidents include detection, response, and clearance times, secondary accidents (i.e., accidents caused by incident related congestion), and various measures of congestion. Common measures such as travel time reliability, throughput, and level of service will all be considered, but it is the incident-related measures that are expected to most clearly show the benefits of SCOUT.

For detection, response, and, sometimes, clearance times, accident reports and motorist assist logs often provide the only available data. The precision of the times must be carefully considered in interpreting the results, but if a change is significant enough to be statistically credible, these times are a very good basis on which to compare before and after conditions. It is difficult to translate this data into a monetary figure that could be used in a benefit-cost assessment, but they may lend themselves to a cost-effectiveness comparison or some other relative evaluation tool. This kind of data is being pursued for use in the SCOUT evaluation.
Reductions in secondary accidents are a very important kind of benefit of urban ITS deployments. Reliable data, however, is virtually nonexistent. Accident records reports frequently have no place to indicate that an accident was a secondary accident except in a field for general comments. As a result, some records may show no indication that an accident was caused by backup from a previous accident rather than some other cause. With respect to the SCOUT evaluation, the identification would almost necessitate examining location and time of each accident and performing some manner of temporal-spatial analysis to identify likely secondary accidents as those occurring near upstream of a known incident within some time frame, which would have to be dependent to some degree upon the characteristics of the incident.

Consideration is still being given to the identification of secondary accidents, but to date no means of reliably distinguishing secondary accidents from primary accidents has been identified.

The measure of effectiveness that is expected to most clearly show a positive change after the implementation of SCOUT is incident-related delay. When SCOUT is fully operational on Phase I corridors, it is expected that all of the incident-related measures already discussed represent areas of real benefits. For each of them the difficulty lies in obtaining the data necessary to quantify (or verify) those benefits. The same difficulty exists for incident-related delay, but the difficulty has been overcome with careful planning and significant effort.

**Calculating Incident-Related Delay**

Delay can be simply defined as an increase in travel time. Using delay, $t_{\text{delay}}$, as a measure implies that some baseline travel time over a given segment exists for which $t_{\text{delay}} = 0$. This baseline mean travel time, $f(t)$, is the travel time when traffic flow is not being affected by any incidents.

If $g(t)$ is the mean travel time during or following an incident on the study segment, then $t_{\text{delay}}$ can be expressed as shown in Equation 1.

$$
t_{\text{delay}} = \left[ \int_{t=T_0}^{T_f} \left( g(t)v_t - f(t)v_{b,t} \right) dt \right]
$$

where $T_0$ is any time before the incident occurs, $T_f$ is any time after traffic flow returns to baseline levels (i.e., after the effects of the incident on traffic have completely dissipated), $v_t$ is the traffic volume at time $t$ during an accident, and $v_{b,t}$ is the traffic volume at time $t$ under baseline conditions.

Since no known function $f(t)$ or $g(t)$ exists, the data must be aggregated temporally to approximate the continuous profile. Samples are extracted from the data to provide an approximation of the temporal profile of travel time across the segment. FIGURE 1 shows a plot of sample data. In the figure, the accident data is actual. However, because the data processing is not yet complete, a hypothetical baseline data set is shown.
FIGURE 1. Plot of Accident and Baseline Temporal Profiles

The total travel time is the area under the plot, and the delay is the difference between the area under the baseline plot and the area under the accident plot.

Once aggregated, \( t_{delay} \) can be calculated as follows.

\[
\begin{align*}
\sum_{m=0}^{M-1} \left( \frac{t_m + t_{m+1}}{2} v_m t_m \right) - \sum_{n=0}^{N-1} \left( \frac{t_{b,n} + t_{b,n+1}}{2} v_{b,n} t_{b,n} \right)
\end{align*}
\]

where \( t_m \) is the average travel time after \( m \) time periods, \( v_m \) is the traffic volume during time period \( m \), and \( t_m \) is the elapsed time between \( m \) and \( m+1 \). Subscript \( b \) indicates the parameter is for baseline conditions, otherwise the parameter represents accident conditions.

**Measuring Travel Time**

The values of \( t_m \) and \( t_{b,n} \) in Equation 3 must be derived from a set of individual travel times. To obtain travel times of individual vehicles, a video surveillance technique was employed. Video cameras were set up to tape the traffic in the through lanes during the peak periods. For each corridor, four video observation sites were used, one for each direction of traffic at each end of the study segment. The distance between the cameras varied between 8 km (5 mi) and 18 km (11 mi), depending on the segment. The video was later catalogued with respect to individual vehicles and their characteristics (e.g., type, color, special markings), along with an observation...
time stamp. Once the video data was catalogued for the two ends of a segment, the catalogues were compared to find matching records, vehicles observed at both locations. When a match was identified, the difference in the time stamps was taken as the travel time across the segment for that vehicle.

