Evaluation of A Dynamic Late Merge System for Work Zone Operations

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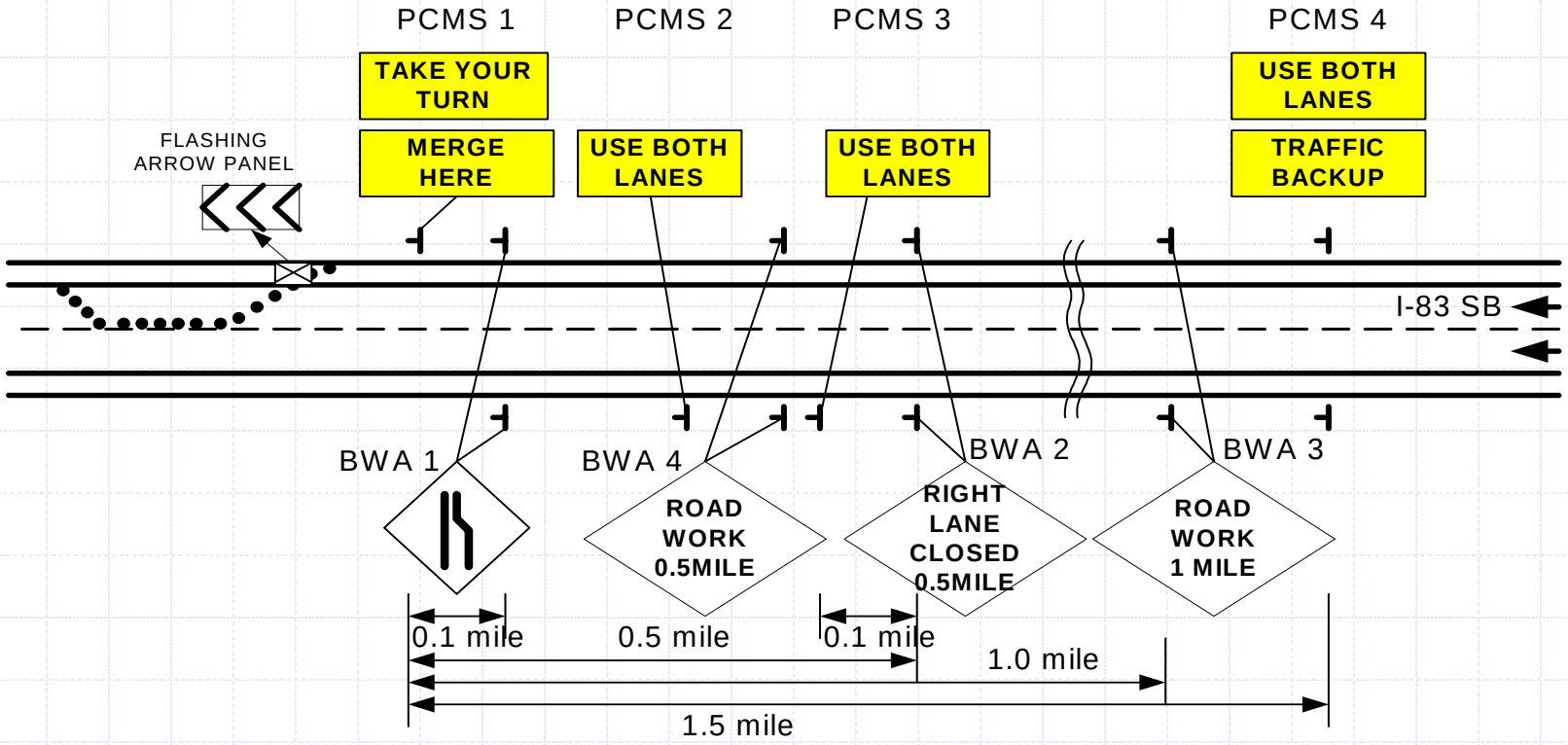
Dynamic Late Merge system overview

- Configuration of the DLM system



Overview of A Dynamic Late Merge System

Operation Algorithms and Control Thresholds

- The DLM System tested by MSHA is supposed to operate with 4 algorithms, based on the occupancy reported by each RTMS in the Late Merge System.
- If all occupancies are below 5%, all PCMS are deactivated.
- If any occupancy among the sensors is over 15%, all PCMSs are activated.

