MEMORANDUM

To: Allan Covlin, Traffic Operations Engineer, NDDOT
Bob Walton, District Engineer, NDDOT-Fargo
Rick Lane, Transportation Engineer, City of Fargo
Chris Brungardt, Engineering Assistant, City of West Fargo

From: Shawn Birst, Transportation Research Engineer, UGPTI-ATAC

Date: April 15, 2001

Re: **45th St. & 13th Ave. S. Operational Analysis**

BACKGROUND

The Advanced Traffic Analysis Center (ATAC) conducted an operational analysis of 45th St. SW (12th Ave. N. - I-94 South Ramp) and 13th Ave. S. (9th St. E. - 43 ½ St. SW) for the City of Fargo, City of West Fargo, and the North Dakota Department of Transportation (NDDOT) – note Figure 1. The study's main objectives were to enhance the current signal plans based on various traffic conditions and determine the potential benefits of the proposed plans using signal timing software and traffic simulation.

For the next few years 45th St. will serve as the designated detour route for I-29 reconstruction. Therefore, signal coordination along this corridor would provide significant reductions in delay time and number of stops. The geometric data, traffic signal information, and turning movement counts were collected and analyzed using SYNCHRO 4.0 and CORSIM. Turning movement counts were performed during the summer of 2000 at the three peak periods: AM peak (7:00 AM - 9:00 AM), mid-day peak (11:00 AM - 1:00 PM), and PM peak (4:00 PM - 6:00 PM).

Originally the study analyzed 14 signalized intersections, however, the City of West Fargo requested that 17th St. E. and Sheyenne St. be included in the signal analysis since they recently received approval for signalization. Signal plans were also developed for these two intersection, however, they were not included in the signal and simulation comparisons since the primary focus of the study was to determine the benefits of signal coordination. The City of Fargo recently added left-turn phases for motorists making left turns from 45th St. SW at 15th Ave. S. and 17th Ave. S. The left-turn phases were accommodated in the proposed signal plans and were used in the simulation analysis.

