Evaluation of Rural Interstate Work Zone Traffic Management Plans in Iowa Using Simulation

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Traffic levels on Interstate Highway 80 in eastern Iowa increased 44 percent between 1988 and 1997, with summer traffic volumes approaching 40,000 vehicles per day. These traffic levels and the expected continued growth create special problems when developing a work zone traffic management plan (WZTMP) at a long-term work zone. Motorists at past work zones on this highway have experienced long delays. A methodology for evaluating the cost-effectiveness of alternative delay-reducing WZTMPs was developed and tested on a past work zone to determine its effectiveness. Using Traffic Software Integrated System (TSIS) 4.2, four WZTMPs were modeled to evaluate their effectiveness at reducing motorist delay. These models were based on a case study of a long-term work zone on Interstate 80 in 1997, where queues developed on 34 different days from May 31, 1997 to September 13, 1997. Of the competing alternatives, the most cost-effective alternative is to direct the contractor to implement a nonstop work schedule until project completion. The results for this alternative indicated that about 9,044,000 vehicle-minutes of delay could have been avoided. This represents an 86% reduction in delay reduction compared with the "do-nothing" alternative. This methodology was developed as a planning tool to determine the potential benefits of alternative traffic management plans at work zones. Highway agencies using this methodology can determine the potential cost-effectiveness of alternative WZTMPs at upcoming work zones. Key words: Corsim, delay, simulation, work zone.

INTRODUCTION

By 1996, the interstate highway system was 99.9% complete (*1*). As the original sections of interstate highway reach the end of their serviceable lives, reconstruction and rehabilitation has become more common. During this same time, there has been rapid growth of vehicle miles traveled on the nation's highway system. Traffic volumes on portions of Interstate Highway 80 in rural eastern Iowa, for example, increased by about 44 percent from 1988 to 1997 (*2*).

Several studies have indicated that capacities are significantly reduced when one or more lanes are removed due to repair or reconstruction (*3,4,5*). When traffic demand exceeds the reduced work zone capacity, congestion and delays result, leading to increased driver frustration (*6*), reduced safety (*7*), and increased user delay cost (*8*).

The quantity and cost of delay caused by a work zone must be determined in order to choose the appropriate mitigation technique. If there is too little improvement, the desired results are not achieved. Too large an investment for a more substantial alternative could reduce the traffic congestion, but would be an inefficient allocation of the finite resources available to a highway agency. Clearly, the delay imposed on the driving public must be determined in order to conduct an analysis of the available alternatives.

This researched used microscopic simulation to evaluate the cost-effectiveness of using alternative work zone traffic management plans (WZTMPs) at rural interstate locations where work zones reduce the number of traffic lanes from two to one in each direction. Computer simulation provides data required for benefit-cost analyses that would be difficult to obtain from other sources.

To prove the effectiveness of this process, data from one Interstate Highway 80 work zone in Iowa County, Iowa in 1997 was analyzed. Four alternative WZTMPs were studied: 1) the "do-nothing" alternative where no changes were made, 2) accelerating the pace of the contractor to a nonstop work schedule, 3) paving additional lanes through the work zone to allow four lanes of traffic at once, and 4) diverting a small percentage of traffic onto a detour route to reduce traffic demand on the interstate.

CASE STUDY BACKGROUND

The work zone chosen for the case study was in place in 1997 on Interstate Highway 80 from mile marker 215 to 221 in Iowa County, Iowa. The project included pavement reconstruction of all four traffic lanes, for a total cost of approximately 10.8 million dollars. On May 31, 1997, interstate traffic was modified into a two-lane, two-way operation (TLTWO) and remained in this configuration until September 13, 1997.

A detour route was established by the Iowa DOT to accommodate traffic during periods of work zone congestion and to serve as a contingency route should the work zone become impassible. The diversion route consisted of using Iowa Highway 21 and US Highways 6 and 151 to bypass the work zone. Figure 1 shows Interstate Highway 80 and the detour route during this construction project. The Iowa DOT's WZTMP did not divert motorists from the interstate and onto the detour route except in emergencies within the work zone.

