

32nd Avenue

Signal Coordination Study



Prepared For:

- Grand Forks-East Grand Forks MPO
- City of Grand Forks
- North Dakota Department of Transportation

Prepared By:

- Alliant Engineering, Inc.
233 Park Avenue South,
Suite 300
Minneapolis, MN 55415

September 15, 2008



Table of Contents

Table of Contents	i
List of Figures	ii
List of Tables.....	ii
List of Appendices	iii
 Executive Summary.....	 ES-1
Interconnect System Summary	1
Project Description and Objective	1
Elements of Study	2
Before/After Travel Time Results	2
Project Benefit	3
Key Project Highlights.....	4
Recommendations.....	5
 1.0 Introduction	 1
1.1 Project Objective.....	1
1.2 Interconnect Zone and Intersection Summary	1
1.3 Elements of Study and Purpose	2
 2.0 Existing Conditions.....	 4
2.1 Existing Roadway, Traffic and Safety Characteristics	4
2.2 Field Studies.....	12
2.3 Model Calibration	13
2.4 Traffic Operation Analysis	14
 3.0 Signal Timing Optimization.....	 19
3.1 32 nd Avenue/Washington Street Coordination Feasibility Review	19
3.2 Signal Operation and Optimized Timing Plan Strategy	23
3.3 Optimized Timing Plan Progression Evaluation.....	27
3.4 Signal Timing Implementation	28
3.5 Final Timing Plan Summary	28
3.6 Traffic Operation Analysis	29

4.0 Project Benefit Analysis.....	32
4.1 Before/After Travel Time Comparison.....	32
4.2 Before/After Average Approach Delay Comparison.....	33
4.3 Benefit/Cost Analysis	34
4.4 Key Project Highlights.....	39
5.0 Recommendations	41
5.1 Immediate Recommendations.....	41
5.2 Near and Long Range Recommendations.....	42

List of Figures

Figure 1. Project Location.....	3
Figure 2. 32 nd Avenue Intersection Location.....	6
Figure 3. 32 nd Avenue Weekday Daily Volume Profile – At 38 th Street.....	8
Figure 4. 32 Avenue Weekend Daily Volume Profile – At 38 th Street	8
Figure 5. 32 nd Avenue Vehicle Speed Characteristics.....	9
Figure 6. Crash Type Percentages –vs- Citywide Average	12

List of Tables

Table ES- 1. Before/After Travel Time Comparison (I-29 West Ramp to 20 th Street) – AM Peak Period.....	ES-3
Table ES- 2. Before/After Travel Time Comparison (I-29 West Ramp to 20 th Street) – PM Peak Period.....	ES-3
Table ES- 3. Measures of Effectiveness – Overall Net Daily Comparison	ES-4
Table ES- 4. 32 nd Avenue Signal Optimization Benefit/Cost Ratio	ES-4
Table 1. Interconnect Zone and Intersection Summary	2
Table 2. Existing Condition Signal Timing Plans	5
Table 3. Heavy Truck Percentage.....	9
Table 4. 32 nd Avenue Crash Type Summary	11
Table 5. Saturation Flow Rate Study	13
Table 6. Intersection Approach Delay Comparison.....	14
Table 7. LOS Criteria.....	15
Table 8. Existing Intersection Level of Service.....	16
Table 9. Existing Arterial Level of Service	17
Table 10. Coordinability Factor (CF) Summary.....	20
Table 11. Overall Network Delay Comparison – Coordination Feasibility Review	21

Table 12. Overall Network Stops Comparison – Coordination Feasibility Review	21
Table 13. Mainline Travel Time (s) Comparison - Coordination Feasibility Review	21
Table 14. 32 nd Avenue/Washington Street Overall Intersection Delay Comparison - Coordination Feasibility Review	22
Table 15. 32 nd Avenue Cycle Length Summary	26
Table 16. Optimized Timing Plan Progression Evaluation – I-29 West Ramp to 20 th Street	27
Table 17. Final Signal Timing Plan Summary – TOD Schedule.....	28
Table 18. Final Intersection Level of Service	30
Table 19. Final Arterial Level of Service	31
Table 20. Before/After Travel Time Comparison (I-29 West Ramp to 20 th Street) – AM Peak Period.....	33
Table 21. Before/After Travel Time Comparison (I-29 West Ramp to 20 th Street) – PM Peak Period	33
Table 22. Before/After Average Approach Delay Comparison.....	34
Table 23. Unit Benefit.....	35
Table 24. Measures of Effectiveness – Overall Net Daily Comparison	36
Table 25. Measures of Effectiveness – Net Average Daily MOE Reduction Breakdown.....	37
Table 26. Annual Net Benefit (dollar)	38
Table 27. 32 nd Avenue Signal Optimization Benefit/Cost Ratio	39

List of Appendices

- Appendix A: Travel Time Comparison (Field vs. Model)
- Appendix B: Minimum Green, Clearance and Pedestrian Interval Timings
- Appendix C: Final Signal Timing Coordination Parameters by Intersection
- Appendix D: Benefit/Cost Analysis

Executive Summary

The following section provides a brief overview and highlights key results obtained as part of the 32nd Avenue Coordination Study completed for the Grand Forks-East Grand Forks Metropolitan Planning Organization (MPO), City of Grand Forks and the North Dakota Department of Transportation (NDDOT).

Interconnect System Summary

The 32nd Avenue Coordination Study included the existing interconnect zone between I-29 and 20th Street – Interconnect Zone 151. Zone 151 consists of the following eight intersections:

- 32nd Avenue at I-29 West Ramp
- 32nd Avenue at I-29 East Ramp
- 32nd Avenue at 38th Street
- 32nd Avenue at 34th Street
- 32nd Avenue at 31st Street
- 32nd Avenue at Columbia Road
- 32nd Avenue at 24th Street
- 32nd Avenue at 20th Street

As part of the project, an evaluation of coordination strategies was conducted for the 32nd Avenue/Washington Street intersection.

Project Description and Objective

32nd Avenue is an east/west Arterial, also designated as US 81B, and a primary commercial destination corridor. The Grand Forks/East Grand Forks MPO has identified a need to maintain a high level of service and to ensure optimal performance. As such, 32nd Avenue is scheduled to receive new optimized timing plans. The objective of the coordination study is to review the existing conditions, optimize the signal system timing, implement the new timing plans and fine-tune in the field. Specific goals of the project include:

- Improve progression and reduce delays for mainline movements along 32nd Avenue.
- Evaluate coordination strategies at the 32nd Avenue/Washington Street intersection.

Five new timing plans were developed, implemented and field fine tuned on a time of day (TOD) schedule. As part of the project, “before” and “after” measures of effectiveness (MOE) data were collected to estimate the benefits of the signal optimization.

Elements of Study

An evaluation of the existing condition was completed. Key components of the existing conditions include collection of intersection and traffic volume characteristics, signal timing characteristics, development and calibration of the traffic model and collection/evaluation of current measures of effectiveness. The traffic signal optimization included developing TOD timing plans consisting of new cycle lengths, intersection splits and offsets for each of the signalized corridors and intersections.

After implementation of the timing plans, Alliant Engineering and the City of Grand Forks staff conducted field reviews during the month of July 2008. During the field reviews, many adjustments were made to the optimized timing plans to further improve traffic flow and minimize cross-street delays. Following the completed implementation of the signal timing plans, field studies were conducted for the “after” condition and compared to the “before” conditions. A benefit/cost analysis was also completed to evaluate the overall cost-effectiveness of the implemented signal timing plans.

The purpose of this document is to present the results of the 32nd Avenue Coordination Study, as will be discussed in the following sections:

- Existing Conditions (Section 2.0)
- Signal Timing Optimization (Section 3.0)
- Project Benefit Analysis (Section 4.0)
- Recommendations (Section 5.0)

Before/After Travel Time Results

A comparison of the “before” and “after” travel time field studies was made as shown in the following. **Table ES-1** provides an overall summary of the travel time runs and percent improvement accomplished for 32nd Avenue (I-29 West Ramp to 20th Street) during the AM peak period. **Table ES-2** provides an overall summary of the travel time runs and percent improvement accomplished for 32nd Avenue (I-29 West Ramp to 20th Street) during the PM peak period.

**Table ES- 1. Before/After Travel Time Comparison (I-29 West Ramp to 20th Street)
– AM Peak Period**

Westbound 32nd Avenue

	Free Flow		AM Peak Hour (730 - 830)			AM Overall (700 - 900)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- 20th Street to I-29 West Ramp	3	7	5 0	4 3	19%	4 48	4 5	15%

Eastbound 32nd Avenue

	Free Flow		AM Peak Hour (730 - 830)			AM Overall (700 - 900)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- I-29 West Ramp to 20th Street	3	0	4 45	3 39	23%	4 44	3 41	22%

1. Ulteig Engineers field collected travel time runs in June, 2008 (before) and July, 2008 (after).

**Table ES- 2. Before/After Travel Time Comparison (I-29 West Ramp to 20th Street)
– PM Peak Period**

Westbound 32nd Avenue

	Free Flow		PM Peak Hour (445 - 545)			PM Overall (300 - 600)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- 20th Street to I-29 West Ramp	3	7	5 22	4 46	11%	5 30	5 0	9%

Eastbound 32nd Avenue

	Free Flow		PM Peak Hour (445 - 545)			PM Overall (300 - 600)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- I-29 West Ramp to 20th Street	3	0	6 34	4 38	29%	6 8	4 46	22%

1. Ulteig Engineers field collected travel time runs in June, 2008 (before) and July, 2008 (after).

Project Benefit

A benefit/cost analysis was completed to establish the annual economic savings incurred as a result of the 32nd Avenue Coordination Study. Typical measures of effectiveness (MOE) used in estimating the benefit of signal optimization projects include approach

vehicle delay, vehicle stops and fuel consumption. **Table ES-3** illustrates the overall daily “before” and “after” MOE comparison and percent improvement.

Table ES- 3. Measures of Effectiveness – Overall Net Daily Comparison

MOE	Monday - Thursday				Friday				Saturday			
	Before	After	Net Reduction	Percent Improvement	Before	After	Net Reduction	Percent Improvement	Before	After	Net Reduction	Percent Improvement
Stops (no. of veh)	113,313	87,636	25,678	22.7%	146,724	115,610	31,114	21.2%	109,642	83,428	26,215	23.9%
Delay (hr)	951	886	65	6.9%	1,408	1,332	77	5.5%	1,136	1,083	52	4.6%
Fuel Consumption (gal)	5,871	5,287	583	9.9%	7,764	7,138	626	8.1%	3,166	2,874	292	9.2%
Dilemma Zone (veh)	6,462	4,125	2,337	36.2%	7,349	4,981	2,369	32.2%	4,690	3,706	985	21.0%

Based on the study results, an annual benefit is estimated at approximately 1.3 million dollars, which includes an estimated annual savings of 164,000 gallons of gasoline. The benefit/cost ratio is computed based on the comparison between the annual net benefit and the total project cost, as shown in **Table ES-4**. As shown, the 32nd Avenue Coordination Study resulted in a benefit/cost ratio of approximately **31:1** considering only one year of benefit.

Table ES- 4. 32nd Avenue Signal Optimization Benefit/Cost Ratio

Segment	Number of Intersections	Total Cost / Zone (\$)	Benefit (\$)	Benefit-Cost Ratio
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street)	8	\$43,000	\$1,336,453	31

Key Project Highlights

The project benefit analysis estimates the 32nd Avenue Coordination Study resulted in a 31:1 benefit/cost ratio and an estimated annual economic savings of 1.3 million dollars, which includes an estimated annual savings of 164,000 gallons of gasoline (average of 600 gallons daily). A number of factors contribute to the exceptional project benefit:

- A significant improvement in travel flow was obtained along 32nd Avenue. Mainline progression was significantly improved, while intersection delays were balanced and overall reduced.
- During the AM peak period. The eastbound travel time was improved by 23 percent and 19 percent in the eastbound and westbound directions,

respectively. The overall travel time savings was found to be approximately one minute (two-mile long corridor).

- During the PM peak period, the eastbound delays and travel times were improved by 29 percent and 11 percent in the eastbound and westbound directions, respectively. The overall travel time savings was found to be approximately two minutes in the eastbound direction. Considering the corridor is only two-miles in length, this is a fairly substantial time savings.
- Overall, an estimated 25 percent reduction in total vehicle stops along the corridor was found.

Based on field observations, travel time studies and the benefit/cost analysis, other key project successes include the following:

- The City of Grand Forks investment into the implementation of “protected/permissive” signal phasing at 38th Street, 34th Street, 31st Street and 20th Street contributes greatly to the improvement of intersection efficiency and reduction of motorist delays.
- Successful implementation of lead-lag left turn operation at I-29 West Ramp, I-29 East Ramp, Columbia Road and 24th Street. Although this is not a new operating strategy, it is new to the Grand Forks area. Lead-lag left turn phase operation contributes significantly to the improved mainly vehicle progression along 32nd Avenue.
- An event plan was developed and fine-tuned in the field to accommodate the Alerus Center. The exiting plan was developed in the field during a recent University of North Dakota Football game to provide additional southbound green time for 38th Street and to provide progression for motorists destined to I-29.

Recommendations

As part of the 32nd Avenue Coordination Study a comprehensive operation review was completed.

Immediate Recommendations

The City of Grand Forks has dedicated resources to improving traffic flow along 32nd Avenue. The following recommendations were or will be implemented as part of the Coordination Study:

- Installation of upgraded signal controllers. The City of Grand Forks replaced all 170 type signal controllers with new Econolite 2070 controllers and the Oasis software. Upgrading the signal controllers and the software revisions

allows for flexibility and compatibility between intersections along the interconnected corridor.

- The addition of northbound/southbound “protected/permissive” left turn arrows at both 38th Street and 34th Street. The 38th Street left turn arrows will be activated in September 2008. The conversion from “protected” only to “protected/permissive” left turn arrows on the eastbound and westbound approaches at both 31st Street and 20th Street. The eastbound/westbound “protected/permissive” left turn arrow conversion is expected to occur in August/September 2008. However, it should be noted there may be a potential change in intersection safety characteristics with the conversion of the signal phasing from “protected” only to “protected/permissive.” Based on the FHWA Issue Brief research data, the left turn related crashes may increase 65 percent at each intersection.
- The video detection camera at the 31st Street intersection was repaired (identified as an existing hardware issue).
- Southbound vehicle detection issues at 32nd Avenue/38th Street intersection will be repaired. The City of Grand Forks will be installing a video detection camera and making it operational in September 2008.
- Re-programming of all local intersection signal controllers. As part of the signal timing implementation, new minimum green times, vehicle clearance intervals, pedestrian timing intervals, right turn lane delayed detection timers and controller configuration settings were inputted. Re-programming of the controllers results in consistency, some intersection efficiency gains and standardization of the signal optimization process. As part of this effort, the vehicle re-service issue noted at the 24th Street intersection was corrected.

Near and Long Range Recommendations

During the field implementation and signal timing review process, a few signal operation or roadway improvements were identified for further review and/or consideration. The suggested geometric improvements may require further feasibility review.

Geometric Improvements

The following geometric improvements are expected to result in a substantial improvement in intersection operation efficiency.

- 32nd Avenue at 38th Street - construct an exclusive 250 foot (plus taper) southbound right turn lane.
- 32nd Avenue at 34th Street – construct an exclusive 250 foot (plus taper) southbound right turn lane. Extend the westbound left turn lane to provide 300 feet of storage (may need to shorten eastbound left turn lane at 31st Street).
- 32nd Avenue at Columbia Road – construct a second northbound and westbound left turn lane.

- 32nd Avenue at 31st Street – lengthen the westbound left turn lane to provide 300 feet of storage. The existing storage length is sufficient from a capacity standpoint; however, its short length is causing diverging/braking vehicles to slow in the through lane disrupting the traffic flow.

The 34th Street and 38th Street right turn lane improvements should be prioritized in the near future. The Columbia Road and 31st Street geometric improvements are of lesser importance and could be prioritized on a longer range schedule.

Signal Detection Improvements

To improve safety and operational efficiency during free mode operation, advanced dilemma zone detection (mainline approaches only) should be installed at 38th Street, 34th Street, 31st Street, Columbia Road, 24th Street and 20th Street. The advanced loop or video detection should be placed at 250 feet for a 40 mph posted speed limit.

Future Signal Coordination or Timing Adjustments

Consideration of cross-coordination with north/south Columbia Road and north/south Washington Street should be made. Based on the coordination feasibility review conducted as part of this project, the following order of priority should be given:

- The optimal cycle lengths should be selected for 32nd Avenue, Columbia Road and Washington Street individually.
- Coordination priority should be given to northbound and southbound phases at the 32nd Avenue/Washington Street intersection.
- At 32nd Avenue/Columbia Road, priority should be given to the eastbound/westbound 32nd Avenue phases.
- Where optimal cycle lengths are similar or close for both 32nd Avenue and Washington Street, a common cycle length should be selected. Provide inter-zone cross-coordination (using master clock scheduler in Translink), with northbound/southbound Washington the coordinated phases during the weekday and consider the eastbound/westbound directions the coordinated phases on the weekend.
- Where optimal cycle lengths are similar or close for both 32nd Avenue and Columbia Road, a common cycle length should be selected. Provide inter-zone cross-coordination (using master clock scheduler in Translink).

Future signal timing adjustments along 32nd Avenue may include the following:

- Consider the implementation of a specific Holiday timing plan. A review of the Saturday traffic conditions in December should be conducted to determine the need for timing adjustments or a separate plan.

- Consider the implementation of an event specific timing plan to assist traffic control officers at the 32nd Avenue/38th Street intersection.
- Continue to monitor the TOD transitions and adjust as traffic conditions warrant.

Roadway Signing and Other

A few other suggestions include:

- Install a speed limit sign along 32nd Avenue between I-29 East Ramp and 38th Street.
- Review the mast arm signing at each intersection to ensure a consistent use of the “Left Turn Yield on Green Ball” sign.
- Continue monitoring the crash history at the 32nd Avenue/38th Street, 34th Street, 31st Street and 20th Street intersections upon completion of the new signal timing plans.

Signal Timing Management Program

The City of Grand Forks operates approximately 60 signalized intersections. Under the City’s jurisdiction there are six major signalized arterials. As shown with the 32nd Avenue Coordination Study, there is a significant traffic operation benefit to the motoring public for a fairly low cost. Although infrastructure improvements may be warranted in locations, many deficiencies may actually be corrected through maintaining optimized signal timing and efficient corridor operation. Considering the typically large benefit to cost ratio of signal timing projects, maintaining efficient corridor operation should be given a high priority. The following should be considered:

- Develop a program (and funding source) for regular retiming of the major signalized corridors (e.g., Demers, Gateway, Washington, Columbia, 32nd Avenue, downtown, etc.). Signal optimization degrades linearly over time due to growth and changes in traffic patterns. Depending upon growth, importance and actual changes in traffic characteristics, fully re-optimizing the system should occur every three to five years.
- To extend the life cycle of newly optimized timing plans, develop a program for managing the corridor. This would include scheduling bi-annual field reviews and fine-tuning.
- Develop a process for managing and record keeping of the current signal timing plans and parameters. This would include a checklist procedure for ensuring the controller, Synchro file, Trankslink, intersection file and cabinet log book is kept up to date and consistent any time a change is made.
- Develop a checklist and procedure for addressing citizen complaints.

1.0 Introduction

The 32nd Avenue Coordination Study includes the segment of 32nd Avenue, also designated US 81B, between the Interstate (I)-29 West Ramp intersection and Washington Street. The 32nd Avenue corridor serves as a primary east/west route between the interstate and the southern portion of Grand Forks, but also serves as a key link to the many adjoining local commercial destinations. Key adjoining land uses accessing 32nd Avenue include the Columbia Mall, Wal-Mart Super Center and other big box retail centers.

In addition to the ramp terminals at I-29, 32nd Avenue intersects with two major north/south roadways at Columbia Road and Washington Street, creating critical intersections during peak periods.

The geographic extent of the project location and 32nd Avenue corridor with respect to greater Grand Forks area is documented in **Figure 1**.

1.1 Project Objective

32nd Avenue is an east/west Arterial and a primary commercial destination corridor. The Grand Forks/East Grand Forks Metropolitan Planning Organization (MPO) has identified a need to maintain a high level of service and to ensure optimal performance. As such, 32nd Avenue is scheduled to receive new optimized timing plans. The objective of the coordination study is to review the existing conditions, optimize the signal system timing, implement the new timing plans and fine-tune in the field. Specific goals of the project include:

- Improve progression and reduce delays for mainline movements along 32nd Avenue.
- Evaluate coordination strategies at the 32nd Avenue/Washington Street intersection.

Five new timing plans were developed, implemented and field fine tuned on a time of day (TOD) schedule. As part of the project, “before” and “after” measures of effectiveness (MOE) data were collected to estimate the benefits of the signal optimization.

1.2 Interconnect Zone and Intersection Summary

The 32nd Avenue Coordination Study included the existing interconnect zone between I-29 and 20th Street, and an evaluation of the 32nd Avenue/Washington Street intersection.

Table 1 summarizes the signalized intersections, existing interconnect zones and existing operation characteristics.

Table 1. Interconnect Zone and Intersection Summary

Zone	System ID	Intersection	Phase	Responsible Agency	Controller	Existing Operation	Hardware / Communication Issues
151	157	32nd Avenue at I29 West Ramp	5	NDDOT	2070	MANUAL (FREE)	--
	156	32nd Avenue at I29 East Ramp	5	NDDOT	2070	MANUAL (FREE)	--
	155	32nd Avenue at 38th Street	5	Grand Forks	2070	MANUAL (FREE)	--
	154	32nd Avenue at 34th Street	8	Grand Forks	2070	MANUAL (FREE)	--
	153	32nd Avenue at 31st Street	5	Grand Forks	2070	MANUAL (FREE)	WB Camera Not Working
	152	32nd Avenue at Columbia Road	8	Grand Forks	2070**	MANUAL (FREE)	--
	150	32nd Avenue at 24th Street	5	Grand Forks	2070	MANUAL (FREE)	Detection Issue (Phase Recall)
	149	32nd Avenue at 20th Street	5	Grand Forks	2070	MANUAL (FREE)	--
222	14	32nd Avenue at Washington Street	8	Grand Forks	170	TOD (COORD)	--

** Master Controller Location

At the onset of the project, hardware issues were noted at the 32nd Avenue/31st Street and 32nd Avenue/24th Street intersections. As part of the project, these items will be reviewed and an evaluation of coordination strategies will be conducted for the 32nd Avenue/Washington Street intersection.

1.3 Elements of Study and Purpose

An evaluation of the existing condition was completed. Key components of the existing conditions include collection of intersection and traffic volume characteristics, signal timing characteristics, development and calibration of the traffic model and collection/evaluation of current measures of effectiveness. The traffic signal optimization included developing TOD timing plans consisting of new cycle lengths, intersection splits and offsets for each of the signalized corridors and intersections.

