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INTEGRATED MANAGEMENT OF HIGHWAY MAINTENANCE

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ABSTRACT

Highway maintenance, especially pavement rehabilitation or resurfacing, requires lane closures. This work develops an integrated model to help highway agencies in developing traffic control plans for maintenance activities and efficiently managing traffic around highway work zones. Thus, the objective of this study is to develop methods for optimizing work zone characteristics in order to minimize the combined total costs for highway agencies and users. Work zone models are developed for three cases: (1) a single maintained road with steady traffic inflows, (2) a single maintained road with time-dependent inflows and, (3) a road network with multiple detour paths, as well as plans for maintenance activities and managing traffic around highway work zones.

Key words: Work Zone Optimization, Work Zone Cost Function, Pavement Rehabilitation, Lane Closures, Highway Maintenance.

1. INTRODUCTION

Highway maintenance, especially pavement rehabilitation or resurfacing, requires lane closures. Given the very substantial cost of the maintenance and the very substantial traffic disruption and safety hazards associated with highway maintenance work, it is desirable to plan and manage the work in ways that minimize the combined cost of maintenance, traffic disruptions and accidents.

1.1 PROBLEM STATEMENT

The overall costs of road maintenance and traffic disruption may be very significantly reduced through properly integrated decisions about the conduct and schedule of maintenance activities and the development of appropriate traffic management plans. Several questions should be considered for comprehensive analysis:

How long and wide should work zones be?

How does the availability of alternate routes and their characteristics (e.g., length, design speed, excess capacity, and traffic patterns) influence the above decisions?

What fraction of traffic should be diverted to alternate routes?

When time-dependent inflows are considered, the analysis becomes more complex. Besides the above questions, the work scheduling, i.e., when the work should be done and how long closures should be last, must also be analyzed. The optimal work zone activities, including the optimized work zone lengths in different periods (day, night, peak period, off-peak period), the preferred starting time and ending time for each zone closure (e.g. terminating work during peak period to avoid to too serious traffic disruption), are also included among the problems considered. When considering time dependent inflows, traffic management plans combining different alternatives, which have different work zone configurations or diversion, for different periods might be developed and applied to highway maintenance projects.

2. LITERATURE REVIEW

Krammes and Lopez (1994) et.al.., provided recommendations for estimating the capacity of the remaining lanes during short-term lane closures based on 45-hour capacity counts between 1987 and 1991 at 33 Texas freeway locations with work zones. Adjustments were suggested for the effects of the intensity of work zone activities, percentage of heavy vehicles in the traffic stream, and presence of entrance ramps near the beginning of a lane closure.

Dudek and Richards (1982) et.al.., presented more detailed information based on field data analysis for estimating road capacity during maintenance work. They considered lane closure strategies and obtained cumulative distribution of observed work zone capacities.

Memmott and Dudek (1984) et.al.., used a regression model to estimate the mean capacity for a work zone. The advantage of using the regression model was that most lane closure types were covered and the restricted capacity used for traffic management purposes could be estimated. However, they only used a capacity estimation risk factor as a variable instead of specifying other possible geometric variables.

Kim and Lovell (2001) et.al.., developed a multiple regression model to estimate capacity in work zones in order to establish a functional relationship between work zone capacity and several key independent factors, including the number of closed lanes, the proportion of heavy vehicles, grade and the intensity of work activities.

3. WORK ZONE OPTIMIZATION FOR STEADY TRAFFIC INFLOWS

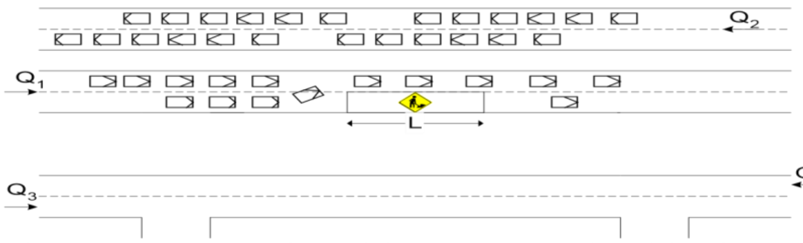
3.1 Work Zone Optimization - Two-Lane Two-Way Highway

The basic method followed here for tow-lane two-way highway and four-lane two-way highway is to formulate a total cost objective function and use it to optimize work zone lengths at work zones for four alternatives. The queuing delays to users are formulated with deterministic queuing models. Then thresholds among alternatives are derived with respect to key variables, to determine the best alternative for different conditions of traffic flow, road characteristics and maintenance characteristics.

