

Adverse Weather Traffic Signal Timing

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I. INTRODUCTION

Rush hour driving is bad enough on an average sunny day, but what happens when it snows? Gridlock is often the result of adverse weather, which creates a complete breakdown of a traffic signal system. Because of snow and icy conditions, slower start-up times, slower speeds and abnormal driver behavior result. The photo below shows road conditions during a typical adverse weather event.



Road Conditions During Adverse Weather

A study is being performed by the consulting firm of Short Elliott Hendrickson, Inc. (SEH) for the Minnesota Department of Transportation (Mn/DOT) to evaluate the feasibility of implementing a traffic signal timing plan for a coordinated signal system that will accommodate traffic in adverse weather conditions. The purpose of the study is to determine what impact bad weather has on the operation of a coordinated traffic signal system and to determine if it would be beneficial to develop a traffic signal timing plan to accommodate the adverse weather conditions.

The corridor being studied is along Trunk Highway 36 between McKnight Road and Hadley Avenue. It is located in the northeast portion of the Minneapolis/St. Paul Twin Cities metropolitan area and is a three-mile section of expressway with a five-signal system

As part of the study, weather data, in addition to the typical traffic data, was collected and evaluated. Weather data was collected both at the site and from a Remote Weather Information System (RWIS) station located approximately 5 miles away. Traffic data was collected both in the field and from the signal system master controller.

This paper documents the process that was taken to determine the effectiveness of an

adverse weather signal timing plan. It includes the data collection that was performed, the analysis of both traffic and weather data, and preliminary conclusions of the study.

II. DATA COLLECTION

A large amount of data was collected for the project. Traffic and weather data were collected during a “normal” P.M. peak period and also during three “adverse weather” P.M. peak periods. For this study, an “adverse weather” event is defined as a snowstorm with three or more inches of snow, resulting in difficult driving conditions. The data that was collected is summarized below:

Traffic Data

The following traffic data was collected either in the field or supplied from Mn/DOT.

- Signal Timing Plans – Mn/DOT supplied the traffic signal controller and timing plan information for the five signals in the corridor. This information was used to set up the Synchro network.
- Geometrics – Mn/DOT supplied the geometric layouts for each intersection. The spacing between the intersections was scaled off a map of the area.
- Turning Movement Counts – Mn/DOT supplied turning movement counts for each intersection. The counts were collected in February 1996 and were used to develop the current timing plans for the signal system.
- Travel Time Runs – Travel time runs were collected using PC Travel software on a portable computer in a data collection vehicle. The setup is shown in the photo below. A travel time run consists of driving the corridor and recording the time it takes to do so. It records the speed at all times along the corridor and the delay encountered at each intersection. Four travel time runs in each direction were gathered per event. Travel time runs were collected on a “normal” day and on three “adverse weather” events. The “normal” day data was used to calibrate the Synchro network. The “adverse weather” data was used to determine what affect the snowfall had on the speed and delay throughout the system.
- Volume and Occupancy – There are 12 system detectors located along the corridor. Eight of the detectors are located on the mainline (four-eastbound and four-westbound), while the remaining are located on the side streets. The detectors are able to collect volume and occupancy data on an hourly basis. Mn/DOT downloaded this information from the master controller for two “normal” days and for the three “adverse weather” events. The volumes collected on a “normal” day were averaged and used to set up the

Synchro network. The “adverse weather” data was used to determine how the volume and occupancy along the corridor is affected by adverse weather. The volumes collected during “adverse” weather will also be used to develop a base in order to optimize coordination timing in adverse weather.

- Start Up Delay – The start up delay was field measured under both “normal” and “adverse” conditions. This was collected on one “normal” day and during three “adverse weather” events. This data was used in the Synchro network.
- Saturation Flow Rate - The saturation flow rate was field measured under both “normal” and “adverse” conditions. This is a parameter used in the Synchro network.



Data Collection Vehicle

Weather Data

Weather data was gathered using two different methods; in the field by SEH personnel and from a Remote Weather Information System (RWIS) station located approximately 5 miles away. The information collected by the two methods will be compared to see how they relate to each other.