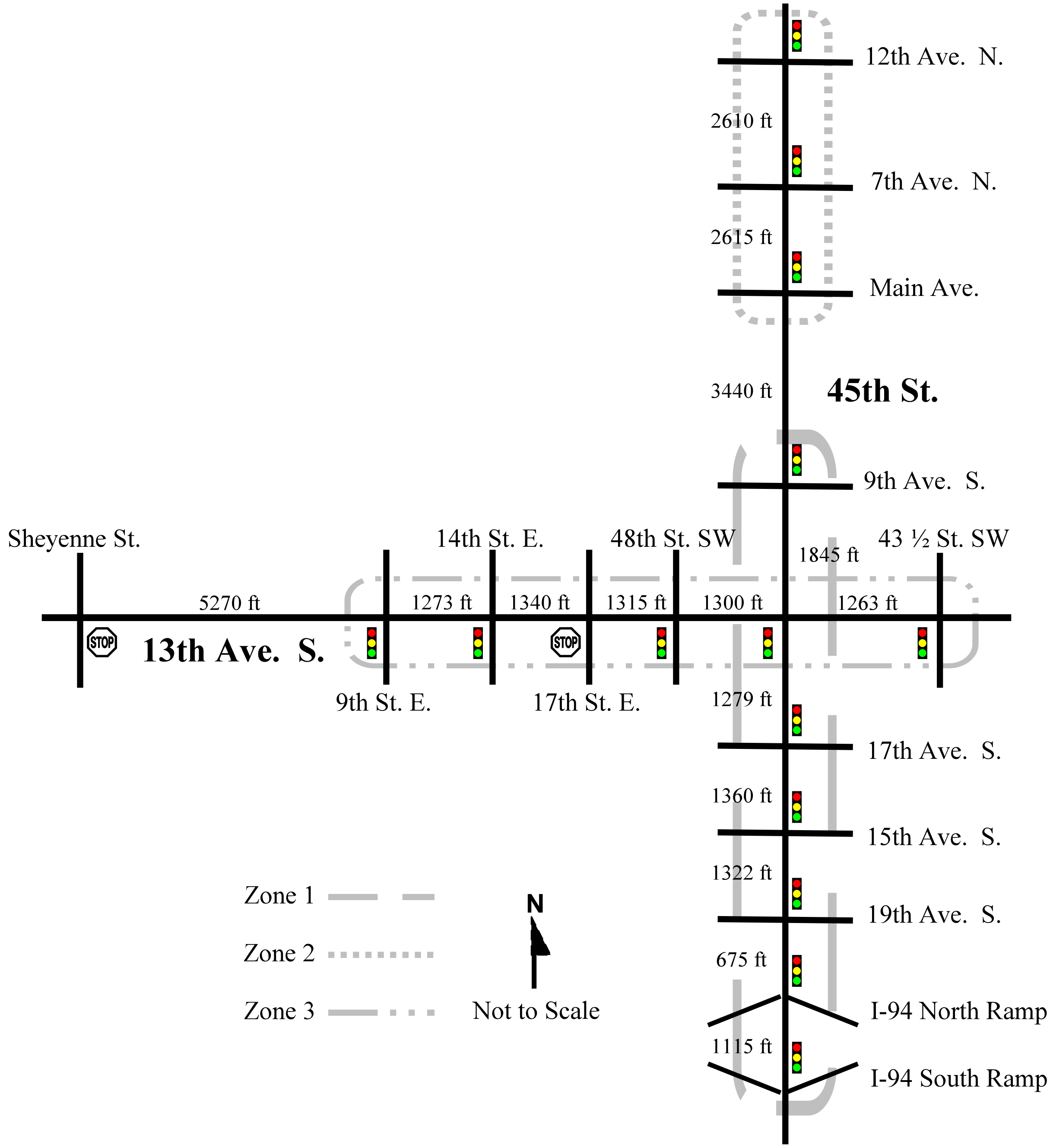

Figure 1. Study Analysis Area Representing Existing Traffic Control and Signal Analysis Zones.

Currently, 2 of the 14 traffic signals operate as actuated-coordinated signals using one time-of-day plan (Appendices A, B, and C). The proposed signal plans would provide coordination for 15 signals (including 17th St. E.) during the AM, mid-day, and PM peak periods. The new signal at Sheyenne St. would operate as an actuated-uncoordinated signal since it is an isolated intersection.

TRAFFIC SIGNAL ANALYSIS

The City of Fargo and the NDDOT stated that the signals between 13th Ave. S. and the I-94 South Ramp would be the critical signals for coordination. The remaining signal plans would be designed around these six intersections and where appropriate, some intersections may operate as actuated-uncoordinated.

The signal analyses were performed by creating three zones (shown in Figure 1). The first zone consisted of the signals between 13th Ave. S. and the I-94 South Ramp. After the cycle length, splits, and offsets were optimized, 9th Ave. S. was added to Zone 1. The signal properties from the original signals of Zone 1 were "locked" or held constant while the splits and offset of 9th Ave. S. were enhanced. Zone 2 consisted of the three signals between 12th Ave. N and Main Ave. The signal properties were evaluated for these three signals while signal plans of Zone 1 remained locked. Zone 3 included the signalized intersections of 13th Ave. S., except for the intersection at 45th St., since it was a part of Zone 1. Zones 2 and 3 were analyzed independently of Zone 1 to determine if a different cycle length would benefit the zone or whether one or more signals should operate as actuated-uncoordinated within the respective zone. The results of the analysis showed that each zone displayed more improvements when it incorporated the same cycle length as Zone 1.

The study designed signal timing plans that would primarily benefit the north/south traffic flow along 45th St., in addition to coordinating the east/west traffic flow of 13th Ave. S. To create and maintain signal coordination for all of the signalized intersections, the cycle length required a minimum of 98 seconds. This cycle length was needed based on vehicle and pedestrian clearance intervals at 13th Ave. S. (note: Main Ave. required 94 seconds). The cycle lengths of these signals could be less if the pedestrian clearances were not considered, however, the signal would be released from coordination when it received a pedestrian call and would remain out of coordination for a minimum of three to five cycles. It is important to point out that longer cycle lengths required by the major intersections did not create excessive delay for the other intersections within the study area.

SIGNAL ANALYSIS RESULTS

The signal analysis provided the most beneficial cycle length for each peak-hour period based on delay time, number of stops, and queue length. After evaluating the three peak periods, a 100-second cycle length provided the best system benefits for the AM and mid-day peak periods (note Appendix D & E), while a 105-second cycle length was best suited for the PM peak period (Appendix F).

The major goals of a coordinated signal system is to provide progression from one signal to the next, thus decreasing the number of stops and delay time along the corridor. SYNCHRO calculates the number of stops by determining the queue time based on the arrival and departure rates. It should be noted that SYNCHRO's stop calculations are based on the TRANSYT-7F model. A full stop is considered to be a delay of 10 seconds, while partial stops are given for delays less than 10 seconds. The number of stop for the AM, mid-day, and PM plans were reduced15.6, 13.6, and 8.3 percent, respectively (note Table 1).

