A SIMULATION BASED EVALUATION OF DYNAMIC ROUTE GUIDANCE FOR TRAFFIC MANAGEMENT AT HIGHWAY RAIL INTERSECTIONS

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ABSTRACT

Highway-rail intersections are unique in the sense that trains always have right of way at these intersections. The increase in travel demand in urban areas with active railway lines makes these grade crossing intersections potential traffic ‘hot spots’, where bottlenecks can very easily arise, disrupting traffic operations and spilling back to impede smooth traffic flow in surrounding areas as well.

This paper suggests the deployment of a dynamic and preferably real-time route guidance infrastructure, using traveler information systems such as Variable Message Signs (VMS). The proposed system is used to advise travelers of alternate routes to their destinations in the event that their original routes entail excessive delays due to the passage of trains and subsequent closure of grade crossings. Microscopic simulation using CORSIM is used to demonstrate the feasibility of this framework by examining its impact on average system-wide origin to destination travel times.

Multiple cases are examined, corresponding to various levels of information that could be used to drive the dynamic route guidance system and an ideal level of information is recommended. An additional case considers a scenario where selected intersections are controlled in real-time using RHODESTM (Real-time, Hierarchical, Optimized, Distributed and Effective System), a traffic adaptive signal control system developed at the University of Arizona.

The cases considered are one-time deployments only and a study of traffic equilibrium was not included. Simulation results indicate that the availability of complete information about train crossing times, in conjunction with adaptive intersection signal control using RHODESTM yields maximum reduction in average vehicle O-D travel times.
1. INTRODUCTION

Traffic management strategies (TMS) specifically targeting highway-rail intersections are relatively recent developments as far as research on Intelligent Transportation Systems goes, and have evolved because of the significant increase in travel demand in urban areas where railway lines run through the area. The distinguishing feature of highway-rail intersections is that at these intersections, trains always have right of way. Research dealing with this case of traffic management has had essentially two objectives: (1) To reduce the risk of incidents at highway-rail intersections and (2) To minimize vehicular travel times across these intersections and prevent excessive wait times or bottlenecks.

Reducing risks to motorists as well as to railroad infrastructure at highway-rail intersections is a very real concern. According to the railroad commission of Texas, the state with the largest number (more than 18,000) of such intersections in the country, as many as 365 collisions occurred at highway-rail crossings in 1999. In recent times, an impressive number of developments have taken place in the area of grade crossing safety and many research publications have suggested approaches based on various practical Intelligent Transportation Systems (ITS) to decrease the risk of incidents at grade crossings.

Lesser attention has been paid until recent years towards identifying potential traffic bottlenecks and managing vehicular traffic at highway-rail intersections with the objective of minimizing vehicle travel times across them or minimizing their actual delay times at these intersections. Further, highway-rail intersections give rise to traffic control problems that have a bearing not only on traffic safety, but also on traffic flow performance. Railroad crossings in the vicinity of freeway access ramps pose particularly acute problems, since long blockages of traffic due to passing trains can lead to backing up on the ramps and potentially interrupt freeway operations.

The suggestion to alleviate the inconvenience of excessive delays in integrated rail-highway traffic networks is to provide real-time route guidance based on perfect or near-perfect information about expected delays to travelers by the means of Variable Message Signs (VMS) and to translate this information into personalized route guidance via on-board computation units. Travelers are informed about ‘best’ or shortest alternative routes to their destinations via the deployment of ATIS, in the event that their original routes entail waiting for a train to pass at a highway-rail crossing.

Advanced Traveler Information Systems (ATIS) have proved to be highly effective in improving traffic conditions by optimizing travelers’ usage of existing transportation infrastructure. This approach is particularly significant to providing emergency vehicles with alternate routes on the basis of prior information about rail times and possible detours. Thus deployment of ATIS, preferably in conjunction with other Intelligent Transportation Systems (ITS) that optimize signal phasing and intersection control has immense potential to significantly improve traffic conditions and give travelers a ‘smoother ride’.