In the field

The weather data was collected in the field during one “normal” and three “adverse weather” events. The following data was collected:

- Air Temperature – The air temperature was collected during each event, using a glass thermometer.
- Pavement Temperature – The pavement temperature was collected using a Mn/DOT supplied infrared temperature gun to measure pavement temperature.

- Relative Humidity – The relative humidity was collected using a psychrometer. This data was only collected in the field if the air temperature was above 20 degrees Fahrenheit.
- Roadway Condition - The roadway condition (i.e. icy, plowed, etc) was observed and recorded.

RWIS

An RWIS is a combination of technologies that uses historic and current climatological data in order to develop road and weather information, which aids in roadway related decision making. The RWIS station collects both weather data and roadway condition data. This technology is commonly used to determine when to plow and how much sand and/or salt to use on the roadways. The RWIS station closest to the corridor under study is located approximately 5 miles away. Weather data from the RWIS station was collected on the same days that the volume and occupancy data was collected. Therefore, data was collected for two “normal” days and three “adverse weather” events. The data was downloaded by Mn/DOT personnel and included the following:

- Air Temperature
- Pavement Temperature
- Dew Point
- Relative Humidity
- Road Condition

III. SYSTEM CALIBRATION

The corridor being studied is along Trunk Highway 36 between Mcknight Road and Hadley Avenue. It is located in the northeast portion of the Minneapolis/St. Paul Twin Cities metropolitan area. It is a three-mile section of two-lane divided expressway with a five-signal system. The spacing between the signals range from 1,600 feet to 4,300 feet. The five-signals are coordinated and actuated. The four westerly intersections are interconnected, while the intersection at Hadley Avenue is coordinated by time of day. The major flow of traffic in the A.M. peak is westbound and is eastbound during the P.M. peak. This study evaluated the P.M. peak hour. The photo below shows the corridor as seen driving eastbound during the P.M. peak period.



Driving Eastbound on TH 36

A Synchro network was developed to analyze the corridor. Synchro is a software package that is used for modeling and optimizing traffic signal timings. Coordinated traffic signal timing plans are developed based on several factors including; traffic volumes, directional splits, start up time, saturation flow rate, and speed.

The network for this study was set up using turning movement counts from February 1996 and the existing signal split/cycle/offset information supplied by Mn/DOT. The intersection geometrics and signal spacing, supplied by Mn/DOT were also used to develop the network. Traffic volume and occupancy data was gathered by Mn/DOT from the 12 system detectors along the corridor during a “normal” peak period on January 28 and February 2, 1999. The volumes collected from the system detectors in 1999 were lower than the volumes in the 1996 turning movement counts. The turning movement volumes in the Synchro network were modified to reflect the existing conditions. The travel time runs were used to determine the actual average speed through the corridor and to adjust the offsets in the Synchro network to reflect field conditions.

IV. SYSTEM ANALYSIS

Existing Conditions

Based on the calibrated system, the corridor was simulated under existing “normal” conditions to act as a base. The MOE’s were calculated and are shown in Table 1.

Adverse Conditions (existing timing)

- **Volumes** - Mn/DOT collected the traffic volume and occupancy data from the 12 system detectors during three “adverse weather” events. The volumes collected during the “adverse weather” events were found to be 15% - 20% lower than volumes collected during the same time period (3:00 p.m. – 8:00 p.m.) on a “normal” day. The “adverse” volumes were 15% - 30% lower than “normal” volumes during the P.M. peak hour (5:00 p.m. – 6:00 p.m.). The

volume reduction could be due to a number of things. During bad weather, people tend to leave work early or stay later to avoid a challenging commute. People also tend to just stay home and avoid unnecessary travel during bad weather. Therefore the volumes on the roadways actually are lower than normal. The turning movement volumes were modified in the Synchro network to reflect the adverse conditions.

- **Speed** - The travel time runs were used to determine the actual average speed of traffic through the corridor. It was found that the average measured speed was 40% lower during adverse conditions. The average speed went from 44 m.p.h. during “normal” conditions to 26 m.p.h. during “adverse” conditions. The speeds between the intersections in the Synchro network were modified to reflect the reduced speeds.
- **Start-Up Delay** - The start-up delay time was found to have increased from 2 seconds to 3 seconds during bad weather. The saturation flow rate went from 1800 vehicles per lane per hour (vplph) to 1600 vplph. It was found that the roadway was very well maintained and that traction was not as large of an issue as first thought (along this particular road). It should be noted that other streets in the area were not as well maintained and traction was a large problem. The start-up delay and saturation flow rate was modified in the Synchro III network to reflect the adverse conditions.