After implementation of the timing plans, Alliant Engineering and the City of Grand Forks staff conducted field reviews during the month of July 2008. During the field reviews, many adjustments were made to the optimized timing plans to further improve traffic flow and minimize cross-street delays. Following the completed implementation of the signal timing plans, field studies were conducted for the “after” condition and compared to the “before” conditions. A benefit/cost analysis was also completed to evaluate the overall cost-effectiveness of the implemented signal timing plans.

The purpose of this document is to present the results of the 32nd Avenue Coordination Study, as will be discussed in the following sections:

- Existing Conditions (Section 2.0)
- Signal Timing Optimization (Section 3.0)
- Project Benefit Analysis (Section 4.0)
- Recommendations (Section 5.0)



32nd Ave Coordination Study

Figure 1
Project Location

2.0 Existing Conditions

An evaluation of the existing conditions was completed. Key components of the existing conditions include:

- Collection of corridor, intersection and traffic volume characteristics,
- Conducting field studies,
- Development and calibration of the traffic model; and
- Evaluation of current measures of effectiveness.

2.1 Existing Roadway, Traffic and Safety Characteristics

The following sections document the key characteristics of the existing conditions.

2.1.1 Interconnect Zone Summary

The 32nd Avenue Coordination Study included developing an existing condition traffic model for one complete interconnect zone – Zone 151. **Figure 2** documents the location of each signalized intersection, intersection spacing and speed limit. The master controller is located at the 32nd Avenue/Columbia Road intersection and interconnect is currently provided between I-29 and 20th Street. The following summarizes the existing interconnect:

- Fiber optic cable between I-29 West Ramp and 38th Street.
- Wireless radio between 38th Street and 31st Street.
- Wireless radio between 34th Street and 31st Street.
- Fiber optic cable between 31st Street and Columbia Road.
- Fiber optic cable between 31st Street and 20th Street (2nd channel).

Currently Zone 151 operates in Manual Free mode and are fully actuated signal systems.

The 32nd Avenue/Washington Street intersection is the furthest south signalized intersection on the Washington Street interconnect zone (referred to as Zone 222). Currently this intersection operates in coordination approximately 15 hours of the day. There is not any communication available between 20th Street and Washington Street.

2.1.2 Lane Geometries, Signal Phasing, and Signal Timing

Aerial photography and traffic signal layouts were acquired from the City of Grand Forks for each of the intersections mentioned previously (**Table 1**). The aerials and signal

layouts were used to establish the lane geometry and signal phasing for each of the intersections. Field reviews of each of the intersections were conducted to confirm this data as well as storage lengths for each of the turn bays.

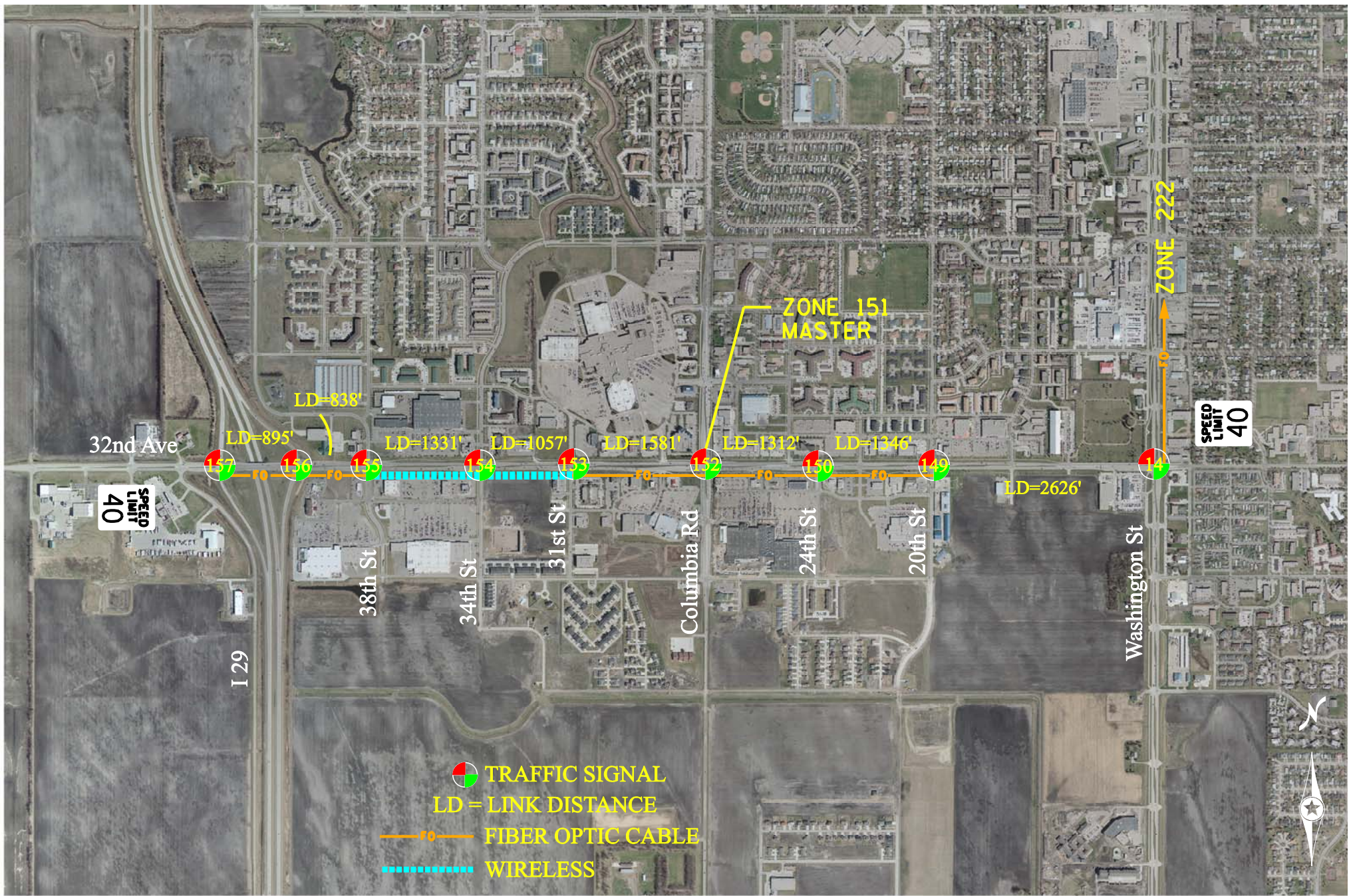
Existing traffic signal timings were obtained from the City of Grand Forks. Key parameters include; minimum green times, clearance intervals, pedestrian intervals and coordination data (cycle length, offset, splits) and time of day (TOD) settings. **Table 2** summarizes the existing daily timing plans for each of the zones. Based on TOD plans provided, the typical timing plans were determined for the AM peak, AM off-peak, midday periods, PM peak and PM off-peak periods.

Table 2. Existing Condition Signal Timing Plans

	Operation	Time	Plan	Cycle Length (s)
Zone 151 (32nd Avenue - I-29 to 20th Street)	FREE	1200 AM to 1159 PM	--	--
Zone 222 (Washington Street - 32nd Avenue to 5th Avenue)	TOD	715 AM to 200 PM	8	105
		200 PM to 600 PM	9	115
		600 PM to 1045 PM	8	105
		1045 PM to 715 AM	FREE	FREE

2.1.3 Traffic Volumes

The MPO conducted turning movement volume counts at each of the nine intersections between the months of April and June 2008. Turning movement counts were collected for a continuous 11 hour time period (7 AM to 6 PM). In addition to turning movement counts, tube counts were conducted for seven continuous days (15-minute interval) along 32nd Avenue, between 38th Street and 34th Street.



The peak hour was identified for each of the three time periods (AM, midday and PM). The AM, midday and PM peak hour traffic volumes used in the Synchro7.0 model were developed by multiplying the highest 15-minute interval within the respective intersections peak hour, for each movement, by four. This method results in the maximum peak volume for each movement, necessary for developing movement splits. Considering each movement is utilizing the maximum peak volume, the peak hour factor is set to 1.0. To support the signal timing evaluation, a SimTraffic7.0 model was developed for the AM and PM peak hours. To more accurately replicate the corridor traffic conditions, a 15-minute interval traffic data set utilizing the raw intersection turning movement volumes were created for both the AM and PM peak hours.

For the AM, mid-day and PM off peak periods, traffic volume cases were developed in consideration of the particular corridor's general daily hourly volume trend. **Figure 3** and **Figure 4** illustrate the daily traffic volume profile existing along 32nd Avenue and graphically shows the volume case boundaries for both weekday and weekend conditions. In general, the traffic volume cases include an AM off peak, AM peak, late morning/mid-day low, mid-day peak, PM off peak (before peak), PM Peak and PM off peak (after peak) and were developed specifically for the corridor. The turning movement volume collected during the off peak periods were used to estimate representative volume levels (i.e., using either the average or the maximum multiplied by four for the volume scenario case).

The intersection turning movement counts were collected over a several month period. As such, the volumes between intersections were balanced to account for the inherent volume demand differences. Balancing of intersection volumes is critical in developing a calibrated traffic model and making reasonable comparison to field observed conditions.

As illustrated by the traffic volume profile, 32nd Avenue is primarily a commercial destination corridor with limited commuter attraction. There is a short AM peak period before dropping to the mid morning low period; however, around 10:30 AM traffic volumes begin to rise and continue to grow through the PM peak period. Consistent with commercial destination corridors, traffic volumes are relatively directionally balanced. Interestingly, traffic volumes collected on Friday were found to be considerably higher than those found during the beginning of the week (i.e., Monday through Thursday).



Figure 3. 32nd Avenue Weekday Daily Volume Profile – At 38th Street

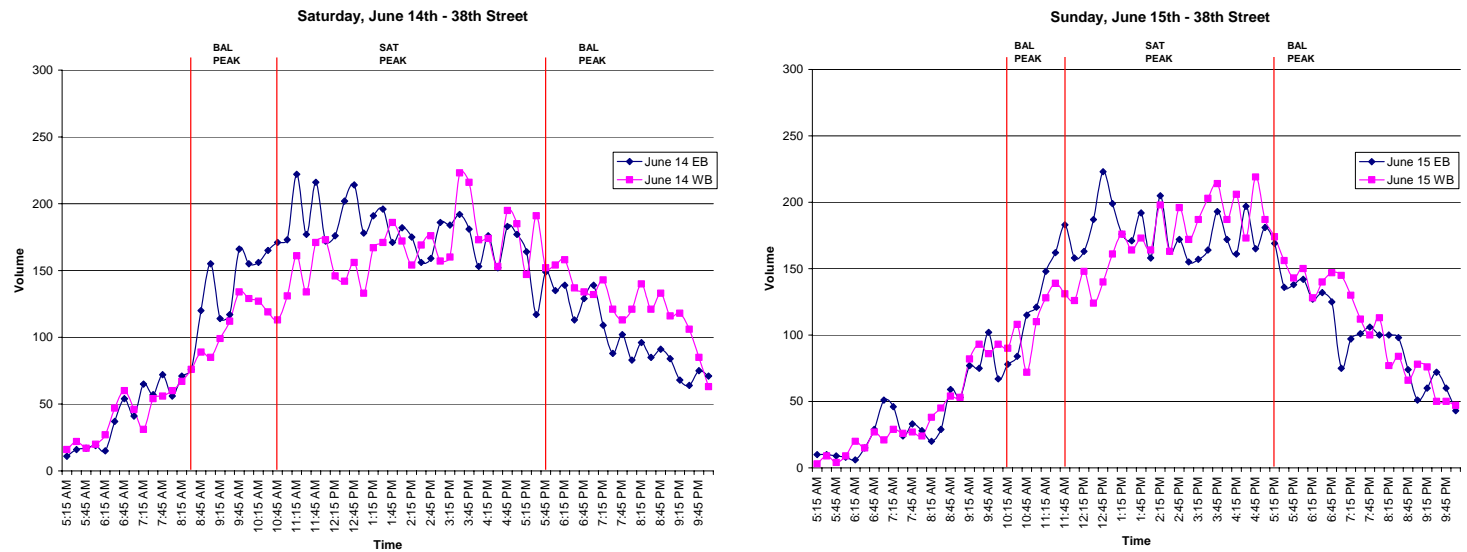


Figure 4. 32 Avenue Weekend Daily Volume Profile – At 38th Street

2.1.4 Heavy Commercial Vehicle Percentage

Existing heavy commercial vehicle volumes were field collected at each intersection as part of the intersection turning movement counts. The heavy vehicles were classified as single-unit or those consisting of more than three axles or being a truck and tractor trailer. The field collected data was utilized to estimate heavy vehicle percentages for the

mainline and cross streets for AM, off-peak and PM peak periods Synchro7.0 and SimTraffic7.0 models. In addition, the commercial truck percentages will be used to estimate the time value of vehicle delay as part of the benefit/cost analysis. The corridor average truck percentages are summarized in **Table 3**.

Table 3. Heavy Truck Percentage

Volume Case	Weekday			Weekend		
	Cross-street	Mainline	Overall	Cross-street	Mainline	Overall
AM PEAK	1.2%	3.1%	2.5%	--	--	--
BAL LOW	2.5%	3.5%	3.2%	--	--	--
BAL PEAK	1.0%	2.0%	1.7%	0.4%	0.5%	0.5%
PM OFF 1	1.3%	2.0%	1.8%	--	--	--
PM OFF 2	0.9%	1.6%	1.4%	--	--	--
PM PEAK	0.4%	0.6%	0.5%	--	--	--

2.1.5 Speed Characteristics

The Grand Forks-East Grand Forks MPO conducted a vehicle speed study on 32nd Avenue. Results of the speed study are shown in **Figure 5**. As shown, the 85th percentile speed was found to be 38 miles per hour (mph) and approximately 13 percent of the motorists were traveling in excess of the posted 40 mph speed limit. The median speed was found to be approximately 30 mph. It should be noted, the speed study found a few motorists traveling in excess of 60 mph (less than 1 percent).

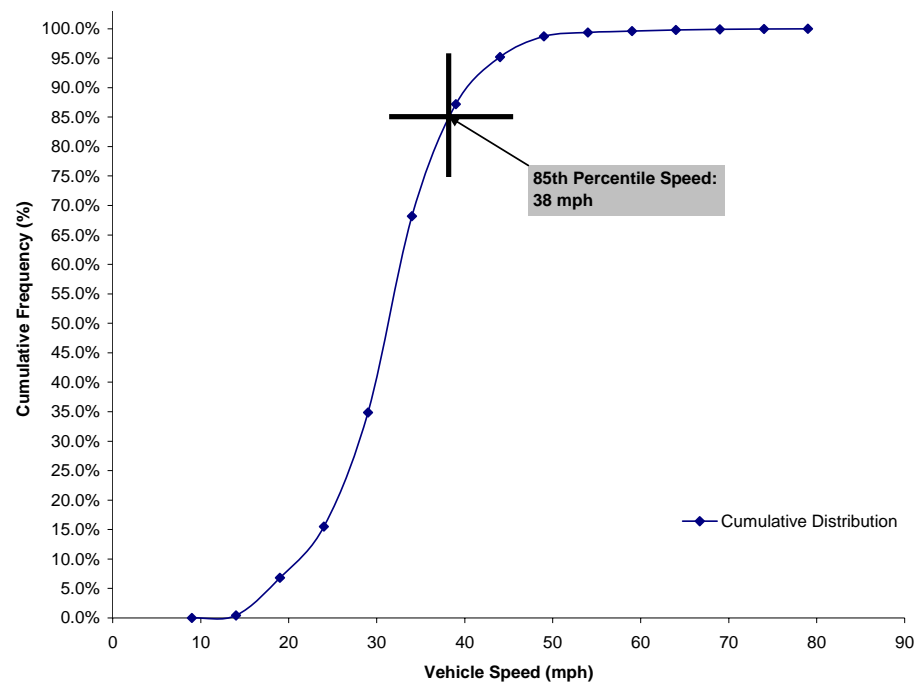


Figure 5. 32nd Avenue Vehicle Speed Characteristics.

2.1.6 Crash Characteristics

The MPO provided intersection crash data for the years 2005 to 2007. Evaluation of current crash characteristics may identify certain patterns correctable by signal timing or signal phasing changes. The intersection crash types are tabulated in **Table 4**, on the following page. **Figure 6**, on Page 11, illustrates the overall corridor crash type percentage and provides a comparison to the City of Grand Forks citywide average. It should be noted, the Grand Forks crash database did not differentiate between right angle and left turn into opposing traffic crash types. It appears all crashes of this type were recorded as right angle. For the 32nd Avenue corridor, each right angle crash was reviewed and segregated by left turn or right angle based on the vehicle direction information provided. This is an estimate, but provides a reasonable comparison of the two crash types. However, the citywide average crash type percentages do not reflect the segregated left turn and right angle crash types. Key observations include:

- Along the 32nd Avenue corridor, the data indicates that the majority of intersection crashes are rear-ends. This is typical of signalized intersections.
- The left turn into opposing traffic and right angle crash types were found to be the second and third most prominent overall crash types along the corridor.
- At the 32nd Avenue/38th Street intersection, the left turn related crash type was found to represent 11 of the 19 total intersection crashes, which is significant. Based on a review of the crash data, the primary directions involved were the eastbound/westbound mainline movements (8 of 11). Nearly all of these crashes occurred between 10:00 AM and 7:00 PM.
- Similarly, left turn into opposing traffic was found significant at the 32nd Avenue/34th Street intersection (10 of 20 total intersection crashes). Eight of the 10 left turn crashes occurred on the mainline 32nd Avenue eastbound/westbound approaches. Again, nearly all occurred during the 10:00 AM and 7:00 PM time period.
- Over the past three years there have been no reported fatalities and injury related crashes were found to be approximately 33 percent.

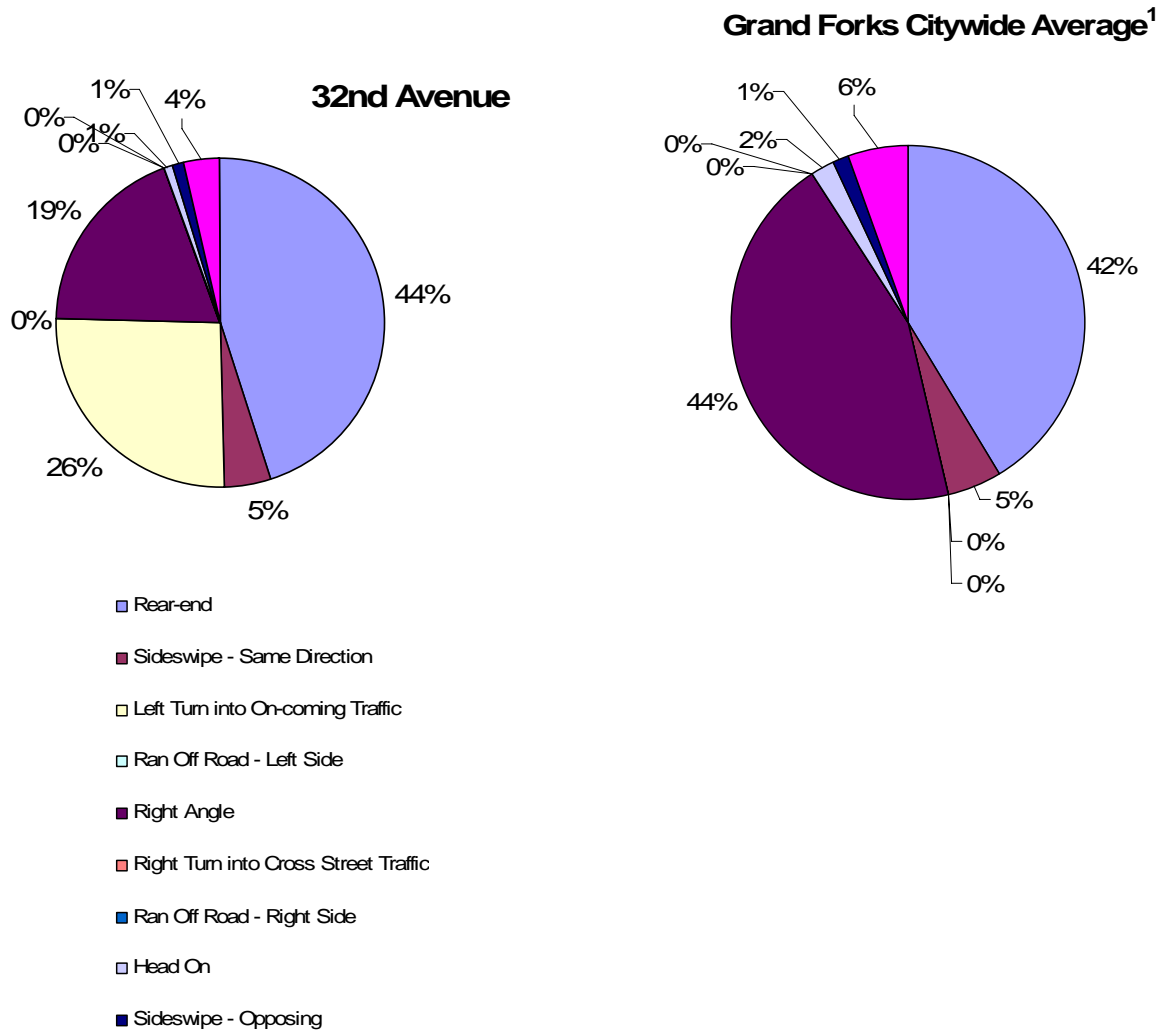
By improving the corridor progression, the number of rear-end and right angle related crashes along the corridor may be expected to be reduced. A key signal timing measure of effectiveness to reduce rear end and right angle crashes is the “vehicles in dilemma zone.” Reducing the number of vehicles in the dilemma zone (i.e., vehicles caught approaching on a ‘yellow’ and having to make a decision whether to go or stop) will be a goal of the optimization and coordination plans. Continued monitoring of the noted intersections upon completion of the new signal timing plans should be considered.

Table 4. 32nd Avenue Crash Type Summary

Segment	SYS ID	Crash Node	Rear-end	Sideswipe - Same Direction	Left Turn into On-coming Traffic	Ran Off Road - Left Side	Right Angle	Right Turn into Cross Street Traffic	Ran Off Road - Right Side	Head On	Sideswipe - Opposing	Non Collision	TOTAL
32nd Avenue at I 29 West Ramp	157												0
32nd Avenue at I 29 East Ramp	156	2133	1	0	0	0	0	0	0	0	0	0	1
32nd Avenue at 38th Street	155	2141	4	0	11	0	4	0	0	0	0	0	19
32nd Avenue at 34th Street	154	2216	4	2	10	0	3	0	0	0	1	0	20
32nd Avenue at 31st Street	153	2185	8	1	3	0	6	0	0	0	0	2	20
32nd Avenue at Columbia Road	152	2135	13	1	3	0	0	0	0	1	0	1	19
32nd Avenue at 24th Street	150	2252	2	0	0	0	1	0	0	0	0	0	3
32nd Avenue at 20th Street	149	2152	9	1	0	0	6	0	0	0	0	1	17
32nd Avenue at 17th Street	--	2151	0	0	0	0	0	0	0	0	0	0	0
34th Avenue at Washington Street	14	1012	8	0	1	0	1	0	0	0	0	0	10
32nd Avenue (I29 West Ramp to Washington Street) Total			49	5	28	0	21	0	0	1	1	4	109

Note: Each right angle crash was reviewed and segregated by left turn or right angle based on the vehicle direction information provided. (e.g., a vehicle crash reported as vehicle 1 eastbound and vehicle 2 westbound was assumed to be a left turn crash)

Source: Grand Forks-East Grand Forks MPO, data dated years 2005-2007.



