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April 25, 2002

RE: Sioux Falls, South Dakota
Traffic Engineering Analysis Services
Red Light Running Study
SEH No. A-SIOUX0211.00 14.00

Ms. Shannon Ausen, P.E.
Office of Public Works
City of Sioux Falls
224 West Ninth Street
Sioux Falls, SD 57104-6407

Dear Shannon:

Attached is the report on the traffic engineering analysis services for the red light running study that we recently prepared. The report is done in a series of technical memorandums, each with a specific purpose. We have included background information, crash analysis, intersection analysis, and signal timing. There is also information relative to individual intersections analyzed for the before and after study of red light violations. Technical Memorandum No. 10 contains recommendations.

It appears that red light violations are a significant concern in the City of Sioux Falls, as they are in a number of communities. A number of violations in the 90 hours of observation was relatively high. The potential changes through signal timing appears to be relatively good. Further review in a few months may be desirable to determine the long term effects. However, it appears that some adjustment in the signal timing policies for clearance intervals may be beneficial.

It is also apparent that red light violations will continue despite efforts through signal timing, signal head placement, and other engineering considerations. For this, some enforcement activity or public program designed to inhibit motorists' willful running of red lights would be necessary.

We intend to continue to review the data we have collected, as we are quite interested in trying to develop some other correlations between the Sioux Falls data and data that we have from other communities. We will keep you informed of any theories or concepts that come from that data.

We appreciated the opportunity to make the study for the City of Sioux Falls. The time schedule was extremely tight, and we were pleased to have been able to meet both the schedule and the budget. If you have any questions regarding the data or the information collected, please feel free to contact any of us who have been involved in the study.

Sincerely,

Glen Van Wormer

Glen Van Wormer, P.E.
Senior Transportation Engineer

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Attachment

Traffic Engineering Analysis Services
Red Light Running Study

Prepared for:

City of Sioux Falls, South Dakota

Prepared by:

Short Elliott Hendrickson Inc.

Table of Contents

Technical Memorandum No. 1

Background Information

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

The City of Sioux Falls, like many cities, is concerned about motorists running red lights. Most frequently, these are motorists who, upon receiving a yellow clearance interval light at a traffic signal, accelerate or continue to travel through the intersection and actually enter the intersection on a red light. However, frequently this is only the beginning of motorists becoming more and more brazen in their red light running. Motorists will occasionally enter the intersection after the all red clearance period has expired and into the green period for the other intersection approaches.

Red light running crashes account for 16 to 20 percent of the total crashes at urban signalized intersections. Observations of any intersection in major cities have shown a significantly high number of red light violations during any period of the day. The City of Sioux Falls has used its web site for questionnaires and information dissemination. One of the questions that has arisen is the impact of traffic signal timing on red light running.

The City was interested in assessing intersections to monitor the effects of adjusting traffic signal timing to improve the safety at intersections and specifically to try to reduce the number of drivers who are running red lights. The City chose to utilize a consultant to perform the studies and make the analysis.

The City provided a list of 10 intersections that have a known crash history from information from the South Dakota DOT accident database. The database provided information relative to contributing circumstances listing "disregard traffic control device" as a major concern. During the proposal period, SEH reviewed all 10 intersections along with four intersections studied by the City of Sioux Falls in a before-after study of the effects of enforcement on red light running

SEH was selected by the City of Sioux Falls to undertake the traffic engineering study. Based on previous reviews and experience, SEH suggested that the intersection of I-29 and 41st Street be removed from the study because of the difficulty in finding a vantage point that will provide a clear view of red light running. In addition, the interchange is somewhat unique, and it was felt that an urban intersection may be a better choice. The City agreed and the intersection of 49th Street and Louise Avenue was added to take the place of the I-29 and 41st Street intersection.

The City provided SEH with a significant amount of information for each intersection including crash data, aerial photographs, traffic volume information, and traffic signal operation. Much of this information is contained in the following technical memorandums relating to each subject.

As the following technical memorandums will illustrate, SEH reviewed each intersection by making observations for 1½ hour periods in the AM Peak Hour, mid-day, and PM Peak Hour. Traffic signal timing was analyzed and adjustments were made, and a subsequent follow-up observation of the same 10 intersections was made. The collected data was reviewed, compared with the previous initial data, and the 10 intersections were then compared to determine some recommendations. Technical memorandums provide more detailed information on several steps in the study.

Technical Memorandum No. 2

Intersection Crash Analysis

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

As part of the preliminary review of the operating characteristics of the intersections to be studied, accident or crash information was obtained for each intersection. The basis for the information was the South Dakota DOT Accident Database.

An accident summary was printed for each of the intersections for the period January 1, 1999 through December 31, 2001, a full three-year period. The data was printed on approximately March 21, 2002 and should be complete for all 3 years. The accident summary provides information relative to driver contributing circumstances, surface condition, weather, driver alcohol or drugs, and vehicle type. This is generalized and is a summary of the total at each intersection. As an example, it may indicate that there were 21 accidents on dry pavement, seven on wet pavement, and three on snow or slush out of a total of 31 accidents. However, this does not relate the surface condition back to a specific accident in this data sheet.

The data sheet does show a breakdown of the accidents by day of the week, month of the year, and time of day. However, it does not have a direct correlation between these three categories. The summary also shows the dark or light conditions and the severity of the accident. Copies of the summary sheets are available and a sample is attached to this report.

In addition, each intersection has a printed collision diagram from the database. The diagrams show the schematic of the accident type and the directional location. It would indicate whether an accident was a rear-end type on a southbound approach or a right angle type involving an eastbound and northbound vehicle. Each of the diagrams also shows information relative to severity of accident, light or dark conditions, alcohol involvement, and the specific date and accident reference number.

Using this information, it was possible to determine which vehicle movements were involved in what proportion of accidents and look for patterns of light versus dark or time of year. However, any more detailed analysis would require specific accident information and a much more detailed analysis, far beyond the scope and schedule of this study. It is possible, however, to look for potential trends with the opportunity to do further in-depth studies, if needed.

The following paragraphs contain a summary of the intersections for which a crash analysis was completed.

18th Street and Grange Avenue

The intersection had 28 accidents in the three-year time period. The accidents were evenly spread amongst the seven days of the week with a small increase on Thursday. The accidents were also spread throughout the year with the total number of accidents in any month ranging from 0 to 5. Nine accidents occurred in the dark and three involved alcohol. Dry conditions were encountered in 19 of the accidents and only four were in snow, slush or ice.

The time of day analysis showed only three accidents in the AM Peak Period and four accidents in the PM Peak Period. Accidents were spread throughout the day with four accidents occurring between 10:00 p.m. and 6:00 a.m.

The information obtained indicated that "traffic signal" was a contributing circumstance in 14 accidents and "failure to yield" in six. Six were coded to "not stopping on the red" and two involved "over safe speeds."

A significant portion of the accidents involved westbound vehicles. Westbound vehicles collided with northbound vehicles in nine accidents, and with southbound vehicles in seven more. One westbound left turn vehicle had a head-on accident with an eastbound vehicle. Two other accidents involved a rear-end collision for westbound vehicles. Thus, 19 of the 28 accidents involved a westbound vehicle. Eastbound vehicles collided with southbound vehicles on three occasions and one accident involved an eastbound and northbound vehicle. Five of the westbound right angle vehicle accidents occurred at night.

10th Street and Minnesota Avenue

This intersection, with a relatively high traffic volume at all approaches, had 42 accidents in the three-year period. There were 10 accidents on Friday and eight on Sunday but only three on Saturday. There were 21 accidents in the Monday through Thursday period. Accidents occurred relatively evenly throughout the year although the range in any month was from one to nine. However, the heaviest months also had adjacent months with low numbers of accidents and therefore there appeared to be no calendar related trend. Eleven accidents occurred in the dark and two involved alcohol. Dry conditions were encountered in 26 of the accidents and only two in snow or slush.

Only four accidents occurred in the 10:00 p.m. to 6:00 a.m. time frame. The AM Peak Hour had two accidents and the PM Peak Hour had six. There was a high proportion of accidents in the early p.m. with 17 accidents occurring between noon and 4:00 p.m.

The driver contributing circumstances noted in the summary sheet included 13 for "traffic signal," seven for "failure to yield", nine for a "lane change", and nine for "following too close."

Thirteen accidents involved westbound vehicles in a rear-end collision. By contrast, there were three southbound rear-end accidents and one northbound rear-end accident. Westbound vehicles were involved in nine accidents with northbound vehicles and eight with southbound vehicles. Five accidents involved a northbound left turn and a southbound through vehicle. With the exception of the high percentage of westbound rear-end accidents, there appeared to be no pattern of collisions in the intersection.

11th Street and Minnesota Avenue

There were a total of 34 accidents at the intersection in the three-year period. The accidents were very evenly spread amongst the seven days of the week with only Saturday having a slightly higher total. The number of accidents in any month was also relatively even throughout the year. Eleven accidents occurred in the dark and five involved alcohol. Dry conditions were encountered in 21 of the accidents and two in snow or slush.

Time of day analysis shows three accidents in the AM Peak Hour and eight in the PM Peak Hour. The heavier volume of accidents occurred in the afternoon and five accidents in the 10:00 p.m. to 6:00 a.m. time frame.

"Traffic signal" was noted as the contributing circumstance for 11 accidents.

The analysis showed a similar pattern to the 10th Street and Minnesota Avenue analysis. Nine accidents involved eastbound rear-end collisions. Eastbound vehicles collided with four southbound vehicles and seven northbound vehicles. There were four northbound rear-end and three southbound rear-end accidents and four involving a southbound left turning vehicle and a northbound through movement. Thus, there were a heavier number of rear-end accidents on the east/west roadway without any other pattern apparent.

18th Street and Minnesota Avenue

This intersection had 31 accidents in the three-year period. The accidents were almost evenly spread amongst the seven days of the week and had no specific month or timeframe when there was a disproportionate number of accidents. Eight accidents occurred in the dark and three involved alcohol. Dry conditions were encountered in 21 of the accidents with only 3 in snow or slush.

The time of day analysis shows only one accident in the AM Peak Hour and five accidents in the PM Peak Hour. Only two accidents occurred between 10:00 p.m. and 6:00 a.m. Thus, most of the accidents were mid-day, with lower levels of traffic.

Driver contributing circumstances had 12 “traffic signal” and 9 “failure to yield”.

The accident analysis also showed that southbound had the most accidents with five rear-end accidents, seven collisions with eastbound vehicles, two collisions with westbound vehicles, and five collisions with a northbound left turning vehicle. One southbound left turn vehicle collided with a northbound vehicle. Thus, almost two-thirds of the accidents involved southbound traffic.

41st Street and Shirley Avenue

There were 53 accidents at this intersection in the three-year period. The highest number of accidents occurred on a Monday where there were 12. The lowest was on Thursday with four. It is unlikely that the variation is caused by the same traffic change occurring on a Monday, since the same relationship did not occur at other 41st Street intersections. Accidents were evenly spread over the 12 calendar months. Only four accidents occurred during darkness, which is a relatively small proportion compared to other intersections. Four involved alcohol. Dry conditions were encountered in 37 of the accidents with 7 in snow, slush, or ice.

There were five accidents that occurred in the AM Peak Hour and twelve accidents that occurred in the PM Peak Hour. Only one accident occurred between 10:00 p.m. and 6:00 a.m. The highest number of accidents occurred between 4:00 and 5:00 p.m., with two other peaks, of 7 accidents each, occurring between 2:00 and 3:00 p.m. and 6:00 and 7:00 p.m. It is obvious that the accidents are related to the commercial aspects of the intersection.

There were 15 accidents in which “traffic signal” was a driver contributing circumstance and 20 attributed to “failure to yield”.

The accident pattern is very interesting. The northbound traffic is limited to right turn only. However, seven accidents involved a northbound left turning vehicle and an eastbound vehicle. One accident involved an eastbound and northbound vehicle, one involved a northbound left turn and westbound vehicle, and three involved northbound and westbound vehicles. Thus, 12 of the 50 accident involved an illegal northbound maneuver.

Ten accidents involved westbound left turning vehicles, another movement prohibited at the intersection. These all occurred as an accident with an eastbound vehicle. Thus, 44 percent of the accidents in the intersection involved an illegal movement.

Of the remaining accidents, five were eastbound rear-end and five were westbound rear-end accidents. Three involved a southbound and eastbound vehicle. Nine involved a westbound and southbound vehicle.