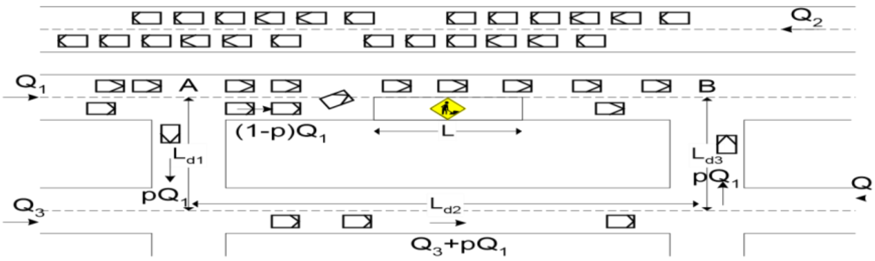
3.1.1 Alternatives and Assumptions

The following four alternatives are considered for two-lane two-way highways in this study:

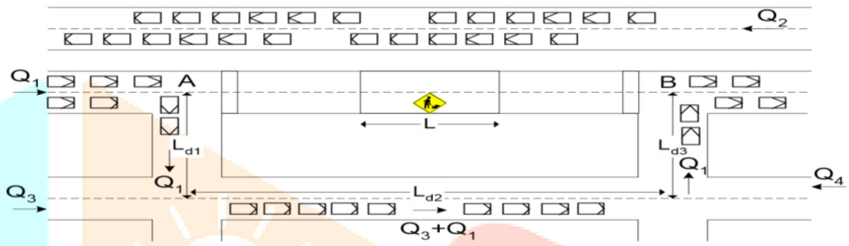
1. Alternating flow on one lane, without any detour
2. Alternating flow on one lane, with a detour
3. One-directional flow on one lane along work zone; other direction on detour
4. Both directions detoured and both lanes closed for work.



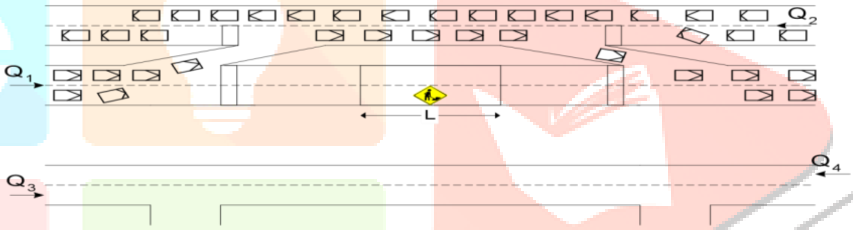
(a) Alternative 4.1: No Detour, One of the Two Lanes closed for Q_1 Traffic



(b) Alternative 4.2: A Fraction of Q_1 Traffic through Detour



(c) Alternative 4.3: All Q_1 through Detour, Allowing Work Zone on Both Lanes in Direction 1



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Alternative : Crossover of All Q_1 into One Lane in Opposite Direction, Allowing Work Zone on Both Lanes in Direction 1

Figure 1: Geometries of Analyzed Work Zones for Four-Lane Two-Way Highways.