¹ Source: Grand Fork-East Grand Forks MPO, 2005-2007 Crash Data

Note: Each right angle crash was reviewed and segregated by left turn or right angle based on the vehicle direction information provided. (e.g., a vehicle crash reported as vehicle 1 eastbound and vehicle 2 westbound was assumed to be a left turn crash). This was completed for only 32nd Avenue and not for the citywide average.

Figure 6. Crash Type Percentages –vs- Citywide Average

2.2 Field Studies

Travel time runs, intersection approach delay studies, and saturation flow studies were conducted to assist in calibration of the Synchro7.0 and SimTraffic7.0 models and to provide data for the “before” conditions. Field Studies were conducted by Ulteig

Engineers and were done according to the methods described in the “Manual of Transportation Engineering Studies”, ITE, 1994. The “before” travel time and intersection delay studies will be presented in Section 4.0 Project Benefit Analysis.

2.3 Model Calibration

The roadway geometrics, traffic volume, and signal timing information were utilized to create a corridor model using the Synchro7.0 modeling software. A SimTraffic7.0 simulation model was created for the AM and PM peak hours.

The travel time and intersection delay data were used to support the model calibration. The model was calibrated by adjusting the saturation flow rates and headway factors (based on field collected data) to obtain values that accurately depict the approach capacities, travel time and intersection delays.

2.3.1 Saturation Flow Rate

Saturation flow rate studies were conducted during both the AM and PM peak periods to assist in the traffic model calibration. The locations chosen were based upon the volume to capacity ratio and observation of longer observed queues. The results of the saturation flow rate studies are documented in **Table 5**.

Table 5. Saturation Flow Rate Study

Intersection	Movement	Saturation Flow Rate (vplphg)	Maximum number of queued vehicles
32nd Avenue at Columbia Road	WB 32nd Avenue Thru Lane	1,850	9
32nd Avenue at Washington Street	EB 32nd Avenue Left Turn	1,850	11
32nd Avenue at 34th Street	WB 32nd Avenue Left Turn	1,900	8
32nd Avenue at 38th Street	EB 32nd Avenue Thru Lane	1,900	6

1. Field collected on June 18, 2008.

Source: Ulteig Engineers.

The raw saturation flow rates were adjusted slightly and applied throughout the model at all approaches with similar characteristics. The headway factors were adjusted within the Synchro7.0 model to correspond with the approximate above saturation flow rates for simulation within SimTraffic7.0.

2.3.2 Intersection Volumes

The SimTraffic7.0 simulation evaluated a 15-minute volume distribution over both the AM and PM peak hours. Raw intersection turning movement volumes, discussed previously, were balanced and read into the SimTraffic7.0 model. After the intersection

approach saturation flow rates, signal timing information, coding of the model network characteristics, and critical approach capacities were validated, the sensitivity of the balanced turning movement volumes were further reviewed in attempt to better replicate actual volume demand.

2.3.3 Travel Time Comparison

A comparison of field collected travel time data to the model output was performed to validate the model calibration. The travel time comparison tables are provided for reference in **Appendix A**. The comparison shows reasonable correlation between the model output and field collected travel times.

2.3.4 Approach Delay Comparison

The field collected intersection approach delay comparison to the SimTraffic7.0 model output is documented in **Table 6**.

Table 6. Intersection Approach Delay Comparison

Intersection	Time Period	Movement	Field Measured Average Delay (seconds)	Model Output Average Delay (seconds)	Percent Difference
32nd Ave at Columbia	PM PEAK	Southbound	33.0	35.4	-7.3%
32nd Ave at 34th St	PM PEAK	Southbound	28.4	29.1	-2.5%

1. Delay studies conducted by Uteig Engineers during the month of June 2008.

As shown, the model output compares favorably to the field collected average approach delay data.

2.4 Traffic Operation Analysis

The following sections document the AM, mid-day peak and PM peak hour traffic operation analysis and operation concerns identified under the existing conditions.

2.4.1. Intersection and Arterial LOS

Using the calibrated models and the field collected data, an operations analysis was conducted. The analysis included an intersection capacity analysis as well as documentation of the arterial level of service. The methods of the Highway Capacity Manual (HCM), 2000 Edition and the Synchro7.0/SimTraffic7.0 software model were

used to conduct the analysis. LOS criteria as defined by the HCM for both signalized intersections and urban arterials is illustrated in **Table 7**.

The approach and overall intersection level of service analysis for the AM, mid-day and PM peak hours is documented in **Table 8**. In North Dakota, the LOS C/D boundary is typically considered the indicator of acceptable congestion. The arterial level of service (based on field collected travel times for AM and PM peak) is documented in **Table 9**. Based on the corridor characteristics and 85th percentile vehicle speed, 32nd Avenue is a Class II urban arterial.

Table 7. LOS Criteria

LOS CRITERIA SIGNALIZED INTERSECTIONS		URBAN STREET LOS			
		CLASS I		CLASS II	CLASS III
		Range of FFS		45 to 35 mph	35 to 25 mph
LOS	Control Delay per Vehicle (s/veh)	LOS	Average Travel Speed (mph)	Average Travel Speed (mph)	Average Travel Speed (mph)
A	≤10	A	>42	>35	>25
B	>10	B	>34	>28	>19
C	>20	C	>27	>22	>13
D	>35	D	>21	>17	>9
E	>55	E	>16	>13	>7
F	>80	F	≤16	≤13	≤7

Source: HCM, Chapter 16, Exhibit 16-2

Source: HCM, Chapter 15, Exhibit 15-2

2.4.2 Existing Traffic Operation Concerns

A review of the intersection capacity analysis, arterial level of service analysis and field observations had found several existing operation concerns.

The intersection capacity analysis found all intersections are operating at an overall acceptable LOS during each the peak time periods. Based on the analysis and observations several specific operation concerns were noted:

- The critical intersections are Columbia Road and Washington Street. Both intersections will govern the operations of the overall corridor. To a lesser extend 38th Street and 34th Street become critical during the mid-day and PM peak periods.
- During the peak periods (PM and weekend), the westbound left turn at the 32nd Avenue/34th Street intersection occasionally extends beyond the available storage, into the adjacent through lane.

Table 8. Existing Intersection Level of Service

Zone	System ID	Intersection	AM Peak Hour						Mid-day Peak Hour						PM Peak Hour					
			EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS	EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS	EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS
151	157	32nd Avenue at I 29 West Ramp	6.0	5.8	0.0	13.4	8.1	A	15.0	8.0	0.0	13.0	11.0	B	13.1	9.9	0.0	16.0	12.9	B
	156	32nd Avenue at I 29 East Ramp	3.5	3.6	8.6	0.0	4.2	A	6.0	9.0	10.0	0.0	8.0	A	5.9	5.7	10.8	0.0	6.5	A
	155	32nd Avenue at 38th Street	6.7	8.6	18.4	17.1	10.2	B	15.0	13.0	18.0	23.0	17.0	B	17.0	16.0	24.1	27.4	19.9	B
	154	32nd Avenue at 34th Street	10.3	10.7	17.4	15.8	12.5	B	25.0	19.0	22.0	31.0	24.0	C	25.4	19.1	23.2	28.4	23.0	C
	153	32nd Avenue at 31st Street	21.0	7.1	19.6	19.6	14.6	B	30.0	13.0	24.0	24.0	22.0	C	29.0	15.4	27.1	23.1	23.2	C
	152	32nd Avenue at Columbia Road	25.8	23.1	17.1	23.4	21.9	C	33.0	32.0	29.0	30.0	31.0	C	35.9	32.7	30.1	33.0	33.4	C
	150	32nd Avenue at 24th Street	14.6	9.0	7.2	0.0	10.9	B	19.0	12.0	11.0	0.0	15.0	B	18.1	12.1	14.9	0.0	15.1	B
	149	32nd Avenue at 20th Street	11.8	9.4	16.6	19.6	12.7	B	19.0	20.0	22.0	23.0	20.0	B	23.4	21.4	23.5	32.3	24.0	C
222	14	32nd Avenue at Washington Street	29.5	33.2	24.8	11.7	24.2	C	34.0	40.0	32.0	12.0	26.0	C	31.8	41.6	36.1	16.1	28.7	C

Note:

1. AM Peak and PM Peak delays computed using SimTraffic.
2. Intersection LOS based on delays computed for the benefit-cost analysis

Table 9. Existing Arterial Level of Service**Eastbound**

Cross-Street Intersection	Urban Street Class	AM Peak Hour		PM Peak Hour	
		Average Travel Speed (mph) ¹	LOS	Average Travel Speed (mph) ¹	LOS
32nd Avenue at I 29 West Ramp	II	29.2	B	22.8	C
32nd Avenue at I 29 East Ramp	II	30.1	B	30.8	B
32nd Avenue at 38th Street	II	34.5	B	15.3	E
32nd Avenue at 34th Street	II	22.0	D	15.6	E
32nd Avenue at 31st Avenue	II	21.5	D	10.7	F
32nd Avenue at Columbia Road	II	19.6	D	14.3	E
33rd Avenue at 24th Street	II	24.8	C	26.0	C
32nd Avenue at 20th Street	II	28.6	B	24.7	C
32nd Avenue at Washington Street	II	19.9	D	22.9	C
Zone 151 - I 29 West Ramp to 20th Street	II	25.1	C	18.2	D

¹ Field collected average speeds (data collected by Ulteig Engineers on June 3 and June 4, 2008)**Westbound**

Cross-Street Intersection	Urban Street Class	AM Peak Hour		PM Peak Hour	
		Average Travel Speed (mph) ¹	LOS	Average Travel Speed (mph) ¹	LOS
32nd Avenue at Washington Street	II	14.6	E	10.7	F
32nd Avenue at 20th Street	II	26.6	C	26.7	C
33rd Avenue at 24th Street	II	22.9	C	22.1	C
32nd Avenue at Columbia Road	II	14.9	E	12.6	F
32nd Avenue at 31st Avenue	II	29.1	B	26.0	C
32nd Avenue at 34th Street	II	23.3	C	27.3	C
32nd Avenue at 38th Street	II	32.7	B	28.3	B
32nd Avenue at I 29 East Ramp	II	37.7	A	35.0	B
32nd Avenue at I 29 West Ramp	II	27.1	C	22.5	C
Zone 151 - 20th Street to I 29 West Ramp	II	24.9	C	23.2	C

¹ Field collected average speeds (data collected by Ulteig Engineers on June 3 and June 4, 2008)

- During the peak periods (PM), the northbound left turn at the 32nd Avenue/Columbia Road intersection occasionally extends beyond the available storage, into the adjacent through lane.

Currently, 32nd Avenue is operating in “Free” mode (non-coordinated); therefore, a common cycle length along the corridor is not occurring. Operating in non-coordinated mode does provide a couple advantages:

- Reduces left turn and cross-street delays,
- Varies the cycle length to the traffic demand present during that particular cycle; and

- Generally results in few to no citizen complaints from the cross-streets.

However, at certain traffic volume levels the cross-street advantages of operating under non-coordinated mode, will come at significant expense to mainline progression and delay. Although intersection delays are acceptable, the quality of progression was low. The results of the travel time study and field observations found this evident. Key corridor observations include:

- Progression through the corridor did not exist during the peak AM, mid-day and PM periods. Numerous stops occurred in both directions.
- The arterial LOS analysis found the 38th Street to Columbia Road segment to operate at the lowest average operating speed, specifically eastbound, with numerous stops occurring. Overall, 32nd Avenue is operating at a LOS D during the PM peak hour and a LOS C during the AM peak hour.
- In the westbound direction, Columbia Road resulted in the lowest mainline average operating speed. Overall, 32nd Avenue is operating at a LOS D during the PM peak hour and a LOS C during the AM peak hour.
- During the PM peak period, a high volume of eastbound traffic proceeded from Columbia Road, 24th Street area (moderately platooned) into the left turn movement at Washington Street. This occurred during the AM peak and mid-day periods, but to a much lesser degree.

As part of the project objective, issues identified above will be reviewed and improved. The implementation of coordination is expected to improve progression and the corridor operating speed and LOS. The City of Grand Forks has dedicated resources to improving traffic flow along 32nd Avenue. Several improvements have recently occurred:

- The addition of northbound/southbound “protected/permissive” left turn arrows at both 38th Street and 34th Street.
- The two hardware issues previously noted in **Table 1** were corrected. The video detection camera was repaired at 31st Street, and the continual vehicle re-service at 24th Street was corrected in the signal controller.

3.0 Signal Timing Optimization

The Synchro7.0 and SimTraffic7.0 models developed for existing conditions were used to create optimized signal timing plans. The traffic signal optimization included conducting a coordination feasibility review, identifying coordination strategies and developing time of day (TOD) timing plans consisting of new cycle lengths, intersection splits and offsets for Zone 151 (32nd Avenue between I-29 West Ramp and 20th Street).

3.1 32nd Avenue/Washington Street Coordination Feasibility Review

A feasibility review was conducted at the 32nd Avenue/Washington Street intersection to assess whether east-west coordination should be considered. Currently, 32nd Avenue/Washington Street is part of the north/south system (Zone 222) on Washington Street. The coordination feasibility review included evaluating the Coordinability Factor (Synchro7.0 output) and intersection measures of effectiveness (MOE).

3.1.1 Coordinability Factor

The coordinability factor (CF)¹ is one measure used to assess the need for signal coordination. The CF is a value ranging from 0 to 100 and is determined based upon several factors; including, travel time, storage space, proportion of traffic in platoon and traffic volumes. A CF greater than 50 suggests coordination is recommended. **Table 10** summarizes the CF's estimated for 32nd Avenue between 20th Street and Washington Street and Washington Street between 32nd Avenue and 24th Avenue.

The CF review indicates coordination between 20th Street and Washington Street may be of value during the mid-day, PM peak and Saturday peak time periods. However, the CF also indicates the northbound/southbound directions of Washington Street should be given preference. Providing coordinated preference to eastbound/westbound 32nd Avenue at Washington Street would be expected to yield minimal benefit during the AM time periods.

¹ Trafficware, Synchro7.0

Table 10. Coordinability Factor (CF) Summary

	Coordinate with 32nd Avenue	Coordinate with Washington Street
Volume Case	Coordinability Factor**	Coordinability Factor**
AM PEAK	37	79
BAL PEAK	45	81
PM PEAK	54	84
SAT PEAK	59	91

** Coordinability Factor (CF) ranges from 0 to >100. Any value greater than 50 indicates coordination is recommended.

3.1.2 Coordination Performance Analysis

The 32nd Avenue/Washington Street intersection was evaluated to identify the optimal operation strategy. The MOE's included network delay, overall intersection delay (32nd Avenue at Washington Street), network travel times and network vehicle stops. Three coordination scenarios were evaluated:

- **Scenario 1:** Two-system interconnect (Zone 151 and Zone 222). The 32nd Avenue/Washington Street intersection is included within the 32nd Avenue (Zone 151) interconnect. Phase 4 (eastbound) and Phase 8 (westbound) are the coordinated movements.
- **Scenario 2:** Two-system interconnect (Zone 151 and Zone 222). The 32nd Avenue/Washington Street intersection is included within Washington Street (Zone 222) interconnect. Phase 2 (southbound) and Phase 6 (northbound) are the coordinated movements. It should be noted, Scenario 2 is the existing interconnect and operation configuration.
- **Scenario 3:** One-system interconnect (Zone 151 and Zone 222). Zone 151 and Zone 222 would operate with a common cycle length. At 32nd Avenue and Washington Street, Phase 2 (southbound) and Phase 6 (northbound) are the coordinated movements.

After review of the CF analysis and a review of the intersection turning movement volume proportions at 32nd Avenue/Washington Street the mid-day peak, PM peak and Saturday peak conditions were evaluated. The overall network delay includes 32nd Avenue between I-29 West Ramp and Washington Street and Washington Street between 32nd Avenue and 24th Avenue. **Table 11** summarizes the overall network delay comparison.

The overall network stop comparison is illustrated in **Table 12**. **Table 13** compares the mainline travel time estimates under each scenario and **Table 14** summarizes the overall intersection delay at the Washington Street/32nd Avenue intersection.

Table 11. Overall Network Delay Comparison – Coordination Feasibility Review

Volume Case	Existing	Coordination Scenarios		
		Scenario 1	Scenario 2	Scenario 3
Mid-day Peak	132.0	133.0	133.0	133.0
PM Peak	164.4	156.5	154.1	156.5
Saturday Peak	190.0	192.0	193.0	186.0

Table 12. Overall Network Stops Comparison – Coordination Feasibility Review

Volume Case	Existing	Coordination Scenarios		
		Scenario 1	Scenario 2	Scenario 3
Mid-day Peak	13,833	12,171	12,112	12,273
PM Peak	12,046	9,677	9,631	9,688
Saturday Peak	17,044	14,189	14,629	14,270

Table 13. Mainline Travel Time (s) Comparison - Coordination Feasibility Review

Volume Case	Existing	Scenario 1	Scenario 2	Scenario 3
	Total (EB/NB + WB/SB)	Total (EB/NB + WB/SB)	Total (EB/NB + WB/SB)	Total (EB/NB + WB/SB)
Mid-day Peak	1133.2	999.1	1002.2	1007.6
PM PEAK	1112.2	976.3	968.9	961.9
Saturday Peak	1217.8	1067.8	1073.3	1045.6

Travel time includes (EB/NB - 29 West Ramp to Washington St + 32nd Ave to 24th Ave) and (SB/WB - 28th Ave to 32nd Ave + Washington St to 29 West Ramp)

Table 14. 32nd Avenue/Washington Street Overall Intersection Delay Comparison - Coordination Feasibility Review

Scenario	Existing	Coordination Scenarios		
		Scenario 1	Scenario 2	Scenario 3
Mid-day Peak	26.0	28.0	26.0	24.0
PM Peak	28.7	32.8	29.0	28.9
Saturday Peak	35.0	33.0	35.0	29.0

3.1.3 20th Street to Washington Street Coordination Feasibility Conclusions

Based on a review of the three primary operating scenarios for the 32nd Avenue/Washington Street intersection, the following key conclusions are made:

- Overall, and across each scenario, the total network delay, corridor travel time and network stops are similar.
- The coordination performance analysis is consistent with the coordinability factor in that coordination along northbound/southbound Washington Street should be given first priority during the AM, mid-day and PM weekday periods.
- Under peak Saturday (i.e., representative of a weekend), benefit may lie with coordinated preference provided along 32nd Avenue.
- With exception to the weekend, the overall intersection delay at 32nd Avenue/Washington Street indicates northbound/southbound Washington Street should be the coordinated movements and be given the higher priority.

Scenario 3 is the optimal operation; and includes using a common cycle length between Zone 151 and Zone 222. The 32nd Avenue/Washington Street Phase 2 (southbound) and Phase 6 (northbound) movements should be the coordinated phases during the mid-day, and PM peak time periods. Interconnect between 20th Street and Washington Street is not necessary. Utilizing inter-zone coordination technique (scheduled master controller time clock syncs from the Translink operating system) would maintain sync between zones.

Based on a review of the traffic volumes along Washington Street, it is expected that the 32nd Avenue/Washington Street, 28th Avenue/Washington Street and 24th Avenue/Washington Street intersections would operate acceptably under the mid-day, PM peak and weekend cycle lengths selected for the 32nd Avenue corridor. However, it should be noted that the Washington Street/Demers intersection is the critical intersection and would control the cycle length selection for all of Washington Street and Zone 222. Further review of the Washington Street corridor (current traffic volumes), in relation to 32nd Avenue, would be required prior to making any final determinations.

The coordination feasibility review does conclude the following order of priority.

- The optimal cycle lengths should be selected for 32nd Avenue and Washington Street individually.
- Coordination priority should be given to northbound and southbound phases at the 32nd Avenue/Washington Street intersection.
- Where optimal cycle lengths are similar or close for both 32nd Avenue and Washington Street, a common cycle length should be selected. Provide inter-zone cross-coordination, with northbound/southbound Washington the coordinated phases during the weekday and consider the eastbound/westbound directions the coordinated phases on the weekend.

As part of the 32nd Avenue Coordination Study, optimized intersection timing will be provided for the 32nd Avenue/Washington Street intersection; however, will not be implemented. The intersection timing parameters may be used as a guide for the future re-timing of Washington Street.

3.2 Signal Operation and Optimized Timing Plan Strategy

As described in Section 2.0 Existing Conditions, there are numerous existing traffic operation inefficiencies throughout the system. The strategy of the signal optimization was to identify signal operating techniques (e.g., lead/lag left turn operation) and zone cycle length patterns in attempt of improving traffic flow and vehicle progression.

Several scenarios were evaluated to determine the overall most efficient operation strategy for 32nd Avenue. Based on assessment, the following general conclusions were made:

- Progression can be greatly improved along 32nd Avenue by implementing lead/lag left turn operation at Columbia Road, the I-29 ramp terminals and 24th Street.
- Although 31st Street and 20th Street currently have “protected” left turn phases and could allow lead/lag operation, a minimal benefit was determined. Greater value would be attained by implementing lead/lead operation and converting the eastbound/westbound approaches to “protected/permissive” signal phasing. The overall intersection delay at 31st Street and 20th Street would be expected to result in a significant reduction.

However, consideration may be given to the potential change in intersection safety characteristics with the conversion of the signal phasing from “protected” only to “protected/permissive.” According to the FHWA Issue

Brief,² a 65 percent increase in left turn related crashes may result. The existing left turn crashes (**Table 4**) at 31st Street and at 20th Street are three and zero, respectively. The oncoming sight distance is acceptable; therefore, motorists are expected to have adequate visibility to choose a safe crossing gap. Based on the FHWA Issue Brief research data, an increase of approximately two crashes may occur at each intersection.

The following discusses other specific operation strategies used in developing the optimized signal timing plans:

- Installation of upgraded signal controllers. The City of Grand Forks replaced all 170 type signal controllers with new Econolite 2070 controllers and the Oasis software. Upgrading the signal controllers and the software revisions allows for flexibility and compatibility between intersections along the interconnected corridor.
- Two-way progression was maximized to the extent feasible. However, under the mid-day, PM peak hour and Saturday peak condition, perfect two-way progression is unattainable, due to the volume, signal spacing characteristics and required lead-lead left turn operation at 34th Street and 38th Street. Logical locations for vehicle stops (also locations to gather vehicle platoons) were chosen. Eastbound 32nd Avenue at 38th Street is a logical location to stop traffic due to the uncontrolled volume approaching from the I-29 exit ramp. Likewise, westbound at 20th Street is a good location to gather the platoon.
- Overall the traffic volumes are relatively balanced along the corridor. However, where a progression preference choice is required, the eastbound direction was selected between I-29 and Columbia Road.
- Use of half-cycles at I-29 ramp terminal intersections. Half-cycles were used to minimize cross-street and left turn movement delays, while still being able to maintain progression.
- The City of Grand Forks has recently modified both the 34th Street and 38th Street signal systems to provide northbound/southbound “protected/permissive” left turn phasing.