41st Street and Louise Avenue

This high volume intersection had 66 accidents in the three-year period. Wednesday was the highest accident day with 16 accidents and the low was Saturday with only 6. Accidents were spread throughout the week with those highs and lows. Traffic was also spread evenly throughout the year, although the range was from one to eight accidents per month. There were 14 accidents in December, which seemed to be heavy compared to all of the remaining months and may be a characteristic of Christmas shopping and the associated volumes rather than any weather or light condition. Thirteen accidents occurred in the dark and four involved alcohol. Dry conditions were encountered in 48 accidents with 5 occurring in snow, slush, or frost.

There were only two accidents that occurred in the AM Peak Hour, and nine that occurred in the PM Peak Hour. Twelve accidents occurred between 3:00 and 4:00 p.m., and the rest spread out between 8:00 a.m. and 8:00 p.m. Five accidents occurred between 10:00 p.m. and 6:00 a.m.

The printout sheet indicates that 10 driver contributing circumstances were “traffic signal” and 10 were “failure to yield”. Fourteen were attributed to “lane changes” and 19 to “following too close.”

As expected, most of the accidents involved rear-end collisions. There were 11 northbound rear-end accidents and 6 southbound. On 41st Street, there were 11 westbound and 6 eastbound rear-end accidents. There were also a number of accidents involving sideswiping vehicles on all four approaches, and some of the rear-ends resulted from lane changes.

Of the remaining accidents, four involved a southbound and eastbound vehicle and six involved a westbound and southbound vehicle. There were also a variety of accidents involving right turning and left turning vehicles, left turning and opposing through vehicles, and other similar movements, but there was no specific pattern.

10th Street and Cleveland Avenue

There were 27 accidents in the three-year period at the intersection of 10th Street and Cleveland Avenue. Almost half of the accidents occurred on a Friday when there were 13 accidents recorded. All of the days of the week had between one and three accidents. The 27 accidents were spread throughout the year with a range of one to five accidents in any specific month. Seven of the accidents occurred in the dark and only one involved alcohol. Dry conditions were encountered in 19 of the accidents, with only four occurring in snow, slush, or ice.

Time of day analysis shows that there were no accidents occurring in the AM Peak Hour and four in the PM Peak Hour. Only three accidents occurred between 10:00 p.m. and 6:00 a.m. The majority of the remaining accidents were spread throughout the day and five occurred during the noon hour.

The accident summary had driver contributing circumstances of “traffic signal” for 10 occurrences and “failure to yield” for 5 occurrences.

Right angle accidents were a small proportion of the total accidents. There were seven rear-end accidents spread throughout the intersection. Six accidents involved southbound and eastbound vehicles, while two accidents involved westbound and northbound vehicles. Four other accidents involved an eastbound left turn and a westbound through movement, while five accidents involved a westbound left turn and an eastbound through vehicle. Thus, there was little pattern to the accidents that had occurred.

12th Street and Kiwanis Avenue

There were 59 accidents at this intersection in the three-year period. Accidents were spread throughout the week relatively evenly. They were also spread very evenly throughout the year, with both the highest and lowest monthly accident numbers occurring in the summer. There were 20 accidents occurring in the dark and 6 involved alcohol. Dry conditions were encountered in 33 of the accidents with 13 involved snow, slush, or ice.

Time of day analysis shows only one accident occurring in the AM Peak Hour and eight in the PM Peak Hour. There were 10 accidents occurring between 10:00 p.m. and 6:00 a.m., and the remainder of the accidents were spread very evenly between 9:00 a.m. and 6:00 p.m.

Of the driver contributing circumstances noted in the summary report, 20 were attributed to “failure to yield” and 10 to “traffic signal”. There were only four attributed to “lane change”, which is small considering the lane drop for eastbound traffic. “Following too close” was attributed in 11 accidents. There were two apparent patterns in the accident records. There were nine rear-end accidents in the eastbound direction, and five each for northbound and southbound. There were 24 accidents involving left turning vehicles and an opposing vehicle. Of those, 11 were left turns in the westbound direction, 4 eastbound, 5 northbound, and 4 southbound left turns.

Right angle accidents were relatively low for the intersection. One involved northbound and westbound vehicles and one involved southbound and eastbound vehicles. Six involved eastbound and northbound vehicles, and none involved southbound and westbound vehicles.

41st Street and Elmwood Avenue

This intersection had 37 total accidents in the three-year period. The number of accidents in each of the days of the week was relatively even, although there were only two on Sunday. Accidents were also evenly distributed throughout the month, with the exception of nine in December, five more than the next highest month. Only three accidents occurred in the dark and none involved alcohol. Dry conditions were encountered in 24 of the accidents and none in snow or slush.

Time of day analysis showed only two accidents in the AM Peak Hour, but twelve in the PM Peak Hour. Only one accident occurred between 10:00 p.m. and 6:00 a.m. The remaining accidents were primarily concentrated in the 12:00 p.m. to 4:00 p.m. period. Thus, the accident numbers seem to be oriented towards 12:00 p.m. to 6:00 p.m.

“Traffic signal” was a driver contributing circumstance in nine accidents and “failure to yield” in eleven. Twelve were attributed to “following too close”.

The most predominate movement involved in accidents was the westbound rear-end. Thirteen accidents involved in this collision, which is consistent with the heavy afternoon westbound movements. There were also four eastbound rear-end accidents.

There were a number of right angle accidents evenly distributed. There were five involving westbound and northbound, and four involving eastbound and northbound. There were also three involving southbound and westbound vehicles, and one involving southbound and eastbound vehicles. The remainder were left turn movements. Including rear-end right angle and left turning accidents, westbound vehicles were involved in 26 of the 37 accidents.

49th Street and Louise Avenue

This intersection had 44 accidents in the three-year period. The highest number of accidents was on a Saturday with 11 and the rest were evenly spread throughout the week. Accidents were also evenly spread throughout the months of the year. Fourteen of the accidents occurred in the dark and three involved alcohol. Dry conditions were encountered in 34 of the accidents, with only 2 in snow or ice.

The time of day analysis shows that only one accident occurred in the AM Peak Hour, but eight occurred in the PM Peak Hour. Three occurred between 10:00 p.m. and 6:00 a.m. Most of the remainder of the accidents occurred between 12:00 p.m. and 8:00 p.m.

The accident summary cites driver contributing circumstances as “traffic signal” in eight accidents and “failure to yield” in eighteen.

The fewest type of accidents occurring was right angle accidents with one involving westbound and southbound, one involving westbound and southbound left turn, and one involving westbound and northbound vehicles. There were also five rear-end accidents for eastbound vehicles, and seven for northbound, and five for southbound.

The remainder of the accidents again involved left turning vehicles. Nine involved a northbound left turning vehicle, six a southbound left turning vehicle, two eastbound, and three westbound.

Technical Memorandum No. 3

Intersection Data

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

Prior to beginning any field work, information relative to the intersections was collected and reviewed. Traffic volume counts for the City of Sioux Falls for the time period 1997 through 2001 were obtained, and the 2001 daily traffic volumes were used in the analysis.

Turning movement volumes were also obtained for each intersection, with most of the counts being taken in 1999, 2000, or 2001. The turning movement counts were made from 6:30 a.m. to 6:30 p.m. This provided an opportunity to determine the variation and traffic flow during the day, the directional distribution, and most importantly the amount of traffic traveling in any specific direction for later comparison to volumes of red light violations.

Aerial photos taken in April 2001 were used to help review the intersection characteristics. These aerials show the location of driveways, the lane arrangements, and generally the characteristics of the intersection.

Wherever possible, intersection layouts for the traffic signals and pavement markings were obtained. This, in combination with the aerial photos, provided some opportunities for overview of the approaches to the intersection providing opportunities to develop theories as to potential reasons for red light running. This data was later reviewed in the field and is the subject of another technical memorandum.

18th Street and Grange Avenue

18th Street and Grange Avenue is an intersection of two collector streets in a predominant residential area. In the southwest corner of the intersection is the Sioux Valley Hospital complex. 18th Street is an east-west roadway with continuity from Kiwanis Avenue to the railroad tracks near 7th Street. It serves primarily as a route within the City. Grange Avenue has a similar role with continuity primarily in the middle of the City of Sioux Falls.

Traffic volumes on 18th Street are approximately 9,000 vehicles per day, while volumes on Grange Avenue are approximately 7,000 vehicles per day. During the day, turning movements are relatively heavy. Through traffic ranges from less than 60 percent northbound to just over 70 percent in the eastbound and westbound directions. Left turns range from 10 percent eastbound to approximately 20 percent westbound and northbound. These heavy volumes justify the left turn lanes installed at the intersection. In the PM Peak Hour, traffic volumes are almost equal eastbound and westbound and almost equal northbound and southbound, meaning there is very little directional flow of traffic. Similarly, in the AM Peak Hour, there is a slightly heavier volume westbound than eastbound, probably associated with the hospital.
There is a single lane of approach on Grange Avenue from either direction. There are left turn lanes painted into the intersection. The northbound left turn is a continuation of a two-way left turn lane. On

18th Street, there are also single lanes of approach to the intersection with painted left turn lanes developed. At the intersection, parking is prohibited on the east side of Grange Avenue and on the north side of the east approach on 18th Street. The environment of the neighborhood is primarily commercial or employment oriented. Parking lots are prevalent and exist in the northeast and southwest corner. Access to the parking lots and to other businesses is substantially far away from the intersection so it does not interfere with the movement of traffic.

A traffic signal is one of the few remaining pole mounted signals in the City. Plans are to install overhead signals at the intersection.

10th Street and Minnesota Avenue

The intersection of 10th Street and Minnesota Avenue is at the west side of the downtown district. Minnesota Avenue is a major north-south route and carries a considerable volume of traffic to and from the downtown. 10th Street is half of a one-way street system pair through the downtown area. Daily volumes on Minnesota Avenue are approximately 25,000 vehicles per day with a slight increase between 10th Street and 11th Street. 10th Street, which is one-way westbound through the downtown area, has a volume of 14,400 east and 15,800 vehicles per day west of Minnesota Avenue.

On a daily basis, approximately 22 percent of the westbound traffic on 10th Street turns left to proceed south on Minnesota Avenue. Approximately 13 percent turn right. These volumes are decreased slightly in both the AM and PM Peak Hours. The percentage of turns is heavy enough to justify the separate turn lanes.

Northbound Minnesota Avenue has approximately 20 percent of the traffic turning left. This percent increased to approximately 24 percent in the PM Peak Hour, but is less in the AM Peak Hour.

Southbound Minnesota Avenue has a relatively heavy right turn, averaging 20 percent of the traffic during the daytime hours. That increased to over 23 percent in the PM Peak Hour. Northbound volume in the PM Peak Hour is almost 1,100 vehicles, while southbound has over 1,300 vehicles. There is a substantial difference in the AM Peak Hour with approximately 1,200 northbound and only 600 southbound.

Minnesota Avenue is a five-lane street from the divided roadway near the airport to south of I-229. Two-way left turns with designated left turn lanes at intersections are painted. At 10th Street, there is a designated right turn lane. 10th Street is a one-way eastbound street with three through lanes in the downtown area and west for several blocks. At Minnesota Avenue, there are right and left turns of approximately one-half block in length. Minnesota Avenue and 10th Street has the feel of a downtown area, although there are open parking lots on two corners of the intersection.

Northbound traffic faces five traffic signal heads with the far left mast arm mounted signal a five-section head with a yellow and green arrow. The far left side pole mounted signal is also a five section head with yellow and green arrows. Southbound traffic faces four signal heads including two pole mounts and two overhead mounts. Westbound traffic has a similar situation with two pole mounts and two overhead mounted signal heads on the far side of the intersection.

11th Street and Minnesota Avenue

The intersection of 11th Street and Minnesota Avenue is a virtual mirror image of 10th Street and Minnesota Avenue. Volumes on Minnesota Avenue are 26,300 to the south, and 26,800 to the north.

However, the 11th Street volumes are significantly heavier to the east with 15,500 on the west side of Minnesota Avenue and 19,200 on the east side.

During the day, approximately 16 percent of the northbound traffic turns right and 15 percent of the southbound traffic turns left. Eastbound 11th Street has approximately 20 percent turning right and 20 percent turning left. In the AM Peak Hour, a slightly heavier volume makes a left turn from 11th Street.

The directional distribution of traffic on Minnesota Avenue is essentially the same as at 10th Street.