4. WORK ZONE COST FUNCTION FOR TIME-DEPENDENT INFLOWS

4.1 Model Formulation – Two-Lane Two-Way Highways

Schonfeld and Chien (1999) developed a work zone cost function which includes user delay and maintenance cost for two-lane highways. Using deterministic queuing analysis for control cycles that alternate traffic directions past work zones, the queuing delays per cycle (each cycle having two phases, one for each direction of travel) incurred in the work zone are derived as follows:

$$Y_1 = 1/2\ \ Q_1 (r + t_2)(t_1 + t_2) \qquad (4.1)$$

$$Y_2 = 1/2\ \ Q_2 (r + t_1)(t_1 + t_2) \qquad (4.2)$$

$$\mathrm{T1} = \frac{r\left(\left(\frac{3600}{H}\right)+Q1-Q2\right)}{\left(\left(\frac{3600}{H}\right)-Q1-Q2\right)} \qquad (4.3)$$

$$\mathrm{T2} = \frac{r\left(\left(\frac{3600}{H}\right)+Q2-Q1\right)}{\left(\left(\frac{3600}{H}\right)-Q1-Q2\right)} \qquad (4.4)$$

Y_1 is delay per cycle in Direction 1 and Y_2 is delay per cycle in Direction 2. Note that t_1 is the discharge phase for servicing the traffic flow Q_1 in Direction 1, while t_2 is the discharge phase for servicing Direction 2. The average clearance time r is the work zone length L divided by the average vehicle moving speed V. Then:

$$Y1 = \frac{2 \cdot 3600.Q1L^2\left(\left(\frac{3600}{H}\right)-Q1\right)}{HV^2\left(\left(\frac{3600}{H}\right)-Q1-Q2\right)} \quad (4.5)$$

$$Y2 = \frac{2 \cdot 3600.Q2L^2\left(\left(\frac{3600}{H}\right)-Q2\right)}{HV^2\left(\left(\frac{3600}{H}\right)-Q1-Q2\right)2} \quad (4.6)$$

Consider work zone i of length L_i, which is one of the zones on a maintained road. The number of cycles N_i for zone i is the maintenance duration for zone i divided by the cycle time. N_i can be obtained as:

$$N_i = D_i / (t^i_1 + t^i_2) \quad (4.7)$$

In Eq.(4.7), t_1^i is the duration of the discharge phase in Direction 1 for work zone i, while t_2^i is the duration of the discharge phase in Direction 2 for zone i. D_i is the total maintenance duration for zone i, which is linear according to the assumption in Eq (3.3):

$$D_i = z_3 + z_4 L_i \quad (4.8)$$

The total queuing delay cost for work zone i is

$$C_{qi} = YN_iv = (Y_1 + Y_2)\frac{D^i}{t1 + t2}{}_{ii}\, v \quad (4.9)$$

Where$Y$ is total delay per cycle. Substituting Eqs.(4.1), (4.2), (4.3), (4.4) (4.8) into Eq.(4.9), we obtain:

$$C_{qi} = \frac{(z_3 + z_4 L_i)L_i[Q_1(\frac{3600}{H} - Q_1) + Q_2(\frac{3600}{H} - Q_2)]v}{V(\frac{3600}{H} - Q_1 - Q_2)} \quad (4.10)$$

The maintenance cost for work zone i, C_{mi}, is according to the assumption in Eq (3.4):

$$C_{mi} = z_1 + z_2 L_i \quad (4.11)$$

Then, the total cost for work zone i, C_{ti}, is

$$C_{ti} = C_{mi} + C_{qi} = z_1 + z_2 L_i + \frac{(z_3 + z_4 L_i)L_i[Q_1(\frac{3600}{H} - Q_1) + Q_2(\frac{3600}{H} - Q_2)]v}{V(\frac{3600}{H} - Q_1 - Q_2)} \quad (4.12)$$

where C_{ti}= total cost for work zone i; C_{mi} = maintenance cost for work zone i; C_{qi} = user queuing delay cost for zone i.