To facilitate the cataloguing and matching of vehicles between the two observation points, a computer package was developed to assist in post-processing the video footage. The package, ReID, comprises two modules, the ReID Cataloguer module and the ReID Matcher module. Initial estimates suggest the software speeds the cataloguing and matching process by a factor of 3 to 5.

**ReID Cataloguer**

*ReID Cataloguer* is used to build a catalogue of vehicles that occur in each of the videotapes during a given time period. The user steps through the video, selecting each vehicle and entering its basic characteristics. For each vehicle, the area designated by the user is saved as a bitmap, and the entire video frame is saved as a second bitmap. The characteristics that can be entered include the vehicle type (or class), color, flag indicating a special characteristic such as racing stripes, and the lane the vehicle was in. In the screen shot of *Cataloguer* shown in FIGURE, these characteristics appear in the upper half of the left side of the window. *Cataloguer* can also be used to catalogue license plates, although multiple cameras must be used at each location if more than two lanes are to be catalogued using license plates. With three or more lanes, the resolution of digital video cameras is not sufficient for the plates to be legible. While data is being entered, *Cataloguer* announces each data item audibly. This provides confirmation to the user that the correct key was pressed.
ReID Matcher

Once the video from both observation points has been catalogued for a given time period, Matcher can be used to help identify vehicles in the upstream data that match vehicles in the downstream data. A screen shot of Matcher is shown in FIGURE 2. The selected downstream vehicle is highlighted in the list in the bottom left, and the associated bitmap is shown in the top left. Matcher determines the most likely matches from the upstream catalogue and displays them as thumbnails. If the user can identify a match, that record is selected and the bitmap is displayed in the top right, side by side with the bitmap from the downstream data. If confirmed, the match is stored, and the speed statistics and distribution shown in the bottom right are updated.
DATA COLLECTION

Digital camcorders were used for the video data collection because their image fidelity is significantly better than that of analog camcorders, and there is no fidelity loss in transferring the video to the computer such as occurs with the analog video capture process. The storage space required for digital video is significant (approximately 3.7 MB/sec), but once a video excerpt is catalogued, the video is no longer needed, because matching is done using the bitmaps extracted from the video by ReID Cataloguer.

Video data was collected Monday through Thursday during June through September of 2002. Further before data is being collected during Summer 2003, and after data will be collected during the summer of 2004 and, if necessary, 2005. Data collection for the morning peak period occurs between 6:30 AM and 8:30 AM. Data collection for the evening peak period occurs between 3:30 PM and 6:30 PM, based on continuous count data obtained from the Kansas Department of Transportation.

Approximately 500 hours of video were collected during Summer 2002. Another 250 hours of video will be collected during Summer 2003. The processing of the video data, even with the aid of the ReID computer modules, is extremely time intensive, requiring an average of approximately 8 hours to process each minute of video data for the segments under study.
DATA ANALYSIS

Once travel times are extracted from the video and incident-related delay is determined for the individual incidents whose effects are captured in the data, some statistical modeling will be necessary to extrapolate the results to characterize delay on an annual basis, and then to compare the annual delay without SCOUT to the annual delay with SCOUT.

MODELING INCIDENT-Related DELAY

Statistical modeling may be done with either regression analysis or artificial neural networks to model incident-related delay on the basis of various input parameters. Candidate parameters include the following.

- Lane-minutes of closure
- Total number of lanes
- Density at the time of the incident
- Incident type or measure of severity
- Clearance time
- Total baseline vehicle count for incident time and duration

These parameters will be explored to determine what relationship, if any, each has with incident-related delay, and which combination of parameters best serves to characterize the delay function.

Once a statistical model has been developed for the data collected with and without SCOUT in operation, both models will be applied to a representative set of accidents to determine the difference in incident-related delay that can be attributed to SCOUT. This can then be scaled to provide an estimated annual benefit in monetary terms.

CONCLUSIONS

The challenges in evaluating an incident oriented system such as SCOUT are substantial. The randomness of accidents requires staking out the study segments for long periods of time, and the processing of the data is very time intensive. However, provided that accident rates during the data collection are consistent with recent annual averages, the methodology described in this paper should provide a new look into the potential incident-related benefits of urban ITS deployments.

The use of video-based reidentification is a powerful tool for assessing traffic conditions for a wide variety of applications. Traditional means of reidentifying vehicles from video have been excessively time consuming, severely limiting the application of this technique. The development of the ReID computer modules improves the processing time substantially, broadening the range of applications for which the technique may be feasible.
In addition to providing information about benefits specific to the SCOUT system, the statistical modeling of incident-related delay will provide a foundation for assessing other improvements that affect incident response and clearance time, not only in Kansas City, but across the country.

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