In the specific case of networks with highway-rail intersections, deployment of ATIS such as Variable Message Signs (VMS) could considerably ease traffic loading at these points in the network. Most VMS systems work on the basic principle that once an incident is detected by loops or other detectors and confirmed by operators through the use of, say CCTV cameras, VMS can be used to inform motorists of changing traffic conditions and other related information. VMS have the potential to enable drivers to make informed decisions on the best alternative route(s) to traverse. A broad overview of the sequence of events involved with this strategy is illustrated in the block diagram shown in Figure 1.
This work aims to evaluate using simulation methods, one such framework, where travelers are provided real-time information about feasible alternate routes based on knowledge of train timings and current network conditions via VMS, onboard computers or other information systems. Based on this information, they can avoid waiting at railroad crossings (assuming that they heed the information and take the suggested routes), and their travel times to their respective destinations will be less than and a marked improvement over the case where no or little information is available to them.

Broadly, the tasks involved in fulfilling this work are:

- Simulating a network of streets and intersections with a railroad and rail-highway crossings.
- Analyzing the network to determine alternate, 'dynamic' shortest-time routes for various origin-destination combinations while a train is traversing the network.
- Implementing the alternate routes determined above in the simulation and performing a comparison of travel times for various levels of information available to travelers.
- Commenting on the optimal level of traveler information that minimizes the origin to destination travel time and making appropriate recommendations.
- Evaluating the simultaneous deployment of traffic adaptive intersection control along with traveler information in the network, in order to determine whether a real-time signal control strategy will further reduce system travel times when used in conjunction with ATIS in the road-rail network considered.

2.0 DYNAMIC ROUTE GUIDANCE AND MICROSCOPIC SIMULATION

Knowledge about the actual state of traffic in the network is the basis of any intelligent transportation system. Recent research work and technological developments have shown that it is possible to estimate link travel times in real-time. This information can be processed further in dynamic route guidance systems to suggest shortest routes to travelers.

Dynamic route guidance provides drivers with directions to their destinations taking account of changing traffic conditions and the status of the road network. Traditionally, static route guidance has been available from road maps and signposts along the route. However, choosing the quickest route to a destination is not always straightforward. There may be a number of possible options and what looks like the quickest route can be affected by traffic conditions.
congestion, resulting in a longer journey time than expected. The consequences to drivers are increased travel cost, time delays and frustration. With regard to the application of route guidance to highway-rail intersections, drivers can be advised of the passage of a train at downstream railroad crossings and about alternative routes, thus reducing delays and improving overall traffic conditions.

Ta-Yin Hu [2001] discusses an algorithmic evaluation framework for dynamic vehicle routing that may be summarized as:

Step 1. Initialization
Step 2. Network Loading
Step 3. Traffic Simulation
Step 4. Real-Time Path generation (for each O-D pair)
Step 5a. Routing Strategies – Travel Time Matrix Generation
Step 5b. Routing Strategies – Route Generation

2.1 Microscopic simulation as an evaluation tool for ATIS

With developments in Intelligent Transportation Systems, it has widely been recognized that the successful collection/estimation and dissemination of accurate real-time information is the key to actually bringing ITS research work out of the laboratories and into the real world without prohibitive costs and with a desired level of benefit. A critical aspect of evaluating ITS is the development of reasonably reflective simulation models that serve to test these concepts before making the decision of whether a particular system is feasible for real-world implementation.