3.2.1 Minimum Green, Clearance and Pedestrian Interval Timings

As part of the optimized timing plan development, Alliant Engineering assisted the City of Grand Forks with the development of new minimum green time, red and yellow clearance and pedestrian timing intervals. The purpose was to develop a standard to maintain consistency between intersections and to improve intersection efficiency. Ultimately, the standard set for 32nd Avenue would be continued throughout the

² U.S. Department of Transportation, Federal Highway Administration September 2007 • Issue Brief 5: Traffic Signals, Table 1.

remainder of the city as those corridors are re-timed. The following summarizes the general standards:

- Minimum green times were set according to the movement type and signal phase operation. The following minimum green times are based on stop bar detection and non-density operation.

Major Approach = 15 seconds (20 seconds for speeds >45 mph)

Minor Approach = 10 seconds

Split Phased or Ramp Terminal Approach = 8 seconds

Protected Left Turn = 7 seconds

Protected/Permissive Left Turn = 5 seconds

- Yellow intervals are based on the perception-reaction time of the motorist (1 second), the posted speed limit, approach grade and deceleration rate of the vehicle (10 feet per second per second). The generalized standard is as follows:

25 mph = 3.0 seconds (typical for left turn movements)

30 mph = 3.5 seconds

35 mph = 4.0 seconds

40 mph = 4.0 seconds

45 mph = 4.5 seconds

50 mph = 5.0 seconds

- Red clearance intervals are based on the width of the intersection, length of vehicle and posted speed and is equal to the calculated time it takes a vehicle to clear the intersection.
- The pedestrian interval consists of the “Walk” time and the “Don’t Walk” time. The pedestrian intervals for 32nd Avenue were re-calculated to cross pedestrians the full distance of the roadway and to account for a 3.5 feet per second walking speed per the upcoming new Federal Manual on Uniform Control Devices (MUTCD) requirement. The following standards were used:

Walk Interval = 6.0 seconds if no median push button. If median push button then the Walk is equal to the total time required to cross the full distance minus the flashing Don’t Walk interval.

Don’t Walk Interval = Total time to cross full distance of roadway divide by 3.5 and minus the yellow time (no median push button). If median push button then Don’t Walk interval is equal to time to cross longest distance to the median divide by 3.5 and minus yellow time.

The minimum green times, yellow and red clearance and pedestrian interval times implemented and provided by the City of Grand Forks are included in **Appendix B**. The measurements for each intersection are also provided. It should be noted the City of Grand Forks implemented a longer red clearance interval at both 34th Street and 38th Street due to the interaction of motorists exiting I-29 and increased probability of red-light running.

3.2.2 Cycle Length

Once the overall operation plan was determined, SimTraffic7.0 was used to test the operation alternatives, and to iterate through different cycle length options. In addition, three other methods were used to help identify potential cycle length options. These included conducting a critical lane analysis, a rule of thumb estimate method based upon speed and signal spacing, and utilizing the PASSER II software. Ultimately the cycle length is governed by the 32nd Avenue/Columbia Road intersection, and the travel time needed to provide progression between 34th Street and 38th Street. **Table 15** highlights the cycle lengths selected. The cycle lengths were selected based on the following key considerations:

- The minimum cycle length for 32nd Avenue is 80 seconds, which is governed by the split requirements of the 32nd Avenue/Columbia Road intersection.
- Long enough to accommodate the mainline traffic volume demand;
- Minimize cross-street queue length impacts at the critical intersection.
- Best maximizes two-way progression given the existing signal spacing, signal phasing limitations, vehicle speeds and traffic volume relationship.

Table 15. 32nd Avenue Cycle Length Summary

Volume Case	32nd Avenue (Zone 151)	Plan ID
AM PEAK	80	PLAN 1
AM LOW	80*	PLAN 2
MID-DAY PEAK	100	PLAN 3
PM PEAK	120	PLAN 4
SATURDAY PEAK	110	PLAN 5

* I-29 West Ramp and I-29 East Ramp operate in free mode (PLAN 66)

3.2.3 Intersection Splits

Intersection splits were optimized to minimize delay along the mainline corridor, while providing adequate time to cross street traffic movements. Further refinement to the intersection splits was completed by determining the green time required to serve the

expected vehicle queue per cycle. The refined split was calculated by multiplying the number of vehicles arriving per cycle by a factor 2.1; and adding a clearance factor (or start up time) of 3 seconds. Using the refined split calculation as a guideline, the overall cross street and left turn movement splits were adjusted accordingly.

3.2.4 Intersection Offsets

The primary objective of the offset optimization process is to maximize two-way vehicle progression, given the constraints and methods discussed in Section 3.2. Offsets were manually manipulated using Synchro7.0. Lead/lag left turn phasing operation was considered where appropriate to improve the corridor green band.

3.3 Optimized Timing Plan Progression Evaluation

The goal of the project is to improve progression while balancing intersection delays. Based on the corridor analysis the optimized timing plans are expected to improve the average travel times by 9 to 25 percent (greater than one minute savings each direction). **Table 16** highlights a comparison between the existing and optimized traffic model results (model output data).

Table 16. Optimized Timing Plan Progression Evaluation – I-29 West Ramp to 20th Street

Eastbound

Time Period	Urban Street Class	"Before" Condition			Proposed			Percent Improvement
		Average Travel Time (s)	Average Travel Speed (mph) ¹	LOS	Average Travel Time (s)	Average Travel Speed (mph) ¹	LOS	
AM Peak Hour	II	294.2	24.4	C	222.1	32.3	B	25%
Mid-day Peak Hour	II	387.2	18.5	D	310.9	23.1	C	20%
PM Peak Hour	II	364.1	19.7	D	277.9	25.8	C	24%

Westbound

Time Period	Urban Street Class	"Before" Condition			Proposed			Percent Improvement
		Average Travel Time (s)	Average Travel Speed (mph) ¹	LOS	Average Travel Time (s)	Average Travel Speed (mph) ¹	LOS	
AM Peak Hour	II	284.0	26.3	C	259.6	28.8	B	9%
Mid-day Peak Hour	II	356.0	21.0	D	306.1	24.4	C	14%
PM Peak Hour	II	338.0	22.1	C	297.3	25.1	C	12%

3.4 Signal Timing Implementation

Alliant Engineering assisted City of Grand Forks staff in entering the optimized timing plans into the Translink database on July 23, 2008. Based upon the daily volume data, an initial time of day (TOD) schedule was developed and implemented.

The Synchro7.0 and SimTraffic7.0 models developed in evaluation of the existing and optimized conditions were used to support the field reviews and fine tuning of the signal systems. Alliant Engineering and City of Grand Forks staff implemented and conducted fine-tuning reviews between July 24th and July 26th, 2008. During the field reviews, adjustments were made to the optimized timing plans to improve mainline progression, minimize stops and provide sufficient time to cross-street and left turn phases. Throughout the fine-tuning process refinement of the TOD schedule was also made.

3.5 Final Timing Plan Summary

A total of six timing plans were developed. The timing plans were developed based upon the existing traffic volume conditions along 32nd Avenue during both a typical weekday and typical weekend. The time of day (TOD) schedule and signal timing plans are illustrated in **Table 17**. The final intersection splits and offsets for each of the timing plans are attached in **Appendix C**.

The TOD schedule is based upon hourly tube counts collected by the City of Grand Forks in June 2008. This is a small sample to represent a “typical” day; however, provides a very good starting point. The TOD was refined in the field during the implementation process. It is recommended the City of Grand Forks continue to monitor the system detector volumes (once configured) and revise the plan transition times as appropriate.

Table 17. Final Signal Timing Plan Summary – TOD Schedule

Day	Operation	Time	Plan (COS)	Cycle Length (s)	Volume Description
Weekday	TOD	630 AM to 830 AM	PLAN 1	80	AM PEAK
		630 AM to 1030 AM	PLAN 2	80	BAL LOW
		1030 AM to 230 PM	PLAN 3	100	BAL PEAK 2
		230 PM to 630 PM	PLAN 4	120	PM PEAK 2
		630 PM to 800 PM	PLAN 3	100	BAL PEAK 2
		800 PM to 1000 PM	PLAN 2	80	BAL LOW
Saturday	TOD	830 AM to 930	PLAN 2	80	BAL LOW
		930 AM to 1100 AM	PLAN 3	100	BAL PEAK
		1100 AM to 600 PM	PLAN 5	110	SAT PEAK
		600 PM to 730 PM	PLAN 3	100	BAL PEAK
		730 PM to 930 PM	PLAN 2	80	BAL LOW
Sunday	TOD	900 AM to 1100 AM	PLAN 2	80	BAL LOW
		1100 AM to 500 PM	PLAN 5	110	SAT PEAK
		500 PM to 730 PM	PLAN 3	100	BAL PEAK
		730 PM to 900 PM	PLAN 2	80	BAL LOW
Event	TOD	Exiting Alerus Center	PLAN 6	110	--

Note: Plan 66 = Free

Time periods not shown (e.g., 10 PM to 6:30 AM) the intersection is operating in manual free mode (Plan 66).

3.6 Traffic Operation Analysis

The following sections document the traffic operation analysis results for the final fine-tuned signal coordination plans.

3.6.1. Intersection and Arterial LOS

Using the final implemented Synchro7.0 and SimTraffic7.0 models, the overall intersection level of service (LOS) was documented. The overall intersection LOS for each of the intersections during the AM, mid-day and PM peak hour is documented in **Table 18**. In North Dakota, the LOS C/D boundary is typically considered the indicator of acceptable congestion.

Using the field collected travel time data, the arterial LOS is documented in **Table 19**. Based on the corridor characteristics and 85th percentile vehicle speed, 32nd Avenue is a Class II urban arterial.

3.6.2 Results Discussion

The results of the traffic operation analysis show all intersections are operating at a LOS C or better. Overall a comparable intersection delay between the existing and proposed timing plans was found. The arterial analysis found the corridor LOS to be improved to a LOS C or better during each of the weekday peak conditions. As shown in Table 19, the westbound arterial link approaching 34th Street and the eastbound arterial segment approaching 38th Street are reported to be a LOS E. This result is by design. As part of the progression scheme, both of these approaches are the scheduled stop. Much of the traffic approaching the eastbound approach to 38th Street is arriving from northbound I-29 and is not controlled by the platoon. Once given the green, the platoon is progressed through the remainder of the system.

The goal of the project is to improve progression while balancing intersection delays. Previously, 32nd Avenue was operating in “Free” mode (non-coordinated). Under moderate traffic volumes, free mode operation typically results in a lower overall intersection delay, but this comes at the expense of degraded mainline operations and vehicle progression. The optimized timing plans implemented signal coordination, which is found to have significantly improved progression. As shown, a much improved balance between delay and progression is attained. Overall the travel times are greatly reduced (i.e., improved), while the overall intersection delays are generally maintained (some intersections improved, others slightly increased).

Table 18. Final Intersection Level of Service

Zone	Intersection	"Before" Condition			Proposed																	
		AM Peak	Mid Peak	PM Peak	AM Peak Hour						Mid-day Peak Hour						PM Peak Hour					
		Int. Delay (s/v)	Int. Delay (s/v)	Int. Delay (s/v)	EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS	EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS	EB Delay (s/v)	WB Delay (s/v)	NB Delay (s/v)	SB Delay (s/v)	Int. Delay (s/v)	LOS
151	32nd Avenue at I 29 West Ramp	8.1	11.0	12.9	4.2	3.7	0.0	25.0	10.4	B	12.0	1.0	0.0	17.0	9.0	A	7.3	7.8	0.0	20.5	11.4	B
	32nd Avenue at I 29 East Ramp	4.2	8.0	6.5	2.0	3.0	11.7	0.0	3.7	A	1.0	7.0	10.0	0.0	5.0	A	3.2	3.2	12.4	0.0	4.4	A
	32nd Avenue at 38th Street	10.2	17.0	19.9	5.3	9.8	30.2	24.9	12.5	B	17.0	7.0	36.0	44.0	23.0	C	21.2	15.3	37.6	45.8	27.1	C
	32nd Avenue at 34th Street	12.5	24.0	23.0	8.0	7.1	27.5	27.9	14.0	B	15.0	19.0	30.0	52.0	25.0	C	19.0	17.7	32.2	45.8	24.6	C
	32nd Avenue at 31st Street	14.6	22.0	23.2	5.6	8.9	23.6	24.3	9.5	A	16.0	17.0	32.0	32.0	20.0	B	11.8	13.6	42.2	30.5	17.3	B
	32nd Avenue at Columbia Road	21.9	31.0	33.4	15.7	16.8	27.4	27.0	21.6	C	20.0	24.0	49.0	38.0	31.0	C	25.1	28.3	46.0	46.9	34.8	C
	32nd Avenue at 24th Street	10.9	15.0	15.1	2.3	2.7	17.4	0.0	3.0	A	5.0	3.0	21.0	0.0	7.0	A	4.2	7.3	24.5	0.0	8.2	A
	32nd Avenue at 20th Street	12.7	20.0	24.0	7.1	9.6	23.6	27.5	13.9	B	23.0	21.0	30.0	33.0	24.0	C	18.1	21.6	29.0	44.6	24.2	C
222	32nd Avenue at Washington Street	24.2	26.0	28.7	30.0	32.2	24.6	11.0	23.7	C	34.0	40.0	32.0	12.0	26.0	C	31.2	41.4	34.5	17.1	28.5	C

Note:

1. AM Peak and PM Peak delays computed using SimTraffic.

Table 19. Final Arterial Level of Service

Eastbound

Cross-Street Intersection	Urban Street Class	"Before" Condition		"After" Condition			
		AM Peak	PM Peak	AM Peak Hour		PM Peak Hour	
		Average Travel Speed (mph) ¹	Average Travel Speed (mph) ¹	Average Travel Speed (mph) ²	LOS	Average Travel Speed (mph) ²	LOS
32nd Avenue at I 29 West Ramp	II	29.2	22.8	34.3	B	27.7	C
32nd Avenue at I 29 East Ramp	II	30.1	30.8	34.9	B	23.0	C
32nd Avenue at 38th Street	II	34.5	15.3	25.2	C	13.2	E
32nd Avenue at 34th Street	II	22.0	15.6	26.5	C	20.1	D
32nd Avenue at 31st Street	II	21.5	10.7	31.6	B	29.7	B
32nd Avenue at Columbia Road	II	19.6	14.3	34.5	B	33.9	B
33rd Avenue at 24th Street	II	24.8	26.0	37.6	A	34.0	B
32nd Avenue at 20th Street	II	28.6	24.7	37.7	A	32.7	B
Zone 151 - I 29 West Ramp to 20th Street	II	25.1	18.2	32.7	B	25.7	C

¹ Field collected average speeds (data collected by Ulteig Engineers on June 3 and June 4, 2008)² Field collected average speeds (data collected by Ulteig Engineers on July 30 and July 31, 2008)

Westbound

Cross-Street Intersection	Urban Street Class	"Before" Condition		"After" Condition			
		AM Peak	PM Peak	AM Peak Hour		PM Peak Hour	
		Average Travel Speed (mph) ¹	Average Travel Speed (mph) ¹	Average Travel Speed (mph) ²	LOS	Average Travel Speed (mph) ²	LOS
32nd Avenue at 20th Street	II	26.6	26.7	28.9	B	25.6	C
33rd Avenue at 24th Street	II	22.9	22.1	35.1	A	32.3	B
32nd Avenue at Columbia Road	II	14.9	12.6	24.3	C	24.0	C
32nd Avenue at 31st Street	II	29.1	26.0	33.7	B	29.4	B
32nd Avenue at 34th Street	II	23.3	27.3	31.1	B	14.3	E
32nd Avenue at 38th Street	II	32.7	28.3	31.1	B	28.3	B
32nd Avenue at I 29 East Ramp	II	37.7	35.0	33.3	B	36.8	A
32nd Avenue at I 29 West Ramp	II	27.1	22.5	35.1	A	36.9	A
Zone 151 - 20th Street to I 29 West Ramp	II	24.9	23.2	30.7	B	26.1	C

¹ Field collected average speeds (data collected by Ulteig Engineers on June 3 and June 4, 2008)² Field collected average speeds (data collected by Ulteig Engineers on July 30 and July 31, 2008)

4.0 Project Benefit Analysis

The purpose of this section is to document the benefit of the 32nd Avenue Coordination Study. To assess the benefit, field studies were completed for the “after” condition and compared to the “before” conditions. In addition, a benefit/cost analysis was completed to evaluate the overall cost-effectiveness of the implemented signal timing plans.

4.1 Before/After Travel Time Comparison

Travel time studies were conducted by Ulteig Engineers during both the “before” and “after” conditions along 32nd Avenue. The following summarizes the travel time study limits:

- Eastbound: Gas Station Commercial Driveway to Washington Street
- Westbound: 10th Street to I-29 West ramp

The “before” travel time study was conducted on June 3 and June 4, 2008. the “after” travel time study was conducted on July 30 and July 31, 2008. A total of 14 runs (each direction) were collected during the AM peak period (7:00 to 9:00 AM) and 16 runs (each direction) were collected during the PM peak period (3:00 to 6:00 PM).

A comparison of the “before” and “after” travel time field studies was made. **Table 20** provides an overall summary of the travel time runs and percent improvement accomplished for 32nd Avenue (I-29 West Ramp to 20th Street) during the AM peak period. **Table 21** provides an overall summary of the travel time runs and percent improvement accomplished for 32nd Avenue (I-29 West Ramp to 20th Street) during the PM peak period.

As shown, the comparison of the “before” and “after” field collected travel times found the following:

- An approximate average 30 seconds to one minute travel time savings during the AM and PM peak period in the westbound direction was found.
- In the eastbound direction, a one minute travel time savings was achieved during the AM peak period. A two minute travel time savings was achieved during the PM peak period.

A one to two minute travel time savings over an only two-mile long roadway segment is a fairly significant improvement.

Table 20. Before/After Travel Time Comparison (I-29 West Ramp to 20th Street) – AM Peak Period**Westbound 32nd Avenue**

	Free Flow		AM Peak Hour (730 - 830)			AM Overall (700 - 900)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- 20th Street to I-29 West Ramp	3	7	5 0	4 3	19%	4 48	4 5	15%

Eastbound 32nd Avenue

	Free Flow		AM Peak Hour (730 - 830)			AM Overall (700 - 900)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- I-29 West Ramp to 20th Street	3	0	4 45	3 39	23%	4 44	3 41	22%

1. Ulteig Engineers field collected travel time runs in June, 2008 (before) and July, 2008 (after).

Table 21. Before/After Travel Time Comparison (I-29 West Ramp to 20th Street) – PM Peak Period**Westbound 32nd Avenue**

	Free Flow		PM Peak Hour (445 - 545)			PM Overall (300 - 600)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- 20th Street to I-29 West Ramp	3	7	5 22	4 46	11%	5 30	5 0	9%

Eastbound 32nd Avenue

	Free Flow		PM Peak Hour (445 - 545)			PM Overall (300 - 600)		
	Min	Sec	Before	After	Percent Improvement	Before	After	Percent Improvement
			Min Sec	Min Sec		Min Sec	Min Sec	
Zone 151- I-29 West Ramp to 20th Street	3	0	6 34	4 38	29%	6 8	4 46	22%

1. Ulteig Engineers field collected travel time runs in June, 2008 (before) and July, 2008 (after).

4.2 Before/After Average Approach Delay Comparison

Cross-street approach delays were field collected by Ulteig Engineers during the PM peak hour for two minor street southbound approaches (peak half hour) at 34th Street and Columbia Road. The two approaches selected were those locations at critical intersections, unique characteristics or those observed to have longer vehicle queues.

The cross-street approach delays are conducted for several reasons. The first is to support the building of the existing traffic models, the second is to use as a measure or benchmark during coordination and the third reason is to support the measures of effectiveness calculations conducted for the benefit/cost analysis. **Table 22** provides a comparison of the “before” and “after” of the average approach delay collected.

Maximizing corridor mainline progression usually comes at the cost of some sacrifice to the cross streets through increasing the cycle length or reducing splits. However, split and cycle length optimization is also a very fine balance. The intersections studied represent the critical intersections that required the greatest attention in balancing progression and delay to address mainline congestion issues. As shown the cross-street delay was increased (typical impact of coordinated signal operation versus free mode operation). However, the queued vehicles were serviced each cycle, and the approach delay operates at an acceptable level.

Table 22. Before/After Average Approach Delay Comparison

Intersection	Zone	Time Period	Before			After			Percent Change	Comments
			Cycle Length (s)	Traffic Volume (vehicle)	Field Measured Average Approach Delay (seconds)	Cycle Length (s)	Traffic Volume (vehicle)	Field Measured Average Approach Delay (seconds)		
32nd Avenue at Columbia Road (Southbound Approach)	151	5:00-5:30	FREE	397	33.0	120	408	44.5	-34.8%	Larger delay expected with coordinated signal operation.
32nd Avenue at 34th Street (Southbound Approach)	151	5:30-6:00	FREE	212	28.4	120	200	34.4	-21.1%	Larger delay expected with coordinated signal operation.

1. Delay studies conducted by Ulteig Engineers during the week of June 16, 2008 (Before Study) and the week of July 28, 2008 (After Study)

4.3 Benefit/Cost Analysis

A benefit/cost analysis was completed to establish the annual economic savings incurred as a result of the 32nd Avenue Coordination Study. Typical measures of effectiveness (MOE) used in estimating the benefit of signal optimization projects include approach vehicle delay, vehicle stops and fuel consumption. The detailed benefit/cost analysis is provided for reference in **Appendix D**.

A tabulation of the change in the vehicles in dilemma zone (i.e., vehicles caught approaching on a ‘yellow’ and having to make a decision whether to go or stop) MOE is also included. However, this MOE was not included in the economic analysis; rather, serves (for information only) as another qualitative benefit of the project. Reducing the number of vehicles in the dilemma zone is a key MOE in improving corridor safety and is a direct result of improving corridor progression and signal timing.

4.3.1 Traffic Volume Cases

In order to compute the daily “before” and “after” MOE’s for the 32nd Avenue Coordination Study, general traffic volume cases were developed. It is not feasible or practical to develop hourly traffic volumes for every hour of the day. Instead, the traffic volume cases were developed in consideration of the particular corridors general daily hourly volume trend. The traffic counts collected along 32nd Avenue found relatively consistent volume levels on a weekday between Monday and Thursday. Friday traffic volumes were found to follow the same daily trend; however, were incrementally higher. Weekend characteristics were also included. The benefit/cost analysis includes the daily volume cases for a Monday to Thursday, a Friday and a Saturday.

Each volume case is assigned and assumed to be applicable for a certain number of hours of the day as previously discussed in Section 2.1.3. In general, the traffic volume cases include an AM off peak, AM peak, late morning/mid-day low, mid-day peak, PM off peak (before peak), PM Peak and PM off peak (after peak) and were developed specifically for the corridor.

