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Operational Analysis of the 13th Ave. Corridor in West Fargo

Final Report

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BACKGROUND

The 13th Ave. S. corridor in the City of West Fargo and the City of Fargo continues to be developed at a rapid rate. In addition, many new dwelling units, including single family dwellings and apartment complexes are being constructed near and adjacent to this corridor. Several businesses, service industries, have been constructed along 13th Ave. S. in recent months. Three businesses are currently being constructed along 13th Ave. S. in West Fargo, which will provide greater traffic volumes for this corridor.

The focus of this study is to evaluate the traffic impacts on 13th Ave. S. and the side streets between 14th St. E. (West Fargo) through 48h St. SW. (Fargo) with various traffic levels and traffic control. The study area is approximately one-half mile in length and contains the three businesses mentioned above (Figure 1).

Traffic Control

The study area includes five intersections: two signalized intersections (14th St. E. and 48th St. SW) and three unsignalized intersections (16th St. E., 17th St. E., and 48th St. SW.). The signalized intersections operate as actuated-uncoordinated signals, while the unsignalized intersections consist of two-way stop controls (TWSC).

Traffic Volumes

Traffic volumes along the 13th Ave. S. corridor increase from west to east. Based on 1996 traffic counts, the average daily traffic (ADT) on 13th Ave. S. ranged from 4,550 to 20,000 vehicles (Sheyenne St. to 45th St. SW.).[1] It should be noted that 13th Ave. S. (west of 14th St. E.) experienced ADT of 21,369 in December 2000. Due to mainly retail and residential development in the area, the corridor does not have a significant heavy vehicle percentage, less than 2 percent.

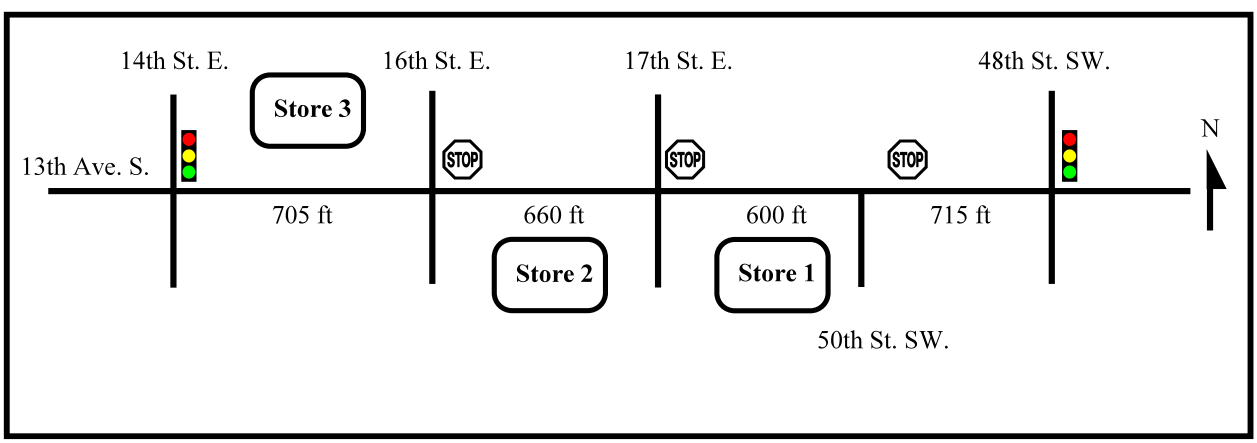

Figure 1. Illustration of Study Area.

OBJECTIVES

The purpose of this study is to showcase the use of microscopic traffic simulation for assisting in the signal warrant analysis process. The City of West Fargo wishes to analyze the effects of additional traffic created by the new retail businesses. The City's main concern is with the potential impacts at the side streets (primarily 17th St. E.) as patrons depart from the new businesses within the study area. The analysis will evaluate various traffic levels for the side street approaches at 16th St. E., 17th St. E., and 50th St. SW. under the existing and alternative traffic control.