“The objective of micro-simulation models is essentially, from the model designers point of view, to quantify the benefits of Intelligent Transportation Systems (ITS), primarily Advanced Traveler Information Systems (ATIS) and Advanced Traffic Management Systems (ATMS). Micro-simulation is used for evaluation prior to or in parallel with on-street operation. This covers many objectives such as the study of dynamic traffic control, incident management schemes, real-time route guidance strategies, adaptive intersection signal controls, ramp and mainline metering, etc. Furthermore some models try to assess the impact and sensitivity of alternative design parameters.” (Source: Deliverables of the SMARTTEST Project, 1997)

Many simulation models have been developed to evaluate the benefits of Intelligent Transportation Systems (ITS), primarily Advanced Traffic Management Systems and Traveler Information Systems (ATMIS). Lately more attention has been paid to microscopic simulation models due to their capability of wide-range application and realistic representation of vehicle movement [Jayakrishnan et al., 1999].

The CORSIM microscopic traffic simulation package was used for the purpose of this work. CORSIM is a microscopic simulation model designed for the analysis of freeways, urban streets, corridors and networks. CORSIM simulates traffic and traffic control systems using commonly accepted vehicle and driver behavior models. CORSIM combines two of the most widely used traffic simulation models, NETSIM for surface streets and FRESIM for freeways. It has been applied widely by practitioners and researchers worldwide over the past 30 years and embodies a wealth of experience and maturity. CORSIM is capable of simulating almost any surface geometry including number of lanes and turn pockets and a wide range of traffic flow conditions. Further, this package is capable of simulating various types and combinations of traffic control strategies such as adaptive or actuated. External interfaces can support testing and simulation of real-time control algorithms in synchronization with the simulation clock as well.

2.2 Need for a ‘Route-Based’ Simulation – Path-Following Tool for CORSIM

The primary difficulty with microscopic simulations such as CORSIM is their inability to handle path dynamics in large networks. The options of being able to inject user-specified vehicles (numbers as well as types of vehicles) into the network that follow predefined paths from their respective origins to destinations and of tracking their progress through the network to monitor individual vehicle-specific parameters are essential to evaluate any form of ATMS/ATIS with microscopic simulation. Since the evaluation of a dynamic route guidance scheme using ATIS such as VMS depends greatly on its impact on individual vehicles’ O-D travel time, it was necessary to make the existing CORSIM package capable of path assignment and path following functionalities.
Path-Following CORSIM (PFCORSIM) is a modified version of CORSIM developed by ITT Industries with support from the ATLAS Center at the University of Arizona. PFCORSIM retains all the features of the original simulation package along with the added features of path assignment and vehicle injection that have been integrated into CORSIM through an Application Program Interface (API).

2.3 Simulation of a Road-Rail Network

The network used for this work and simulated in CORSIM is described below.

- The CORSIM network used for this project has 67 nodes (intersections) and 94 links (including entry/exit links and nodes)
- A fixed-time control strategy is initially used for intersections timing and control logic.
- Each intersection is configured to have two phases: Green Ball configuration for the east-west and north-south approaches respectively. The phase length is assumed to be 30 seconds per phase.
- There are seven ‘train nodes’ i.e., seven highway-rail crossing intersections running through the street network from east to west.
- The railway line has been modeled by dedicating a set of links, each with just one lane through which passage of vehicles is allowed in only one direction across the network (west to east). Delays at these railroad crossings have been modeled using fixed-time controlled intersections with a red phase for traffic while the train is passing through that particular intersection and green otherwise.
- A train has been modeled, for all practical purposes by a fleet of trucks (predefined vehicle type in CORSIM) that move across the network together with user-defined speed. Trucks are used because CORSIM does not define a vehicle type with sufficient length to be used realistically as a train.
- Thirteen nodes are defined as possible origins/destinations for injecting vehicles into the network with 83 possible O-D pairs. O-D pairs are defined such that the origin and destination for a given pair are on opposite sides of the railroad. Thus, every O-D pair corresponds to a vehicle that must pass through a railroad crossing once every trip.