In order to make an accurate “apple-to-apple” comparison, the traffic volumes used in the “before” condition (and number of hours) has to equal the volumes used in the “after” condition (and number of hours) analysis. With the traffic volume cases constant between the “before”/“after” conditions, the only variable is the signal timing plans and duration each timing plan is in operation.

4.3.2 Project Benefit

The project benefit MOE’s are measured through the reduction in mainline travel time, reduction in vehicle stops and reduction in fuel consumption. **Table 23** provides a summary of the unit dollar values assumed for each measure of effectiveness.

Table 23. Unit Benefit

MOE	Unit Price
Value of Time - Truck ¹	\$21.00
Value of Time - Auto ¹	\$13.00
Vehicle Stop ²	\$0.065
Fuel Cost ³	\$3.22

¹ Mn/DOT Office of Investment Management Benefit-Cost Analysis for Transportation Projects, Appendix A, Table A.1, SFY2008 Recommended Standard Values. (NDDOT values not available)

² Life-Cycle Cost Analysis in Pavement Design, US Dept of Transportation, FHWA, Table 2.3 (Vehicle Cost per Stop), September 1998 (Refer to Appendix D for calculations) (Adjusted to include an estimated 2% per year rate of inflation).

³ US Department of Energy, Energy Information Administration, Average Fuel Prices 8/01/07 to 8/01/08

To determine the annual economic benefit of the 32nd Avenue Coordination Study, the daily estimated reductions (or increases) in MOE's are calculated and are then applied to the unit benefit.

Net Average Daily MOE

The daily savings for each MOE was determined by multiplying the number of hours each implemented plan is in effect and comparing against the corresponding existing timing plan and traffic volume conditions. It should also be noted, the overall net benefit of these measures accounts for the impact (i.e., typically an increase in vehicle delay) to cross-street MOE. Output used in determining each MOE was computed using Synchro7.0 (off peak and mid-day or balanced plans) and SimTraffic7.0 (AM and PM peak hours). Where collected, the field obtained average approach delays were used in lieu of the model results. **Table 24** illustrates the overall daily "before" and "after" MOE comparison and percent improvement.

Table 25 provides a detailed summary of the daily MOE's and documents the net reduction in vehicle delay, vehicle stops, fuel consumption and vehicles in dilemma zone. A positive value shown in **Table 25** is a benefit (i.e., reduction) and a negative value shown is an impact (i.e., increase).

Table 24. Measures of Effectiveness – Overall Net Daily Comparison

MOE	Monday - Thursday				Friday				Saturday			
	Before	After	Net Reduction	Percent Improvement	Before	After	Net Reduction	Percent Improvement	Before	After	Net Reduction	Percent Improvement
Stops (no. of veh)	113,313	87,636	25,678	22.7%	146,724	115,610	31,114	21.2%	109,642	83,428	26,215	23.9%
Delay (hr)	951	886	65	6.9%	1,408	1,332	77	5.5%	1,136	1,083	52	4.6%
Fuel Consumption (gal)	5,871	5,287	583	9.9%	7,764	7,138	626	8.1%	3,166	2,874	292	9.2%
Dilemma Zone (veh)	6,462	4,125	2,337	36.2%	7,349	4,981	2,369	32.2%	4,690	3,706	985	21.0%

Table 25. Measures of Effectiveness – Net Average Daily MOE Reduction Breakdown

Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Weekday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹				
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Fuel Consumption (gal) (All Approaches)	Dilemma Zone (veh) (All Approaches)
	AM Period (630 to 1100)	4,483	40.8	-28.8	252	553
	Mid-day Period (1100 to 1445)	7,681	91.4	-68.3	101	445
	PM Period (1445 to 2200)	13,514	134.0	-103.9	231	1340
		25,678	266.2	-201.0	583	2,337
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Friday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹				
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Fuel Consumption (gal) (All Approaches)	Dilemma Zone (veh) (All Approaches)
	AM Period (630 to 1030)	3,754	35.3	-24.4	245	489
	Mid-day Period (1030 to 1445)	11,585	171.7	-153.2	128	485
	PM Period (1445 to 2200)	15,775	197.7	-150.2	254	1395
		31,114	404.7	-327.8	626	2,369
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Saturday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹				
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Fuel Consumption (gal) (All Approaches)	Dilemma Zone (veh) (All Approaches)
	All Day Period (830-1800)	26,215	322.9	-270.5	292	985
		26,215	322.9	-270.5	292	985

¹ A positive value equals the net reduction (i.e., benefit) and a negative value equals a net increase (i.e., impact)

² AM period includes the AM OFF and AM PEAK Plans. The OFF period includes the BALANCED Plans and the PM period includes the PM OFF and PM PEAK Plans.

³ Where obtained, AM and PM peak hour cross-street field collected approach delays (before and after) were used in lieu of model output.

Annual Economic Benefit

The net annual economic benefit is based upon 199 Monday to Thursdays (10 holiday days were excluded), 52 Fridays and 52 Saturdays. Applying the number of day and the unit savings to each computed daily MOE, the annual net benefit (or economic savings) can be estimated. **Table 26** documents the overall annual net benefit estimated as a result of the 32nd Avenue Coordination Study. Based on the results, the total estimated annual benefit is estimated at approximately 1.3 million dollars.

Table 26. Annual Net Benefit (dollar)

Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Weekday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross- Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	AM Period (630 to 1100)	3.5%	1.9%	1.08	199	\$115,993.68	-\$81,163.89	\$58,117.76	\$161,620.74	\$254,568.28
	Mid-day Period (1100 to 1445)	2.0%	1.3%	1.08	199	\$257,970.83	-\$192,031.24	\$99,567.94	\$64,398.39	\$229,905.92
	PM Period (1445 to 2200)	1.1%	0.5%	1.08	199	\$376,397.03	-\$291,132.07	\$175,179.69	\$147,798.54	\$408,243.19
	Subtotal (Weekday Annual Total Benefit)					\$750,361.54	-\$564,327.20	\$332,865.39	\$373,817.67	\$892,717.39
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Friday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross- Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	AM Period (630 to 1030)	3.5%	1.9%	1.08	52	\$26,245.84	-\$17,995.24	\$12,715.44	\$40,976.75	\$61,942.79
	Mid-day Period (1030 to 1445)	2.0%	1.3%	1.08	52	\$126,586.98	-\$112,528.42	\$39,243.00	\$21,348.60	\$74,650.16
	PM Period (1445 to 2200)	1.1%	0.5%	1.08	52	\$145,110.12	-\$109,965.39	\$53,437.04	\$42,513.41	\$131,095.19
	Subtotal (Friday Annual Total Benefit)					\$297,942.93	-\$240,489.04	\$105,395.49	\$104,838.77	\$267,688.14
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Saturday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross- Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	All Day Period (830-1800)	0.5%	0.4%	1.08	52	\$236,267.02	-\$197,910.68	\$88,798.93	\$48,892.48	\$176,047.76
	Subtotal (Saturday Annual Total Benefit)					\$236,267.02	-\$197,910.68	\$88,798.93	\$48,892.48	\$176,047.76
Total Project - Zone 151 (Average Annual Benefit)						\$1,284,571.49	-\$1,002,726.92	\$527,059.80	\$527,548.92	\$1,336,453.29

¹ Mn/DOT Metro Traffic Office² Total weekday days were reduced by 10 to account for Holidays. Sundays were not included as part of the Benefit/Cost Analysis.³ AM period includes the AM OFF and AM PEAK Plans. The OFF period includes the BALANCED Plans and the PM period includes the PM OFF and PM PEAK Plans.

4.3.3 Project Cost

Costs for most roadway improvement projects are associated with capital costs, future costs, and operations and maintenance costs. At the end of the analysis period, there would also be a remaining capital value. For the 32nd Avenue Coordination Study, there is not a capital or future cost. The only cost is an “operations” cost and includes the labor required to develop and implement the new signal timing plans. The estimated project cost was **\$43,000** and includes consulting fees, City of Grand Forks expenses for converting 38th Street, 34th Street, 31st Street and 20th Street to “protected/permissive” signal phasing, data collection and City of Grand Forks/Grand Forks-East Grand Forks MPO staff time. Grand Forks staff labor costs for the project management, implementation/fine-tuning of the new timing plans and general project involvement

assumed a labor rate of \$60 per hour. The labor rate for data collection personnel is assumed to be \$20 per hour.

4.3.4 Project Benefit/Cost Ratio

The benefit/cost ratio is computed based on the comparison between the annual net benefit and the total project cost. **Table 27** documents the estimated benefit/cost ratio for 32nd Avenue Coordination Study.

Table 27. 32nd Avenue Signal Optimization Benefit/Cost Ratio

Segment	Number of Intersections	Total Cost / Zone (\$)	Benefit (\$)	Benefit-Cost Ratio
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street)	8	\$43,000	\$1,336,453	31

As shown, the Coordination Study and implementation of optimized signal timing plans resulted in a benefit/cost ratio of approximately **31:1**, considering only one year of benefit.

4.4 Key Project Highlights

The project benefit analysis estimates the 32nd Avenue Coordination Study resulted in a 31:1 benefit/cost ratio and an estimated annual economic savings of 1.3 million dollars, which includes an estimated annual savings of 164,000 gallons of gasoline (average of 600 gallons daily). A number of factors contribute to the exceptional project benefit:

- A significant improvement in travel flow was obtained along 32nd Avenue. Mainline progression was significantly improved, while intersection delays were balanced and overall reduced.
- During the AM peak period. The eastbound travel time was improved by 23 percent and 19 percent in the eastbound and westbound directions, respectively. The overall travel time savings was found to be approximately one minute (two-mile long corridor).
- During the PM peak period, the eastbound delays and travel times were improved by 29 percent and 11 percent in the eastbound and westbound directions, respectively. The overall travel time savings was found to be approximately two minutes in the eastbound direction. Considering the corridor is only two-miles in length, this is a fairly substantial time savings.
- Overall, an estimated 25 percent reduction in total vehicle stops along the corridor was found.

Based on field observations, travel time studies and the benefit/cost analysis, other key project successes include the following:

- The City of Grand Forks investment into the implementation of “protected/permissive” signal phasing at 38th Street, 34th Street, 31st Street and 20th Street contributes greatly to the improvement of intersection efficiency and reduction of motorist delays.
- Successful implementation of lead-lag left turn operation at I-29 West Ramp, I-29 East Ramp, Columbia Road and 24th Street. Although this is not a new operating strategy, it is new to the Grand Forks area. Lead-lag left turn phase operation contributes significantly to the improved mainly vehicle progression along 32nd Avenue.
- An event plan was developed and fine-tuned in the field to accommodate the Alerus Center. The exiting plan was developed in the field during a recent University of North Dakota Football game to provide additional southbound green time for 38th Street and to provide progression for motorists destined to I-29.

5.0 Recommendations

As part of the 32nd Avenue Coordination Study a comprehensive operation review was completed.

5.1 Immediate Recommendations

The City of Grand Forks has dedicated resources to improving traffic flow along 32nd Avenue. The following recommendations were or will be implemented as part of the Coordination Study:

- Installation of upgraded signal controllers. The City of Grand Forks replaced all 170 type signal controllers with new Econolite 2070 controllers and the Oasis software. Upgrading the signal controllers and the software revisions allows for flexibility and compatibility between intersections along the interconnected corridor.
- The addition of northbound/southbound “protected/permissive” left turn arrows at both 38th Street and 34th Street. The 38th Street left turn arrows will be activated in September 2008. The conversion from “protected” only to “protected/permissive” left turn arrows on the eastbound and westbound approaches at both 31st Street and 20th Street. The eastbound/westbound “protected/permissive” left turn arrow conversion is expected to occur in August/September 2008. However, it should be noted there may be a potential change in intersection safety characteristics with the conversion of the signal phasing from “protected” only to “protected/permissive.” Based on the FHWA Issue Brief research data, the left turn related crashes may increase 65 percent at each intersection.
- The video detection camera at the 31st Street intersection was repaired (identified as an existing hardware issue).
- Southbound vehicle detection issues at 32nd Avenue/38th Street intersection will be repaired. The City of Grand Forks will be installing a video detection camera and making it operational in September 2008.
- Re-programming of all local intersection signal controllers. As part of the signal timing implementation, new minimum green times, vehicle clearance intervals, pedestrian timing intervals, right turn lane delayed detection timers and controller configuration settings were inputted. Re-programming of the controllers results in consistency, some intersection efficiency gains and standardization of the signal optimization process. As part of this effort, the vehicle re-service issue noted at the 24th Street intersection was corrected.

5.2 Near and Long Range Recommendations

During the field implementation and signal timing review process, a few signal operation or roadway improvements were identified for further review and/or consideration. The suggested geometric improvements may require further feasibility review.

5.2.1 Geometric Improvements

The following geometric improvements are expected to result in a substantial improvement in intersection operation efficiency.

- 32nd Avenue at 38th Street - construct an exclusive 250 foot (plus taper) southbound right turn lane.
- 32nd Avenue at 34th Street – construct an exclusive 250 foot (plus taper) southbound right turn lane. Extend the westbound left turn lane to provide 300 feet of storage (may need to shorten eastbound left turn lane at 31st Street).
- 32nd Avenue at Columbia Road – construct a second northbound and westbound left turn lane.
- 32nd Avenue at 31st Street – lengthen the westbound left turn lane to provide 300 feet of storage. The existing storage length is sufficient from a capacity standpoint; however, its short length is causing diverging/braking vehicles to slow in the through lane disrupting the traffic flow.

The 34th Street and 38th Street right turn lane improvements should be prioritized in the near future. The Columbia Road and 31st Street geometric improvements are of lesser importance and could be prioritized on a longer range schedule.

5.2.2 Signal Detection Improvements

To improve safety and operational efficiency during free mode operation, advanced dilemma zone detection (mainline approaches only) should be installed at 38th Street, 34th Street, 31st Street, Columbia Road, 24th Street and 20th Street. The advanced loop or video detection should be placed at 250 feet for a 40 mph posted speed limit.

5.2.3 Future Signal Coordination or Timing Adjustments

Consideration of cross-coordination with north/south Columbia Road and north/south Washington Street should be made. Based on the coordination feasibility review conducted as part of this project, the following order of priority should be given:

- The optimal cycle lengths should be selected for 32nd Avenue, Columbia Road and Washington Street individually.
- Coordination priority should be given to northbound and southbound phases at the 32nd Avenue/Washington Street intersection.
- At 32nd Avenue/Columbia Road, priority should be given to the eastbound/westbound 32nd Avenue phases.
- Where optimal cycle lengths are similar or close for both 32nd Avenue and Washington Street, a common cycle length should be selected. Provide inter-zone cross-coordination (using master clock scheduler in Translink), with northbound/southbound Washington the coordinated phases during the weekday and consider the eastbound/westbound directions the coordinated phases on the weekend.
- Where optimal cycle lengths are similar or close for both 32nd Avenue and Columbia Road, a common cycle length should be selected. Provide inter-zone cross-coordination (using master clock scheduler in Translink).

Future signal timing adjustments along 32nd Avenue may include the following:

- Consider the implementation of a specific Holiday timing plan. A review of the Saturday traffic conditions in December should be conducted to determine the need for timing adjustments or a separate plan.
- Consider the implementation of an event specific timing plan to assist traffic control officers at the 32nd Avenue/38th Street intersection.
- Continue to monitor the TOD transitions and adjust as traffic conditions warrant.

5.2.4 Roadway Signing and Other

A few other suggestions include:

- Install a speed limit sign along 32nd Avenue between I-29 East Ramp and 38th Street.
- Review the mast arm signing at each intersection to ensure a consistent use of the “Left Turn Yield on Green Ball” sign.
- Continue monitoring the crash history at the 32nd Avenue/38th Street, 34th Street, 31st Street and 20th Street intersections upon completion of the new signal timing plans.

5.2.5 Signal Timing Management Program

The City of Grand Forks operates approximately 60 signalized intersections. Under the City's jurisdiction there are six major signalized arterials. As shown with the 32nd Avenue Coordination Study, there is a significant traffic operation benefit to the motoring public for a fairly low cost. Although infrastructure improvements may be warranted in locations, many deficiencies may actually be corrected through maintaining optimized signal timing and efficient corridor operation. Considering the typically large benefit to cost ratio of signal timing projects, maintaining efficient corridor operation should be given a high priority. The following should be considered:

- Develop a program (and funding source) for regular retiming of the major signalized corridors (e.g., Demers, Gateway, Washington, Columbia, 32nd Avenue, downtown, etc.). Signal optimization degrades linearly over time due to growth and changes in traffic patterns. Depending upon growth, importance and actual changes in traffic characteristics, fully re-optimizing the system should occur every three to five years.
- To extend the life cycle of newly optimized timing plans, develop a program for managing the corridor. This would include scheduling bi-annual field reviews and fine-tuning.
- Develop a process for managing and record keeping of the current signal timing plans and parameters. This would include a checklist procedure for ensuring the controller, Synchro7.0 file, Tranklink, intersection file and cabinet log book is kept up to date and consistent any time a change is made.
- Develop a checklist and procedure for addressing citizen complaints.

Appendix A:
Travel Time Comparison (Field vs. Model)

Table A-1. 32nd Avenue Travel Time Comparison - AM PEAK

WESTBOUND

Intersection	Distance (feet)	Field Collected			Synchro Model		SimTraffic Model ¹		Statistical "Z" Test			
		Average Travel Time (seconds)	Travel Time Range (Min)	Travel Time Range (Max)	Travel Time (seconds)	Percent Difference	Travel Time (seconds)	Percent Difference	S _a	Allowable Difference	Field vs. Model Difference	Within Allowable
10th Street	0											
Washington Street	1,156	53.9	29.0	114.0	66.5	-23.4%	61.4	-13.9%	11.72	23.0	7.5	Yes
20th Street	2,626	67.2	46.0	125.0	57.1	15.1%	60.2	10.4%	8.52	16.7	7.0	Yes
24th Street	1,346	40.0	32.8	48.8	33.7	15.7%	33.2	16.9%	2.90	5.7	6.8	No
Columbia Road	1,312	59.9	49.2	73.2	51.0	14.9%	49.1	18.1%	4.35	8.5	10.8	No
31st Avenue	1,581	37.0	29.0	57.0	31.6	14.6%	36.2	2.2%	3.63	7.1	0.8	Yes
34th Street	1,057	30.9	17.0	54.0	41.5	-34.4%	30.5	1.3%	5.77	11.3	0.4	Yes
38th Street	1,331	27.7	22.0	41.0	36.8	-33.0%	34.1	-23.3%	2.02	4.0	6.4	No
I 29 East Ramp	838	15.1	13.0	17.0	26.7	-76.7%	19.2	-27.1%	0.41	0.8	4.1	No
I 29 West Ramp	895	22.4	15.0	42.0	22.0	2.0%	21.5	4.2%	3.66	7.2	0.9	Yes
Total	12,142	354.1	253.0	572.0	366.9	-3.6%	345.4	2.5%	22.53	44.2	8.7	Yes

1. Average of 5 simulation runs with different random seed numbers

EASTBOUND

Intersection	Distance (feet)	Field Collected			Synchro Model		SimTraffic Model ¹		Statistical "Z" Test			
		Average Travel Time (seconds)	Travel Time Range (Min)	Travel Time Range (Max)	Travel Time (seconds)	Percent Difference	Travel Time (seconds)	Percent Difference	S _a	Allowable Difference	Field vs. Model Difference	Within Allowable
Business Driveway	0											
I 29 West Ramp	2,180	50.8	42.0	77.0	52.5	-3.3%	45.5	10.4%	4.51	8.8	5.3	Yes
I 29 East Ramp	895	20.2	16.0	27.0	21.3	-5.4%	19.7	2.5%	1.58	3.1	0.5	Yes
38th Street	838	16.5	13.0	30.0	24.2	-46.7%	21.7	-31.5%	1.88	3.7	5.2	No
34th Street	1,331	41.2	23.0	69.0	43.4	-5.3%	34.2	17.0%	5.42	10.6	7.0	Yes
31st Avenue	1,057	33.5	18.0	70.0	43.6	-30.1%	42.0	-25.4%	7.10	13.9	8.5	Yes
Columbia Road	1,581	54.8	28.0	95.0	54.3	0.9%	57.2	-4.4%	8.75	17.2	2.4	Yes
24th Street	1,312	36.0	23.9	52.5	41.8	-16.0%	39.0	-8.2%	3.95	7.7	3.0	Yes
20th Street	1,346	32.0	21.2	46.5	33.6	-5.1%	34.9	-9.2%	3.50	6.9	2.9	Yes
Washington Street	2,626	89.6	50.0	154.0	74.8	16.5%	78.7	12.2%	12.34	24.2	10.9	Yes
Total	13,166	374.6	235.0	621.0	389.5	-4.0%	372.9	0.5%	24.43	47.9	1.7	Yes

1. Average of 5 simulation runs with different random seed numbers

Table A-2. 32nd Avenue Travel Time Comparison - PM PEAK

WESTBOUND

Intersection	Distance (feet)	Field Collected			Synchro Model		SimTraffic Model ¹		Statistical "Z" Test			
		Average Travel Time (seconds)	Travel Time Range (Min)	Travel Time Range (Max)	Travel Time (seconds)	Percent Difference	Travel Time (seconds)	Percent Difference	S _d	Allowable Difference	Field vs. Model Difference	Within Allowable
10th Street	0											
Washington Street	1,156	73.1	38.0	105.0	67.2	8.1%	65.7	10.2%	12.02	23.6	7.4	Yes
20th Street	2,626	67.0	47.0	98.0	69.6	-3.9%	70.8	-5.7%	9.42	18.5	3.8	Yes
24th Street	1,346	41.5	17.4	50.0	34.1	17.8%	34.7	16.4%	5.08	10.0	6.8	Yes
Columbia Road	1,312	70.7	29.6	85.1	61.8	12.5%	59.9	15.2%	8.65	17.0	10.8	Yes
31st Avenue	1,581	41.4	31.0	55.0	38.3	7.6%	43.2	-4.3%	5.89	11.5	1.8	Yes
34th Street	1,057	26.3	21.0	35.0	45.6	-73.5%	39.8	-51.4%	2.81	5.5	13.5	No
38th Street	1,331	32.0	27.0	72.0	42.0	-31.3%	42.9	-34.1%	2.54	5.0	10.9	No
I 29 East Ramp	838	16.3	15.0	22.0	28.1	-72.5%	22.7	-39.4%	1.26	2.5	6.4	No
I 29 West Ramp	895	27.0	15.0	39.0	22.8	15.6%	24.0	11.1%	4.24	8.3	3.0	Yes
Total	12,142	395.3	241.0	561.0	409.5	-3.6%	403.7	-2.1%	31.70	62.1	8.4	Yes