Safety issues may arise at unsignalized intersections due to unacceptable gaps needed for side-street turning movements. As side-street traffic increases and the gap time between main-street traffic decreases, crash potential also increases, especially right-angle crashes. Increased delay time will also be observed for side-street traffic due to the situation described above. In this instance, a traffic signal would provide effective intersection control.

It is equally important to study the negative aspects of implementing an unwarranted signal installation. The Manual of Uniform Traffic Control Devices (MUTCD) 2000 provides eight warrants to determine if a traffic signal installation is justified. The warrants are primarily based on existing numerical data of the system. However, future traffic conditions can be analyzed using trip generation values. Therefore, this study will examine signal warrants based on the MUTCD 2000 and the delay time for 17th St. E., 13th Ave. S., and the overall network using traffic simulation. Both analyses will incorporate a range of side-street traffic volumes under unsignalized and signalized control at 17th St. E.

DATA COLLECTION

An extensive amount of data were collected to perform the operational analysis, including geometric data, traffic control data, and traffic demands. Geometric data and the existing signal timing plans were provided by Moore Engineering, Inc. and the City of Fargo. The Fargo-Moorhead Council of Governments provided trip generations for the three businesses.

Turning movement counts were conducted in May and June 2000 during the morning and afternoon peak periods at 14th St. E., 17th St. E. (north approach), and 48th St. SW. Since construction of three businesses is not yet complete and the south approach of 17th St. E. was just recently constructed, limited traffic data is available. Since 17th St. E. is the focus of the analysis, the traffic volumes for the side-street approaches used a percentage of the trip generation values for the businesses in addition to potential traffic volumes from the residential areas. The traffic volumes for 16th St. E. and 50th St. SW. only accounted for a percentage of the trip generation values based on the Institute of Transportation Engineer's (ITE) *Trip Generation* publication.

To illustrate how the traffic was assigned to and from the businesses, a description of the trip generation and traffic assignment will be described for Store 1. Based on trip generation values, the store will produce an average of 5700 trips per day. Therefore, half of the trips travel to the store while the other half leave the store. To simulate peak-hour conditions, a percentage of the daily trips are used, typically ranging from 8 - 12%. Ten percent of the ADT were used, therefore, 285 vehicles traverse to the store and 285 depart the store.

Assumptions also had to be made about the trips entering the network and traveling to each of the businesses. It was assumed that 60% of the trips destinating at the three business originate from Fargo, while the remaining 40% originate from West Fargo. Two side streets provide access to each business in the study area. It was assumed that 80% of the vehicles would use the first side street that they encountered while driving to the store, having the remaining 20% use the second side street. Based on the 285 trips traveling to Store 1, 170 of these trips originate from the eastern boundary of 13th Ave. S. and 114 originate from the western boundary of 13th Ave. Of the 170 vehicles entering from the east, 136 use 50th St. and 33 use 17th St. E. To simulate the traffic leaving Store 1, the 170 vehicles proceed back to east in the same manner: 136 leave from 50th St. and 33 leave from 17th St. E. This practice was used for the trips entering from the west and for the remaining two businesses.

ANALYSIS SCENARIOS

The analysis evaluated two categories of scenarios: existing traffic control and alternative traffic control. The existing signal plans at 14th St. E. and 48th St. SW. were updated using Synchro 4.0 to provide coordination through the corridor. The alternative traffic control scenarios implemented a signal at 17th St. E. and was coordinated with 14th St. E. and 48th St. SW. Percentages of trip generation volumes for the three businesses were evaluated to simulate peak-hour traffic, consisting of 5%, 7.5%, and 10%, respectively. To account for the total side-street volume on 17th St. E., additional volume increases of 50, 100, and 200 were also used in addition to the 10% trip generation values. To simulate the 8-highest hours of traffic, the peak-hour traffic was multiplied by 62.5%. It should be noted that there were no reductions of right turns at 17th St. E. since the approach geometry consists of an exclusive left-turn lane with a shared through and right-turn lane. The range of scenarios will provide guidance to determine what traffic levels at 17th St. E. make a traffic signal justified. The scenarios evaluated are list below:

<u>Existing Traffic Control</u>
Scenario 1: Existing volumes + 5% of trip generation volumes
Scenario 2: Existing volumes + 7.5% of trip generation volumes
Scenario 3: Existing volumes + 10% of trip generation volumes
Scenario 4: Existing volumes + 10% of trip generation volumes + 50 vehicles to 17th St. E.
Scenario 5: Existing volumes + 10% of trip generation volumes + 100 vehicles to 17th St. E.
Scenario 6: Existing volumes + 10% of trip generation volumes + 200 vehicles to 17th St. E.

<u>Alternative Traffic Control</u>
Scenario 1: Existing volumes + 5% of trip generation volumes
Scenario 2: Existing volumes + 7.5% of trip generation volumes
Scenario 3: Existing volumes + 10% of trip generation volumes

Scenario 4: Existing volumes + 10% of trip generation volumes + 50 vehicles to 17th St. E.
Scenario 5: Existing volumes + 10% of trip generation volumes + 100 vehicles to 17th St. E.
Scenario 6: Existing volumes + 10% of trip generation volumes + 200 vehicles to 17th St. E.
Note: Half of the added vehicles were added to both the north and south approaches of 17th St. E.

OPERATIONAL ANALYSIS

The operational analysis consists of performing a warrant analysis and simulation analysis for the corridor. The MUTCD provides guidance to transportation engineers in the signal warranting process. Traffic signals should only be installed at unsignalized intersection when the signal would improve safety, operation, or both.[2] Traffic simulation models provide Measures of Effectiveness (MOE), such as delay time and queue length, that further enhance the signal warrant analysis.

The operational analysis analyzed two of the eight warrants according to the MUTCD: Warrant 1, Eight-Hour Vehicular Volume, and Warrant 3, Peak Hour. These warrants were selected due to the data available, including ADT, peak-hour volumes, trip generation values, and road geometry.

Eight-Hour Vehicular Volume - Warrant Analysis

Warrant 1 evaluates the need for a traffic signal based on 8-hour vehicular volumes and consists of two conditions. The Minimum Vehicular Volume, Condition A, is intended for intersections experiencing large traffic volumes and is the main reason for considering signal installation. The Interruption of Continuous Traffic, Condition B, is intended for use where traffic on the major street is so heavy that the minor street traffic experiences excessive delay or conflict in entering or crossing the major street. According to Section 4C.02 of the MUTCD, Warrant 1 consists of two standards and include the following:[3]

> Standard:
>
> The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:
>
> A. The vehicles per hour given in both of the 100% columns of Condition A in Table 4C-1 exist on the major street and on the higher volume minor-street approaches, respectively, to the intersection, or
>
> B. The vehicles per hour given in both of the 100% columns of Condition B in Table 4C-1 exist on the major street and on the higher volume minor-street approaches, respectively, to the intersection.
>
> In applying each condition the major street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:

A. The vehicles per hour given in both of the 80% columns of Condition A in Table 4C-1 exist on the major street and on the higher volume minor-street approaches, respectively, to the intersection, and

B. The vehicles per hour given in both of the 80% columns of Condition B in Table 4C-1 exist on the major street and on the higher volume minor-street approaches, respectively, to the intersection.

These major street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street the higher volume shall not be required to be on the same approach during each of the 8 hours.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume.