Figure 2 illustrates the CORSIM network used for this analysis.
2.4 Dynamic Shortest Route Calculations with ATIS

The fundamental issue involved with suggesting alternate routes to travelers is to actually determine these routes. The problem of finding the shortest path from an origin to a destination over a network in which the link travel times are time-dependent is important to Dynamic Traffic Assignment (DTA) and many other applications. The Dynamic Traffic Assignment problem was originally formulated by Merchant and Nemhauser, [1978a, 1978b] and has evolved substantially over the years to include various elements of traffic dynamics. Numerous formulations and solutions have been introduced ranging from mathematical programming, to variational inequality, to optimal control and simulation-based approaches.

Many heuristics and some theoretically feasible solutions to the time dependent shortest path problem have been suggested in recent research. Ahuja, Orlin et al. [2000] have shown that the dynamic shortest path problem in a network where link travel times change dynamically may be solved in polynomial time as a minimum cost walk problem. They also discuss polynomial time solutions for realistic cases of the minimum cost path problem for street networks with traffic lights [Ahuja et al., 2000]. It is evident that in order to make the transition from first-generation (static) to second-generation (dynamic) route guidance, the dynamic shortest path must be solved in near real-time, at least for relevant or critical sections of the network under consideration. Peeta [1999] addresses dynamic traffic assignment problems in the ATIS context, where a central controller with partial or complete information about time-dependent origin-destination (O-D) trips aims at achieving certain system-wide objectives by providing real-time routing information and/or route guidance instructions to vehicles. Mahmassani et al. [1993] introduced a basic simulation-based approach to address a few of the implementation challenges related to using DTA with ATMS/ATIS applications on actual large urban networks.

While evaluating this framework, a variation of the Floyd-Warshall all pairs shortest path algorithm was implemented in the C programming language to determine the dynamically varying shortest routes between origin-destination pairs under various levels of traveler information. Average link travel time figures for the network were found from network geometry and by running the CORSIM model. These travel times were then used to generate an O-D travel time matrix, which served as an input to the program to represent the network being analyzed.

The following assumptions were made while calculating dynamic shortest routes:

- Average link travel times and background traffic conditions in the network remain constant across the different cases being considered. The rationale for this assumption lies in the fact that our objective is to compare various scenarios of traveler information deployment in the same network. Hence, the same basic network framework with the same average travel time for corresponding links and the same background traffic conditions may be used without affecting the results of the comparison. The ‘dynamics’ in the system are modeled by variable intersection delays and the variable delays at railroad crossings.

- A fundamental assumption for this work is that of perfect driver compliance with information about shortest routes. That is to say, all vehicles follow the routes suggested by the ATIS (e.g. VMS). However, this is not a valid assumption as the success or failure of ATIS deployment depends largely on driver behavior and compliance levels. A suggestion for future work in this area is to incorporate an appropriate model for driver route selection behavior [Mahmassani et al, 1988] into the process used to determine dynamic shortest routes.

- A study of model behavior under traffic equilibrium was not conducted for the purpose of this work and the route guidance and allocations are regarded as one-time deployments.

- It has also been assumed that a state of ‘perfect information’ about intersection phase timings and rail crossing times may actually be available in real-time. This is a realistic enough assumption. Train crossing times may be detected and/or predicted using many techniques (one example is the AWARD project in San Antonio), while signal phasing schemes can be tracked at the TMC as well.

3.0 DESCRIPTION OF CASES CONSIDERED

Each case corresponds to a specific level of information that is available to travelers when they enter the network. Travelers then follow shortest routes to their destinations based on this information

3.1 CASE 1 – No Information

- Information about Signal Phase Timings is not available
Information about Train Crossing Times is not available

In this case, the problem of finding the shortest routes from origins to destinations is a special case of the time-dependent shortest path problem, without dynamic equilibrium, where the link travel-times are known, average values. This case corresponds to a scenario wherein a driver starting out from his origin does not have any knowledge about possible future delays en route to his destination (i.e., no information about delays at street intersections or at railroad crossing intersections). In this case, the traveler would arguably perceive his delays at these points in the network on the basis of averages. For example, if in the fixed-time intersection control scheme the length of a red phase is, say 30 seconds, then a traveler would possibly use the following analysis to reach a figure for average expected delays at each intersection:

- Probability of arriving at the intersection during a red phase: $\frac{1}{2}$
- Length of a red phase: 30 seconds.
- Average delay time at the intersection, given arrival during a red phase: $\{\frac{1}{2} \times 30\} = 15$ seconds.
- Therefore,
  - Expected value of delay at each normal intersection in the network: $\{\frac{1}{2} \times 15\} = 7.5$ seconds.