1. Average of 5 simulation runs with different random seed numbers

EASTBOUND

Intersection	Distance (feet)	Field Collected			Synchro Model		SimTraffic Model ¹		Statistical "Z" Test			
		Average Travel Time (seconds)	Travel Time Range (Min)	Travel Time Range (Max)	Travel Time (seconds)	Percent Difference	Travel Time (seconds)	Percent Difference	S _d	Allowable Difference	Field vs. Model Difference	Within Allowable
Business Driveway	0											
I 29 West Ramp	2,180	65	41.0	97.0	56.7	12.9%	53.6	17.7%	8.84	17.3	11.5	Yes
I 29 East Ramp	895	20	16.0	25.0	21.0	-6.3%	22.6	-14.4%	1.47	2.9	2.9	Yes
38th Street	838	37	15.0	59.0	36.5	2.0%	34.6	7.1%	6.98	13.7	2.7	Yes
34th Street	1,331	58	27.0	80.0	54.3	6.4%	51.1	11.9%	12.17	23.8	6.9	Yes
31st Avenue	1,057	67	24.0	86.0	48.1	28.1%	48.8	27.0%	8.76	17.2	18.1	No
Columbia Road	1,581	75	37.0	107.0	63.1	16.1%	65.6	12.8%	12.98	25.4	9.7	Yes
24th Street	1,312	34	23.0	48.0	45.3	-32.2%	42.4	-23.8%	4.72	9.3	8.1	Yes
20th Street	1,346	37	25.0	52.0	42.7	-15.0%	45.4	-22.3%	5.12	10.0	8.3	Yes
Washington Street	2,626	78	48.0	138.0	72.0	7.8%	81.5	-4.3%	11.35	22.2	3.4	Yes
Total	13,166	471.8	256.0	692.0	439.7	6.8%	445.6	5.5%	24.15	47.3	26.2	Yes

1. Average of 5 simulation runs with different random seed numbers

Appendix B:
Minimum Green, Clearance and Pedestrian Interval
Timings

32nd Avenue Yellow, All Red, Pedestrian Intervals (YARP)

*** Measurements Attached ***

Columbia Road - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
WBL	Phase 1			3.0	2.3	2.0	7
EB	Phase 2	6	14	4.0	2.5	2.5	15
NBL	Phase 3			3.0	2.1	2.0	7
SB	Phase 4	6	15	4.0	2.3	2.5	10
EBL	Phase 5			3.0	2.6	2.0	7
WB	Phase 6	6	15	4.0	2.4	2.5	15
SBL	Phase 7			3.0	2.7	2.0	7
NB	Phase 8	6	14	4.0	2.4	2.5	10

Note: USE CALCULATED FDW and 6 SEC WALK. CROSS TO MEDIAN DUE TO CYCLE LENGTH LIMITATION

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
113			
129	105	63	30
106			
115	107	65	31
135			
121	111	66	32
136			
119	104	62	30

I-29 West Ramp - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
	Phase 1	NC	NC	NC	NC	NC	5
	Phase 2	NC	NC	NC	NC	NC	15
	Phase 3	NC	NC	NC	NC	NC	
	Phase 4	NC	NC	NC	NC	NC	
	Phase 5	NC	NC	NC	NC	NC	
	Phase 6	NC	NC	NC	NC	NC	15
	Phase 7	NC	NC	NC	NC	NC	
	Phase 8	NC	NC	NC	NC	NC	8

NO CHANGES TO CLEARANCE INTERVAL

NEW MIN GRN TIMES

I-29 East Ramp - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
	Phase 1	NC	NC	NC	NC	NC	
	Phase 2	NC	NC	NC	NC	NC	15
	Phase 3	NC	NC	NC	NC	NC	
	Phase 4	NC	NC	NC	NC	NC	8
	Phase 5	NC	NC	NC	NC	NC	5
	Phase 6	NC	NC	NC	NC	NC	15
	Phase 7	NC	NC	NC	NC	NC	
	Phase 8	NC	NC	NC	NC	NC	

NO CHANGES TO CLEARANCE INTERVAL

NEW MIN GRN TIMES

38th Street - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
EBLT	Phase 1			3.0	1.9	2.5	5
WB	Phase 2	6	19	4.0	1.6	2.5	15
NBLT	Phase 3			3.0	2.2	2.5	5
SB	Phase 4	10	15	4.0	2.0	2.5	10
WBLT	Phase 5			3.0	1.7	2.5	5
EB	Phase 6	6	21	4.0	1.9	2.5	15
SBLT	Phase 7			3.0	2.2	2.5	5
NB	Phase 8	14	14	4.0	2.2	2.5	10

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
92			
75	80	80	19
111			
100	99	64	25
82			
90	85	85	21
111			
108	110	60	28

34th Street - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
WBLT	Phase 1			3.0	1.6	2.5	5
EB	Phase 2	6	13	4.0	1.5	2.5	15
SBLT	Phase 3			3.0	2.3	2.5	5
NB	Phase 4	13	12	4.0	2.4	2.5	10
EBLT	Phase 5			3.0	2.2	2.5	5
WB	Phase 6	6	11	4.0	1.7	2.5	15
NBLT	Phase 7			3.0	2.1	2.5	5
SB	Phase 8	10	16	4.0	2.4	2.5	10

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
72			
67	57	57	13
113			
118	101	56	25
110			
78	50	50	11
102			
122	104	69	26

31st Street - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
EBLT WB	Phase 1			3.0	1.6	2.0	5
	Phase 2	6	20	4.0	1.7	2.5	15
	Phase 3						
NB WBLT EB	Phase 4	8	14	4.0	2.2	2.5	10
	Phase 5				1.7	2.0	5
	Phase 6	6	18	4.0	1.5	2.5	15
SB	Phase 7						
	Phase 8	10	15	4.0	2.4	2.5	10

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
74			
82	82	82	20
109	90	60	22
82			
68	74	74	18
122	101	65	25

24th Street - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
WBLT EB NBLT	Phase 1			3.0	0.9	2.0	5
	Phase 2	13	11	4.0	2.0	2.0	15
	Phase 3			3.0	1.9	2.0	8
WB	Phase 4						
	Phase 5						
	Phase 6			4.0	1.0	2.0	15
NB	Phase 7						
	Phase 8	13	9	4.0	1.1	2.0	8

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
31			
96	97	51	24
92			
40			
44	88	45	22

20th Street - Controller Input

Direction	Phase	Walk	FDW	Yellow	All Red (Calculated)	All Red (USE)	Min Green
WBLT EB	Phase 1			3.0	1.4	2.0	5
	Phase 2	6	14	4.0	1.6	2.5	15
	Phase 3						
NB EBLT WB	Phase 4	11	9	4.0	1.9	2.5	10
	Phase 5			3.0	1.6	2.0	5
	Phase 6	6	14	4.0	1.6	2.5	15
SB	Phase 7						
	Phase 8	12	10	4.0	1.9	2.5	10

Measurements

Car Dist (For All Red) ("c")	Total Crossing Distance ("a")	Longest Leg to Median Button ("b")	Total ped time
63			
74	61	61	14
92	84	45	20
74			
74	60	60	14
91	88	46	22

All Red = (width of intersection + Length of vehicle) / (1.467 * speed in mph),

Yellow = 1 + ((1.467 * (speed in mph))/(2 * (deceleration rate + 64.4 * grade in percent)))

Deceleration Rate = 10

Total Ped Time = (Total Crossing Distance / 3.5) - Yellow

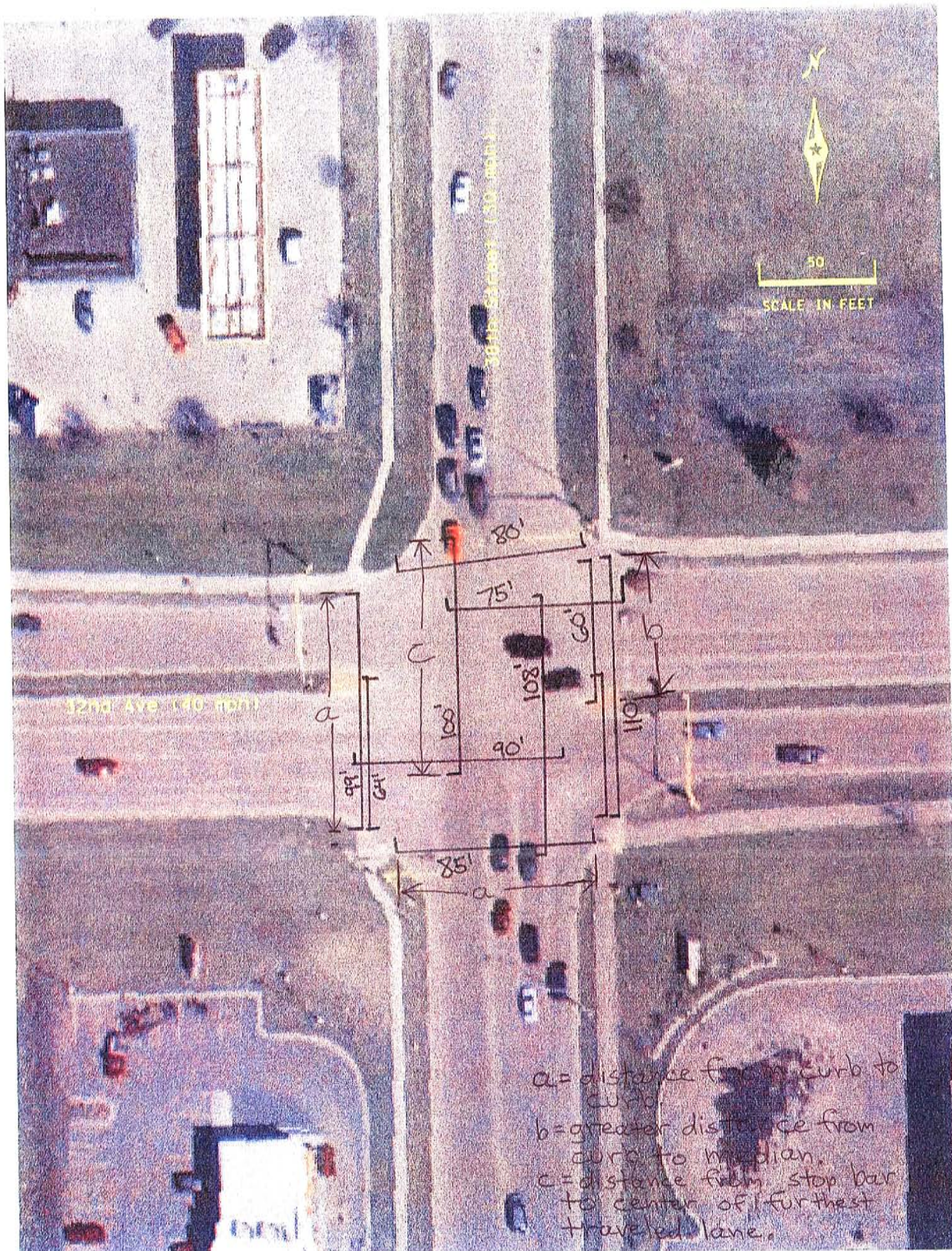
FDW = (Longest Distance to Median Button / 3.5) - Yellow

Use Total distance / 3.5 - Yellow if no median button

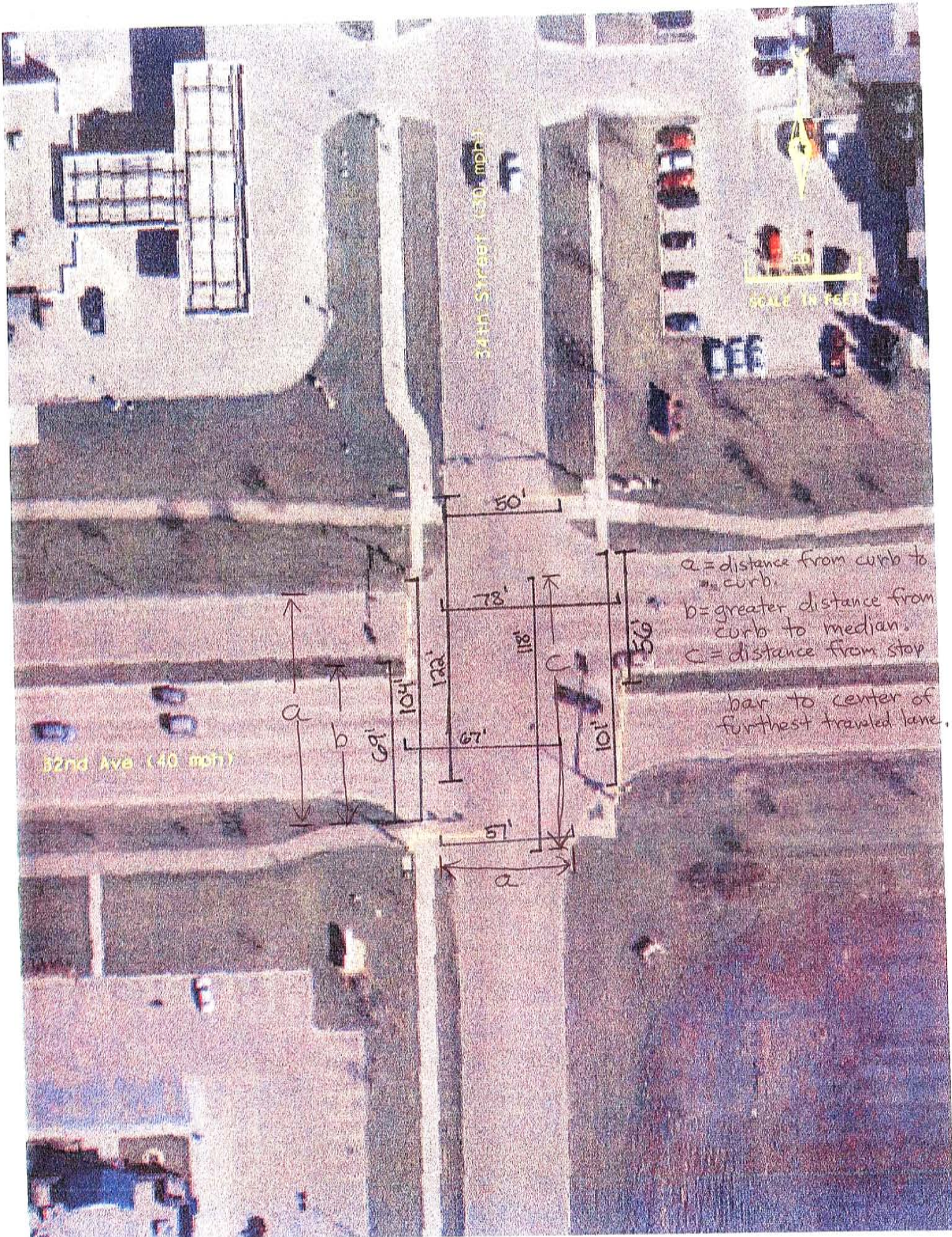
Walk = Total Ped Time - FDW

Use 6 seconds if no median button.

Source: City of Grand Forks



a = distance from curb to curb
b = greater distance from curb to median
c = distance from stop bar to center of furthest traveled lane

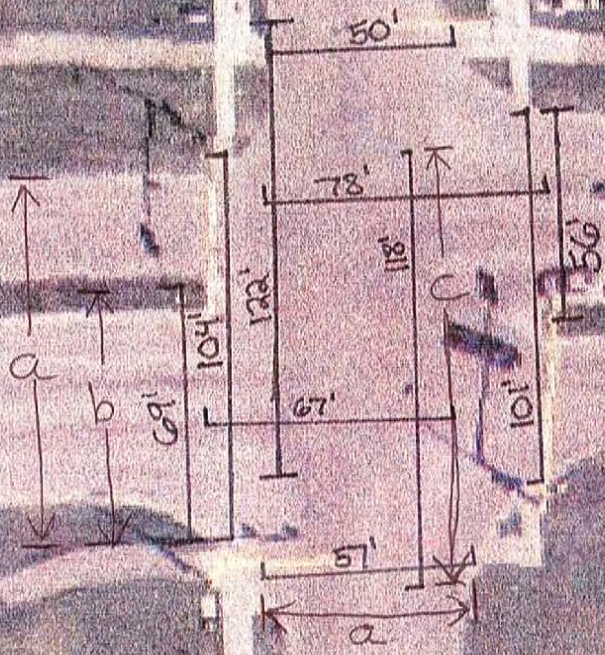


32nd Street (30 mph)

52nd Ave (40 mph)

50
SCALE IN FEET

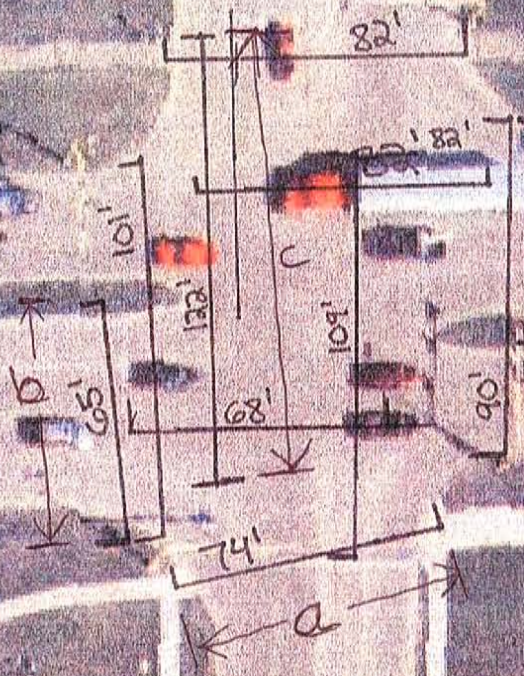
a = distance from curb to curb.
 b = greater distance from curb to median.
 C = distance from stop bar to center of furthest traveled lane.





SCALE IN FEET

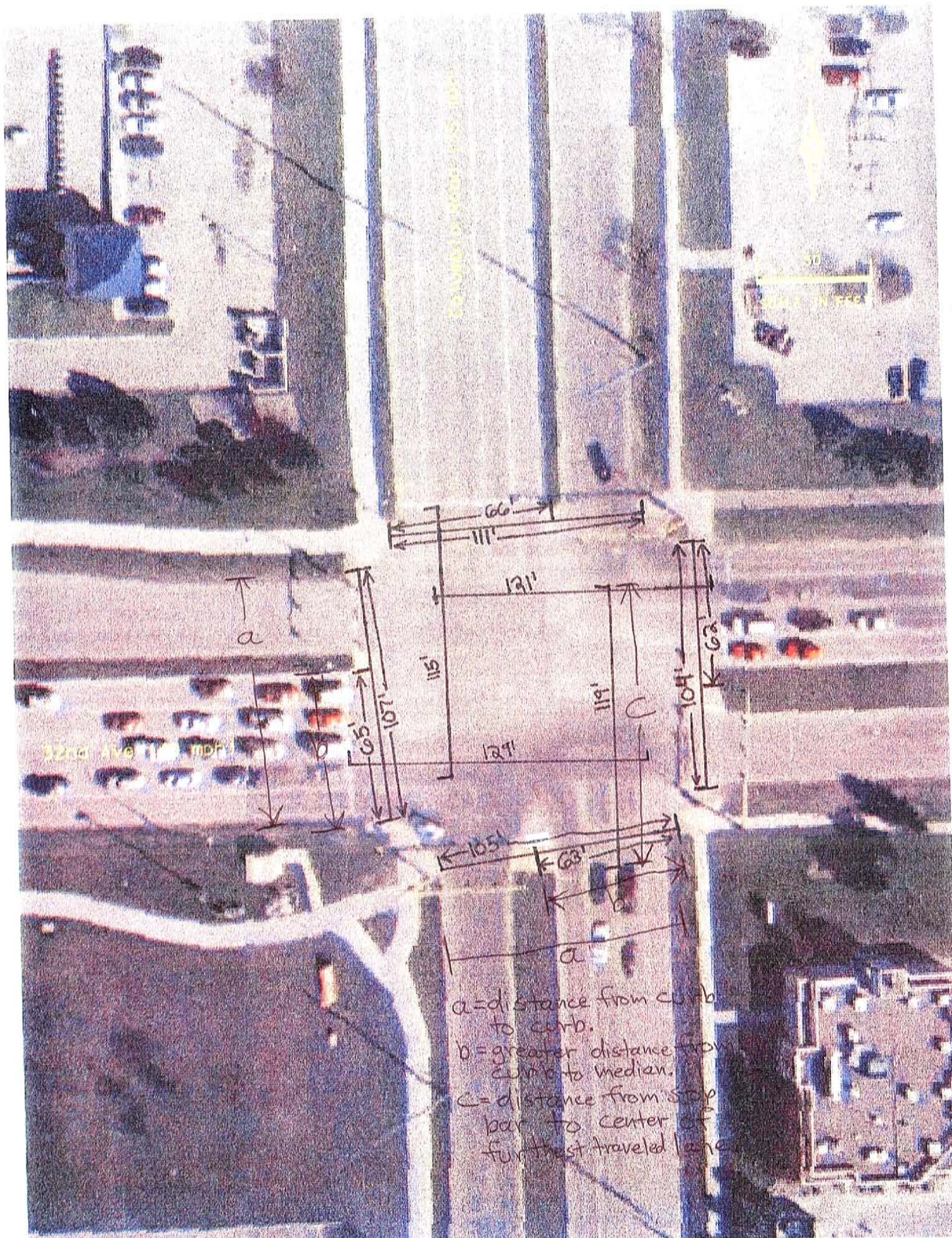
32nd Ave 140 mph



a = distance from curb to curb.
 b = greater distance from curb to median.

a c = distance from

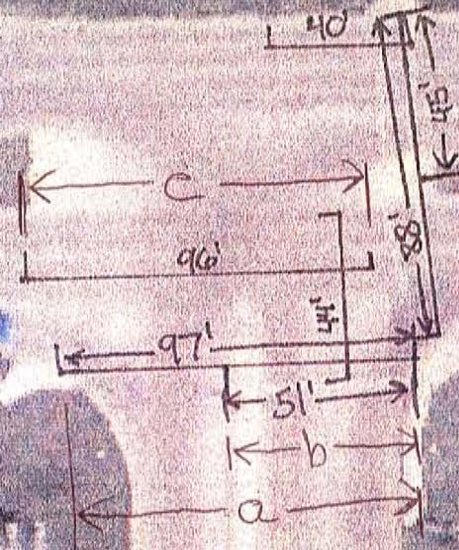
stop bar to center of furthest traveled lane.