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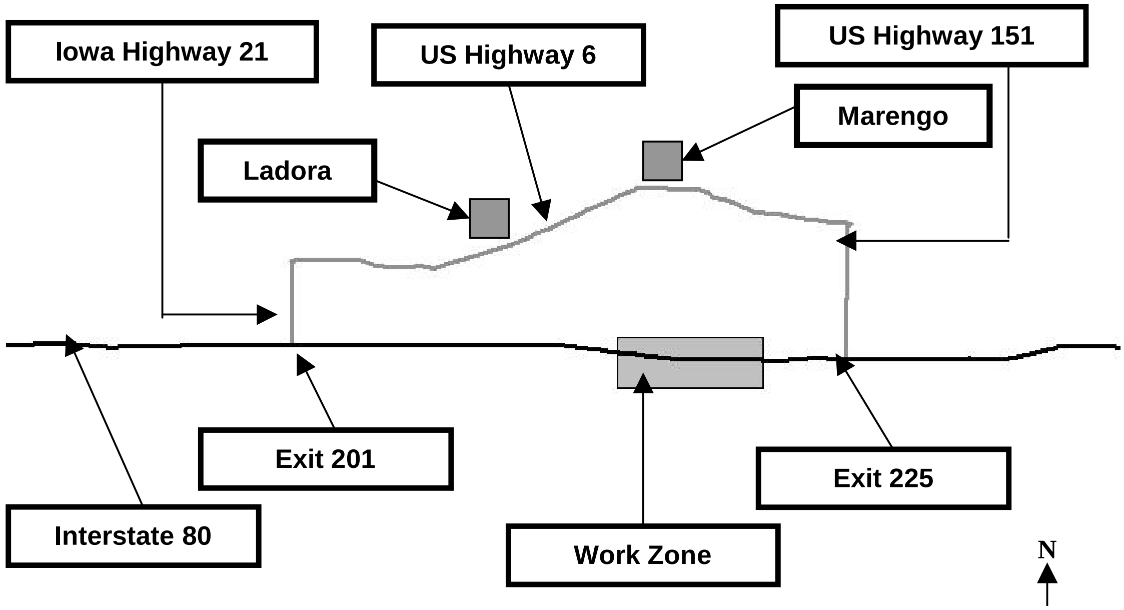

FIGURE 1 Work zone location and diversion route, Iowa County, Iowa

Case Study Alternatives

Four alternative WZTMPs were prepared for analysis in the case study. These alternatives were developed with the assistance of Iowa DOT engineers, and although these were not implemented, they represent potential solutions deemed worthy of investigation at this site. Each alternative is summarized below.

Do-Nothing Alternative

The first alternative represents the traffic management plan that was actually used during reconstruction in 1997. For modeling purposes, the FRESIM component of TSIS was used to simulate Interstate Highway 80, from mile marker 211 to 226, with one lane blocked in each direction by an incident to simulate the work zone location. This alternative was modeled for comparison to the remaining alternatives.

Nonstop Work Alternative

The second alternative accelerated the pace of the project by requiring the contractor to work 24 hours per day, 7 days per week during the time the TLTWO traffic plan was in place. The benefit of such an alternative would be the elimination of delays between the theoretical early finish date and September 13, 1997, when the TLTWO was actually removed. No other modification to the do-nothing traffic plan was made in this alternative.

After a review of the Iowa DOT records concerning construction schedule and reported weather for this project, estimates by Iowa DOT engineers, and estimates by a Des Moines-based paving contractor, a revised schedule was created with an early finish date of July 19, 1997, 56 days ahead of the do-nothing schedule. The contractor believed that for the case study, a premium of $1,000,000 would be required for a nonstop work schedule.

Four Traffic Lanes through the Work Zone

The third alternative investigated provided two additional traffic lanes through the work zone. This involved strengthening and widening the shoulders along the interstate through the work zone, and widening four bridges to accommodate the additional traffic lanes. In this manner, the basic TLTWO would be modified to allow two lanes in each direction. No other modifications to the traffic control plan would be made for this alternative compared with the do-nothing alternative. The Iowa DOT estimated the cost of paving all of the shoulders to a width of 12 feet for six miles and widening the four bridges in this case study to be about $4,946,000.