Geometrically, the intersection is virtually identical to 10th Street and Minnesota Avenue, but a mirror image. There are three through lanes and left and right turn lanes on eastbound 11th Street. Northbound has two through lanes and a right turn lane while southbound has two through lanes and a left turn lane

Traffic signal design is also identical to Minnesota Avenue and 10th Street. Southbound traffic faces five signal heads with the left mast arm mount and far left side pole mount having a five-section head with yellow and green arrows. Eastbound and northbound traffic both face four heads, two pole mounted and two mast arm mounted.

18th Street and Minnesota Avenue

Minnesota Avenue is a major north/south roadway carrying a volume of approximately 27,000 vehicles per day at 18th Street. Signals along Minnesota Avenue are coordinated. Approximately 90 percent of the daily traffic on Minnesota Avenue proceeds through the intersection with approximately 7 percent making northbound left or southbound right turns to the west and the remaining traffic turning to the east. Northbound traffic volumes are relatively heavy throughout the day with the PM Peak Hour volumes close to the AM Peak Hour volumes and the total volume ranging from 650 to 900 vehicles per hour for through traffic with an additional 100 per hour turning. Southbound traffic is heavier in the PM Peak Hour and ranges from approximately 600 in the AM Peak Hour to almost 1,200 in the PM Peak Hour. Right turning traffic for the southbound direction is relatively consistent between 60 and 75 vehicles per hour.

18th Street has a daily volume of 6,500 to the east and 8,700 to the west of the intersection. Eastbound traffic approaching the intersection has a high proportion of turning movements throughout the day. Total volumes range from 150 at mid-morning to almost 350 in the PM Peak Hour. In the PM Peak Hour, there are approximately 80 left turns, 100 right turns and 140 through vehicles. During the day, approximately 30 percent of the traffic turns right, 30 percent left, and the remainder through. Westbound traffic on 18th Street is also represented by relatively high turning movements during the day. More than 21 percent turns left, more than 21 percent turns right, and the remaining 57 percent travels through on a daily basis. The proportions stay relatively the same throughout the day.

Minnesota Avenue has painted left turn lanes at the intersection and two through lanes in each direction. The northbound right through lane is next to the curb and there is enough room for parking in the southbound direction that allows some bypassing by right turning traffic.

Eastbound and westbound 18th Street approaching the intersection also have painted turn lanes in the middle of the street. There is a single through lane in each direction.

Three of the corners of the intersection have driveways adjacent to the corner. The fourth has driveways approximately one half block distant. All four corners are commercial and there is background signing and lighting.

The traffic signal has an actuated northbound left turn phase and an actuated eastbound left turn phase. Both are protected permissive operation.

41st Street and Shirley Avenue

This is an unique intersection on 41st Street near the Empire Mall. The north leg of the intersection is Shirley Avenue that provides access to a commercial area. The south leg of the intersection is West Empire Place and is offset from Shirley Avenue by 30 feet. Empire Place is theoretically a right turn in/right turn out access controlled primarily by signs. Westbound 41st Street has a two-way left turn lane that becomes painted out at the West Empire Place intersection. It is posted for no left turn

41st Street has an average daily traffic of 35,000 to the west and 33,000 to the east of Shirley Avenue. Shirley Avenue has a daily volume of almost 8,000 vehicles per day.

During the daytime, 85 percent of the 41st Street traffic continues through the intersection. Almost 15 percent turns right onto Shirley Avenue from westbound 41st Street. In the eastbound direction, approximately 12 percent turns left and 2 percent turns right from 41st Street. This same percentage holds true in the PM Peak Hour, but obviously in the morning, the volumes turning are significantly less. The same holds true for the westbound direction.

On southbound Shirley Avenue, over 50 percent turns left, 42 percent turns right, and 7 percent continues straight through the intersection during the day. This percentage holds true during most hours with the overall volumes obviously significantly lower in the AM Peak Hour.

Interestingly, in the 12-hour count period, there were 21 westbound left turns, 27 northbound through movements, and 10 northbound left turns, all of which are prohibited. Again, as noted earlier, this intersection will be reconstructed in 2003 to provide for a four-legged intersection and the illegal turns will be made legal and part of the signal system.

41st Street has three through lanes in both directions at this intersection. There is a very short painted eastbound left turn lane that comes from a two-way left turn lane. The westbound left turn lane is painted out. Southbound Shirley Avenue has been painted to provide three lanes; a right turn, a left turn, and a combined left turn and through lane. The single northbound lane is relatively narrow for traffic turning from 41st Street.

West Empire Place is not part of the signal system, but has one lane of approach that is marked for right turn only.

41st Street and Louise Avenue

The intersection of 41st Street and Louise Avenue is the busiest in the state of South Dakota. Not only does it have high traffic volumes on the approaches, but it has a high volume of turning traffic. On 41st Street, east of the intersection, the average daily traffic is over 46,000. To the west, the volume drops to just under 34,000. Louise Avenue has more than 21,000, both north and south of 41st Street.

Much of the traffic comes from the combination of purposes that both roads serve. 41st Street is a major east-west arterial in the southwest side of Sioux Falls. It provides access to the Empire Mall, has a major interchange with I-29, and serves as the access point for numerous commercial establishments from Minnesota Avenue to the west.

Louise Avenue is a major north-south route having an interchange on I-229. It provides access to the east side of the Empire Mall and to many other commercial establishments. It also is a major road to the south and, in combination with 26th Street, to the west.

On a daily basis, only 54 percent of the westbound traffic on 41st Street continues through the Louise Avenue intersection. Twenty percent turns left and twenty-six percent turns right. These percentages are approximately the same in the PM Peak Hour, but the total volume and the turning movement percentages are decreased in the AM Peak Hour.

Eastbound 41st Street has approximately 70 percent of the traffic continuing through the intersection with only 9 percent turning left and 22 percent turning right. Again, these turn percentages hold true in the PM Peak Hour, but are lower in the AM Peak Hour.

Westbound volumes in the PM Peak Hour approaching the intersection are just short of 2,000 vehicles. Eastbound volume in the PM Peak Hour is approximately 1,300 vehicles. This contrasts with the AM Peak Hour of 970 eastbound and 670 westbound. This reflects the impact of the commercial traffic in the area.

Northbound Louise Avenue has 30 percent of the traffic turning right and 24 percent turning left. Southbound has 46 percent turning left and only 10 percent turning right. This reflects on the limited number of crossings of the Big Sioux River and the necessity of much traffic coming from cross-streets to use 41st Street as the crossing. This high turning percentage should also be reflected in the red light running data collection.

The intersection has dual left turn lanes on all four approaches. 41st Street has three through lanes in both directions with a westbound right turn lane. Northbound and southbound have two through lanes of traffic in addition to the dual left turns, but only northbound has a right turn lane. This is consistent with the traffic volumes in the intersection.

The traffic signal indications are mounted across the long mast arm poles and pole mounted as well. With the multiple number of heads and the multiple number of lanes, the signal heads should be visible for all approaching traffic.

The high volume of turning traffic requires relatively long red lights for all approaches in the signal cycle sequence. Thus, while traffic can be coordinated through other intersections with relatively large green “bands”, there are often restrictions in the band width or stoppage is caused by turning movements. Most traffic anticipates that it will not be able to clear the intersection without a stop.

10th Street and Cleveland Avenue

10th Street is a major arterial east of the Sioux Falls downtown area. It connects the east side and the rural area to the City. Cleveland Avenue is a north-south roadway with continuity from Rice Street to 26th Street.

Average daily traffic volumes on 10th Street are 24,700 towards I-229 and 23,200 to the east. Daily volumes on Cleveland Avenue are 12,400 vehicles to the north and 8,000 vehicles to the south of 10th Street.

Most westbound traffic approaching the intersection travels through the intersection with approximately 9 percent turning right and 3 percent turning left on a daily basis. This varies slightly during the day with a maximum of about 17 percent turning right in the PM Peak Hour.

Eastbound 10th Street has a higher percentage of turning traffic with almost 16 percent turning left and 10 percent turning right on a daily basis. This holds true in both the AM and PM Peak Hours.

In the AM Peak Hour, there are over a 1,000 vehicles westbound and slightly over 500 eastbound. In the PM Peak Hour, the eastbound has over 1,200 vehicles and westbound under 1,000.

The majority of traffic traveling north on Cleveland Avenue turns left. The specific daily percentages are 48 percent turning left, 42 percent going through, and 11 percent turning right. In the PM Peak Hours, the higher percent of traffic travels through the intersection with the left turn percentage dropping to approximately 40 percent.

Southbound traffic also exhibits a high turning volume. Approximately 41 percent turns right and 31 percent turns left on a daily basis. In the AM Peak Hour, the southbound right turn increases to over 62 percent and drops to less than 30 percent in the PM Peak Hour. Left turning volume is low in the morning and increases to almost 38 percent in the PM Peak Hour. Through traffic, however, remains at approximately 30 percent throughout the day.
10th Street through the intersection has two continuous through lanes. A left turn lane with a raised median occurs on each approach. In the eastbound direction, the road widens and a wide right turn lane is provided. On the east side of the intersection, there are two eastbound lanes with a third lane painted out becoming a right turn lane to the shopping center.

Northbound Cleveland Avenue is a two-lane roadway with a painted median and left turn lane developed at the intersection. The southbound approach to the intersection also has a painted left turn lane being developed from the single southbound lane.

The intersection is immediately adjacent to I-229 and has heavy commercial development across I-229, through the intersection, and further to the east. The median that is carried through the I-229 interchange begins just east of Cleveland Avenue.

12th Street and Kiwanis Avenue

12th Street is a major roadway connecting the downtown area to the west. It continues as a major roadway into the rural area. Kiwanis Avenue is a major north-south route on the east side of the Big Sioux River.

Average daily traffic on 12th Street is 31,600 to the west and 27,600 to the east. Kiwanis Avenue has an average daily traffic of 16,900 to the north and 19,900 to the south.

Eastbound 12th Street has a heavy right turning volume during the day. Approximately 27 percent of the traffic turns right and additional 10 percent left. In the westbound direction, only 15 percent turns left and approximately 11 percent turns right. These volumes both hold relatively the same through the PM

Peak Hour and in the AM Peak Hour. Northbound Kiwanis Avenue has 37 percent turning left and 17 percent turning right during the day. The turning volumes are slightly decreased in the PM Peak Hour and in the AM Peak Hour.

Southbound Kiwanis Avenue has 26 percent turning left and 16 percent turning right during the day and slightly less turning percentages in the both the PM and AM Peak Hours.

12th Street has two through lanes and a left turn lane in the westbound approach. The left turn lane comes from a two-way left turn on the remainder of 12th Street. The eastbound approach has four lanes with the right through lane, developed at I-29, becoming a right turn only lane at the intersection. Observations have shown some traffic attempting to get out of the right turn only lane at the intersection.

Northbound Kiwanis Avenue and southbound Kiwanis Avenue both have two through lanes and a painted left turn lane.. The left turn lanes are extensions of two-way left turn lanes on either side of 12th Street.

The intersection is relatively open having parking lots on three sides and a park on the fourth side. Traffic signals are all mast arm mounted extending over the roadway, as well as pole mounted.

41st Street and Elmwood Avenue

The intersection of 41st Street and Elmwood Avenue is in the easterly commercial area of 41st Street. 41st Street is the major east-west roadway in the commercial area of southwest Sioux Falls. Elmwood Avenue is a local street to the north extending only to 26th Street. The south leg of the intersection is a driveway to the commercial area including the Western Mall. The traffic signal was installed to provide access to the Western Mall. As part of the 41st Street traffic study, it was suggested that the traffic signal be moved from Elmwood Avenue to Holly Avenue.

Traffic volumes on 41st Street are 38,800 to the west and 35,300 to the east of Elmwood Avenue. Traffic volume on Elmwood Avenue is estimated to be less than a 1,000 vehicles per day. The access from the Western Mall is estimated to have 2,500 vehicles per day.

Over 90 percent of the eastbound and almost 95 percent of westbound traffic on 41st Street continues through the intersection. With several alternate access opportunities to reach the Western Mall, it is logical that the turning volumes at Elmwood Avenue would be relatively low.

By contrast, less than 12 percent of the northbound traffic at the intersection continues on Elmwood Avenue. This is also expected since Elmwood Avenue has limited continuity or capacity. Fifty-four percent turns left, and thirty-four percent turns right. Southbound Elmwood Avenue has traffic almost evenly split between right turns, left turns, and through movements.

41st Street has two through lanes in each direction at the intersection. Short, painted left turn lanes are in place. The left turn lanes are extensions of the two-way left turn lane on 41st Street.

Southbound Elmwood Avenue has two lanes of approach, a designated painted left turn lane, and a combined, through, and right turn lane.