We consider the varying traffic flows in Directions 1 and 2 over one day. A maintenance project for a two-lane two-way road with total length L_T in one direction would be maintained by scheduling m work zones over the entire maintenance period. Assume that zone i (i = 1, 2, …., m) is resurfaced over n duration units (different zones would likely have different n values) and D_{ij} (j =1, 2, …., n) is a duration unit selected so that in it inflows stay appropriately constant, as shown in Figure 4.2. Then the duration for zone i, denoted D_i, is:

$$D_i = \sum_{j=1}^{n} D_{ij} \quad (4.13)$$

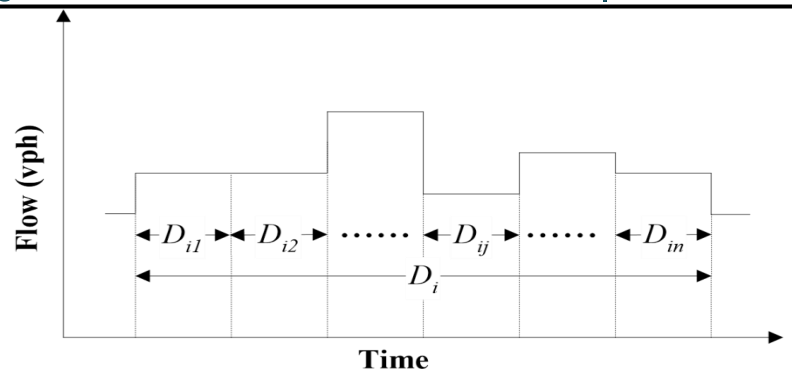

Figure 2: *Duration for Work Zone i with Time-dependent Traffic Inflows*

4.2 NUMERICAL ANALYSIS – TWO-LANE TWO-WAY HIGHWAY

The effects of various parameters on work zone lengths and starting times for two-lane highway work zones are examined in this section. The baseline numerical values for each variable in this section are defined in Table 4.2. A numerical example sequences and schedules unequal work zones for a 7.5-km maintenance project on a twolane highway. Table 4.3 shows the hourly traffic distribution on the maintained road. The annual average daily traffic (AADT) is 15,000 vehicles. Two daily peak periods are shown in Figure 4.15.

Table 1: AADT and Hourly Traffic Distribution on a Two-Lane Two-Way Highway

Hour	Volume (Both Direction)	% of AADT	% of Direction1	Q_1 (vph)	Q_2 (vph)
0	349	2.33%	0.48	167	182
1	350	2.33%	0.48	168	182
2	349	2.33%	0.45	157	192
3	350	2.33%	0.53	185	165
4	349	2.33%	0.53	185	164
5	350	2.33%	0.53	186	164
6	552	3.68%	0.57	315	237
7	900	6.00%	0.56	504	396
8	1,152	7.68%	0.56	645	507
9	1,002	6.68%	0.54	541	461
10	800	5.33%	0.51	408	392
11	649	4.33%	0.51	331	318
12	600	4.00%	0.50	300	300
13	552	3.68%	0.52	287	265
14	650	4.33%	0.51	332	318
15	852	5.68%	0.53	452	400
16	1,100	7.33%	0.49	539	561
17	844	5.63%	0.47	397	447
18	750	5.00%	0.47	353	397
19	702	4.68%	0.47	330	372
20	600	4.00%	0.46	276	324
21	500	3.33%	0.48	240	260
22	349	2.33%	0.48	167	182
23	349	2.33%	0.48	167	182

AADT	15,000	100.00%	-	7,632	7,368

Compared to Powell's Method, we find in Figure 4.15 that for most project starting times considered (18 of 24) SA finds lower total costs while using less computer time (3 minutes with SA vs. 20 minutes with Powell's).Two algorithms are implemented in Visual Basic 6.0 and tested on a personal computer with a 1.8GHz Pentium 4 CPU and 512 MB memory. Two different but almost equally good project starting times are found by using the SA optimization process. The first best project starting time is 11:00. Its minimized total cost is $627,714/project, with nine work zones whose optimized lengths of 0.53, 0.76, 1.07, 0.82, 1.76, 1.08, 0.71, 0.45, and 1.34 km add up to 7.5 km, and whose idling time is 3.96 hours, as shown in Table 4.4(a). The second best project starts at 17:00. Its minimized total cost is $627,753/project, with eight zones whose optimized lengths of 0.80, 1.03, 0.77, 0.55, 1.50, 0.77, 0.56, and 1.49 km add up to 7.5 km, and whose idling time is 1.97 hours, as shown in Table 4.4(b). Thus, the solution starting at 17:00 has fewer (8 vs. 9) but longer work zones. When starting at 11:00 the first zone is shortened to avoid the afternoon peak period, during which there is a pause. The 17:00 start has already avoided the afternoon peak; it schedules less idling than the 11:00 start. Both cases have pauses during the morning peak, which has the highest traffic flow of the day. In Table 4.4(a) and (b), the agency cost, including maintenance cost and idling cost, is higher if starting at 11:00 ($612,167) than at 17:00 ($609,580). However, the user cost, including queuing delay cost, moving delay cost, and accident cost, is lower ($15,547) for starting at 11:00 than at 17:00 ($18,174). Such tradeoffs between agency costs and user costs should be carefully considered in project scheduling.