Diversion Route Alternative

In this alternative, the Iowa DOT would divert a small percentage of vehicles off the interstate and onto the existing diversion route. This alternative was divided into three separate sub-alternatives. One sub-alternative assumed that 5% of all vehicles were diverted, the second assumed a 10% diversion, and the third assumed a 15% diversion.

The benefit of this alternative was a reduction of delay over the entire network by reducing the traffic levels on the interstate. The delay for vehicles on the diversion route, however, would increase because local non-interstate traffic would be delayed by an increase in traffic on the detour route and because the diverted interstate traffic would have a longer path than if it stayed on the interstate. In order for this alternative to be beneficial, the interstate delay savings must outweigh the detour's delay increase.

The costs associated with diverting traffic onto the detour route are not well defined. Discussions with Iowa DOT traffic engineers revealed that the state has little experience with diverting rural interstate traffic for non-emergency situations. To estimate the costs for such an alternative, several assumptions were made. First, it was assumed that additional manpower would be required to implement this alternative. It was assumed that 6 to 10 people would be occupied full-time during TLTWO operation to run traveler information equipment, hand out fliers at rest areas, or other work to convince drivers to divert. It was assumed that the 5, 10, and 15% diversions could be successfully accomplished for $370,000, $470,000, and $670,000, respectively.

Traffic Data

The interstate traffic volumes used in this research were obtained from the Iowa DOT's Office of Transportation Data. The traffic volumes were recorded from an automatic traffic recorder (ATR) permanently installed about 2 miles from the east end of the case study. Twenty percent of the traffic stream was assumed heavy trucks, based on a previous study of Interstate Highway 80 through eastern Iowa (*9*). The traffic volumes on the detour route were obtained from ATR sites on US Highway 6. This information allowed the model to include "background" traffic on the network, with which the diverted interstate traffic would interact.

Determination of Congested Days

From the Iowa DOT project files, it was determined that congestion due to high traffic volumes was reported on 34 days during the project. Table 1 shows the dates and times when the CMS and HAR units were active due to high traffic volumes. These 34 days were modeled for each of the alternative traffic management plans. Each of these days were modeled using the available traffic data starting one hour prior to the onset of congestion and terminating one hour after congestion subsided.

SIMULATION MODEL

In this research, microscopic simulation was used to determine the amount of motorist delay that would accrue using several alternative traffic management plans over the life of a work zone. Traffic Software Integrated System (TSIS), developed by the Federal Highway Administration, was chosen for this research because of its ability to simulate a work zone environment and provide the measures of effectiveness needed to effectively compare alternative traffic management plans.

The model was constructed in two parts: the interstate portion was constructed using the FRESIM portion of the TSIS software package. The interstate consisted of two freeway lanes in each direction with a speed limit of 65 mph. The work zone was created using the incident function in FRESIM. This function was originally developed to model traffic crashes or incidents. The work zone was created by blocking the left lane of the interstate in each direction with an incident the length of the work zone and with duration as long as the simulation run time. Highways of the detour network were created using the NETSIM portion of the TSIS software.

TABLE 1 Dates and Times When HAR and CMS Were Active

Date	Time Activated	Time Deactivated
6/1/97	15:10	23:00
6/13/97	15:00	22:30
6/14/97	10:00	17:15
6/20/97	14:30	23:40
6/22/97	15:55	20:30
6/26/97	15:25	16:45
6/27/97	13:35	00:30 (6/28)
6/28/97	12:00	21:00
6/29/97	10:25	20:30
7/3/97	11:45	23:15
7/4/97	10:30	15:30
7/6/97	12:10	22:45
7/11/97	16:30	19:35
7/13/97	10:00	21:30
7/18/97	9:50	14:00
7/20/97	15:20	22:45
7/25/97	15:00	21:30
7/26/97	11:30	15:00
7/27/97	12:30	21:15
8/1/97	9:35	01:30 (8/2)
8/2/97	9:00	21:30
8/3/97	11:10	22:04
8/7/97	11:00	15:00
8/8/97	10:35	00:25 (8/9)
8/9/97	9:05	20:20
8/10/97	2:00	22:50
8/15/97	11:30	02:50 (8/16)
8/16/97	10:15	17:30
8/17/97	11:55	22:30
8/24/97	16:15	22:30
8/29/97	12:00	21:25
8/30/97	11:10	15:30
9/1/97	12:50	21:30
9/6/97	10:20	20:50