Algorithm	Occupancy	
	Deactivated	Activated
Dynamic On – Dynamic Off (Early lane merge)	5% (Free flow index)	15% (Congestion index)
Dynamic On – Dynamic Off		
All On – All Off		
Dynamic On – All Off		

Design of Data Collection

- Work zone data under conventional control (No-control): 1 day
- Work zone data under DLM control : 4 days

Measures of Effectiveness	Data types	Locations	Methods
Work zone throughput	Volume	Merging point	Camcorder RTMS
Lane volume distribution	Traffic counts	Merging, middle, and upstream point.	Camcorder RTMS
Queue length	Maximum queue length	Merging, middle, and upstream point.	Camcorder
Speed distribution	Speed	Merging and middle point	Speed gun RTMS
Traffic conflicts	Forced merge Lane straddle Lane blocking Stop and go	Merging and middle point.	Camcorder

DLM evaluation

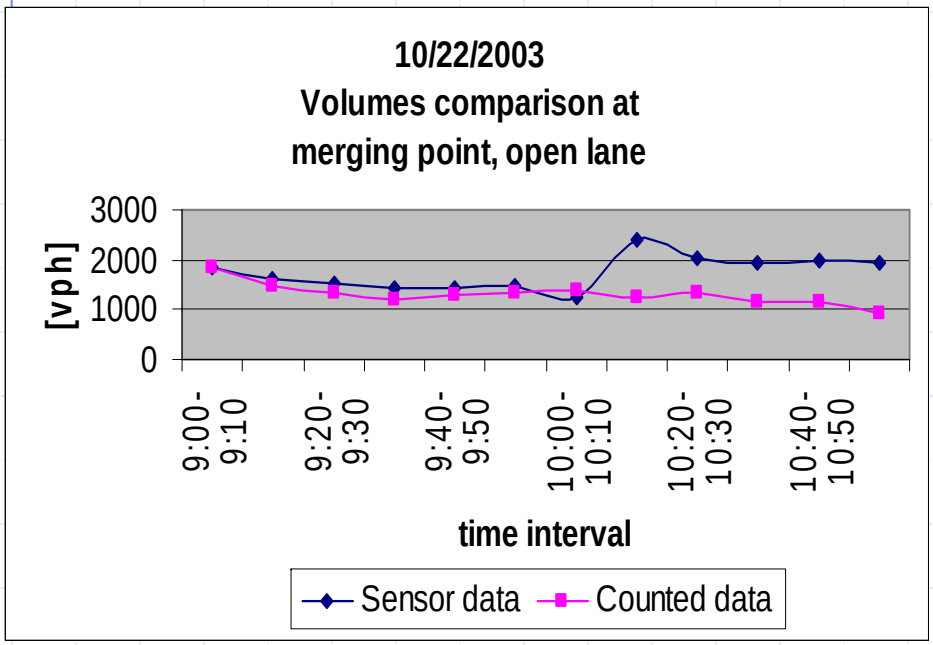
Main contents

- Evaluation of Sensor Accuracy
  - Volume data
  - Speed data
- Evaluation of System Performance
  - Work zone throughputs
  - Lane volume distributions
  - Maximum queue length
- Evaluation of Traffic Safety
  - Traffic conflicts
- Conclusions
- Recommendations

Evaluation of Sensor Accuracy

Volume data

- The difference between manual counted and sensor detected volumes increases as traffic becomes congested.

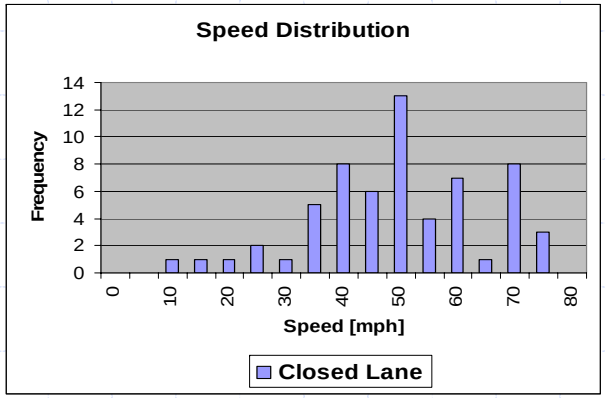


10/22/2003			
Location	**Counted**	**Sensor**	**Difference**
Merging point, open lane	1307	1738	33%
Merging point, closed lane	262	284	8%
Middle point, open lane	856	1941	127%
Middle point, closed lane	673	1251	86%
10/23/2003			
Location	**Counted**	**Sensor**	**Difference**
Merging point, open lane	1330	1454	9%
Merging point, closed lane	348	338	-3%
Middle point, open lane	811	1706	110%
Middle point, closed lane	726	1305	80%

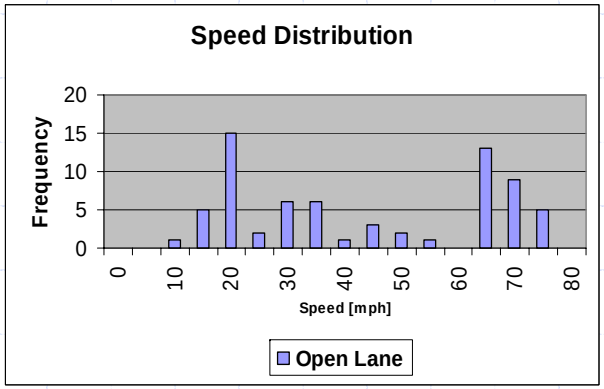
Evaluation of Sensor Accuracy

Speed data

- Based on our recorded speed data and observations at the deployment site, the speeds obtained from the sensors are unreasonably high.