Traffic coming from the shopping center has two painted lanes, but no lane designation. With the majority of traffic turning left, right turning traffic and through traffic generally share the right lane. However, through traffic has used both lanes based on observations.

The access to the Western Mall has a relatively open parking lot immediately south of the 41st Street intersection. Traffic going into the mall can turn right or left or continue towards various parking aisles or cut through the parking area. Similarly, traffic coming back to the intersection has opportunities to approach from 180 degree area. With the openness, and the frequently occurring conflicts and congestion, traffic seems to approach the intersection relatively slowly, even when there is a green light.

49th Street and Louise Avenue

The intersection is located at the southwest corner of the Empire Mall area. Louise Avenue serves not only the east side of the Empire Mall, but a significant adjacent commercial area both north and south of 41st Street. It has interchanges at I-229 and provides access to the south rural area of Sioux Falls. 49th Street is a major east-west roadway, but currently has continuity only between Western Avenue and essentially Marion Road before it becomes a residential street.

49th Street has an average daily traffic of 20,300 vehicles per day to the west, and 15,000 to the east. Louise Avenue has volumes of 21,000 vehicles per day to the north and 21,700 to the south.

Turning movements are relatively heavy in the intersection. Westbound 49th Street has 56 percent of the traffic traveling through the intersection on a daily basis with 28 percent turning right and 15 percent turning left. A higher percentage travels through the intersection in the evening, focusing on the access to the residential areas to the west. Total volume westbound in the PM Peak Hours is approximately 800 vehicles. In the AM Peak Hour, there are slightly over 200 westbound vehicles with slightly higher percentages of traffic turning to the left.

Eastbound 49th Street has almost 37 percent of the traffic turning right and 19 percent turning left on a daily basis. This same percentage holds true in the PM peak hour, but is up to 41 percent turning right in the AM Peak Hour. Both the AM and PM Peak Hour eastbound movement is approximately 970 vehicles.

As anticipated, northbound Louise Avenue has almost 34 percent of its traffic turning left on a daily basis. Only approximately 9 percent turns to the right. This percentage holds true in the PM Peak Hour, but the left turn percent is up to 40 percent in the AM Peak Hour. The AM Peak Hour volume approaching the intersection is approximately 660, while the evening is over 960. This is consistent with the commercial area to the north.

Southbound Louise Avenue has 15 percent turning right and 23 percent turning left on a daily basis. These percentages are approximately the same in the PM Peak Hour when the volume is over 1,100 vehicles. In the AM Peak Hour, the total volume is less than 300 vehicles.

The approaches to the intersection are almost identical. Each has two through lanes and a painted left turn lane. In all instances, the painted left turn lane is developed from a two-way left turn lane on both 49th Street and Louise Avenue.

Louise Avenue has an environment on both sides of commercial activity with a number of driveways directly to parking lots. Traffic signals are in place at adjacent intersections. 49th Street has a

combination of multi-family and commercial and has more controlled access, but still has the feel of a major street with traffic signals anticipated at major intersections.

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Technical Memorandum No. 4

Intersection Field Review

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

One of the concerns in evaluating red light running is whether there is adequate visibility to the traffic signal heads when they are changing from green to yellow to red. Therefore, a field review was made of each of the intersections in the study. All four approaches to the intersection were driven in traffic with the visibility of signal heads, competition for attention, and general approach traffic noted. This was done prior to the collection of any data and notes taken. A second review of the intersection approaches was done by a different individual so a collaborative effort could be obtained.

Some of the intersections did have some distractions while others had some sight distance visibility problems for certain indications. None of the intersections had deficiencies in terms of visibility that would have been adequate to allow motorists to approach the intersection without seeing the traffic signal heads.

This technical memo provides detailed information on the approaches to each intersection that has been studied.

18th Street and Grange Avenue

18th Street and Grange Avenue is one of the few intersections in Sioux Falls that has traffic signals without overhead mounted indications. It does have far right and left pole mounted traffic signal heads with 12-inch red and 8-inch yellow and green indications. The west side far right side yellow and green are 12 inch indications.

Visibility to the intersection and to the traffic signal indications for southbound traffic is good once traffic gets within one block. Northbound traffic has a far left side indication partially blocked by the traffic signal pole on the southwest corner. Traffic does see the far left side indication approximately one-half block from the intersection and has good visibility to the far right side indication from some distance away.

Eastbound traffic has good visibility to the far left side indication but the far right side indication is poorly visible at about one-half block away due to utility poles and the near side signal pole location. Westbound traffic has partially obscured vision to the traffic signals on both sides due to trees on the left side and utility poles on the right side.

The northwest and southeast corners of the intersections are relatively open having parking lots with some landscaping features. The northeast side has a building built to the property line while the southwest side has a building set back from the property lines. The change from residential to urban commercial development is apparent to motorists approaching the intersection.

10th Street and Minnesota Avenue

10th Street westbound is a one-way street with five lanes of approach to the intersection at Minnesota Avenue. However, the array of traffic signal heads for westbound traffic affords good visibility to

traffic in all lanes. Even in heavy traffic, traffic has clear view of at least one signal indication, even when following a taller vehicle.

Northbound traffic has good visibility of the traffic signal heads, especially the overhead and far left indication. Southbound traffic also has good visibility to the signal heads. There is potential for distraction of motorists' attention from the YMCA dynamic message sign on the far left side of the intersection.

The intersection has open parking lots on the southwest and northeast sides and a parking area on the northwest side. Only the southwest corner has a building built to the property line. The intersection is in a series of intersections in the fringe of the downtown area and the traffic signal should not be unexpected.

11th Street and Minnesota Avenue

The intersection is very similar to the 10th Street and Minnesota Avenue intersection. There are five lanes of approach eastbound on one-way 11th Street. The number of traffic signal heads and positions are good for traffic approaching the intersection. However, a sign bridge approximately one-half block to the west does create a sight distance restriction for traffic so they do not have a clear continuous view of the traffic signals until they are about one-half block away from the intersection.

Northbound traffic also has good visibility to the traffic signal heads. As with southbound traffic at 10th Street, the YMCA dynamic message sign on the far right side for northbound traffic may cause a distraction. However, the signal heads are very visible and not overpowered by the sign. Southbound traffic also has good visibility of the traffic signal heads.

The southwest corner of the intersection has an open area for the service station while the southeast corner has a parking lot with minimal landscaping. The northeast corner has a building built to the property lines and the northwest has a building built close to the property lines with some landscaping. The intersection is on the fringe of the downtown area and the traffic signal should be anticipated.

18th Street and Minnesota Avenue

The field review found no unusual visual impacts on the approaches to the intersection. In the southbound direction, visibility is good to the intersection and the traffic signals. Three section traffic signal heads are overhead mounted.

Traffic approaching northbound also has good visibility to the intersection in general. It also has overhead mounted three section heads. The far right side three section head, which is pole mounted, is somewhat obscured by an advertising sign and light pole.

Westbound traffic has an overhead mounted three section head and far left and far right pole mounts. The left side indication is somewhat hidden because of light poles and overhead utility poles. Otherwise, there is good visibility to the traffic signal and the intersection.

Eastbound traffic faces four traffic signal heads. The right overhead mounted and right pole mounted signals are three section while the left overhead mounted and the far left pole mounted signals are five section heads with yellow and green turn arrows. The far right side pole mounted head is obscured near the intersection by overhead utility poles. There is good overall visibility to the traffic signal system.

With overhead mounted traffic signals, a lack of parked vehicles or other close obstructions, and with left turn lanes, overall visibility to the traffic signal and intersection is good with the exception of some details pointed out previously. The intersection does have emergency vehicle preemption and does not have LED indications.

41st Street and Shirley Avenue

The intersection of 41st Street and Shirley Avenue is unique and will be reconstructed in 2002. Currently, the intersection is controlled by a traffic signal for the eastbound, westbound and southbound approaches. The northbound approach in theory is a right turn in/right turn out operation. The westbound left turn is painted out so theoretically no traffic makes a left turn from westbound 41st Street to southbound Shirley Avenue into the Empire Mall.

Westbound traffic has only overhead indications to view. Because of the turn prohibition, no far left side indications have been provided. There are also no pole mounted far right side indications. This does create some restricted visibility when following a taller vehicle in heavy traffic.

Eastbound traffic has good visibility to the traffic signal indications that are pole mounted, far right and far left. The far left side indication is a five-section head.

Southbound traffic at the intersection has three lanes of approach and a single lane northbound. Southbound traffic turning right has a far right side head and an overhead five-section head. Left turning traffic also has a three-section overhead mounted indication. The total number of indications is adequate and very visible for southbound traffic. The offset intersection, dual left turn and potential for southbound traffic to continue to the Empire Mall does create a few odd maneuvers in heavy traffic when a through motorist makes the move somewhat unexpectedly.

There are no traffic signal heads visible for northbound traffic. This seems to confuse some traffic although the traffic generally stops as it tries to sort through options. Most traffic does turn right without much hesitation while other traffic takes more time.

Observations and traffic counts made during the 41st Street Study have shown that westbound traffic often violates the turn prohibition and makes the left turn into the southbound Shirley Avenue/Empire Mall entrance. Some traffic has been observed making the northbound left turn. Much of this is to be corrected when the intersection is rebuilt.

The intersection is quite tight in terms of space. A building is built almost to the property lines in the northeast corner. The southwest corner has a car lot with vehicles parked to and possibly overhanging into the right-of-way. The southeast corner has a parking lot also very close to the property line while the northwest corner has a McDonalds with some landscaping and close-spaced driveways to the Shirley Avenue intersection. Fortunately, the traffic signals are quite visible for eastbound and westbound traffic, otherwise the intersection might be missed.

41st Street and Louise Avenue

The intersection of 41st Street and Louise Avenue is the busiest intersection in South Dakota. It has continuous flow of traffic to the intersection on all four approaches. There are dual left turn lanes on all four approaches. 41st Street has three through lanes in addition to the dual left turn lanes and there is a westbound right turn lane. Louise Avenue has five lanes of approach northbound and four lanes southbound.

Because of the multiple lanes, there are numerous traffic signal heads on all four approaches. There is good visibility to the traffic signals on all four approaches.

The intersection has parking lots on all four corners although the Wendy's building in the southwest corner is relatively close to 41st Street. The intersection is very obvious to approaching traffic, and with the good visibility to the traffic signal heads, motorists are very aware that this is a major intersection.

10th Street and Cleveland Avenue

The intersection is relatively close to the single point interchange on 10th Street at I-229. The intersection is quite visible to approaching traffic and the traffic signal heads are all visible on all four approaches.

Northbound and southbound traffic have a left turn lane and a single through and right turn combined lane. Even in heavy traffic, the traffic signals are very visible.

Eastbound and westbound traffic have two through lanes, a left turn lane and a right turn lane. The eastbound approach has good visibility to the traffic signal, even when coming off of the northbound exit ramp from I-229. There is adequate distance to see the signal heads and to react to traffic. The intersection geometrics are a little unique with a painted out third lane on the east side for eastbound traffic. However, observations have shown little confusion on the part of motorists.

Westbound traffic has good visibility of the traffic signal indications. There is some concern that traffic may be looking at the relatively close intersection for I-229. Some traffic might be anticipating proper lanes or reading the message on the overhead sign. However, the traffic signals for the Cleveland Avenue intersection are very visible and motorists should not be able to ignore or not see them.

There are parking lots on all four sides of the intersection with a drive-through restaurant building relatively close to the 10th Street property line but not in an interfering action.

12th Street and Kiwanis Avenue

12th Street and Kiwanis Avenue is one of the busier intersections in the northwest section of Sioux Falls. While the four quadrants are relatively free of buildings, there are a significant number of signs and poles that do have an impact on clear visibility from the various approaches.

Westbound traffic has two through lanes and a left turn lane coming from a two-way left turn lane approaching the intersection. The far right side pole mounted signal indication is somewhat obscured by the Ace Hardware sign until traffic is approximately one-half block away. The far left side sign is also partially obscured by the Walgreens sign on the near side of the intersection. Both these indications can be seen by traffic as it gets close to the intersection, but there is some visibility obscurement potential in heavy traffic following a tall vehicle.

Eastbound traffic has good visibility of all traffic signal heads except that the pole mounted signals on the far side are partially obscured occasionally by poles on 12th Street. The three lanes of approach to the intersection become two lanes on the east side with the right lane becoming a right turn only lane. While the lane drop can distract motorists' attention from the traffic signal, it should not lead to red light running.