Condition A - Minimum Vehicular Volume							
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)			Vehicles per hour on higher-volume minor-street approach (One direction only)		
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
1................	1................	500	400	350	150	120	105
2 or more...	2 or more...	600	480	420	150	120	105
2 or more...	2 or more...	600	480	420	200	160	140
1................	1................	500	400	350	200	160	140

Condition B - Interruption of Continuous Traffic							
Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)			Vehicles per hour on higher-volume minor-street approach (One direction only)		
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
1................	1................	750	600	525	75	60	53
2 or more...	2 or more...	900	720	630	75	60	53
2 or more...	2 or more...	900	720	630	100	80	70
1................	1................	750	600	525	100	80	70

[a] Basic minium hourly volume.
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures.
[c] May be used when the major street speed exceeds 70 km/h (40 mph) or in an isolated community with a population of less than 10,000.

The geometry of the 17th St. E. & 13th Ave. S. intersection corresponds to the "2 or more..." category for both the major-street and the minor-street approaches. To determine the 8-highest hour vehicular volume, assumptions were made based on the existing ADT and peak-hour volume. According to the Institute of Transportation Engineer's *Manual of Traffic Signal Design*, a reasonable assumption of the 8 highest hour traffic is 6.25% of the ADT.[2] In addition, a reasonable estimation of the peak-hour demand is 10% of the ADT. Therefore, for the approaches that only had peak-hour data, the 8 highest hour traffic was estimated to be 62.5% of the peak hour traffic. Based on these assumptions, Tables 1 and 2 illustrate the 8 highest hour traffic for the intersection of 13th Ave. and 17th St. E.

Table 1. 8 Highest Hour Traffic for 13th Ave. & 17th St. E. (10% of the Peak Hour Volume).

	2000 ADT (1)	Directional ADT (1) x ½ = (2)	Directional Peak Hour Volume (2) x 10% = (3)	8 Highest Hour Traffic (Directional) (2) x 6.25% = (4)
13th Ave. S.	21369	10685	1068	668
17th St. E. (N. Approach)	2135	1068	107	67
17th St. E. (S. Approach)*	2660	1340	133	83

* Based on business trip generations and does not account for additional residential traffic.

Table 2. 8 Highest Hour Traffic for 13th Ave. & 17th St. E. for all of the Scenarios.

	Directional Peak Hour Volume Directional ADT x 10% = (1)	8 Highest Hours Traffic (Directional) [(1) / 10%] x 6.25%
13th Ave. S.	1068	668 (1336 both directions)
17th St. E. (South Approach)	--	--
Scenario 1	67	42
Scenario 2	100	63
Scenario 3	133	83
Scenario 4	158	99
Scenario 5*	183	114
Scenario 6*	233	146

*Meet Warrant 1 requirement.

According to the Warrant 1, Scenarios 5 and 6 clearly meet the warrant based on the Interruption of Continuous Traffic, Condition B. Scenario 4 is very close to satisfying the warrant, only needing one additional vehicle on 17th St. E. for the 8-hour volume. It is important to point out that the requirement for Condition B is 900 vehicles per hour on the major-street approaches and 100 vehicles for the higher-volume-minor-street approach. The calculated 8-hour traffic for 13th Ave. S. is approximately 49% higher than the required amount for the major-street volume. Therefore, minor-street traffic of Scenarios 3 and 4 may also experience excessive delay even though they are below the 100 vehicle benchmark.

Eight-Hour Vehicular Volume - Simulation Analysis

The simulation analysis used CORSIM, 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 length delay time.

The input parameters for CORSIM included the intersection's geometry, turning movement counts, and traffic control. Each scenario was simulated 30 times to represent a normal distribution and had a simulation duration of one hour. It also should be noted that the simulations were "seeded" with traffic before numerical were accumulated.

The 8 highest hour volume was simulated for a 1- hour period. The traffic volumes used for the simulation runs were the same as those used for Warrant 1 (note Table 2). The six scenarios of the Existing Traffic Control category used current traffic control along with signal optimization at 14th St. E. and 48th St. SW. The optimization incorporated a 90-second cycle length that provided coordination between the two signals. The six scenarios of the Alternative Traffic Control category implemented a traffic signal at 17th St. E. To limit the variability between the two categories, a 90-second cycle length was also used at 14th St. E. and 48th St. SW, while 17th St. E. operated at a 45-second cycle length.