Similarly, extending the above analysis to rail-crossing intersections and given that the train blocks railroad crossings for an average duration of, say, 60 seconds, the average delays expected by travelers at railroad crossing intersections, in the absence of concrete information may be assumed to be a constant, average delay of, say 15 seconds.

3.2 CASE 2 – Partial Information (a)

- Information about Signal Phase Timings is available
- Information about Train Crossing Times is not available

In this case, the problem of finding the shortest routes from origins to destinations is a dynamic shortest path problem (without considering dynamic equilibrium). This case corresponds to a scenario wherein a driver starting out from his origin is given information about future delays that he will face at normal, non-railroad (street) intersections en route to his destination but has no information about how long he will have to wait at the railroad crossing intersections. In this case, the traveler would arguably perceive his delays at railroad crossings in the network on the basis of averages, as in case 1. For the other intersections (non-railroad crossing), the traveler knows exactly (or with reasonable approximation) how long he will have to wait, if he arrives during a red phase. This is achieved in the program used for this project for finding dynamic shortest routes by feeding in the phasing scheme of all street intersections as an input. The program then keeps track of phase changes and timings of each intersection as the simulation runs to completion (in synchronization with the simulation clock).

Thus, when the shortest path algorithm scans ahead and branches out from a particular node, it accounts for future, variable delays at non-railroad intersections along with considering possible future (assumed constant) link delays and a constant, average delay at all rail-crossing intersections. Once again, it is emphasized that link travel times are considered to remain constant for the purpose of this work.

3.3 CASE 3 – Partial Information (b)

- Information about Signal Phase Timings is not available
- Information about Train Crossing Times is available

In this case also, the problem of finding the shortest routes from origins to destinations is a dynamic shortest path problem (without considering dynamic equilibrium). This case corresponds to a scenario wherein a driver starting out from his origin is not given any information about future delays he will face at normal, non-railroad intersections en route to his destination but knows exactly how long he will have to wait at railroad crossing intersections. In this case, the traveler would arguably perceive his delays at non-railroad or street intersections in the network on the basis of averages, as in case 1. For the rail-crossing intersections however, the traveler knows exactly (or with reasonable approximation) how long he will have to wait, if he arrives during a red phase. This is achieved in the program used for this project for finding dynamic shortest routes by feeding in the (known or acquired/predicted in real-time) phasing scheme of all these intersections as an input.
3.4 CASE 4 – Perfect Information

- Information about Signal Phase Timings is available
- Information about Train Crossing Times is available

This case corresponds to a scenario wherein a driver starting out from his origin is given complete information about future delays he will face at normal, non-railroad intersections as well as the rail-crossing intersections en route to his destination. For all intersections, the traveler knows exactly (or with reasonable approximation) how long he will have to wait, if he arrives during a red phase or during the period for which the train blocks railroad crossing intersections. This is achieved in the program used for this project for finding dynamic shortest routes by feeding in the phasing scheme of all (normal as well as railroad-crossing) intersections as an input. Thus, when the shortest path algorithm scans ahead and branches out from a particular node, it accounts for future variable delays at all intersections and then decides the shortest route to the destination node.