Northbound traffic generally has good visibility to the traffic signal. The far side pole mounted signal indication on the right is sometimes difficult to see due to overhead utility poles. The far left side pole mount indication is also difficult to see from a far distance because of the traffic signal pole in the southwest corner.

Southbound traffic also has a far right side pole mounted signal indication somewhat obscured by a light pole. However, there is good overall visibility to the traffic signals.

As pointed out there is a park on the southwest corner and parking lots on the other three corners to provide for good open visibility through the intersection. There are a significant number of overhead signs from businesses at both the intersection and the approaches to it.

41st Street and Elmwood Avenue

The intersection of 41st Street and Elmwood Avenue is in the narrower section of 41st Street having only two lanes in each direction with a center painted left turn lane. The left turn lanes are very short, but are a continuation of the two-way left turn lanes that are painted.

Both eastbound and westbound traffic have good visibility to the traffic signals. Although the intersection is not prominent compared to others, the signal visibility is very adequate.

Southbound traffic has no overhead indications and must rely on pole mounted far left and far right side indications. There is good visibility to the two pole mounted indications, primarily because there are only two lanes of approach to the intersection and the intersection itself is very obvious.

Northbound traffic also has no overhead indications and has a very short approach from the parking area. There is good visibility to the far left and far right pole mounted traffic signal indications. There is some confusion or failure of northbound traffic to become lined up with the intersection that partially offsets the good visibility. As an example, traffic coming from the area to the west of the intersection makes a left turn immediately adjacent to the intersection and has very little time to see the lights. There have also been observations of traffic coming from the right or left in the parking areas and pulling into the intersection on the end of the clearance period.

The traffic signal will be moved in the future to an intersection to the east which is better situated for traffic coming from the shopping area on the south.

The wide open area to the south and the parking area is somewhat beneficial in that it has little distraction for motorists on 41st Street. There are parking lots in the northwest and northeast corners. There is some competition from private signs but not for traffic on 41st Street.

49th Street and Louise Avenue

The intersection of 49th Street and Louise Avenue is a major intersection at the southeast corner of the Empire Mall shopping area. It is in a combined commercial and multi-family residential area and has open areas on three of the four sides.

Southbound traffic has only overhead indications, with no pole mounted far side indications that seems to be the usual practice in the City. However, visibility is good to the traffic signals with the exception of traffic following a tall vehicle in heavy traffic periods.

Northbound traffic also has only overhead indications with no far side or far left side indications. Again, visibility is good except in heavy traffic behind a tall vehicle.

Eastbound and westbound traffic approaching the intersection also have only overhead indications. There are five section heads for the left turn lanes as well as two heads mounted over the two through lanes of traffic. The heads for the left turn lanes do obscure each other for traffic approaching the intersection, until they get approximately one-half block away. With the other two heads visible except in heavy traffic behind tall vehicles, this should not be a distraction to motorists.

There is a major parking lot in the northwest corner and smaller parking lots in the southeast and southwest corners. There is an open area somewhat landscaped in the northeast corner. There are minimal signs and other distractions in the intersection.

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Technical Memorandum No. 5

Data Collection – Initial

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

At each intersection, observations were made of traffic approaching the intersection and running the red light. To do this, the data collector found a location in the intersection where all approaches and all lanes were visible at the intersection. The intersection was observed very carefully at each traffic signal indication change. The stop bar, which was either painted or otherwise located by some field delineation, was noted. The amount of all red clearance for those phases where the yellow and red indications were not visible was noted. The observer was then able to clearly define whether a motorist had entered the intersection on the yellow or after the beginning of the red indication.

Each intersection was monitored for three periods during the day. Each section of observation was 1½ hours long. A morning peak period, generally from 7:00 to 8:30 was observed. An evening period, generally from 4:00 to 5:30 was also observed. A midday section, which could vary from before noon to early afternoon, was also observed. This was to obtain both morning and evening traffic flows and a midday review.

All information was recorded into a tape recorder. Thus, the observer could continue to keep watching the intersection without having to make notes or find a recording device. The information was later transcribed. Time of day information was also recorded, frequently with the time when a red light violation was observed.

Finally, for each noted red light violation, some additional information was obtained. Where possible, the time of day of the violation was recorded. The type of vehicle making the maneuver was also noted along with the direction and turning movement and with the driver behavior. Specifically, motorists were noted where they sped up to make it through the signal or where they were following in a queue of traffic and seemed to be dragged along. It was also observed whether the vehicle was at the end of a platoon of traffic. Finally, motorists who may have been distracted by cell phones or passenger conversations were noted wherever possible.

A typical recording of information would then include notes such as follows:

1:08 p.m., car, northbound, sped up.
1:13 p.m., car, southbound, sped up.
1:56 p.m., pickup truck, southbound left turn, at back of other left turning traffic.

This information was then tabulated by determining the number of vehicles making the various maneuvers. The total number of violations by direction and turning movement were calculated for each intersection for comparison to the after study. The number of "speed ups" and the number of "following" were calculated. Observations of data were also reviewed to determine if there was a type of vehicle or other element that might be of value in analyzing the intersection.

Rather than provide details of this information at each intersection in the before study in this technical memorandum, the data collection information from this and the after will be compared in a following technical memorandum.

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Technical Memorandum No. 6

Operational Characteristics

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

The main focus of the study is to determine if traffic signal timing changes can be utilized to decrease the number of red lighting running violations. The major focus of that would be to compare the before and after number of violations with the changes made to the clearance timing, specifically to the yellow clearance. However, the amount of data collected at any one intersection will be adequate to provide insight, but not to draw complete conclusions. In addition, the question remains as to whether motorists may be able to adapt to the slightly longer or modified yellow clearance periods or whether they will even notice that there is a difference.

The total amount of data does provide opportunities to try to draw other conclusions from the information. By evaluating the operational characteristics of the intersections that have been studied, those with similar characteristics can be compared to determine if there is some trend in either the red light violations or changes because of the signal timing. The following paragraphs provide some discussion over the various characteristics and how they might be compared or how the data that may seem significant, may, in reality, not be.

One consideration is the number of violations proportional to the volumes of traffic. This could be done by simply comparing the volumes on the various approaches for through traffic to the number of violations by through traffic. This could be done by taking peak hour volumes for both the AM and PM for each of the four approaches to the intersection and compare them to violations and see if there is any range that shows a trend.

Unfortunately, traffic volumes may not be related to the opportunities for traffic to run a red light. If 100 vehicles travel through an intersection in one direction in a single signal cycle at one intersection, but only 5 travel through the other intersection on the single signal cycle, there remain opportunities for only a few of the vehicles to enter on the red light at the beginning of the cross-street green. The other 95 or so vehicles would have been through the intersection on the green, and thus, there would not be any direct correlation between opportunity and volume. However, the comparison should still be reviewed in conjunction with some of the other intersection characteristics, where it might prove valuable.

There has been a speculation on the fact that traffic in the AM and PM Peak Hours may be more inclined to rush through an intersection because of congestion or familiarity with an intersection. Thus, the number of violations in the AM and PM Peak Hours would be higher than those in the off peak period, taking into account the number of signal cycles in the different periods. Thus, one comparison might be between the number of vehicles in the westbound direction on 41st Street in the evening and in the eastbound direction in the morning with those in the eastbound and westbound directions at mid-day. A similar comparison could be made on Minnesota Avenue. However, some of the directional distributions of traffic are not quite so obvious.

It has been suggested in the field review that some of the intersections have some distraction or some impairment of clear view of all the traffic signals for certain approaches. This could be a comparison at the specific intersection by seeing if the number of violations in the direction in which there is an impairment is higher than those in the other directions. This would help lead to the conclusion as to whether red light

running is by lack of notice of the change or by driver decision when they have adequate information on the change from green to yellow.

A major consideration is the impact that coordinated systems would have on the number of red light runners. A coordinated signal system does not look for a gap in traffic, but instead terminates the green at a specific time sequence. This means that motorists are more likely to be caught in a dilemma zone in a coordinated system than at an independent signal. A major consideration in the 10 intersections studied would be that most are in some type of a coordinated system on the main street. Comparison of the main street and cross street by number of violations may not reflect on other motorist characteristics.

An often voiced complaint is that individuals in sports utility vehicles are more likely to ignore the rules of the road. This is generally a comment by owners of non-sport utility vehicles. Although the type of vehicle was always recorded with the violation, there is not base data on which to draw a specific conclusion. A review of the information analyzed individually at intersections does not seem to show any higher percentage of any type of vehicle. One noticeable missing element is heavy trucks. Few seem to be involved in red light running, even though they have longer stopping distances.

As the data is assembled and the comparisons between before and after are made, a final technical memorandum will compare all of the data and make a summary judgment on some of these operational characteristics.

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Technical Memorandum No. 7

Traffic Signal Timing Adjustments

Red Light Running Study

Traffic Engineering Analysis Services
Sioux Falls, South Dakota

One of the classic elements that have been discussed by traffic engineers for many years is the creation of a dilemma zone for motorists approaching a traffic signal. A motorist on the approach to an intersection is shown a yellow indication and needs to make an immediate decision whether to approach the intersection and continue through or whether to apply the brakes and try to stop in time.

The dilemma zone answer has often been to provide traffic signal detectors at a far enough spacing so when motorists cross the detector, they will have adequate time to continue through the intersection or, if the light turns yellow just before they reach the detector, they will have adequate distance to comfortably stop. In heavy traffic conditions where the traffic signal runs to maximum time or where traffic signals are coordinated and will be terminated without attempting to find a gap in traffic, motorists often find themselves in the dilemma zone where they can stop by braking hard or can continue through.

The yellow signal clearance interval should be long enough to provide an opportunity for motorists who are too close to comfortably stop to enter the intersection. A following all red clearance is generally utilized to provide an opportunity for vehicles that have entered the intersection before the end of the yellow clearance to have an opportunity to clear the intersection before any conflicting traffic is given a green indication.

For each of the intersections being studied, traffic signal timing information was obtained and analyzed. Information obtained included both local controller operation information and the coordinated signal system information. A considerable amount of the information related to the coordination data including time of day, dial, split and offset information. While the primary focus of the traffic signal timing analysis should have been on yellow and red clearance, it was felt that an overall knowledge of the operation of the system and the intersection was necessary and a detailed review was done, independently of City staff. While it was recognized that standards and policies of individual communities are important, the review was done on an independent basis so that any local bias towards a preferred operation was removed. However, there was the opportunity for the reviewers to insert their bias.

SEH provided a review by a traffic engineer having experience in the responsibility for the operation of the City of Minneapolis traffic signal system. After reviewing the operation, some concepts for changing the yellow and all red clearance intervals were developed and specific recommendations for individual intersections were made. These concepts and individual recommendations were reviewed by other SEH staff also having had responsibility for traffic signal operation in the past. The suggested signal timing changes were then sent to the City for implementation.
Between the development of the concepts for the timing changes and the implementation, information on red light running in the first data collection stage was reviewed for several intersections. It appeared that the data collected was consistent with some of the recommendations being made. Therefore, the suggested changes were sent for implementation immediately upon completion of the data collection.

This technical memorandum provides two sections for each intersection. The first is the traffic signal operation characteristics for each intersection prepared by the City. This is a series of points indicating general operation. The second section in each of the intersection discussions is the recommendations for timing changes prepared by SEH.

18th Street and Grange Avenue

Traffic Signal Operation Characteristics

- "Pre-timed" Eagle EPIC controller.
- Operates free – no coordination to other signals.
- No "LED" lenses.
- Timings:
  - Intervals 1-4 – 18th Street

    Int. 1 – Green w/Walk
    Int. 2 – Green w/Flashing Don't Walk
    Int. 3 – Amber
    Int. 4 – All Red
  - Intervals 5-8 – Grange Avenue

    Int. 5 – Green w/Walk
    Int. 6 – Green w/Flashing Don't Walk
    Int. 7 – Amber
    Int. 8 – All Red
- Flashes from 11 PM to 6 AM – amber on 18th, red on Grange.
- Follows TBC dial changes.

Suggested Signal Timing Changes

Increase red clearance intervals for both phases from 1.2 sec to 1.5 sec. To accomplish this, for Dial 1-Split 1, for Dial 2-Split 1, and for Dial 3-Split 1 coordination timings:

Change interval 2 time from 9.7 sec to 9.4 sec.
Change interval 4 time from 1.2 sec to 1.5 sec.
Change interval 6 time from 10.7 sec to 10.4 sec.
Change interval 8 time from 1.2 sec to 1.5 sec.