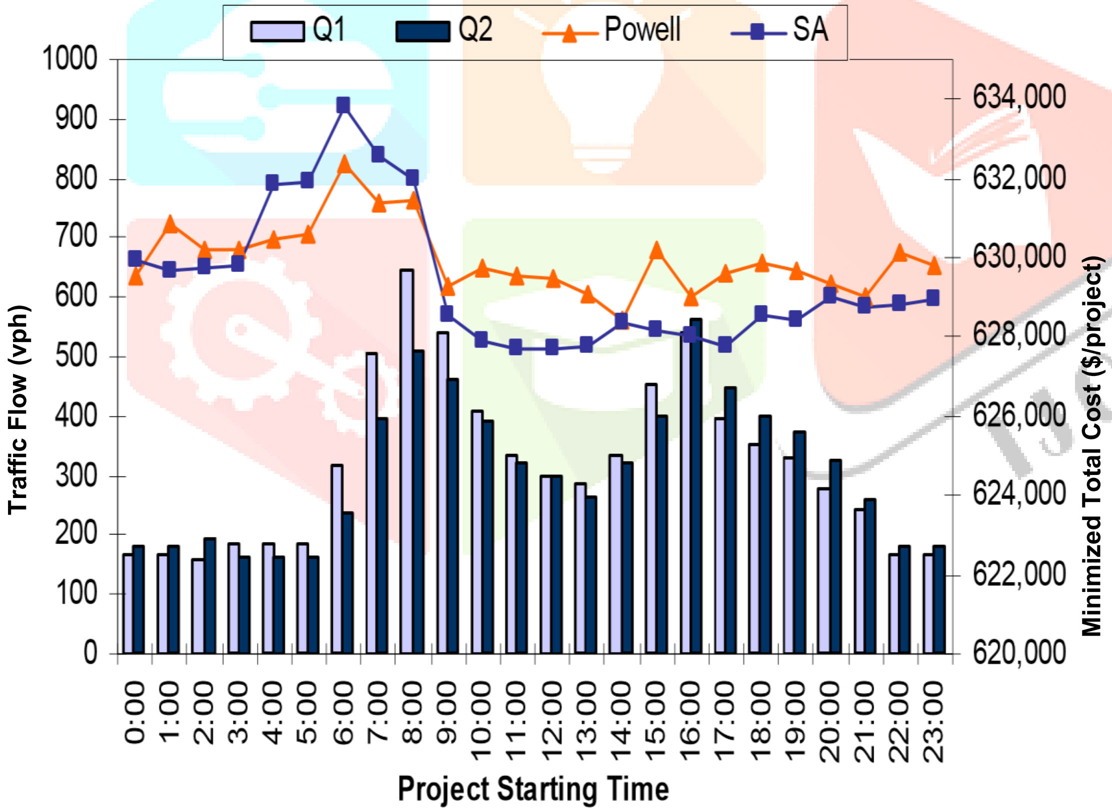

Figure 3: Hourly Traffic Distributions on Two-Lane Highway and Minimized Total Cost vs. Project Starting Time

Table 2 Optimized Results for Numerical Example (Two-Lane Highway), Project Starting Time: 11:00, v_d=\$800/hr