In the C program used, all intersections for which perfect information is available are modeled as individual structures containing signal timing and phasing information that is available in real time, as the simulation runs to completion. For example, if a particular signal is red for the north-south approach from 0 to 30 seconds and red for the east west approach for the next thirty seconds (30-60) and so on, given the green ball phasing, the program automatically sets a counter at each phase change so that if a vehicle was to reach that intersection at, say time = 45 seconds, then the program is aware that it will have to wait at that intersection for 15 seconds i.e., until the phase changes to allow movement (green phase).

4.0 RESULTS AND FINDINGS: CASES I THROUGH 4

The CORSIM simulation was run with different random number seeds for each of the aforementioned cases in order to compare the impact of various levels of traveler information. As stated earlier, dynamic shortest routes were calculated for each case and these routes were then incorporated within the CORSIM simulation to achieve the desired effects of ATIS and route guidance, assuming full compliance by travelers. Simulation runs were performed with 6 sets of random seeds for each case. Comparisons between various cases were performed on the basis of average origin-destination travel times. The different random seeds serve to introduce stochastic variations in the internal processes of the CORSIM simulation so as to induce confidence that the output of the simulation will be representative of the scenarios being analyzed and will be free of any bias from the effects of random processes in the model.

Comparisons in the following section compare the impact of information when the intersections in the network are under fixed time control. (An alternative signal control scheme is described in the next section.) To summarize the framework for comparing various cases:

- Each case is simulated with six sets of random seeds.
- Averaging across the travel times obtained for six runs, an average, representative set of O-D travel times is obtained for each test case.
- The primary objective is to evaluate which test case improves travel time performance at a system-wide level. Thus, the measure of effectiveness that is used to compare the cases is the average travel time for each O-D vehicle in the system. This is achieved by keeping track of individual vehicular O-D travel times and then averaging over all vehicles that complete a trip in the network.

Based on these comparisons, a recommendation can be made as to which of the four cases will yield maximum benefits upon deployment.

4.1 Average Travel Times

The following figures display the average travel time per vehicle in the network for each vehicle that completes an origin to destination trip, for each case. This figure is a simple average, calculated from the average over multiple simulation runs with 6 random seeds for each case.
Table 1 Travel times per O-D vehicle: Cases 1 through 1

<table>
<thead>
<tr>
<th>Case</th>
<th>Average O-D Travel Times (Seconds/vehicle-trip)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
</tr>
<tr>
<td></td>
<td>251.8133</td>
</tr>
</tbody>
</table>

As seen in Table 1, case 4 yields the lowest (average) travel time per vehicle. This is in agreement with the expectation that the maximum information available to travelers will result in minimum travel times, with fewest stops or delays, provided of course that travelers act according to the route guidance information that is provided.

4.2 Case 4 versus Case 2

It has been established by the previous calculations that case 4 offers the best overall system performance for the network considered. However, it was observed that case 2 does in fact show a lower travel time for certain O-D pairs. This can be justified by considering the following scenario:

In case 2, a traveler assumes a constant delay of, say 7.5 seconds at every street intersection and a certain optimal ‘expected shortest O-D route’ is generated for this traveler. Now, in case 4, the same traveler receives a shortest route based on the availability of complete information about rail-crossing as well as normal street intersection
timings. This route obtained in case 4 may, in fact be the same as that obtained for case 2 for some O-D pairs (i.e., even with perfect information, it may still remain the shortest route to take). The difference is that in case 4, the vehicle in question may have to wait at a given intersection for longer than the average 7.5 seconds assumed for case 2. Hence it is entirely possible that case 2 could show lower travel times for a few O-D pairs. Therefore the primary objective is defined to be an overall reduction in system wide average travel time per vehicle and case 4 proves to be the best-case scenario for the purpose of this work.

The percent improvements in average system O-D travel times observed in test case 4 over cases 1, 2 and 3 are illustrated in the Table 2.