The primary goal of signal performance improvements to reduce delay time. SYNCHRO incorporates a Percentile Delay Method, in addition to Webster's Delay Model. Percentile delay is calculated by taking the volume weighted average of the delay experienced for five percentile flow scenarios. The percentile flow scenarios account for variations in traffic levels and include the 90^{th}, 70^{th}, 50^{th}, 30^{th}, and 10^{th} percentile scenarios. If 100 cycles were observed, the 90^{th} percentile cycle would be the 90^{th} busiest cycle. Each of the five percentile scenarios represent 20% of the cycles actually occurring. On the other hand, Webster's Delay Model calculates delay using one set of green times (which correlates with SYNCHRO's 50^{th} percentile flow scenario), therefore, the delay values between the two methods may slightly differ. The Percentile delay reductions for the AM, mid-day, and PM plans were 21.2, 17.4, and 14.3 percent, respectively (note Table 1).

Table 1. Signal Delay and Stop Comparisons based on SYNCHRO.

	Network Total Number of Stops		Network Total Percentile Signal Delay (hr)	
Time Period	Existing	Proposed	Existing	Proposed
AM	14895	12575	99	78
	-15.6%		**-21.2%**	
Mid-day	20115	17370	121	100
	-13.6%		**-17.4%**	
PM	25361	23262	210	180
	-8.3%		**-14.3%**	

SIMULATION ANALYSIS

In addition to performing a signal timing analysis, a traffic simulation analysis was conducted to compare the operational characteristics between the existing signal plans and the proposed plans. Traffic simulation provides a higher level of detail compared to signal analysis programs since simulation models are able to analyze individual vehicle interactions. The analysis used the CORSIM model, a microscopic stochastic simulation model that was developed by the Federal Highway Administration. CORSIM provides numerical and visual output to assess the operational conditions of a transportation network, such as queue lengths and delay time.

Six simulation scenarios (two for each time period) were analyzed to determine how the proposed coordination plans operate compared to the existing signal plans. To evaluate the operational benefits of coordination, the delay time for both arterials was extracted from the CORSIM output. CORSIM calculates delay whenever a vehicle is traveling less than the desired free-flow speed. Thus, the time that a vehicle accelerates, decelerates, and stops because of traffic control or congestion would be included in the delay time.

Link delay time was aggregated for the major street links along 45th St. and 13th Ave. S. Each simulation scenario was simulated 30 times to represent a normal distribution and had a duration of one hour. It also should be noted that the simulations were "seeded" with traffic before numerical and visual output were gathered.

The simulation results showed that the proposed coordination plans provided significant delay time reductions for both arterials (Table 2). Delay time reduction for the AM, mid-day, and PM peak periods along 45th St. SW were 14.2, 13.7, and 16.2 percent, while 13th Ave. S. were 25.0, 26.6, and 24.0 percent, respectively.

Table 2. Delay Comparisons for the Proposed Signal Plans Based on CORSIM.

	45th St. SW Delay Time (veh-min)		13th Ave. S. Delay Time (veh-min)	
Time Period	Existing	Proposed	Existing	Proposed
AM	6131	5261	1131	848
	-14.2%		**-25.0%**	
Mid-day	5080	4382	2997	2200
	-13.7%		**-26.6%**	
PM	8041	6738	3094	2352
	-16.2%		**-24.0%**	

Note: All values are statistically significant at a 95% confidence interval.

CONCLUSIONS

This study developed signal plans for the AM, mid-day, and PM peak periods for16 signals along 45th St. SW. and 13th Ave. S. Since the primary focus of the study was to evaluate the benefits of signal coordination, 14 of the 16 signals were included in Tables 1 and 2. However, signal plans were developed for Sheyenne St. and 17th St. E. and are shown in Appendices D, E, and F. The study analyzed three measures of effectiveness (MOEs): network signal delay, stops, and arterial delay time. The benefits of signal coordination included the following:

- Network signal delay reductions ranged from 14.3 - 21.2 percent,
- Number of stops were reduced by 8.3 - 15.6 percent,
- Delay time reductions along 45th St. range from 14.2 - 16.2 percent, and
- Delay time reductions along 13th Ave. S. range from 24.0 - 26.6 percent.

Based on these numerical comparisons, field implementation of the three coordination plans should provide similar benefits to 45th St. and 13th Ave. S. The traffic analysis for this study used traffic counts from the 2000 I-29 construction activities. Last summer, 45th St. was not identified as a detour route (although motorists used 25th St and 45th St. as the congestion on I-29 increased). Therefore, additional benefits of coordination could occur with increases in north/south traffic that use the detour route.

Appendix A: Existing AM Plans

Appendix B: Existing Mid-day Plans

Appendix C: Existing PM Plans

Appendix D: Proposed AM Plans (100-Second Cycle)

Appendix E: Proposed Mid-day Plans (100-Second Cycle)

Appendix F: Proposed PM Plans (105-Second Cycle)