10th Street and Minnesota Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated Minnesota Avenue system using fiber-optic interconnect cable.
- Operates using three dial coordination plans by time of day selection.
- Red lenses are LED.
- Northbound left turn is only actuated phase and is a leading left.
- Phase 2 is northbound through movement then follows NEMA phasing structure.
- Coordination plan operation:

- Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plan is its minimum time. Phase 8 (10th Street) is on maximum recall (dual coordination) providing maximum coordination time.
- All other phases are actuated and times shown in timing plans are maximums.
- Timing plan "times" include green plus amber and all red.
- Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
- This signal does not flash at night.
- Under coordination data: mode 0 means phase is actuated, 1 means coordination phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change all yellow clearance times (ϕ2, ϕ4, ϕ5, ϕ6, ϕ8) to 3.5 sec.

With the yellow clearance times changed to 3.5 sec, the red clearance times for NB (ϕ2) and SB (ϕ6) can be reduced from 2.0 sec to 1.7 sec.

Change the red clearance time for the NBLT (ϕ5) from 0.0 sec to 1.7 sec.

Change phase times as follows to avoid coordination faults:

	ϕ1	ϕ2	ϕ3	ϕ4	ϕ5ϕ6	ϕ7	ϕ8
Dial 1, All Splits	0	55	0	25	1144	0	25
Dial 2, All Splits	0	65	0	25	1156	0	33
Dial 3, All Splits	0	67	0	33	1156	0	33

11th Street and Minnesota Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated Minnesota Avenue system using fiber-optic interconnect cable.
- Operates using 3-dial coordination plans by time of day selection.
- Red lenses are LED.
- Southbound left turn is only actuated phase and is a leading left.
- Phase 2 is northbound through movement then follows NEMA phasing structure.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time. Phase 4 (11th Street) is on maximum recall (dual coordination) providing maximum coordination time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
  - This signal does not flash at night.

- Under coordination data: mode 0 means phase is actuated, 1 means coordination phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change all yellow clearance times (ϕ1, ϕ2, ϕ4, ϕ6) to 3.5 sec.

With the yellow clearance times changed to 3.5 sec, the red clearance times for NB (ϕ2) and SB (ϕ6) can be reduced to 1.7 sec.

Change the red clearance time for the SBLT (ϕ1) from 0.0 sec to 1.7 sec.

18th Street and Minnesota Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated Minnesota Avenue system using fiber-optic interconnect cable.
- Operates using 3-dial coordination plans by time of day selection.
- No LED lenses.
- Northbound and eastbound left turns are the only actuated phases and are leading lefts.
- Phase 2 is northbound through movement then follows NEMA phasing structure.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time. Phase 4 and 8 (18th Street) is on maximum recall (dual coordination) providing maximum coordination time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
  - This signal does not flash at night.
  - Under coordination data: mode 0 means phase is actuated, 1 means coordination phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change all yellow clearance times (ϕ2, ϕ4, ϕ5, ϕ6, ϕ7, ϕ8) to 3.5 sec.
With the yellow clearance times changed to 3.5 sec, the red clearance times for NB (ϕ2) and SB (ϕ6) can be reduced to 1.4 sec.

Change the red clearance time for the NBLT (ϕ5) from 0.0 sec to 1.4 sec.

Change the red clearance time for the EBLT (ϕ7) from 0.0 sec to 2.0 sec.

41st Street and Shirley Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated 41st Street system using "FSK" communication interconnect cable.
- Operates on a "traffic responsive" closed loop signal system (4-dial, 4-split, 3-offsets).
- No LED lenses.
- Shirley Avenue and eastbound left turn are the only actuated phases.
- Phase 2 is eastbound through movement then follows NEMA phasing structure.
- Phase 5 (eastbound LT) is a lagging green.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
  - This signal flashes at night from 11:00 p.m. to 6:00 a.m.
  - Under coordination data: mode 0 means phase is actuated, 1 means coordination phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change minimum green time for ϕ5 (EBLT) from 2 to 5 sec.

Change yellow clearance time for ϕ2 (EB) and ϕ6 (WB) from 3.9 sec to 3.6 sec.

Change yellow clearance time for ϕ5 (EBLT) from 4.0 sec to 3.6 sec.

Change red clearance time for ϕ4 (N/S) from 1.8 to 2.5 sec.

Change red clearance time for ϕ6 (WB) from 1.4 sec to 1.6 sec.

Change red clearance time for ϕ2 (EB) from 1.4 sec to 2.3 sec.

Change red clearance time for ϕ5 (EBLT) from 0.0 sec to 2.3 sec.

The current phase timings and the dial 1 coordination phase times for ϕ4 currently would cause coordination faults whenever there is a ϕ4 pedestrian call (ϕ4 minimum pedestrian time is 5+13+3.6+1.8=23.4 while the coordination phase time is 21 on dial 1). The following coordination phase times are recommended:

	ϕ1	ϕ2	ϕ3	ϕ4	ϕ5ϕ6	ϕ7	ϕ8
Dial 1, All Splits	0	71	0	25	1655	0	0

41st Street and Louise Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated 41st Street system using "FSK" communication interconnect cable.
- Operates on a "traffic responsive" closed-loop signal system (4-dial, 4-split, 3-offsets).
- All red and pedestrian lenses are LED.
- All phases except eastbound and westbound through movements (41st Street) are actuated.
- Phase 2 is eastbound through movement then follows NEMA phasing structure.
- All left-turn movements are operating in lead-lag mode. Eastbound LT is leading, westbound LT is lagging, southbound LT is leading and northbound LT is lagging.
- All left-turn movements have two left-turn lanes.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
  - This signal does not flash at night.
  - Under coordination data: mode 0 means phase is actuated, 1 means coordinated phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change minimum green time for ϕ1 (WBLT), ϕ3 (NBLT), ϕ5 (EBLT), and ϕ7 (SBLT) from 2 sec to 5 sec. (Probably not a factor in red-light-running).

Change yellow clearance time for ϕ1 (WBLT), ϕ2 (EB), ϕ5 (EBLT), and ϕ6 (WB) from 4.0 sec to 3.6 sec.

Change yellow clearance time for ϕ3 (NBLT), ϕ4 (SB), ϕ7 (SBLT), and ϕ8 (NB) from 4.0 sec to 3.5 sec.
Change red clearance time for ϕ3 (NBLT), ϕ4 (SB), ϕ7 (SBLT), and ϕ8 (NB) from 2.0 sec to 2.7 sec.

The current phase timings and the dial 1 coordination phase times for ϕ4 and ϕ8 currently may cause coordination faults when there is a ϕ4 or ϕ8 pedestrian call (ϕ4 and ϕ8 minimum pedestrian time is 5+20+4+2=31 while the coordination phase times on dial 1 are 22 for ϕ4 and 20 for ϕ8). If this was not intentional, the following coordination phase times are recommended:

	ϕ1	ϕ2	ϕ3	ϕ4	ϕ5ϕ6	ϕ7	ϕ8
Dial 1, All Splits	17	33	15	31	1238	15	31

10th Street and Cleveland Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated Eagle EPAC controller.
- Operates in a coordinated E. 10th Street system using "FSK" communication cable.
- Operates using 3-dial coordination plans selected by time of day.
- No LED lenses at this intersection.
- Phase 2 is eastbound through movement then follows NEMA phasing structure.
- All left-turn movements are leading lefts.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated Phases, 2 and 6.
  - This signal does not flash at night.
  - Under coordination data: mode 0 means phase is actuated, 1 means coordination. Phase 6 means phase is omitted in that timing plan.

Suggested Signal Timing Changes

Increase yellow clearance times for all phases, which currently are 3.0 sec to 3.2 sec. Increase all to 3.6 sec. Red clearance times for through movements can be reduced slightly (to 2.6 sec N/S and 1.5 sec E/W) if yellow clearance times are increased.

Add red clearance times for left-turn phases to match through movement clearance times; coordination timings will require modification, or minimum green times must be reduced, to avoid split times less than the phase minimum times.

Change phase times as follows to avoid coordination faults:

	ϕ1	ϕ2	ϕ3	ϕ4		ϕ5ϕ6	ϕ7	ϕ8
Dial 1, All Splits	11	22	0	29		033	0	29
Dial 2, All Splits	11	26	12	28	0	37	12	28
Dial 3, Splits 1/2/4	11	38	12	25	0	49	12	25
Dial 3, Split 3	11	38	13	24	0	49	12	25
Dial 4, All Splits	11	33	12	30	0	44	12	30

12th Street and Kiwanis Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated 12th Street/West Avenue/Kiwanis Avenue system using a 7-wire interconnect.
- Red and pedestrian are "LED" lenses and green will soon be converted to LED also.
- Phase 2 is eastbound through movement then following NEMA phasing structure.
- Operates using 4-dial coordination plans selected by time of day.
- All left-turn movements are leading lefts.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated Phases, 2 and 6.
  - This signal does not flash at night.
  - Under coordination date: mode 0 means phase is actuated, 1 means coordination. Phase 6 means phase is omitted in this timing plan.

Suggested Signal Timing Changes

Increase red clearance interval for N/S through phases (ϕ4 and ϕ8) from 1.8 sec to 2.0 sec.

Add red clearance intervals for left-turn phases. All are currently 0.0 sec; change to 2.0 sec for NBLT (ϕ3) and SBLT (ϕ7), and change to 1.8 sec for EBLT (ϕ5) and WBLT (ϕ1).

In conjunction with the red clearance interval changes, all yellow clearance intervals can be reduced to 3.5 sec (currently set at 3.6 sec for through phases, 4.0 sec for left-turn phases).

41st Street and Elmwood Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated 41st Street system using "FSK" communication interconnect cable.
- Operates on a "traffic responsive" closed-loop signal system (4-dial, 4-split, 3-offsets).
- No LED lenses.
- All phases are actuated except eastbound and westbound (41st Street) through movements.
- Phase 2 is eastbound through movement then follows NEMA phasing structure.
- All 41st Street left turns are leading lefts.
- Coordination plan operation:

- Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
- All other phases are actuated and times shown in timing plans are maximums.
- Timing plan "times" include green plus amber and all red.
- Any unused time n the actuated phases is given back to the coordinated phases, 2 and 6.
- This signal flashes at night from 11:00 p.m. to 6:00 a.m.
- Under coordination data: mode 0 means phase is actuated, 1 means coordinated phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change minimum green time for ϕ1 (WBLT) and ϕ5 (EBLT) from 2 sec to 5 sec. (Probably not a factor in red-light-running)

Change yellow clearance time for ϕ1 and ϕ5 from 4.0 sec to 3.6 sec.

Change red clearance time for ϕ1 and ϕ5 from 0.0 sec to 1.5 sec.

Change red clearance time for ϕ2 (EB) and ϕ6 (WB) from 1.4 sec to 1.5 sec.

Change red clearance time for ϕ4 (SB) and ϕ8 (NB) from 1.6 sec to 1.9 sec.

49th Street and Louise Avenue

Traffic Signal Operation Characteristics

- "Semi-actuated" Eagle EPAC controller.
- Operates in a coordinated Louise Avenue system using "FSK" communication interconnect cable that is connected to the 41st Street coordinated system.
- Operates in a "traffic responsive" closed-loop signal system (4-dial, 4-split, 3-offsets).
- All red and pedestrian lenses are LED.
- All left-turn phases are actuated, 49th Street and Louise Avenue through movements are operating in dual coordinated mode.
- Phase 2 is eastbound through movement then follows NEMA phasing structure.
- All left turns are leading lefts.
- Coordination plan operation:
  - Phase 2 and 6 are the coordinated phases, not actuated, and its time shown in the timing plans is its minimum time.
  - All other phases are actuated and times shown in timing plans are maximums.
  - Timing plan "times" include green plus amber and all red.
  - Any unused time in the actuated phases is given back to the coordinated phases, 2 and 6.
  - This signal does not flash at night.

- Under coordination data: mode 0 means phase is actuated, 1 means coordinated phase, 6 means phase is omitted in that timing plan, 7 means dual coordinated phase.

Suggested Signal Timing Changes

Change the yellow clearance time for ϕ1 (WBLT), ϕ3 (NBLT), ϕ5 (EBLT), and ϕ7 (SBLT) from 4.0 sec to 3.6 sec.
Change the yellow clearance time for ϕ2 (EB), ϕ4 (SB), ϕ6 (WB), and ϕ8 (NB) from 3.9 sec to 3.6 sec.

Change the red clearance time for ϕ1 and ϕ5 from 0.0 sec to 1.7 sec.

Change the red clearance time for ϕ2 and ϕ6 from 1.6 sec to 1.7 sec.