<table>
<thead>
<tr>
<th>Percent Reduction</th>
<th>Over Case 1</th>
<th>Over Case 2</th>
<th>Over Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.55%</td>
<td>2.19%</td>
<td>9.76%</td>
</tr>
</tbody>
</table>

4.3 Further Analysis: Adaptive Signal Control

So far, the cases considered all involved fixed-time signal control at the intersections. In the following section, an attempt is made to replace fixed-time control and use a real-time traffic adaptive signal control system to pro-actively control the intersection signal phase sequences and timing, depending on traffic demand patterns. The proposed system to be used for this model is RHODESTM (Real-Time Hierarchical Optimized Distributed Effective System) and is described further in the next section. Therefore, the next steps are:

- To analyze the same network with a traffic-adaptive signal control strategy in place of fixed-time control.
- To evaluate whether the reduction in vehicular O-D travel times achieved by the deployment of ATIS such as VMS to disseminate traveler information is benefited further by the use of an adaptive strategy.

5.0 REAL-TIME TRAFFIC ADAPTIVE SIGNAL CONTROL USING RHODESTM

Having established the advantage of deploying traveler information systems in previous sections, further analysis will now study if the overall performance of the traffic system considered can be further improved by replacing the fixed-time intersection control strategy with a real-time, traffic-adaptive signal control strategy. In this section, pre-specified CORSIM network intersections (except the rail-crossing intersections) are controlled in real-time by RHODESTM, a real-time, traffic adaptive signal control algorithm developed at the University of Arizona [Head et al, 1992; Mirchandani and Head, 2001]. The objective here is to determine whether the adaptive strategy will further reduce average O-D travel times when deployed along with traveler information and route guidance systems described in the previous sections.

5.1 RHODESTM

RHODESTM is a real-time, traffic adaptive signal control system that uses inputs from detectors to predict traffic conditions further downstream, both spatially and temporally. An optimization algorithm then realizes a set of optimal signal settings based on these traffic predictions. This results in pro-active intersection control and offers greater coordination between signals in a network than a simple actuated control strategy. Based on the estimation and/or prediction of traffic volumes and turning proportions, RHODESTM allocates optimized green times to different phases so as to serve different demand patterns at different points in the network. The RHODESTM algorithm looks ahead and predicts traffic conditions over a rolling horizon of one minute.

RHODESTM intersection control is incorporated into the CORSIM simulation by configuring a software implementation of the algorithm as a run-time extension (RTE) to TSIS (the software shell that houses CORSIM). The RTE is the medium through which RHODESTM optimization and prediction algorithms are interfaced with CORSIM at runtime and hence real-time signal optimization and control is enabled.

5.2 CASE 5 – Replace Fixed-Time Signal Control in Case 4 with RHODESTM
Information about Signal Phase Timings is available.
Information about Train Crossing Times is available.
Signal Phasing is Controlled by RHODESTM

For case 5, dynamic origin to destination shortest routes are not recalculated but remain the same as those yielded by case 4. That is to say, the best test case determined until now will be further analyzed to evaluate the added effects of using real-time, traffic-adaptive signal control. Although the RHODESTM algorithm does predict future traffic conditions and expected link travel times, it does so over a rolling time horizon of one minute. However, the simulation model under consideration runs to completion in 900 seconds. Hence link travel times are not extracted from RHODESTM and the same information that was used to calculate dynamic shortest routes for case 4 will be used in case 5 as well. Thus, the difference now is that instead of using fixed time intersection control as was done in the previous four cases, the intersections (except the rail-crossing intersections) is controlled in real-time by RHODESTM. The motivation for using the optimal-case simulation from the previous cases (1 to 4) and then exchanging fixed-time control for RHODESTM is basically to verify the efficiency of simultaneously deploying traveler information along with a real-time signal control strategy with regard to further reducing origin-destination travel times. Once the best-case scenario is simulated with RHODESTM controlling the intersections, it can be determined whether RHODESTM will further enhance system performance and reduce average O-D travel times for the network being analyzed. Further and more importantly, by using a traffic-adaptive control mechanism that runs in real-time and the parameters of which may be configured individually for each RHODESTM-controlled intersection, it may be possible that apart from simply achieving the objective of reducing overall system O-D travel times, the individual performance of each intersection can also be controlled to an extent so as to reduce the O-D travel times along each route from origin to destination. Examples of these user-defined intersection control parameters that may be varied according to the specific network being considered are minimum green time and maximum green time.