F

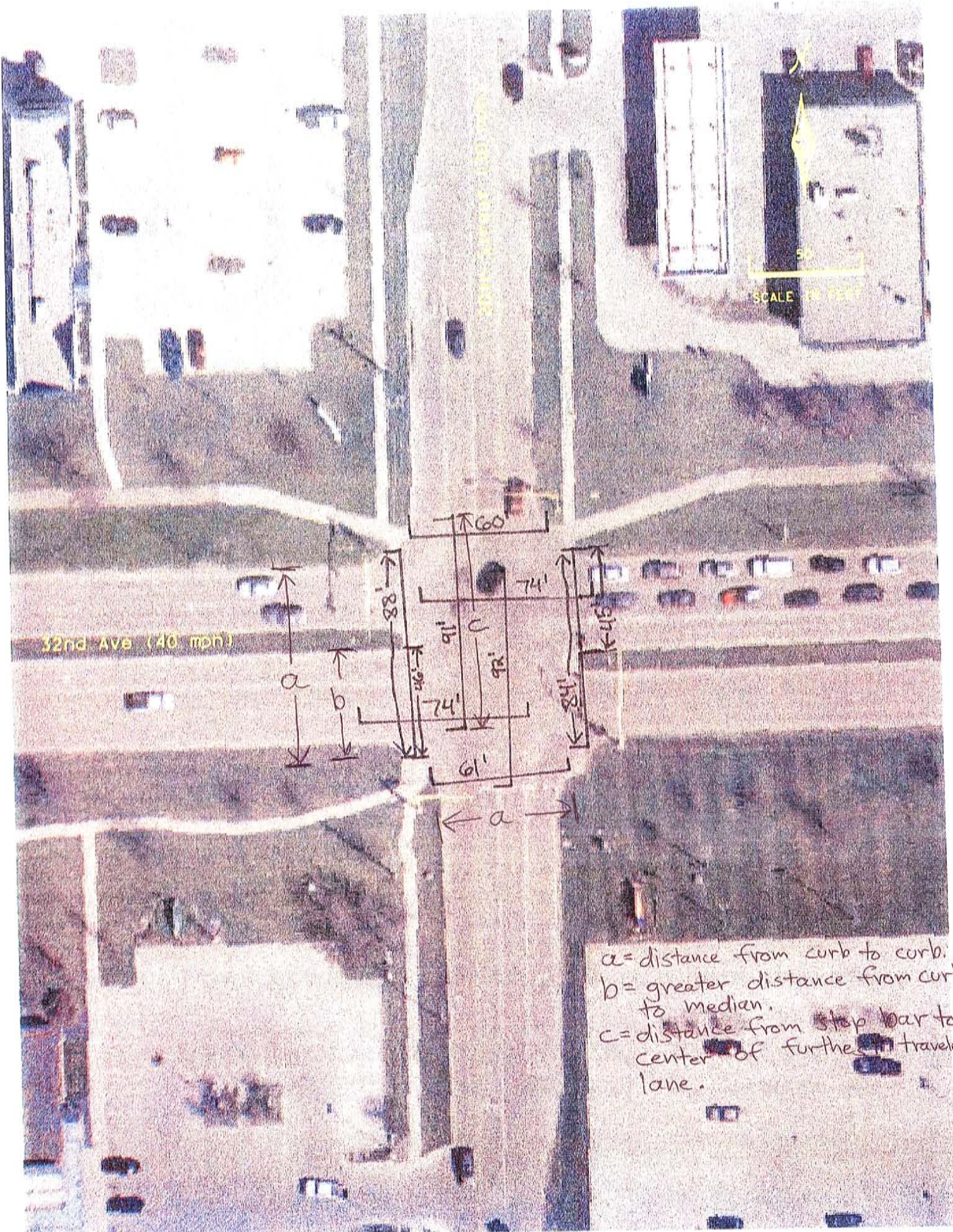
SCALE 1" = 100'

32nd Ave (40 mph)



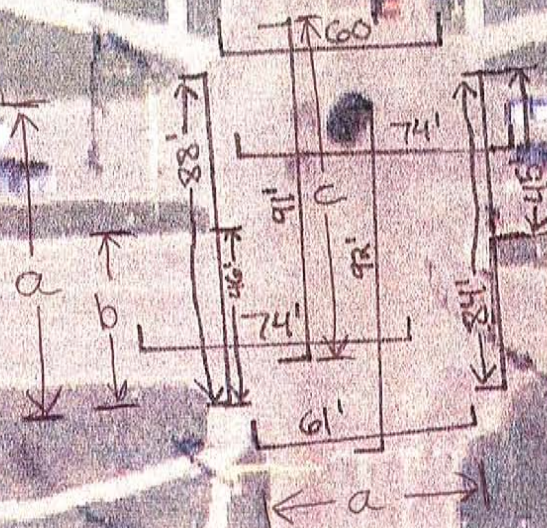
a = distance from curb to curb
b = greater distance from curb to median.

c = distance from stop bar to center of furthest traveled lane.



32nd Ave (40 mph)

SCALE 1" = 50'



a = distance from curb to curb.
b = greater distance from curb to median.
c = distance from stop bar to center of furthest traveled lane.

Appendix C:
Final Signal Timing Coordination Parameters by
Intersection

Zone 151 - 32nd Avenue (I-29 West Ramp to 20th Street)

Revised: September 6, 2008

32nd Avenue at I-29 West Ramp

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	157	15	25	0	0	0	40	0	40	80	63	2	26	2	
Plan 2	157	30	45.7	0	0	0	45.7	0	40.3	0	0	1	0	1	Manual Free - PLAN 66
Plan 3	157	13	21	0	0	0	34	0	16	50	38	2	26	2	
Plan 4	157	15	25	0	0	0	40	0	20	60	17	2	26	2	
Plan 5	157	13	24	0	0	0	37	0	18	55	34	2	26	2	
Plan 6 (EVENT EXIT)	157	55	35	0	0	0	90	0	20	110	37	1	26	1	
MinSplit	157	10	20.7	0	0	0	21.7	0	13.3						

32nd Avenue at I-29 East Ramp

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	156	0	50	0	30	13	37	0	0	80	60	5	26	1	
Plan 2	156	0	45.7	0	30.7	30	45.7	0	0	0	0	5	0	1	Manual Free - PLAN 66
Plan 3	156	0	34	0	16	12	22	0	0	50	36	6	26	3	
Plan 4	156	0	44	0	16	13	31	0	0	60	8	6	26	3	
Plan 5	156	0	37	0	18	13	24	0	0	55	27	6	26	3	
Plan 6 (EVENT EXIT)	156	0	90	0	20	15	75	0	0	110	76	6	26	3	
MinSplit	156	0	20.7	0	13.7	10	21.7	0	0						

32nd Avenue at 38th Street

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	155	13	36	13	18	13	36	13	18	80	55	1357	26	1	
Plan 2	155	13	36	13	18	13	36	13	18	80	69	1357	26	1	
Plan 3	155	17	44	18	21	12	49	12	27	100	59	1357	26	1	
Plan 4	155	18	54	22	26	12	60	13	35	120	32	1357	26	1	
Plan 5	155	13	51	22	24	30	34	13	33	110	15	1357	26	1	
Plan 6 (EVENT EXIT)	155	13	35	44	18	11	37	11	51	110	12	1357	26	1	
MinSplit	155	10.5	31.5	10.5	31.5	10.5	33.5	10.5	34.5						

32nd Avenue at 34th Street

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	154	13	36	13	18	13	36	13	18	80	2	1357	26	1	
Plan 2	154	13	36	13	18	13	36	13	18	80	10	1357	26	1	
Plan 3	154	23	43	16	18	12	54	11	23	100	62	1357	26	1	
Plan 4	154	25	50	18	27	13	62	12	33	120	43	1357	26	1	
Plan 5	154	28	37	18	27	12	53	12	33	110	9	1357	26	1	
Plan 6 (EVENT EXIT)	154	28	37	18	27	12	53	12	33	110	10	1357	26	1	
MinSplit	154	10.5	25.5	10.5	31.5	10.5	23.5	10.5	32.5						

32nd Avenue at 31st Avenue

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	153	15	45	0	20	15	45	0	20	80	2	15	26	1	
Plan 2	153	15	47	0	18	15	47	0	18	80	5	15	26	1	
Plan 3	153	16	66	0	18	17	65	0	18	100	89	15	26	1	
Plan 4	153	15	80	0	25	20	75	0	25	120	58	15	26	1	
Plan 5	153	15	67	0	28	15	67	0	28	110	26	15	26	1	
Plan 6 (EVENT EXIT)	153	15	69	0	26	15	69	0	26	110	26	15	26	1	
MinSplit	153	12	32.5	0	16.5	12	21.5	0	16.5						

32nd Avenue at Columbia Road

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	152	15	30	15	20	15	30	15	20	80	46	1357	26	1	
Plan 2	152	15	32	15	18	15	32	15	18	80	50	1357	26	1	
Plan 3	152	18	39	21	22	20	37	18	25	100	8	1367	26	3	
Plan 4	152	19	48	26	27	23	44	23	30	120	80	1367	26	3	
Plan 5	152	23	43	23	21	23	43	22	22	110	45	1367	26	3	
Plan 6 (EVENT EXIT)	152	23	43	23	21	23	43	22	22	110	45	1367	26	3	

MinSplit 152 12 26.5 12 27.5 12 27.5 12 26.5

32nd Avenue at 24th Street

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	150	13	49	18	0	0	62	0	18	80	43	1	26	1	
Plan 2	150	13	49	18	0	0	62	0	18	80	49	1	26	1	
Plan 3	150	15	65	20	0	0	80	0	20	100	36	2	26	2	
Plan 4	150	20	75	25	0	0	95	0	25	120	108	2	26	2	
Plan 5	150	23	62	25	0	0	85	0	25	110	72	2	26	2	
Plan 6 (EVENT EXIT)	150	23	62	25	0	0	85	0	25	110	72	2	26	2	

MinSplit 150 10 30 13 0 0 21 0 28

32nd Avenue at 20th Street

Plan Identification	System ID	Split 1 (Sec)	Split 2 (Sec)	Split 3 (Sec)	Split 4 (Sec)	Split 5 (Sec)	Split 6 (Sec)	Split 7 (Sec)	Split 8 (Sec)	Cycle Length (s)	Offset (Sec)	Leading Phase	Coordinated Phase	Sequence	Notes
Plan 1	149	15	43	0	22	15	43	0	22	80	10	15	26	1	
Plan 2	149	15	43	0	22	15	43	0	22	80	17	15	26	1	
Plan 3	149	20	51	0	29	20	51	0	29	100	53	15	26	1	
Plan 4	149	18	64	0	38	25	57	0	38	120	21	15	26	1	
Plan 5	149	25	56	0	29	25	56	0	29	110	97	15	26	1	
Plan 6 (EVENT EXIT)	149	25	56	0	29	25	56	0	29	110	97	15	26	1	

MinSplit 149 12 26.5 0 26.5 12 26.5 0 28.5

Sequence 1	1	2	3	4
	5	6	7	8
Sequence 2	2	1	3	4
	5	6	7	8
Sequence 3	1	2	3	4
	6	5	7	8

Appendix D:
Benefit/Cost Analysis

Traffic Volume Cases and TOD Signal Timing Plans

Final TOD/Volume Case

Existing TOD/Volume Case

Volume/Time Check

Zone 151 and 222

Zone 151 and 222

Zone 151 and 222

Tab	Time	Pattern 151-222	Cycle Length (s)	Volume Description	Hours/day	Tab	Time	Pattern 151-222	Cycle Length (s)	Volume Description	Hours/day	Vol Case	Proposed	Existing	OK?
1a	630-830	1-8	80-105	AM PEAK	2	1b	630-845	FREE-8	FREE-105	AM PEAK	2.25	Mon-Thurs			
2a	830-845	2-8	80-105	AM PEAK	0.25	2b	845-1100	FREE-8	FREE-105	BAL LOW	2.25	AM PEAK	2.25	2.25	OK
3a	845-1030	2-8	80-105	BAL LOW	1.75	3b	1100-115	FREE-8	FREE-105	BAL PEAK 1	2.25	BAL LOW	5.75	5.75	OK
4a	1030-1100	3-8	100-105	BAL LOW	0.5	4b	115-200	FREE-8	FREE-105	PM OFF 1	0.75	BAL PEAK 1	2.25	2.25	OK
5a	1100-115	3-8	100-105	BAL PEAK 1	2.25	5b	200-245	FREE-9	FREE-115	PM OFF 1	0.75	PM OFF 1	1.5	1.5	OK
6a	115-200	3-8	100-105	PM OFF 1	0.75	6b	245-430	FREE-9	FREE-115	PM OFF 2	1.75	PM OFF 2	2.5	2.5	OK
7a	200-245	3-9	100-115	PM OFF 1	0.75	7b	430-545	FREE-9	FREE-115	PM PEAK 1	1.25	PM PEAK 1	1.25	1.25	OK
8a	245-430	4-9	120-115	PM OFF 2	1.75	8b	545-600	FREE-9	FREE-115	PM OFF 2	0.25	TOTAL	15.5	15.5	OK
9a	430-545	4-9	120-115	PM PEAK 1	1.25	2b	600-630	FREE-8	FREE-105	PM OFF 2	0.5				
8a	545-600	4-9	120-115	PM OFF 2	0.25	2b	630-1000	FREE-8	FREE-105	BAL LOW	3.5	Fri			
10a	600-630	4-8	120-105	PM OFF 2	0.5	1b	630-845	FREE-8	FREE-105	AM PEAK	2.25	AM PEAK	2.25	2.25	OK
4a	630-800	3-8	100-105	BAL LOW	1.5	2b	845-1030	FREE-8	FREE-105	BAL LOW	1.75	BAL LOW	4	4	OK
3a	800-1000	2-8	80-105	BAL LOW	2	9b	1030-200	FREE-8	FREE-105	BAL PEAK 2	3.5	BAL PEAK 2	4.75	4.75	OK
1a	630-830	1-8	80-105	AM PEAK	2	10b	200-245	FREE-9	FREE-115	BAL PEAK 2	0.75	BAL PEAK 1	1.25	1.25	OK
2a	830-845	2-8	80-105	AM PEAK	0.25	11b	245-415	FREE-9	FREE-115	PM OFF 3	1.5	PM OFF 3	1.5	1.5	OK
3a	845-1030	2-8	80-105	BAL LOW	1.75	12b	415-600	FREE-9	FREE-115	PM PEAK 2	1.75	PM PEAK 2	1.75	1.75	OK
11a	1030-200	3-8	100-115	BAL PEAK 2	3.5	9b	600-630	FREE-8	FREE-105	BAL PEAK 2	0.5	TOTAL	15.5	15.5	OK
12a	200-245	3-9	100-115	BAL PEAK 2	0.75	3b	630-745	FREE-8	FREE-105	BAL PEAK 1	1.25				
13a	245-415	4-9	120-115	PM OFF 3	1.5	2b	745-1000	FREE-8	FREE-105	BAL LOW	2.25	Sat			
14a	415-600	4-9	120-115	PM PEAK 2	1.75	2b	830-930	FREE-8	FREE-105	BAL LOW	1	BAL LOW	1	1	OK
15a	600-630	4-8	120-105	BAL PEAK 2	0.5	3b	930-1100	FREE-8	FREE-105	BAL PEAK 1	1.5	BAL PEAK 1	1.5	1.5	OK
5a	630-745	3-8	100-105	BAL PEAK 1	1.25	13b	1045-200	FREE-8	FREE-105	SAT PEAK	3	SAT PEAK	7	7	OK
3a	745-1000	2-8	80-105	BAL LOW	2.25	14b	200-600	FREE-9	FREE-115	SAT PEAK	4	TOTAL	9.5	9.5	OK
3a	830-930	2-8	80-105	BAL LOW	1										
5a	930-1100	3-8	100-105	BAL PEAK 1	1.5										
16a	1100-200	5-8	110-105	SAT PEAK	3										
17a	200-600	5-9	110-120	SAT PEAK	4										

151 = 32nd Ave (I-29 to 20th Ave) - 8 Intersections

222 = Washington Street (32nd Avenue) - 1 Intersection

P:\alliant\Grand Forks\1080033\COST-BENEFIT\32nd_Cost Benefit Analysis.xls\COST PER STOP

TRUCK PERCENTAGES (MAINLINE)

Zone 151 (32nd Avenue) - WEEKDAY

Average of all Intersections (29 to Washington Street)

Start Time	Mainline Volume (Total)	Cross-street Volume (Total)	Mainline Volume (Trucks)	Cross-street Volume (Trucks)	Mainline % Trucks	Cross-street % Trucks
07:00 AM	945	445	27	6	2.9%	1.3%
07:15 AM	1249	720	21	7	1.7%	1.0%
07:30 AM	1688	826	48	12	2.8%	1.5%
07:45 AM	2056	832	49	8	2.4%	1.0%
08:00 AM	1525	716	55	6	3.6%	0.8%
08:15 AM	1399	607	74	9	5.3%	1.5%
08:30 AM	1379	655	47	9	3.4%	1.4%
08:45 AM	1484	555	77	14	5.2%	2.5%
09:00 AM	1417	533	67	23	4.7%	4.3%
09:15 AM	1537	646	66	28	4.3%	4.3%
09:30 AM	1521	634	63	14	4.1%	2.2%
09:45 AM	1603	656	58	14	3.6%	2.1%
10:00 AM	1654	702	58	12	3.5%	1.7%
10:15 AM	1685	710	43	10	2.6%	1.4%
10:30 AM	1845	768	48	16	2.6%	2.1%
10:45 AM	1940	855	47	22	2.4%	2.6%
11:00 AM	2100	872	62	17	3.0%	1.9%
11:15 AM	2044	998	49	13	2.4%	1.3%
11:30 AM	2100	954	53	12	2.5%	1.3%
11:45 AM	2362	1084	46	12	1.9%	1.1%
12:00 PM	2544	1098	56	10	2.2%	0.9%
12:15 PM	2419	1091	31	10	1.3%	0.9%
12:30 PM	2481	1105	32	6	1.3%	0.5%
12:45 PM	2484	1115	39	12	1.6%	1.1%
01:00 PM	2324	1113	32	12	1.4%	1.1%
01:15 PM	2379	1020	77	12	3.2%	1.2%
01:30 PM	2411	952	48	12	2.0%	1.3%
01:45 PM	2388	970	32	14	1.3%	1.4%
02:00 PM	2274	1051	49	13	2.2%	1.2%
02:15 PM	2406	984	59	18	2.5%	1.8%
02:30 PM	2405	1013	39	12	1.6%	1.2%
02:45 PM	2353	1072	60	10	2.5%	0.9%
03:00 PM	2376	1050	52	10	2.2%	1.0%
03:15 PM	2584	1189	51	9	2.0%	0.8%
03:30 PM	2656	1258	56	14	2.1%	1.1%
03:45 PM	2762	1158	42	16	1.5%	1.4%
04:00 PM	2838	1229	34	7	1.2%	0.6%
04:15 PM	2861	1236	29	7	1.0%	0.6%
04:30 PM	2961	1258	16	7	0.5%	0.6%
04:45 PM	3261	1404	41	8	1.3%	0.6%
05:00 PM	3602	1576	20	8	0.6%	0.5%
05:15 PM	3221	1342	28	3	0.9%	0.2%
05:30 PM	2903	1030	19	5	0.7%	0.5%
05:45 PM	10367	10849	36	32	0.3%	0.3%

Zone 151 (32nd Avenue) - WEEKEND

Average of all Intersections (29 to Washington Street)

Start Time	Mainline Volume (Total)	Cross-street Volume (Total)	Mainline Volume (Trucks)	Cross-street Volume (Trucks)	Mainline % Trucks	Cross-street % Trucks
07:00 AM						
07:15 AM						
07:30 AM						
07:45 AM						
08:00 AM						
08:15 AM						
08:30 AM						
08:45 AM						
09:00 AM						
09:15 AM						
09:30 AM						
09:45 AM						
10:00 AM	1079	383	7	5	0.6%	1.3%
10:15 AM	1279	493	8	7	0.6%	1.4%
10:30 AM	1451	541	7	2	0.5%	0.4%
10:45 AM	1386	548	13	5	0.9%	0.9%
11:00 AM	1664	610	10	3	0.6%	0.5%
11:15 AM	1625	733	7	5	0.4%	0.7%
11:30 AM	1817	702	5	2	0.3%	0.3%
11:45 AM	1830	757	19	5	1.0%	0.7%
12:00 PM	1842	850	4	2	0.2%	0.2%
12:15 PM	1723	803	7	5	0.4%	0.6%
12:30 PM	1800	763	17	2	0.9%	0.3%
12:45 PM	2155	909	5	5	0.2%	0.6%
01:00 PM	2218	974	6	1	0.3%	0.1%
01:15 PM	2154	792	3	3	0.1%	0.4%
01:30 PM	2041	878	5	1	0.2%	0.1%
01:45 PM	1849	875	2	3	0.1%	0.3%
02:00 PM	1952	861	2	4	0.1%	0.5%
02:15 PM	1961	866	3	2	0.2%	0.2%
02:30 PM	1882	846	13	0	0.7%	0.0%
02:45 PM	1971	888	9	7	0.5%	0.8%
03:00 PM	2113	884	14	2	0.7%	0.2%
03:15 PM	1958	891	6	2	0.3%	0.2%
03:30 PM	1729	844	8	2	0.5%	0.2%
03:45 PM	1731	879	12	7	0.7%	0.8%
04:00 PM	1891	890	7	2	0.4%	0.2%
04:15 PM	1992	904	8	5	0.4%	0.6%
04:30 PM	2008	876	8	1	0.4%	0.1%
04:45 PM	2031	917	10	6	0.5%	0.7%
05:00 PM	1981	1046	10	2	0.5%	0.2%
05:15 PM	1869	931	13	3	0.7%	0.3%
05:30 PM	1833	882	14	2	0.8%	0.2%
05:45 PM	1707	848	12	1	0.7%	0.1%

AM PERIOD (630-1030)	22987	10005	801	188	3.5%	1.9%							
OFF PERIOD (1030-230)	37061	16275	751	207	2.0%	1.3%	WEEKEND (830-600)	58522	25864	274	104	0.5%	0.4%
PM PERIOD (230-1000)	44745	25651	484	136	1.1%	0.5%							

Cost per Stop Calculations

Table 2.3. Added time and vehicle running cost/1,000 stops and idling costs (Aug 96)

Initial Speed (mph)	Added Cost (\$/1,000 Stop) (Excludes idling time)		
	Pass Cars	Single-Unit Trucks	Combination Truck
5	2.70	9.25	33.62
10	8.83	20.72	77.49
15	15.16	33.89	129.97
20	21.74	48.40	190.06
25	28.67	63.97	256.54
30	36.10	80.23	328.21
35	44.06	96.88	403.84
40	52.70	113.97	482.21
45	62.07	130.08	562.14
50	72.31	145.96	642.41
55	83.47	160.89	721.77
60	95.70	178.98	798.99
65	109.02	195.84	NA*
70	123.61	NA*	NA*
75	139.53	NA*	NA*
80	156.85	NA*	NA*

* Original data did not provide values for trucks at higher speeds.