Change the red clearance time for ϕ3 and ϕ7 from 0.0 sec to 2.0 sec.

Change the red clearance time for ϕ4 and ϕ8 from 1.6 sec to 2.0 sec.

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Technical Memorandum No. 8

Data Collection – Follow-up

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

In the initial study, the data was collected starting on a Thursday and Friday in Week 1, and continued the following Monday through Thursday of Week 2. On Friday of Week 2 and the following Monday, the traffic signal timing changes were made. During Week 3, no data was collected. On Monday of Week 4, following the completion of the timing changes, the after data collection began and was completed during the week. The motorists only had one week during which to adapt to longer clearance periods or modifications to other timing.

At each intersection, the same timeframes were utilized for a.m., mid-day, and p.m. data collection. The same format was followed for data to be collected and for the process utilized. As soon as the information was collected, the tape recorded information was retrieved, written out, and sent for analysis.

The tabulation of the information at each intersection was also done identically to the initial study. The initial and after data information at each intersection will be compared in a following technical memorandum.

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Technical Memorandum No. 9

Violation Data – Intersection Review

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

Red light running data collected in both the initial and follow-up program were recorded chronologically based on time of day with information relative to type of vehicle, direction and turning movement, and driver behavior. This information was then condensed to a summary of each period of time and each direction. As an example, the data summary might indicate that there were three northbound and one northbound left turn violations in the AM Peak Hour.

The information in the initial and the follow-up studies were compared on the basis of total number of violations, violations in each of the three periods during the day, and violations by each of the directions of approach. In addition, the information was compared to some of the concerns found during the field review or in the intersection analyses. As an example, the somewhat restricted view of the traffic signals at 18th Street and Grange Avenue in the westbound direction was compared to the violations occurring. The noted queuing of traffic on Minnesota Avenue was reviewed in terms of the number of vehicles in the northbound or southbound direction where driver behavior was quoted as "following" or "end of queue."

In each instance, the information was compared only to that specific intersection in this analyses. A subsequent memo will compare the results of the overall study and provide recommendations.

18th Street and Grange Avenue

The before study of violations at 18th Street and Grange Avenue showed only 14 violations in 4½ hours of checking. Violations were evenly spread throughout the three periods, and were spread throughout the movements. Based on signal concerns, the westbound movement could have had some problems. However, northbound had five violations, and eastbound and westbound only had three each.

There were no changes made to the yellow clearance period primarily because of the existing times and the lack of violations. The red clearance intervals were slightly increased.

The after period had a reduction of violations to eight. There was only one violation spotted in the mid-day period. The only violation in the evening was the deliberate running of the red light where an individual stopped and then drove through the red light. There were three northbound violations, and no westbound or eastbound violations. Thus, the before and after data is relatively small and conveys no pattern, little change, and no logic for the changes.

10th Street and Minnesota Avenue

The number of noted violations of red lights at the intersection of 10th Street and Minnesota Avenue in the before study was amazing. Two hundred forty-seven observations were made in a 4½ hour period. One hundred sixteen occurred in the mid-day count and One hundred six in the

PM Peak Hour. They were equally spread amongst the movements with 24 northbound, 68 southbound, and 48 westbound. Additionally, 59 northbound left turns and 41 westbound left turn motorists made red light violation moves. There are almost 50 noted "speeding up" by motorists to enter the intersection at the beginning of the red light. Amazingly, there were also a number of individuals who deliberately ran the red light. Most of those were left turn motorists who simply waited until the light was red and then proceeded through the intersection.

The major change in the signal timing was to increase the yellow clearance time from 3.0 to 3.5 seconds for all phases. The red clearance times were reduced from 2.0 to 1.7 for the through movements for northbound and southbound. Red clearance time was added to the northbound left turn.

The theory behind the changes was to extend the yellow clearance to reflect the higher actual travel speeds in the off peak periods and for some of the peak periods. The changes to the yellow clearance for the left turns was to reflect the longer time left turning traffic would take to get to and through the intersection. The red clearance added to the left turns would reflect the need for clearance after vehicles could legally enter the intersection. The reduction in red clearance was to balance the total clearance for through traffic.

The after study results were so dramatically reduced that it is almost desirable to recount to make certain there was not an anomaly occurring on the day the count was made. Total number of after red light violations was 57, which is approximately 1/5 the number in the before study. Most of the after study violations occurred during mid-day with 36 noted violations. The westbound accounted for 17 of the total violations and the rest were spread throughout the northbound and southbound and the turning movements.

11th Street and Minnesota Avenue

In the before period, there were a significant number of observations of red light running. In total, there were 207 noted violations. In the morning count time, 83 violations occurred with only 49 in the afternoon count period. There are more signal cycles in the morning than in the afternoon, but this does not appear to have total correlation with the number difference.

Equally puzzling is the significant number of northbound violations compared to southbound. In the northbound direction for all three count periods, 76 observations of red light running were made with only 13 in the southbound direction, the opposite of 10th Street and Minnesota Avenue. There were 49 red light runs made by through traffic in the eastbound direction. When the eastbound left turn and right turn violations are added, there are over 100 violations in the 4½-hour period.

The timing changes were relatively small. Yellow clearance intervals were adjusted to a uniform 3.5 seconds for the three through phases and the left turn phase. The northbound and southbound red clearance was set back to 1.7 seconds from 2.0. Red clearance time was added to the southbound left turn movement.

In the after data collection periods, there were a total of 115 violations. Northbound was reduced from 76 to 44 noted violations. Eastbound through movements went from 49 to 23, and the total eastbound violations went from 102 to 52.

As expected, the number of vehicles speeding up to violate the red light also was reduced from 64 to 28. Thus, there is a uniform reduction in the overall violations and consistent with virtually every move with the exception of northbound right turns, which actually increased from 8 to 14.

It appears that the change in violations was due to primarily to those individuals who were running the red light and barely getting into the intersection as the yellow clearance expired. The additional ½-second seemed to make enough difference to reduce the number of violations, but the driver characteristics did not seem to change.

18th Street and Minnesota Avenue

In the 4½-hour before observation period, there were 63 noted red light running violations. Thirteen occurred in the AM Peak Hour, eighteen between 1:00 and 2:30 p.m., and thirty-two in the PM Peak Hour. As would be expected, 21 were northbound and 16 southbound. In addition, five involved the northbound left turn and seven involved a southbound left turn. Three more involved a southbound right turn. The northbound and southbound directions accounted for 82 percent of all red light runnings.

Observations of driver behavior showed that 26 motorists sped up, while one was distracted on a cell phone. Three others were following a queue of traffic and entered on a red light.

Changes to the traffic signal included an extension of the yellow clearance period from 3.0 to 3.5 seconds. The red clearance timing for all four through phases was reduced from 3.2 to 1.4 seconds. The northbound left turn and eastbound left turn phases had yellow clearance increased from 3.0 to 3.5 seconds. Red clearance intervals of 1.4 seconds were added to the northbound left turn and 2.0 to the eastbound left turn.

The data collected after the timing changes showed the total number of violations were reduced to only 23. There were nine in the northbound direction and four in the southbound direction, which accounted for most of the reduction. Eastbound and westbound combined were reduced from 10 to 6 and the northbound left turn from 5 to 3.

The driver behavior observed showed a decreased in speeding up from 26 to 7 incidents. However, the “following” category went from three to nine.

This seems to indicate that the additional 0.5 of a second added to the yellow clearance would protect some of the motorists who were previously entering on the red light. The reduction in “speed ups” is parallel to the reduction in total violations. The change in “following” may be coincidental or attributed to interpretation of the observer. The reduction is significant in that the motorists who technically were running the red light previously by entering a split second after the beginning of red are now entering legally, but still clearing the intersection before termination of the red clearance time.

41st Street and Shirley Avenue

In the before study, there were three red light violations in the AM Peak Hour, five in the time period of 10:00 a.m. to 11:30 a.m., and thirteen in the PM Peak Hour, for a total of twenty-one. In the after study, there were still three in the AM Peak Hour, five in the mid-day timeframe, but a reduction to seven in the PM Peak Hour, for a total of 15. The total number of eastbound and westbound was reduced from 16 to 13. Southbound was reduced from three to one.

There were a significant number of timing changes made, primarily to reduce the yellow clearance times on eastbound and westbound to 3.6 seconds and increasing the red clearance times to various intervals to reflect on the operational characteristics of the intersection. These are explained in the Signal Timing Technical Memorandum.

Because of the low number of violations noted, the change in total number or to any specific movement is not significant. The information for this intersection will have to be taken in conjunction with the other intersections to draw any conclusions.

41st Street and Louise Avenue

The total number of red light violations at 41st Street and Louise Avenue in the before period was 100. The four through phases accounted for only 23 of the total violations. The biggest number of violations occurred with the southbound left turn movement where 26 were counted. The other three left turns accounted for an additional 20 violations. The remainder, 31, was attributed to the four right turn movements. Twenty-three vehicles sped up to travel through the intersection on the red light. Four distractions were noted.

The timing changes at 41st Street and Louise Avenue were different than at some of the other intersections. The yellow clearance period was reduced from 4.0 to 3.5 or 3.6 seconds. This was primarily to provide uniformity of the yellow clearance period among the intersections. The red clearance times on four of the phases were raised from 2.0 to 2.7 seconds to provide slightly longer total clearance time.

As might be expected, the number of violations in the after study increased to 178. The through movement violations went up to 47. The southbound left turn continued to be the heaviest violation phase with 66 counted in the after study. The other left turns accounted for an additional 38 violations. Right turns accounted for 33.

A significant increase in “platoon” violations occurred with the number raising from 23 to 62. The number that sped up remains somewhat constant at 26, and there was only one distraction noted. There is also one additional violation with the driver stopping for a red light and then driving through the intersection on a left turn.

It appears that the slight decrease in yellow clearance time of 0.5 or 0.4 seconds makes a significant difference in the violation rate. When comparing these numbers to other intersections, it may be necessary to consider reversing the before and after studies because of the timing changes that were made.

10th Street and Cleveland Avenue

There were 54 red light violations observed in the before study. Twenty-three of these were westbound through movements, which was one of the concerns in the field review. There are also nine northbound left turn violations. The remaining violations were evenly spread amongst the other movements.

The predominate number of violations was in the AM Peak Hour where there were 27 noted. Fifteen of these, better than ½, were westbound. By contrast, there were only two eastbound in the a.m. and none in the mid-day or PM Peak Hours.

The primary timing changes were to increase the yellow clearance periods from 3.0 or 3.2 to 3.6 seconds. Red clearance times were reduced slightly to offset the increase in yellow clearance periods. Red clearance times were added to the left turn phases.

In the after period, the red violations actually increased to 63. With the extended yellow clearance period, a reduction would be anticipated. The westbound violations decreased by one going from 23 to 22. Most occurred in the AM Peak Hour. Northbound left turns increased from nine to fourteen. Eastbound violations increased from two to six, and remaining movements were close to the before period.

The total number of violations observed in the mid-day went from nine to sixteen. The number of violations was spread throughout the various movements in the intersection.

12th Street and Kiwanis Avenue

The 73 violations noted in the before study were spread throughout the various movements. The northbound left turn had 19 and the eastbound through movement had 17, 10 in the AM Peak Hour. Most of the violations (37) occurred in the AM Peak Hour with 18 in the mid-day and 18 in the PM Peak Hours.

The timing changes made to the signal were relatively minor. North-south phases had the red clearance intervals increased from 1.8 to 2.0 seconds. Red clearance intervals were added to left turn phases. Yellow clearances were adjusted with through phases reduced by 0.1 second and left turn phases reduced from 4.0 to 3.5 seconds .

With the minor timing adjustments made, the after violations, as expected, were similar to the before period. There were 66 total violations, again with the northbound left turn having the highest number with 14. Eastbound through was slightly reduced and the westbound through increased significantly from eight to fourteen. The remainder of the movements were spread throughout the intersection.

The AM Peak Hour was reduced from 37 to 15 violations, with the mid-day and PM Peak Hours both increasing from 18 to 26 and 25, respectively.

There does not seem to correlation between the changes in violations on an approach and the timing changes that were made.

41st Street and Elmwood Avenue

In the before period, there were 28 violations noted. Sixteen of these occurred in the p.m. period. Eastbound, as expected, had 14 of the violations and westbound had 13. This accounted for all but one violation.

Some changes were made in the clearance timing, but the eastbound and westbound yellow clearance timing remained unchanged. Timing changes were made primarily to add red clearance time to left turn phases, to provide a more uniform red clearance, and the slightly reduced eastbound and westbound left turn timing.