The numerical output extracted from CORSIM pertained to delay time. It is important to evaluate the impacts of the different traffic control on the side street in question, the major street, and the overall network. Therefore, the delay time was calculated for the north and south approaches of 17th St. E., 13th Ave. S. (all east-west traffic), and the overall network. The results of the simulation analysis are shown in Table 3.

Table 3. Simulation Results for Warrant 1 - Eight-Hour Vehicular Volume.

	Network Delay (Seconds/Vehicle)		13th Ave. S. Delay (Vehicle-Min.)		17th St. E. South Approach Delay (Sec./Vehicle)		17th St. E. North Approach Delay (Sec./Vehicle)	
Scenario	Existing	Alternate	Existing	Alternate	Existing	Alternate	Existing	Alternate
1	22.3	23.9	487.9	570.6	15.9	13.8	11.1	10.3
	7.2%		**17.0%**		**-13.2%**		**-7.2%***	
2	22.8	24.0	556.9	618.4	17.0	13.6	12.5	11.9
	5.3%		**11.0%**		**-20.0%**		**-4.8%***	
3	23.2	25.2	620.1	736.9	20.1	13.9	14.5	12.3
	8.6%		**18.8%**		**-30.8%**		**-15.2%**	
4	23.2	24.7	618.2	719.6	20.8	14.4	14.8	12.7
	6.5%		**16.4%**		**-30.8%**		**-14.2%**	
5	23.2	25.1	624.0	724.1	21.3	14.9	15.2	14.2
	8.2%		**16.0%**		**-30.0%**		**-6.6%**	
6	23.4	24.9	630.7	723.9	23.6	13.1	16.4	12.8
	6.4%		**14.8%**		**-44.5%**		**-22.0%**	

* values are statistically insignificant based on a 95% confidence interval.

The south approach of 17th St. E. is the critical approach since is has higher traffic projections and left-turning movements (note Figure 2 & 3 for 17th St. E. approach volumes). The volumes for the south approach range from 42 to 145 vehicles per hour with left-turn percentages ranging from 55% to 65%. Signal installation at 17th St. E. provided delay reductions for all of the scenarios, ranging from 13.2% to 44.5% for the south approach.

It is expected that adding additional traffic control along an arterial will have some negative impacts for the arterial's through traffic. 13th Ave. S. incurred additional delay ranging from 11.0% to 18.8%.

The overall network delay time included every vehicle traveling in the case-study corridor. Signal installation increased the delay for the overall network from 5.3% to 8.6%. However, It should be noted that the additional signal at 17th St. E. creates a delay time reduction of up to 10.5 seconds/vehicle for the south approach of 17th St. E. while increasing the network delay by up to 2.0 seconds/vehicle.

Peak Hour Volume - Warrant Analysis
According to the MUTCD 2000, the Peak Hour warrant is intended for use when "traffic conditions are such that for a minimum of one hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street".[3] As stated in Section 4C.04 of the MUTCD, the standard and criteria are as follows:[3]

Standard:

This signal warrant shall be applied only in unusual cases. Such cases include, but are not limited to, office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:

A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:

1. The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach; or 5 vehicle-hours for a two-lane approach, and

2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes, and

3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

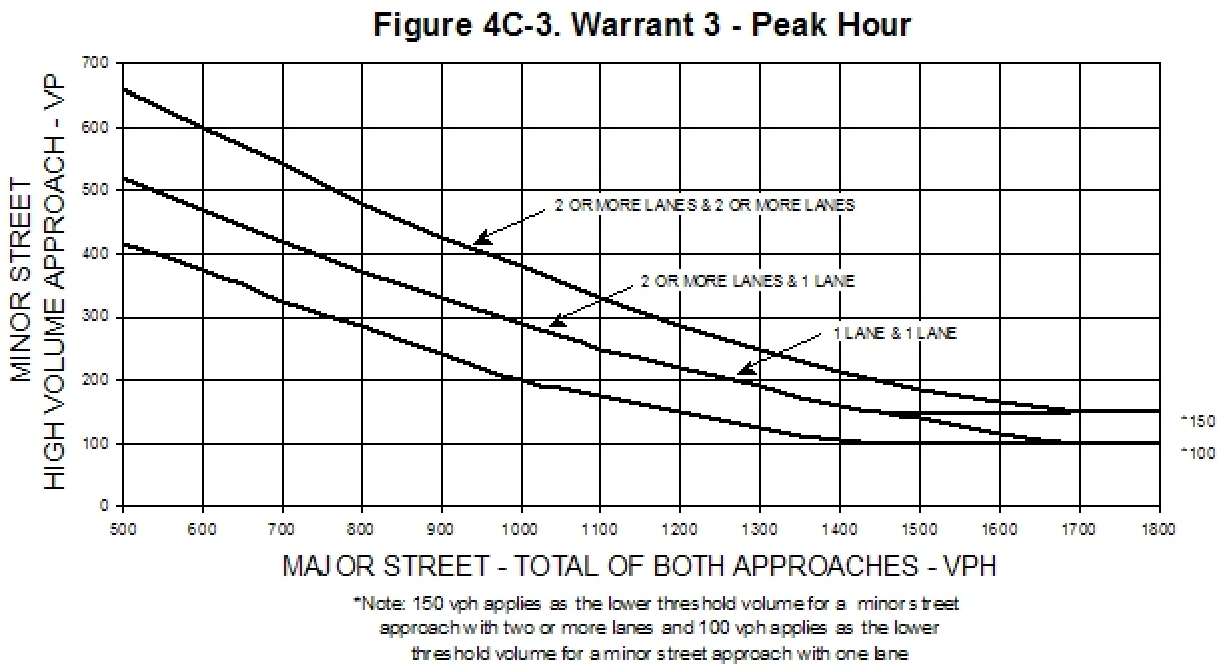

Table 4. Warrant Analysis Results of Warrant 3 - Peak Hour.

17th St. E. (South Approach)	Scenario 1	Scenario 2	Scenario 3	Scenario 4*	Scenario 5*	Scenario 6*
1) The total stopped delay experienced by the traffic on one minor-roadway approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one lane approach; or 5 vehicle-hours for a two-lane approach.	.7	2.1	5.4	7.8	11.5	19.1
2) The volume on the same minor-roadway approach (one direction only) equals or exceeds 100 vph for one moving lane of traffic on 150 vph for two moving lanes.	67	100	133	158	183	233
3) The total entering volume serviced during the hour equals or exceeds 650 vph for intersections with three approaches or 800 vph for intersections with four or more approaches.	2774	2824	2877	2927	2977	3077
Major Street (13th Ave. S.) - Both Approaches	2738	2771	2804	2854	2904	3004

* Meet Warrant 3 requirements.

It should be noted that the total delay (not the stopped delay) for Warrant 3 was determined by the CORSIM simulation. This was performed since the analysis uses traffic projections for 17th St. E. making it difficult to perform stop-delay field calculations. Based on the warrant analysis, Scenarios 4-6 meet all of the criteria for the Peak Hour warrant. Scenario 3 did not meet the warrant based on the volume of the 17th St. E. approach, which was 17 vehicles less than the required 150 vehicle for the peak-hour period. However, the warrant makes it difficult to assess this scenario since the current volume of the major street (13th Ave. S.) is 2804, which is 65% more than the 1700 volume that requires the 150 vehicles for the minor street.

Peak Hour Volume - Simulation Analysis

Similar to the Eight-Hour Vehicular Volume - Simulation Analysis, CORSIM was used to evaluate the signal implementation at 17th St. E. The scenarios were also simulated 30 times and simulated the peak-hour traffic for duration of one hour.