Zone No.	Optimized length (km)	Duration (hr)	Starting time (0-23.99)	Ending time (0~23.99)	Idling time (hr)	Total Cost ($/zone)
1	0.53	5.17	11.00	16.17	-	44,251
2	0.76	6.55	17.01	23.55	0.84	63,766
3	1.07	8.41	23.55	7.96	0.00	88,218
4	0.82	6.91	9.06	15.96	1.10	69,723
5	0.76	6.55	16.99	23.53	1.02	63,933
6	1.08	8.47	23.53	8.00	0.00	89,063
7	0.71	6.25	9.00	15.25	1.00	60,292
8	0.45	4.69	15.25	19.93	0.00	38,366
9	1.34	10.03	19.93	5.96	0.00	110,103
Total	7.50	63.00			3.96	627,714

Maintenance cost	609,000
Queuing delay cost	12,862
Moving delay cost	2,612
Idling cost	3,167
Accident Cost	73
Total cost	627,714
Total cost/project-km ($/lane-km)	83,695

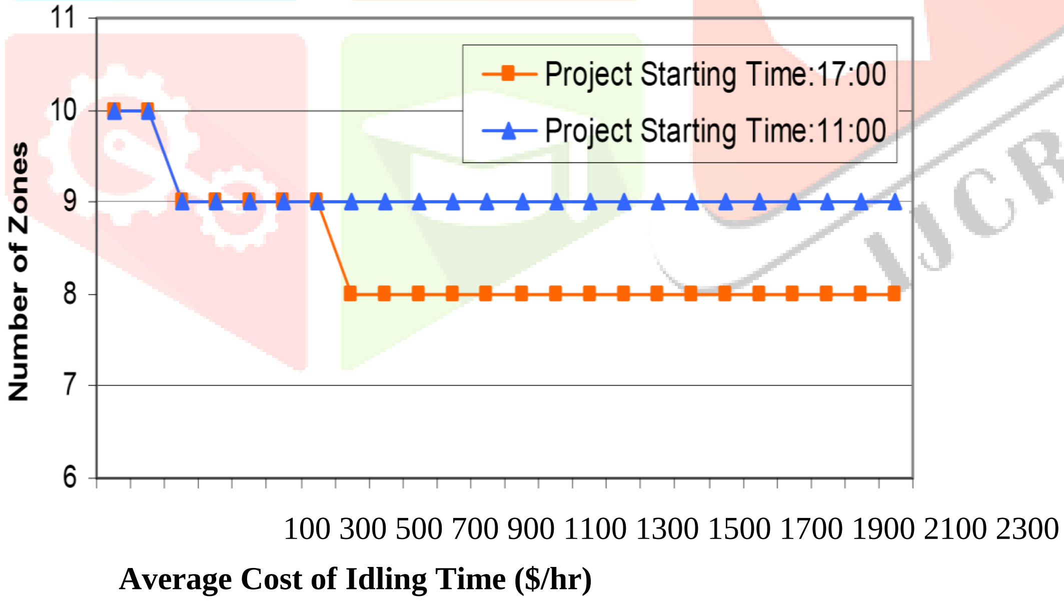

Figure 4: Numbers of Zones vs. Average Cost of Idling Time

Table 3: Current Work Zone Policy for Case Study (p=0, k=0), Project Starting Time: 9:00

Zone No.	Zone length (miles)	Duration (hr)	Starting time (0-23.99)	Ending time (0~23.99)	Idling time (hr)	Total Cost ($/zone)
1	0.417	6.00	9.00	15.00	-	49,056
2	0.833	10.00	19.00	5.00	4.00	37,420
3	0.417	6.00	9.00	15.00	4.00	52,256
4	0.833	10.00	19.00	5.00	4.00	37,420
5	0.465	6.46	9.00	15.46	4.00	66,001
Total	2.965	38.46			16.00	242,153
Maintenance cost						104,345
Queuing delay cost						113,311
Moving delay cost						11,108
Idling cost						12,800
Accident Cost						589
Total cost						242,153
Total cost/project-mile ($/lane-mile)						81,671