Once all the information in the Synchro III model was modified to reflect the “adverse weather” conditions, the system was analyzed to determine what impact bad weather had on the operation of the system. The “adverse” weather MOE’s (using the existing cycle/splits/offsets) can be seen in Table 1.

As can be seen in Table 1, the percentile signal delay per vehicle actually goes down for adverse weather (because there are fewer vehicles in the system), the stops per vehicle stays the same, and the average speed on Trunk Highway 36 goes down. This data shows that the operation of the system is not drastically affected by the bad weather conditions. This is mainly due to the fact that there are fewer vehicles in the system.

Adverse Conditions (optimized)

An optimization run was performed on the Synchro network to determine if a new timing plan could improve upon the “adverse” weather MOE’s. Cycle lengths between 100 – 180 seconds were analyzed. It was found that a cycle length of 125 seconds would improve upon the MOE’s, although the improvements were less than 6 percent.

The MOE’s for the “normal”, “adverse” (existing), and “adverse” (optimized) can be seen in the table below.

**Table 1
Measures of Effectiveness**

SCENARIO	CYCLE LENGTH (SEC)	VOLUME ON TH 36 (VEH/HR)	PERCENTILE SIGNAL DELAY/VEH (SEC.)	STOPS/VEH (AVG)	AVERAGE SPEED* (MPH)
"Good" Weather	160	2513	55	0.72	16
"Adverse" Existing	160	1912	52	0.72	13
"Adverse" Optimized	160	1912	48	0.68	13

* This is the average speed of throughout the network (including side streets).

At the time this paper was being written, it was still being evaluated what magnitude of operational improvements were needed in order to implement a new timing plan.

V. WEATHER INFORMATION

One of the initial goals of the project was to tie the weather data collected by the RWIS system to the traffic signal controllers in order to automatically switch to the "adverse weather" timing plan when the weather is severe. It was thought that the RWIS information could be used to determine the thresholds at which a snowstorm would cause problems to the signal system. These thresholds could be used to determine the ideal time to implement the timing plan in order to prevent gridlock and a breakdown of the system.

Based on the data collected, there does not seem to be a direct correlation between any of the weather data collected and how bad the roads actually are. For example, it can snow at a relatively wide range of temperatures and the relative humidity and the barometric pressure can vary between storms. A storm's magnitude can also vary across a metro area. The timing of the snow plows also have an effect on the roadway condition. Therefore, it appears that the most effective way to initiate this type of timing plan is to manually switch it on.

VI. IMPLEMENTATION

If a new timing plan is developed and implemented, it cannot be tested until next winter. If the upcoming winter is the same as recent ones, it may be challenging to test and fine tune the timing plan once it is in place because of the minimal adverse weather events during recent P.M. peak periods.

VII. CONCLUSION

At the time this paper was being written, it was still being evaluated what magnitude of operational improvements were needed in order to develop and implement a new timing plan for adverse weather conditions.

Once the final analysis is complete, the final report for this study will be posted on the Mn/DOT website at www.dot.state.mn.us

Some lessons learned along the way are:

- Based on the Synchro III networks, it appeared that the corridor operation was not radically affected by the adverse weather. Even though the speeds decreased, the delay per vehicle did not increase significantly. This is mainly due to the fact that there are fewer vehicles to cause delay to during bad weather. The existing band widths are also large enough to allow for lower speeds.
- Each corridor has different characteristics. The volumes, directionality, signal spacing and road maintenance (i.e. snow plowing) all affect the operation of the signal system. This particular corridor has a highly directional peak, the signals are spaced 2,500 feet apart and it was very well maintained during the snowstorms.
- The weather in Minnesota is very unpredictable, and the winters are usually notorious for snow. During the winter of 1998/99, it snowed a significant amount only four times during the P.M. peak. This was good for the motoring public, but bad for our data collection.

VIII. AUTHOR'S INFORMATION

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