In the after period, the number of violations was almost cut in half to 15. Ten eastbound and four westbound accounted for virtually all violations. The mid-day period had the highest number, with the PM Peak Hour having only three. In the before study, the PM Peak Hour had 16 violations.

With virtually no change in the yellow clearance periods, there is no correlation between clearance period timing and the number of violations in these before and after studies.

49th Street and Louise Avenue

There were 33 noted violations of the red light at 49th Street and Louise Avenue in the before study. There were nine southbound and five southbound left turns with the rest distributed amongst eastbound, westbound, northbound, and two other turns. Eighteen of these occurred in the p.m. There were 20 noted driver speed ups and three distractions amongst the driver behaviors.

The yellow clearance time was reduced for the left turns from 4.0 to 3.6 seconds. The yellow clearance time for the through phases was reduced from 3.9 to 3.6 seconds. Red clearance times were set to 1.7 or 2.0 seconds.

In the after study, the decreased yellow time did not seem to have an impact since there were 29 noted red light violations. Eighteen of these occurred in the p.m. with six in the a.m. and five at mid-day. There were five northbound, three southbound, four eastbound, and two westbound total. There were 13 left turn and 2 right turn violations. Four drivers were noted to have sped up and two were in queues of traffic. Thus, the number did not significantly change and the pattern by direction changed just slightly.

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Technical Memorandum No. 10

Discussion and Recommendations

Red Light Running Study
Traffic Engineering Analysis Services
Sioux Falls, South Dakota

Total Number of Violations

The first conclusion that can be drawn, which may only mirror the thoughts of those observing traffic in Sioux Falls, is that there are a significant number of violations of the red light. Most of these seem to occur when motorists enter the intersection very close to the expiration of the yellow clearance and the beginning of the all red clearance. Each of 10 intersections was observed for 4½ hours for a total of 90 hours of observation. There were 1,409 observed violations in those 90 hours. That comes out to a meaningless average of 15.6 violations per hour. The most violated intersection was 10th Street and Minnesota Avenue which in the before period had 247 violations in 4½ hours. Lowest number of observed violations was eight in the 4½-hour after study at 18th Street and Grange Avenue.

Further calculations can be made to show the extent of the red light running concern. Making some general assumptions regarding cycle lengths, phase usage at the intersections observed, and the total number of opportunities for individuals to enter an intersection either on a yellow ball or a left turn yellow arrow, the calculations show that there is one violation for every 12.8 opportunities. At 11th Street and Minnesota Avenue, the same type of calculation would indicate that a violation in the before period could be observed almost each signal cycle.

Clearance Timing

The primary purpose of this study was to determine the impact of traffic signal timing adjustments on the number of red light running violations. A review of some individual intersections would indicate that it could be significant. However, a review of all 10 together, coupled with some experience, indicates that it can have some impact, but perhaps not as vivid as might be indicated by an individual intersection. As an example, red light violations in the before and after study periods at the 10th Street and Minnesota Avenue intersection, were reduced from 247 to 57. The primary change was to adjust the yellow clearance intervals for the through traffic from 3.0 to 3.5 seconds. Through traffic violations were reduced from 140 to 38 in the two study periods.

A review of the intersection of 11th Street and Minnesota Avenue, which is a mirror image of the 10th Street intersection, shows a total reduction of 207 to 115 violations in the two study periods. The same timing changes were made, which resulted in a longer yellow clearance period for the through traffic. Through traffic violations at 11th Street and Minnesota Avenue were reduced from 138 to 71.

The third intersection on Minnesota Avenue, at 18th Street, had a similar change made in the yellow clearance interval timing. Total violations were reduced from 63 to 23 with the through traffic violation reduction of 37 to 15.

Combining the three intersections for through traffic violations only, the number of violations was reduced from 315 to 124, a 60 percent reduction. It would appear that increasing the length of yellow clearance interval would have a significant impact on the amount of violations.

At the intersection of 10th Street and Cleveland Avenue, the yellow clearance interval was increased from 3.0 to 3.6 seconds. The total violations at the intersection in the before and after studies increased from 54 to 63. Through traffic violations stayed virtually the same with 28 in the before and 25 in the after study. Thus, the increase in yellow clearance interval time does not necessarily result in an automatic reduction in violations.

At the very busy and large 41st Street and Louise Avenue intersection, the yellow clearance interval was reduced to 3.6 seconds from previously set 4.0 seconds. The total number of violations in the intersection increased from 100 to 178 with the through traffic violations increasing from 23 to 47. This would also indicate that a reduction in yellow clearance interval would result in more violations.

At 49th Street and Louise Avenue, the yellow clearance interval was similarly reduced, but the number of violations stayed virtually the same with 33 and 29 respectively counted. The through traffic violations decreased from 17 to 14, which is not statistically significant.

At 41st Street and Elmwood Avenue, there were no changes made in the yellow clearance intervals and the number of through traffic violations on 41st Street was reduced from 27 to 14.

The tentative conclusions to be drawn from the through traffic violations and their relationship to the yellow clearance period is that reasonably set yellow clearance intervals for the intersection will result in a reduced number of red light violations. The changes on Minnesota Avenue to 3.5 seconds were reasonable based on experiences in other cities. The reduction in yellow at Louise Avenue and 41st Street brought the yellow clearance interval in line with past experiences in other communities. Recognizing the size and the congestion at the intersection, traffic may drive a little more aggressively and the longer yellow clearance interval may be justified on that basis. However, uniformly increasing yellow clearance intervals will not automatically reduce the number of red light violations and more importantly, will definitely not eliminate them. In the after period study at the three intersections on Minnesota Avenue, there is still an average of nine violations per hour of through traffic only.

A similar analysis of the yellow clearance interval and the associated all red following period can be made for the left turns that have specific phases at some of the intersections. A review of the four left turn phases at 41st Street and Louise Avenue showed red light violations increased from five to fifteen, with a reduction in a yellow clearance interval of 0.5 seconds. The left turn phases on Minnesota Avenue at 10th Street and 11th Street had a 0.5 second increase in the yellow clearance interval. The number of violations was reduced from 67 to 5.

At the intersection of 10th Street and Cleveland Avenue, the yellow clearance interval was increased to 3.6 seconds for the eastbound and westbound left turn phases and the number of violations changed from eight to six. At 12th Street and Kiwanis Avenue, the yellow clearance interval for the left turns was decreased from 4.0 to 3.5 seconds, but the number of violations decreased from 28 to 23. At 49th Street and Louise Avenue, the yellow clearance intervals for the left turns were reduced from 4.0 to 3.6 seconds and the number of violations increased from nine to thirteen. Thus, there is no totally consistent change in violations with the change in yellow clearance interval timing for the left turns. However, there certainly is a potential benefit for increasing the amount of yellow clearance interval to 3.5 seconds at major intersections.

Volume of Traffic

A relationship between the number of violations and volumes of traffic does not seem to exist. The significant change in numbers of violations at some intersections make the comparison of before or after periods somewhat difficult and certainly statistically insignificant. It would be possible to do a statistical

analysis of the volumes of each of the movements within an intersection compared to the violations for that intersection, but the total number of observations may not yield a significant correlation.

Distractions

In the field analysis, some distractions were noted at a few intersections along with some location specific interference with clear sight lines to traffic signal heads. There are also some intersections that did not have pole mounted heads on the far side of the intersection. Although the data is somewhat minimal, it was not possible to demonstrate any correlation between the sight distance restrictions or lack of pole mounted heads and a number of violations occurring in that direction.

Peak Hour

A concept was advanced early in the review of red light running that motorists may tend to run red lights more frequently in the peak hour. The observations during the off peak period in many instances were higher than the peak hour period. In some directionally oriented intersections, the heavier volume in the afternoon period did not have the higher number of red light violations. Thus, while a number of correlations were attempted to be made, there is no clear or even preliminary indication that there is a direct relationship between peak hour high volumes of traffic and red light running.

Coordinated Systems

Initially, it appeared that coordinated signal systems may have a higher incidences of red light violations. The Minnesota Avenue system, especially in the downtown area, does tend to stop motorists more frequently than some of the other signal systems, just because of the frequency of signals. The significant reduction with the change in yellow clearance interval somewhat tempered that concept. It was also interesting to note that there were 68 southbound violations at 10th Street in the before period, but only 13 southbound violations at 11th Street. Similarly, northbound had 76 violations at 11th Street and only 24 at 10th Street in the before period. At 10th Street and Minnesota Avenue, there were 59 northbound left turn violations in the before period, with most of them occurring in the p.m. when southbound traffic was heaviest. There were only two in the a.m. when this turn is frequently easier to make. But the reduction in the after study was far more than anticipated and diminished the validity of the theory.

The southbound left turn at 11th Street and Minnesota Avenue, which is a mirror image and also faces heavy northbound traffic in the a.m., had only eight red light violations total in the before period with five occurring in the a.m. This was reduced to one in the after study.

While there are a number of theories and thoughts that could be advanced, statistically they cannot be proven with the data collected.

The comments made during data collection relative to driver actions were very interesting. In many instances, drivers sped up to travel through the intersection at the end of the yellow clearance period and became red light violators. This phenomena occurs at any intersection being observed whether for a red light running study or for any other purpose. This tends to justify the development of a standard yellow clearance in an urban section, but more importantly, justifies the inclusion of all red clearance intervals behind all phases at an intersection.

Many of the observations of left turn violations indicated that motorists were caught in traffic and when the queue of left turning vehicles moved through the intersection on the clearance interval, traffic which may have been behind the stop line decided to join the queue of traffic and travel through the left turn becoming a red light violator. This is possible only in permissive left turn conditions. At intersections with red, yellow, and green left turn arrows, such as 41st Street and Louise Avenue, there appeared to be a tendency of motorists to follow traffic through the yellow and into the red clearance periods recognizing that opposing traffic (or other phase left turning traffic depending upon signal cycles) would be waiting for this queue of traffic to travel through the intersection.

These types of violations are clearly a driver decision where there is adequate opportunity to wait for the beginning of the next green interval for their approach.

Equally disconcerting is the significant number of distracted motorists traveling into the intersection. Of the 1,409 observed violations, 35 violations were referenced to cell phone, distraction, or deliberate. The deliberate category included motorists who stopped on a red light and then drove through the intersection. Another 343 were noted as "sped up."

Recommendations

There is an apparent correlation between providing an adequate yellow clearance interval for today's traffic and the number of red light violators. This is demonstrated by both the increases and decreases in yellow clearance interval. It appears that an interval of approximately 3.5 seconds for many of the urban streets with 30 mph speed limits is desirable. For major intersections, such as 41st Street and Louise Avenue, it may be desirable to provide a slightly longer interval for left turn phases recognizing higher approach speeds. At all intersections and for all movements, the number of red light violators indicates the desirability of providing red clearance interval.

Whenever clearance intervals are increased, there is concern that motorists will recognize the increase and take further advantage of the yellow and all red clearance intervals. To review this, it is suggested that a further follow-up study of the three intersections on Minnesota Avenue, and the 41st Street and Elmwood Avenue, 41st Street and Louise Avenue, 49th Street and Louise Avenue, and 10th Street and Cleveland Avenue intersections be again observed through the same timeframes in approximately two months.

It is also apparent with the high number of red light violations, even in the after period, that violations will not be eliminated. The driver behavior, both those speeding up and those oblivious to the clearance interval introduction, demonstrates that some enforcement actions may be desirable. However, red light violations are difficult for enforcement personnel. Generally, the enforcement officer needs to be able to clearly witness the violation and then be able to pursue and stop the violator. At a busy intersection in peak hours, this is often extremely difficult to do. Some communities have successfully employed enforcement teams to work a specific high volume violation direction. Instead of having a very noticeable marked squad car in a specific location in order to be able to pursue the violator, an unmarked or enforcement officer on foot at the intersection will make the observation and radio to other officers a block away to stop a specific vehicle that has violated a red light. This works only in one direction and requires two to three officers.

The authorized utilization of red light running video cameras will significantly reduce the personnel requirements for red light violations. While there are a number of other issues associated with it, it is by far the most efficient method of both establishing opportunities for enforcement actions and to inhibit chronic violators of red light running. With the number of observations made of individuals knowingly driving through a red light, such actions may be justified and the inhibiting feature may be the most beneficial.

There are other correlations that may be possible to make through the information collected. However, the ones which seem to have opportunities for mitigation, such as signal timing, signal

visibility, coordinated signal system green bands, and time of day/congestion seem to have been addressed, as well as possible with the information.

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