5.CONCLUSIONS

Highway maintenance, especially pavement rehabilitation or resurfacing, requires lane closures. Given the very substantial cost of the maintenance and the very substantial traffic disruption and safety hazards associated with highway maintenance work, it is desirable to plan and manage the work in ways that minimize the combined cost of maintenance, traffic disruptions and accidents. The overall costs of road maintenance and traffic disruption may be very significantly reduced through properly integrated decisions about the conduct and schedule of maintenance activities and the development of appropriate traffic management plans. Highway agencies have developed associated regulations to design work zone configurations to improve workers' and users' safety. Related regulations about scheduling maintenance work have also been developed to enhance public awareness and to decrease traffic disruption in peak periods. The objective of work zone optimization is to minimize the total cost, including agency cost and user cost by optimizing work zone lengths for each alternative and finding optimal diversion fraction. In work zone optimization for time-dependent inflows developed a model to optimize the scheduling of work zone activities associated with traffic control for two-lane two-way highways where one lane at a time is closed. However, their inflows are overly simplified and the "greedy" search approach used to determine each zone length tends to produce sub-optimal results. Two optimization methods, Powell's and Simulated Annealing, are adapted for this problem and compared. In numerical tests, the Simulated Annealing algorithm yields better solutions using less computer time than Powell's Method. The reliability of Simulated Annealing algorithm is also assessed. The models for two-lane highway and four-lane highway work zones for time-dependent inflows are developed. In work zone optimization with a detour , optimization models are developed for four work zone alternatives on two-lane highways and four alternatives on four-lane highways, all with time dependent inflows. The SAUASD (Simulated Annealing for Uniform Alternatives with a Single Detour) algorithm is developed for alternative selection. Moreover, the SAMASD (Simulated Annealing for Mixed Alternatives with a Single Detour) algorithm is developed to search through mixed alternatives and to optimize diverted fractions in order to find lower total cost than for uniform alternatives. In work zone optimization models for a road network with multiple detour paths and the SAMAMD (Simulated Annealing for Mixed Alternatives with Multiple Detour paths) algorithm are developed. For analysing traffic diversion through multiple detour paths in a road network, the SAUAMD (Simulated Annealing algorithm for Uniform Alternatives with Multiple Detour paths) and the SAMAMD algorithms are used to optimize work zone lengths and schedule the resurfacing work. Simulation analyses based on CORSIM are used not only to estimate delay cost, but also to evaluate the effectiveness of optimization models. In a case study, a comparison of the results from optimization and simulation models indicates that they are consistent. The optimization models do significantly reduce total cost, including user cost and maintenance cost.

REFERENCES

1. Aarts, E., and Korst, J. (1989) “Simulated Annealing and Boltzmann Machines.” *John Wiley & Sons Ltd.*, Eindhoven, the Netherlands.
2. Adamopoulos, G. I., and Pappis, C. P. (1998) “A Neighbourhood-based hybrid method for Scheduling with Fuzzy Due-dates.” *International Transaction in Operational Research*, Vol.5, No.2, 147-153.
3. Cassidy, M. J., Son, Y. T., and Rosowsky, D.V. (1994). “Estimating Motorists Delay At Two-Lane Highways Work Zones.” *Transp*. *Res*. *A*, 28(5), 433-444.
4. Cassidy, M. J., and Bertini, R.L. (1999). “Some Traffic Features at Freeway Bottlenecks.” *Transp*. *Res*. *B*, 33, 25-42.
5. Carr, R. I. (2000). “Construction Congestion Cost (CO^3) Traffic Impact And Construction Cost.”, *J*. *Transp*. *Engrg*., ASCE, 126(2), 114-121.
6. Chang, Y., Sawaya, O. B., and Ziliaskopoulos, A. K. (2001). “A Tabu Search Based Approach for Work Zone Scheduling.” *TRB 80rd Annu*. *Meeting*, Transportation Research Board, Washington,
7. D.C. Chen, C. H. (2003) “Notes of Meeting at the Telangana State Highway Administration on Integrated Management of Highway Maintenance and Traffic – March 12, 2003.”