Model Calibration

The work zone portion of the model was calibrated to achieve the proper traffic behavior by changing the headway between vehicles at the incident location. The headway between vehicles can be increased in TSIS by from 0 to 100% using the incident function.

To determine the appropriate headway adjustment factor for this research, a two-lane interstate test section was simulated, consisting of 6,000 feet of two-lane freeway and representing one direction of a rural interstate. A work zone was placed in the center of the model, which closed one lane. The speed limit was established as 55 mph through the work zone and 65 mph for the remainder. The work zone headway was increased by 20% for the first iteration. Traffic volumes were input into the traffic generator at the upstream end of the model, starting at a rate of 1,000 vehicles per hour (vph) with 20% trucks. This volume was increased by small increments to 1,500 vph at regular intervals. This test was repeated with the work zone headway increased to 30%, 40%, 50%, and 60%. The results were then analyzed to determine when delays began for each percentage of headway increase. Figure 2 shows the results of the calibration process.

A 40% increase in work zone headway showed an increase in vehicle delay beginning at about 1,250 vph. This work zone capacity

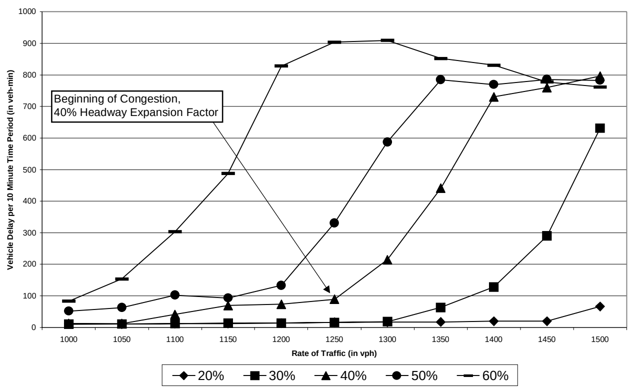

FIGURE 2 Analysis of delay for varying headway expansion factors

is similar to that observed by Dudek and Richards for Texas work zones in of this type (*4*). Additionally, Iowa State University's Center for Transportation Research and Education (CTRE) studied the capacity of rural Iowa interstate work zones in the summer of 1998 and found a capacity of between 1,216 to 1,302 vph for a rural Iowa work zone (*9*). The 40% headway increase was determined to be the most reasonable value to calibrate the model and was used throughout the research.

CASE STUDY ANALYSIS

Each alternative simulation was executed using the CORSIM software. Simulation runs were performed to model the 34 congested days for the 6 different alternatives. Five simulation runs of each day for each alternative were completed using different random seed numbers for each simulation run. A statistical summary of the total delay was performed to show the average total delay, standard deviation, maximum value, minimum value, and range for each alternative. Table 2 summarizes the case study descriptive statistics.

TABLE 2 Descriptive Statistics, in Vehicle-Minutes (in Thousands)

Alternative	Average Delay	Standard Deviation	Min. Value	Max. Value	Range
Do-Nothing	10,473	249	10,030	10,620	590
Nonstop Work	1,428	11	1,416	1,439	23
4-Lane Work Zone	1,177	8	1,167	1,187	20
5% Traffic Diversion	7,092	18	7,071	7,111	40
10% Traffic Diversion	4,589	290	4,426	5,107	681
15% Traffic Diversion	3,029	149	2,913	3,218	304

Benefit-Cost Analysis

The average delay for each alternative for each day was determined in order to calculate their value. Using a previously prepared study on the value of time for the Iowa DOT (*8*) and converting these to 1997 values (*10*), a dollar value was placed on the delay for each alternative. The values of delay for automobiles are shown in Table 3. This value varies depending on the length of delay, as laid out in the AASHTO's *Manual on User Benefit Analysis of Highway and Bus-Transit Improvements* (*11*). The incremental cost as well as the incremental benefit for each alternative is shown in Table 4.