The six scenarios of the Existing Traffic Control category incorporated optimized signal plans at 14th St. E. and 48th St. SW having a 100-second cycle. The Alternative Traffic Control category incorporated a traffic signal at 17th St. E. with a 100 second cycle length. The results of the simulation analysis are shown in Table 5.

Table 5. Results of Simulation Analysis Warrant 3 - Peak Hour.

	Network Delay (Seconds/Vehicle)		13th Ave. S. Delay (Vehicle-Min.)		17th St. NB Delay (Sec./Vehicle)		17th St. SB Delay (Sec./Vehicle)	
Scenario	Existing	Alternate	Existing	Alternate	Existing	Alternate	Existing	Alternate
1	28.5	30.5	1032.1	1161.3	36.7	35.4	21.0	24.2
	7.0%		**12.5%**		**-3.5%***		**15.2%**	
2	31.2	32.3	1189.5	1361.8	75.4	35.9	27.5	25.3
	3.5%		**14.5%**		**-52.4%**		**-8.0%**	
3	36.5	34.2	1363.4	1498.9	147	33.7	24.4	26.4
	-6.3%		**9.9%**		**-77.1%**		**8.2%**	
4	38.7	34.1	1377.9	1516.2	177	31	26.7	24.3
	-11.9%		**10.0%**		**-82.5%**		**-9.0%**	
5	41.8	34.3	1356.1	1533.2	226.5	29.8	49.2	27.2
	-17.9%		**13.1%**		**-86.8%**		**-44.7%**	
6	49.5	34.2	1335.6	1548.9	296.5	29.9	91.9	28.0
	-30.9%		**16.0%**		**-89.9%**		**-69.5%**	

The peak-hour volumes for the south approach range from 67 to 283 vehicles per hour with left-turn percentages ranging from 55% to 65%. The benefits of implementing a signal at 17th St. are realized even with the lowest approach volume of 67 vehicles. Significant delay time occurs at the south approach under unsignalized control ranging from 37 to 297 seconds/vehicle. Even the delay for Scenario 2 was over one minute per vehicle. Compared to signal implementation, delay time reductions at 17th St. E. range from 4 to 90 percent (from approximately 5 minutes to .5 minutes per vehicle).

Signal implementation at 17th St. E. will also effect the delay of vehicles traveling along 13th Ave. S. Based on this analysis, delay time increased from 10% to 16%.
The delay time reductions ranged from -7% to 31% for the overall network. As the side-street volumes for 17th St. E. increase, so do the benefits of having signalized control. This occurs when the delay per vehicle is large for 17th St. E., thereby offsetting the negative impacts the traffic on 13th Ave. S.

SUMMARY

This study analyzed the signal warrant analysis using the MUTCD 2000 and the CORSIM simulation model. The operational analysis focused on Warrant 1, Eight-Hour Vehicular Volume, and Warrant 3, Peak Hour of the MUTCD based on a range of potential traffic volumes. CORSIM provided additional insight into potential delay experienced at 17th St. E., 13th Ave. S., and the overall network. The analysis determined that a signal installation at 17th St. E. meets both Warrant 1 and 3 typically for Scenarios 4-6. According to the simulation results, signal installation is beneficial at 17th St. E. for all of the scenarios while not significantly hindering the efficiency of the overall network.

Traffic simulation enhanced the signal warrant process for several reasons. First, simulation allows the user to determine the delay experienced for the side-street approaches. Excessive delay is the result of inadequate gaps to make a safe turning maneuvers onto or crossing the major street. Second, the affects of different traffic control can be determined for the major street and the overall network. Therefore, the numerical values of the side street, major street, and the overall network can be compared to guide the transportation engineer. Simulation also provides insight to evaluate different signalized operations. For example, the negative aspects of signal installation at 17th St. E. during the Warrant 1 - Simulation Analysis were significantly reduced when a half cycle was used at the intersection. Finally, simulation provides visual animation that is used to observe queue lengths and signal progression.

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