Figure 4 The CORSIM network with RHODESTM controlled intersections

5.3 Results and Findings with RHODESTM Control - Test Case 5

For test case 5, the same network is simulated again with the same set of ‘optimal routes’ that was used for test case 4 (Perfect Information with fixed-time control). However, the difference for this case is that RHODESTM now controls fifteen intersections in real-time, according to varying traffic demand patterns (Figure 4). Again, it is
assumed that all drivers will comply with the information being provided and will consider the alternate routes suggested by the ATIS and Variable Message Signs.

From the simulation output, the corresponding O-D travel times were gathered and averaged over runs with the same six sets of random seeds that were used for the previous cases. The average travel time for each vehicle that completed an O-D trip was calculated to be **214.9398 seconds**.

### 5.4 Comparison – RHODESTM versus Case 4

Figure 5 compares the average origin to destination travel times per vehicle observed for case 4 (Perfect Information with fixed-time control) as against case 5 (Perfect Information with RHODESTM control).

![Travel times bar chart](chart)

**Figure 5 Travel times per O-D vehicle for case 4 and case 5 (RHODES)**

Clearly, deploying RHODESTM in the traffic network along with ATIS-driven route guidance serves to further reduce average O-D vehicle travel times. The percent improvement in average system O-D travel times is illustrated in Table 4.

**Table 4 Percent reduction in average O-D travel times observed by using RHODESTM with ATIS**

<table>
<thead>
<tr>
<th>Percent Reduction</th>
<th>Over Case 1</th>
<th>Over Case 2</th>
<th>Over Case 3</th>
<th>Over Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average O-D Travel Times (Seconds/vehicle-trip)</td>
<td>222.7329</td>
<td><strong>214.9398</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6.0 CONCLUSIONS

This paper introduced a simulation framework for evaluating the benefit of providing travelers with dynamic and real-time route guidance based on information about current network conditions using ATIS such as VMS to the specific case of a highway network with railroad crossings. Simulation results showed that a dynamic route guidance infrastructure based on the availability of complete information about intersection phasing as well as rail crossing...
times makes for an ideal route guidance scheme with minimum delays and lower system-wide origin to destination travel times.

Additionally, this information based route guidance scheme implemented in conjunction with real-time, traffic signal control using RHODESTM further improves system performance and reduces average travel times.

The results of the five test scenarios implemented prove to be along anticipated lines. Even with the assumptions governing this work, the final results are amenable to intuitive logic and with more data and a more compete model, incorporating a traveler route-selection infrastructure, a more detailed and accurate analysis of the feasibility of ATIS-driven route guidance with adaptive signal control can be performed.

It is possible that the proposed dynamic route guidance system could be of greatest use to the specific case of emergency vehicles in the vicinity of rail-highway crossings. Hence, an additional study may be conducted targeting the impact of the system on emergency vehicles only, assuming nominal background traffic in the network.

Real-time traffic-adaptive intersection control, using RHODESTM has been evaluated vis-à-vis dynamic shortest route guidance for each O-D pair and results in a marked improvement in overall system travel-time performance. However, in this case, fifteen intersections have been randomly targeted for RHODESTM control and here it is observed that RHODESTM intersection optimization results in some O-D vehicles having to actually experience longer delays than they would have without RHODESTM in operation. This is the cost accrued to the system for an overall improvement in system performance. However, with further analysis of the actual network being considered, specific intersections (or ‘hot spots’) can be identified and targeted for RHODESTM control selectively so as to improve system travel-time performance, with minimum added travel-time cost to some vehicles.

REFERENCES


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