Speed distribution 10/22/2003 at middle point



10/10/2003 - average speed mph		
Location	Field observations	
	open lane	closed lane
Merging point	22	24
Middle point	21	26

10/22/2003 - average speed mph		
Location	Sensor data	
	open lane	closed lane
Middle point	44	57

10/23/2003 - average speed mph		
Location	Sensor data	
	open lane	closed lane
Merging point	36	70
Middle point	48	40

Evaluation of System Performance

Work zone throughputs

- First method: Manual counted data analysis
- The DLM control has yielded a higher throughput than the No-control.

Date	Average throughput	Increased percentage
10/10/2003-no control	**1888**	**Base line**
10/22/2003	**1814**	**-4%**
10/23/2003	**1928**	**12%**
11/07/2003	**1883**	**4%**
11/10/2003	**1987**	**3%**

Evaluation of System Performance

Work zone throughputs (cont.)

- Second method: Simulation data analysis
- Model calibration
  - Key simulation parameters
    - Rubbernecking factor
    - Car-following sensitivity factor
    - Desired free-flow speed
  - Target traffic conditions
    - Work zone throughput
    - Average speed at the merging point

Traffic conditions	Actual data	Simulation results	
		Before calibration	After calibration
Upstream volume	1887 vph	-	-
Heavy truck percent	15%	-	-
Average speed at merging point	17.0 mph	30.6 mph	17.7 mph
Work zone throughput	1536 vph	1845 vph	1531 vph

Evaluation of System Performance

Work zone throughputs (cont.)

- Under DLM control the work zone throughputs are greater than under No-control.

Date	Manual counted Th. (DLM)	Simulation Th. (No-control)	Increased %
10/22/2003	1814	1375	14%
10/23/2003	1928	1476	14%
11/07/2003	1883	1450	9%
11/10/2003	1987	1390	34%

Evaluation of System Performance

Lane volume distributions

- The volume differences become decreased under the DLM control as time passed.
- Differences (volume at the open lane) - (volume at the close lane)

Date	Merging Point		Middle Point		Upstream Point	
	Average difference [pcph]	Standard deviation	Average difference [pcph]	Standard deviation	Average difference [pcph]	Standard deviation
10/10/2003 No control	1297	158	199	168	-26	122
10/22/2003	1207	249	122	200	No data	
10/23/2003	1114	159	17	126	-47	125
11/07/2003	901	208	1	146	-69	136
11/10/2003	932	174	-4	150	-162	143

Evaluation of System Performance

Maximum queue lengths

- Simulation analysis
- The DLM control has resulted in a substantial reduction of the maximum queue length.

Date	Measured queue (DLM)	Simulated queue (NC)	Reduced %
10/22/2003	1.2 miles	1.3 miles	8.3%
10/23/2003	1.2 miles	1.4 miles	16.7%
11/07/2003	1.8 miles	2.0 miles	11.1%
11/10/2003	0.9 miles	1.2 miles	33.3%

Evaluation of Traffic Safety

Traffic conflicts

- The traffic conflicts counted at the merging point show a higher number of stop-and-go patterns under the DLM control than under No-control, in both open and closed lanes.

Date	Merging point				
	Forced Merges	Lane Blocking	Lane Straddle	Stop & Go	
				OL	CL
10/10/2003 No control	**8**	**3**	**2**	**10**	**2**
10/22/2003	9	1	2	21	6
10/23/2003	9	4	3	22	5
11/07/2003	13	6	2	21	10
11/10/2003	8	3	5	18	6

Evaluation of Traffic Safety

Traffic conflicts (cont.)

- The traffic conflicts counted at the middle point show a higher number of forced merges under the No-control than under the DLM control.

Date	Middle point				
	Forced Merges	Lane Blocking	Lane Straddle	Stop & Go	
				OL	CL
10/10/2003 No control	**17**	**7**	**4**	**24**	**7**
10/22/2003	12	4	6	20	6
10/23/2003	7	1	3	23	8
11/07/2003	10	1	5	26	8
11/10/2003	5	1	3	21	3

Conclusions

Evaluation

- **Advantages of a DLM Control**
  - Increases throughput
  - Leads to more uniformed lane volume distribution
  - Reduces maximum queue length

- **Disadvantages of a DLM Control**
  - Number of stop-and-go maneuvers may be increased
  - Experiences multiple merging locations

Conclusions

Recommendations

- Selection of the best threshold for control
- Estimation of the potential maximum queue length
- Inclusion of Speed limit signs
- Combination with Variable Speed Limit controls for smooth merging operations
- The locations and spacing between the PCMS should be in consistence with the perception and reaction time of the drivers
- Separation of the PCMS system from conventional merging signs
- Placements of PCMS at both right and left sides
- Improvement of PCMS resolution
- Improvement of RTMS sensor accuracy