TABLE 3 Iowa-Specific Per Automobile Hour Travel Time Value Estimate

Time Savings Increments	
Minutes	Average Value
0 to 5	$5.37
5 to 10	$8.06
11 or more	$10.74

TABLE 4 Benefits and Costs for Each Alternative (in Thousands)

	Do-Nothing	Diversion 5%	Diversion 10%	Diversion 15%	Nonstop Work	4-Lanes
Incremental Benefit	$0	$480	$909	$1,123	$2,034	$2,026
Incremental Cost	$0	$370	$470	$670	$1,000	$4,947

After determining the benefits and the costs of each of each of the competing alternatives, the incremental benefit-cost analysis was then performed. The results of the incremental benefit-cost analysis are presented in Table 5. The nonstop work alternative had an incremental benefit-cost analysis of 2.03 when compared to the do-nothing alternative and remained the most cost-effective compared to the competing alternatives.

CONCLUSIONS

This research indicates that there are cost-effective measures that can be implemented to reduce rural interstate work zone delays. While the results of this analysis should not be construed to mean that requiring contractors to work nonstop would be the best alternative in all work zone situations, it does indicate that cost effective congestion reducing measures can be found using simulation.

Additionally, research showed that microscopic simulation is an effective tool in determining appropriate WZTMPs at interstate work zones. Determining the delay values for competing WZTMPs for upcoming projects would allow highway agencies to have quantifiable estimates of what these delays will cost and provide them with the information needed to choose the most appropriate alternative for a given situation.

TABLE 5 Incremental Benefit-Cost Analysis Results

	Defender	Challenging Alternatives				
Step 1	Do-Nothing	5% Diversion	10% Diversion	15% Diversion	Nonstop Work	4-Lanes
Incremental Benefit	N/A	$480,000	$909,000	$1,123,000	$2,034,000	$2,025,000
Incremental Cost	N/A	$370,000	$470,000	$670,000	$1,000,000	$4,946,000
B/C Ratio		1.30	1.93	1.68	2.03	0.41
Outcome		Becomes New Defender	Remains a Challenger	Remains a Challenger	Remains a Challenger	Removed from Consideration
Step 2	5% Diversion	10% Diversion	15% Diversion	Non-Stop Work		
Incremental Benefit	N/A	$429,000	$643,000	$1,554,000		
Incremental Cost	N/A	$100,000	$300,000	$630,000		
B/C Ratio		4.28	2.14	2.47		
Outcome		Becomes New Defender	Remains a Challenger	Remains a Challenger		
Step 3	10% Diversion	15% Diversion	Non-Stop Work			
Incremental Benefit	N/A	$214,000	$1,125,000			
Incremental Cost	N/A	$200,000	$530,000			
B/C Ratio		1.07	2.12			
Outcome		Becomes New Defender	Remains a Challenger			
Step 4	15% Diversion	Non-Stop Work				
Incremental Benefit	N/A	$911,000				
Incremental Cost	N/A	$330,000				
B/C Ratio		2.76				
Outcome		**The non-stop work alternative is the most attractive alternative**				

Finally, the methodology used in this research could be used to predict congestion at future interstate work zones, allowing highway agencies to determine the appropriate strategy to minimize congestion cost-effectively. Only two modifications would need to be made in the methodology shown in this research to apply the process to future work zones. First, future traffic volumes would need to be estimated by inflating current data by a reasonable growth factor. Second, without knowing in advance the congested days, a reasonable assumption of when congestion is likely— such as time-of-day and day-of-week— would need to be determined based on past experience on the highway in question.

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