Source: Life-Cycle Cost Analysis in Pavement Design, US Dept of Transportation, FHWA, September 1998

Weighted Average Vehicle Fleet Percentages (Total Project)

	Pass Cars (10-Hr Total)	Single-Unit Trucks (10-Hr Total)	Combination Truck (10-Hr Total)	% Pass Cars	% Single-Unit	% Combination Truck
Weekday	156,724	2,567	0	98.4%	1.6%	0.0%
Weekend	84,386	378	0	99.6%	0.4%	0.0%
Project Total	241,110	2,945	0	98.8%	1.2%	0.0%

Reference: "Trucks" excel tab

Weighted Average Free Flow Speed (Mainline)

Eastbound

	Cross-Street	Distance	Free Flow Travel Time (sec)
Zone 151	I 29 West Ramp	2,180	37.2
	I 29 East Ramp	895	15.3
	38th Street	838	14.3
	34th Street	1,331	22.7
	31st Avenue	1,057	18
	Columbia Road	1,581	26.9
	24th Street	1,312	22.4
	20th Street	1,346	22.9
	Washington Str	2,626	44.8
Total Project		13,166	225
Average Free Flow Speed			40

Weighted Average Cost per Stop (Total Project)

Average Cost per Stop	\$0.053
Inflation Adjusted (2% per year)	\$0.065

Grand Forks Labor and Data Collection Cost Estimate

Optimization and Implementation Hours

	GF Local Staff		
June	4		
July	48		
August	8		
SubTotal Hours	60	60	
Misc. Hours	8	8	
Total Hours	68	68	
Hourly Rate		\$	60.00
Estimated Labor		\$	4,080.00

Data Collection (Turning Counts)

Number of Intersections (1-Person)	0		
Number of Intersections (2-Person)	9		
Hours per intersection (1-person)	10		
Total Hours	180		
Hourly Rate		\$	20.00
Estimated Labor		\$	3,600.00

Note: Included Consultant Scope/Fee

Equipment

2070 Controllers ¹	0	\$	4,000.00
Phasing Conversions (4 Intersection)	4	\$	2,500.00
Estimated Equipment Cost		\$	10,000.00

Total Miscellaneous Project Cost

	\$	17,680.00
--	-----------	------------------

¹ Cost of controllers is included as part of the City wide controller upgrade and is not included as part of the optimization benefit.

Alliant Engineering, Inc.
#080033

Measures of Effectiveness Summary

Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Weekday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹					
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Fuel Consum ption (gal) (All Approac hes)	Dillema Zone (veh) (All Approaches)	
		AM Period (630 to 1100)	4,483	40.8	-28.8	252	553
		Mid-day Period (1100 to 1445)	7,681	91.4	-68.3	101	445
		PM Period (1445 to 2200)	13,514	134.0	-103.9	231	1340
			25,678	266.2	-201.0	583	2,337
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Friday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹					
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Fuel Consum ption (gal) (All Approac hes)	Dillema Zone (veh) (All Approaches)	
		AM Period (630 to 1030)	3,754	35.3	-24.4	245	489
		Mid-day Period (1030 to 1445)	11,585	171.7	-153.2	128	485
		PM Period (1445 to 2200)	15,775	197.7	-150.2	254	1395
			31,114	404.7	-327.8	626	2,369
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Saturday	Aggregate Timing Plans ²	MOE - Net Reduction from Existing to Proposed Condition ¹					
		Stops (no. of veh) (All Approaches)	Delay (veh-hr) (Mainline)	Delay (veh-hr) (Cross Street) ³	Consum ption (gal) (All Approac hes)	Dillema Zone (veh) (All Approaches)	
		All Day Period (830-1800)	26,215	322.9	-270.5	292	985
		26,215	322.9	-270.5	292	985	

¹ A positive value equals the net reduction (i.e., benefit) and a negative value equals a net increase (i.e., impact)
² AM period includes the AM OFF and AM PEAK Plans. The OFF period includes the BALANCED Plans and the PM period includes the PM OFF and PM PEAK Plans.
³ Where obtained, AM and PM peak hour cross-street field collected approach delays (before and after) were used in lieu of model output.

Unit Benefit

MOE	Unit Price
Value of Time - Truck ¹	\$21.00
Value of Time - Auto ¹	\$13.00
Vehicle Stop ²	\$0.065
Fuel Cost ³	\$3.22

¹Mn/DOT Office of Investment Management Benefit-Cost Analysis
for Transportation Projects, Appendix A, Table A.1, SFY2008
Recommended Standard Values. (NDDOT values not available)
²Life-Cycle Cost Analysis in Pavement Design, US Dept of Transportation, FHWA,
Table 2.3 (Vehicle Cost per Stop), September 1998 (Refer to Appendix D for calculations)
(Adjusted to include an estimated 2% per year rate of inflation).
³US Department of Energy, Energy Information Administration,
Average Fuel Prices 8/01/07 to 8/01/08

Total Project Benefit

Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Weekday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross-Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	AM Period (630 to 1100)	3.5%	1.9%	1.08	199	\$115,993.68	-\$81,163.89	\$58,117.76	\$161,620.74	\$254,568.28
	Mid-day Period (1100 to 1445)	2.0%	1.3%	1.08	199	\$257,970.83	-\$192,031.24	\$99,567.94	\$64,398.39	\$229,905.92
	PM Period (1445 to 2200)	1.1%	0.5%	1.08	199	\$376,397.03	-\$291,132.07	\$175,179.69	\$147,798.54	\$408,243.19
	Subtotal (Weekday Annual Total Benefit)					\$750,361.54	-\$564,327.20	\$332,865.39	\$373,817.67	\$892,717.39
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Friday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross-Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	AM Period (630 to 1030)	3.5%	1.9%	1.08	52	\$26,245.84	-\$17,995.24	\$12,715.44	\$40,976.75	\$61,942.79
	Mid-day Period (1030 to 1445)	2.0%	1.3%	1.08	52	\$126,586.98	-\$112,528.42	\$39,243.00	\$21,348.60	\$74,650.16
	PM Period (1445 to 2200)	1.1%	0.5%	1.08	52	\$145,110.12	-\$109,965.39	\$53,437.04	\$42,513.41	\$131,095.19
	Subtotal (Friday Annual Total Benefit)					\$297,942.93	-\$240,489.04	\$105,395.49	\$104,838.77	\$267,688.14
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street) Saturday	Aggregate Timing Plans ³	Truck Percent (Mainline)	Truck Percent (Cross-Street)	Occupancy ¹	Days/ Year ²	Value of Time Benefit (\$) (Mainline)	Value of Time Impact (\$) (Cross-Street)	Stops Reduction Benefit (\$)	Fuel Reduction Benefit (\$)	Total Benefit (\$)
	All Day Period (830-1800)	0.5%	0.4%	1.08	52	\$236,267.02	-\$197,910.68	\$88,798.93	\$48,892.48	\$176,047.76
	Subtotal (Saturday Annual Total Benefit)					\$236,267.02	-\$197,910.68	\$88,798.93	\$48,892.48	\$176,047.76
Total Project - Zone 151 (Average Annual Benefit)						\$1,284,571.49	-\$1,002,726.92	\$527,059.80	\$527,548.92	\$1,336,453.29

Mn/DOT Metro Traffic Office

² Total weekday days were reduced by 10 to account for Holidays. Sundays were not included as part of the Benefit/Cost Analysis.

³ AM period includes the AM OFF and AM PEAK Plans. The OFF period includes the BALANCED Plans and the PM period includes the PM OFF and PM PEAK Plans.

Total Estimated Project Costs

Cost Description	Unit Cost
Alliant Eng. Consultant Contract	\$24,890.00
Agency Staff Time ¹	\$4,080.00
Data Collection ¹	\$3,600.00
Equipment ²	\$10,000.00
	\$43,000.00

¹ Assumes agency labor rate of \$60 per hour and data collector labor rate of \$20 per hour

² Includes signal phasing modifications (conversion to prot/pern left turn phasing at 4 intersections)

Benefit-Cost Ratio

Segment	Number of Intersections	Total Cost / Zone (\$)	Benefit (\$)	Benefit-Cost Ratio
Zone 151 (32nd Avenue - 29 West Ramp to 20th Street)	8	\$43,000	\$1,336,453	31

ZONE 151 - EXISTING MOE (VOLUME / TIMING PLAN CASES)

1b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	0.4	0.5	0.0	0.8	1.7	67.0	97.0	0.0	161.0	325.0	22.7	15.3	0.0	13.8	51.8	31.0	31.0
2 32nd Ave at 29	0.3	0.5	0.3	0.0	1.1	49.0	35.0	101.0	0.0	185.0	27.4	29.1	9.6	0.0	66.1	60.0	60.0
3 32nd Ave at 38	0.8	1.2	0.5	1.0	3.5	157.0	196.0	76.0	161.0	590.0	24.0	47.9	5.5	10.6	88.0	53.0	53.0
4 32nd Ave at 34	1.2	1.3	0.9	0.9	4.3	193.0	196.0	148.0	156.0	693.0	39.3	28.5	9.9	10.2	87.9	44.0	44.0
5 32nd Ave at 31	2.5	0.9	0.5	0.2	4.1	303.0	102.0	70.0	33.0	508.0	36.2	53.9	3.6	1.3	95.0	40.0	40.0
6 32nd Ave at Cc	2.9	3.1	2.6	2.1	10.7	313.0	367.0	314.0	243.0	1237.0	49.1	43.4	36.2	21.9	150.6	72.0	72.0
7 32nd Ave at 24	1.3	1.3	0.1	0.0	2.7	142.0	181.0	21.0	0.0	344.0	33.6	49.1	0.6	0.0	83.3	42.0	42.0
8 32nd Ave at 20	1.0	1.5	0.8	1.2	4.5	127.0	217.0	124.0	169.0	637.0	30.2	29.7	7.0	8.7	75.6	66.0	66.0
Zone 151	10.4	10.3	5.7	6.2	32.6	1351.0	1391.0	854.0	923.0	4519.0	262.5	296.9	72.4	66.5	698.3	408.0	408.0

2b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	0.7	0.4	0.0	0.7	1.7	140.0	105.0	0.0	143.0	388.0	5.0	3.0	0.0	3.0	11.0	25.0	25.0
2 32nd Ave at 29	0.6	0.6	0.2	0.0	1.3	168.0	140.0	41.0	0.0	349.0	4.0	3.0	2.0	0.0	9.0	49.0	49.0
3 32nd Ave at 38	1.1	0.8	0.6	0.9	3.4	229.0	179.0	97.0	141.0	646.0	5.0	6.0	2.0	3.0	16.0	40.0	40.0
4 32nd Ave at 34	1.9	1.5	0.7	1.0	5.1	278.0	239.0	100.0	141.0	758.0	8.0	7.0	2.0	3.0	20.0	47.0	47.0
5 32nd Ave at 31	3.4	1.0	0.5	0.4	5.3	368.0	185.0	62.0	46.0	661.0	9.0	7.0	1.0	1.0	18.0	39.0	39.0
6 32nd Ave at Cc	2.9	2.8	1.5	2.2	9.4	317.0	298.0	189.0	224.0	1028.0	10.0	9.0	5.0	6.0	30.0	52.0	52.0
7 32nd Ave at 24	1.9	1.3	0.3	0.0	3.6	240.0	222.0	39.0	0.0	501.0	7.0	7.0	1.0	0.0	15.0	33.0	33.0
8 32nd Ave at 20	1.1	1.6	0.5	0.8	4.1	215.0	287.0	68.0	118.0	688.0	7.0	7.0	1.0	2.0	17.0	50.0	50.0
Zone 151	13.5	10.0	4.3	6.1	33.9	1955.0	1655.0	596.0	813.0	5019.0	55.0	49.0	14.0	18.0	136.0	335.0	335.0

3b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	1.4	1.1	0.0	1.2	3.7	228.0	233.0	0.0	200.0	661.0	9.0	6.0	0.0	5.0	20.0	40.0	40.0
2 32nd Ave at 29	0.9	1.6	0.6	0.0	3.1	231.0	310.0	71.0	0.0	612.0	6.0	8.0	3.0	0.0	17.0	79.0	79.0
3 32nd Ave at 38	2.6	2.6	2.2	2.8	10.1	360.0	359.0	238.0	308.0	1265.0	9.0	12.0	6.0	7.0	34.0	51.0	51.0
4 32nd Ave at 34	5.2	4.6	3.1	3.6	16.4	530.0	502.0	257.0	298.0	1587.0	16.0	15.0	7.0	7.0	45.0	47.0	47.0
5 32nd Ave at 31	7.6	3.3	2.0	1.5	14.3	733.0	478.0	153.0	127.0	1491.0	19.0	17.0	4.0	3.0	43.0	65.0	65.0
6 32nd Ave at Cc	8.6	7.0	5.3	6.1	27.0	721.0	564.0	476.0	498.0	2259.0	23.0	18.0	12.0	13.0	66.0	74.0	74.0
7 32nd Ave at 24	3.9	2.7	1.0	0.0	7.7	487.0	427.0	113.0	0.0	1027.0	14.0	14.0	3.0	0.0	31.0	57.0	57.0
8 32nd Ave at 20	4.3	4.6	1.4	2.1	12.4	535.0	581.0	136.0	188.0	1440.0	16.0	14.0	3.0	4.0	37.0	73.0	73.0
Zone 151	34.4	27.4	15.5	17.4	94.7	3825.0	3454.0	1444.0	1619.0	10342.0	112.0	104.0	38.0	39.0	293.0	486.0	486.0

4b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	1.1	0.6	0.0	0.7	2.4	201.0	155.0	0.0	137.0	493.0	8.0	4.0	0.0	3.0	15.0	30.0	30.0
2 32nd Ave at 29	0.6	1.0	0.2	0.0	1.8	161.0	206.0	41.0	0.0	408.0	4.0	5.0	1.0	0.0	10.0	54.0	54.0
3 32nd Ave at 38	1.4	1.4	1.4	2.0	6.2	251.0	257.0	188.0	252.0	948.0	6.0	8.0	4.0	5.0	23.0	42.0	42.0
4 32nd Ave at 34	2.9	2.5	1.4	1.8	8.6	368.0	343.0	147.0	197.0	1055.0	10.0	10.0	4.0	4.0	28.0	49.0	49.0
5 32nd Ave at 31	4.8	1.4	1.1	0.9	8.2	514.0	255.0	101.0	88.0	958.0	13.0	10.0	2.0	2.0	27.0	51.0	51.0
6 32nd Ave at Cc	5.1	5.2	2.4	4.0	16.7	489.0	478.0	247.0	348.0	1562.0	16.0	15.0	6.0	9.0	46.0	62.0	62.0
7 32nd Ave at 24	3.0	2.2	0.8	0.0	5.9	364.0	363.0	87.0	0.0	814.0	11.0	12.0	2.0	0.0	25.0	49.0	49.0
8 32nd Ave at 20	2.6	3.0	0.8	1.5	7.9	362.0	444.0	92.0	151.0	1049.0	11.0	11.0	2.0	3.0	27.0	61.0	61.0
Zone 151	21.5	17.3	8.1	10.8	57.8	2710.0	2501.0	903.0	1173.0	7287.0	79.0	75.0	21.0	26.0	201.0	398.0	398.0

5b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	1.1	0.6	0.0	0.7	2.4	201.0	155.0	0.0	137.0	493.0	8.0	4.0	0.0	3.0	15.0	30.0	30.0
2 32nd Ave at 29	0.6	1.0	0.2	0.0	1.8	161.0	206.0	41.0	0.0	408.0	4.0	5.0	1.0	0.0	10.0	54.0	54.0
3 32nd Ave at 38	1.4	1.4	1.4	2.0	6.2	251.0	257.0	188.0	252.0	948.0	6.0	8.0	4.0	5.0	23.0	42.0	42.0
4 32nd Ave at 34	2.9	2.5	1.4	1.8	8.6	368.0	343.0	147.0	197.0	1055.0	10.0	10.0	4.0	4.0	28.0	49.0	49.0
5 32nd Ave at 31	4.8	1.4	1.1	0.9	8.2	514.0	255.0	101.0	88.0	958.0	13.0	10.0	2.0	2.0	27.0	51.0	51.0
6 32nd Ave at Cc	5.1	5.2	2.4	4.0	16.7	489.0	478.0	247.0	348.0	1562.0	16.0	15.0	6.0	9.0	46.0	62.0	62.0
7 32nd Ave at 24	3.0	2.2	0.8	0.0	5.9	364.0	363.0	87.0	0.0	814.0	11.0	12.0	2.0	0.0	25.0	49.0	49.0
8 32nd Ave at 20	2.6	3.0	0.8	1.5	7.9	362.0	444.0	92.0	151.0	1049.0	11.0	11.0	2.0	3.0	27.0	61.0	61.0
Zone 151	21.5	17.3	8.1	10.8	57.8	2710.0	2501.0	903.0	1173.0	7287.0	79.0	75.0	21.0	26.0	201.0	398.0	398.0

6b

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zone (No.)	
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		All	All
1 32nd Ave at 29	1.5	1.0	0.0	1.4	3.8	236.0	212.0	0.0	213.0	661.0	9.0	5.0	0.0	5.0	19.0	37.0	37.0
2 32nd Ave at 29	0.9	1.7	0.6	0.0	3.2	246.0	300.0	71.0	0.0	617.0	6.0	8.0	4.0	0.0	18.0	75.0	75.0
3 32nd Ave at 38	2.8	2.6	2.3	3.2	10.9	388.0	367.0	243.0	332.0	1330.0	10.0	12.0	6.0	7.0	35.0	55.0	55.0
4 32nd Ave at 34	5.4	4.8	2.9	3.6	16.8	548.0	520.0	253.0	314.0	1635.0	16.0	15.0	6.0	7.0	44.0	51.0	51.0
5 32nd Ave at 31	6.9	2.7	1.8	1.3	12.7	680.0	430.0	149.0	118.0	1377.0	18.0	16.0	4.0	3.0	41.0	64.0	64.0
6 32nd Ave at Cc	8.4	8.1	4.9	7.3	28.7	691.0	640.0	423.0	570.0	2324.0	22.0	20.0	11.0	15.0	68.0	80.0	80.0
7 32nd Ave at 24	4.3	2.9	1.2	0.0	8.4	525.0	452.0	130.0	0.0	1107.0	15.0	15.0	3.0	0.0	33.0	61.0	61.0
8 32nd Ave at 20	4.7	5.4	2.4	3.5	16.1	562.0	634.0	210.0	289.0	1695.0	17.0	16.0	4.0	6.0	43.0	72.0	72.0
Zone 151	34.9	29.2	16.1	20.4	100.5	3876.0	3555.0	1479.0	1836.0	10746.0	113.0	107.0	38.0	43.0	301.0	495.0	495.0

7b

8b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.5	1.0	0.0	1.4	3.8	236.0	212.0	0.0	213.0	661.0	9.0	5.0	0.0	5.0	19.0	37.0
2 32nd Ave at 29	0.9	1.7	0.6	0.0	3.2	246.0	300.0	71.0	0.0	617.0	6.0	8.0	4.0	0.0	18.0	75.0
3 32nd Ave at 38	2.8	2.6	2.3	3.2	10.9	388.0	367.0	243.0	332.0	1330.0	10.0	12.0	6.0	7.0	35.0	55.0
4 32nd Ave at 34	5.4	4.8	2.9	3.6	16.8	548.0	520.0	253.0	314.0	1635.0	16.0	15.0	6.0	7.0	44.0	51.0
5 32nd Ave at 31	6.9	2.7	1.8	1.3	12.7	680.0	430.0	149.0	118.0	1377.0	18.0	16.0	4.0	3.0	41.0	64.0
6 32nd Ave at Cc	8.4	8.1	4.9	7.3	28.7	691.0	640.0	423.0	570.0	2324.0	22.0	20.0	11.0	15.0	68.0	80.0
7 32nd Ave at 24	4.3	2.9	1.2	0.0	8.4	525.0	452.0	130.0	0.0	1107.0	15.0	15.0	3.0	0.0	33.0	61.0
8 32nd Ave at 20	4.7	5.4	2.4	3.5	16.1	562.0	634.0	210.0	289.0	1695.0	17.0	16.0	4.0	6.0	43.0	72.0
Zone 151	34.9	29.2	16.1	20.4	100.5	3876.0	3555.0	1479.0	1836.0	10746.0	113.0	107.0	38.0	43.0	301.0	495.0

9b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.9	1.3	0.0	1.6	4.8	280.0	282.0	0.0	231.0	793.0	11.0	7.0	0.0	6.0	24.0	45.0
2 32nd Ave at 29	1.1	1.9	0.7	0.0	3.7	268.0	359.0	79.0	0.0	706.0	7.0	9.0	4.0	0.0	20.0	87.0
3 32nd Ave at 38	3.6	3.3	3.2	4.1	14.1	442.0	423.0	293.0	388.0	1546.0	11.0	14.0	7.0	9.0	41.0	51.0
4 32nd Ave at 34	7.5	7.0	4.2	5.4	24.1	662.0	620.0	311.0	373.0	1966.0	20.0	19.0	9.0	9.0	57.0	51.0
5 32nd Ave at 31	9.7	4.5	2.6	2.0	18.7	884.0	608.0	183.0	149.0	1824.0	24.0	21.0	5.0	3.0	53.0	73.0
6 32nd Ave at Cc	11.6	9.5	7.4	8.3	36.8	893.0	737.0	593.0	653.0	2876.0	29.0	23.0	16.0	17.0	85.0	88.0
7 32nd Ave at 24	5.0	3.3	1.4	0.0	9.7	587.0	511.0	135.0	0.0	1233.0	17.0	16.0	3.0	0.0	36.0	70.0
8 32nd Ave at 20	6.0	6.3	1.9	2.9	17.0	672.0	714.0	158.0	221.0	1765.0	20.0	18.0	4.0	5.0	47.0	77.0
Zone 151	46.2	37.1	21.3	24.2	128.9	4688.0	4254.0	1752.0	2015.0	12709.0	139.0	127.0	48.0	49.0	363.0	542.0

10b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.9	1.3	0.0	1.6	4.8	280.0	282.0	0.0	231.0	793.0	11.0	7.0	0.0	6.0	24.0	45.0
2 32nd Ave at 29	1.1	1.9	0.7	0.0	3.7	268.0	359.0	79.0	0.0	706.0	7.0	9.0	4.0	0.0	20.0	87.0
3 32nd Ave at 38	3.6	3.3	3.2	4.1	14.1	442.0	423.0	293.0	388.0	1546.0	11.0	14.0	7.0	9.0	41.0	51.0
4 32nd Ave at 34	7.5	7.0	4.2	5.4	24.1	662.0	620.0	311.0	373.0	1966.0	20.0	19.0	9.0	9.0	57.0	51.0
5 32nd Ave at 31	9.7	4.5	2.6	2.0	18.7	884.0	608.0	183.0	149.0	1824.0	24.0	21.0	5.0	3.0	53.0	73.0
6 32nd Ave at Cc	11.6	9.5	7.4	8.3	36.8	893.0	737.0	593.0	653.0	2876.0	29.0	23.0	16.0	17.0	85.0	88.0
7 32nd Ave at 24	5.0	3.3	1.4	0.0	9.7	587.0	511.0	135.0	0.0	1233.0	17.0	16.0	3.0	0.0	36.0	70.0
8 32nd Ave at 20	6.0	6.3	1.9	2.9	17.0	672.0	714.0	158.0	221.0	1765.0	20.0	18.0	4.0	5.0	47.0	77.0
Zone 151	46.2	37.1	21.3	24.2	128.9	4688.0	4254.0	1752.0	2015.0	12709.0	139.0	127.0	48.0	49.0	363.0	542.0

11b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	2.1	1.4	0.0	2.0	5.5	291.0	261.0	0.0	264.0	816.0	11.0	7.0	0.0	7.0	25.0	45.0
2 32nd Ave at 29	1.2	2.4	0.8	0.0	4.3	288.0	370.0	85.0	0.0	743.0	8.0	10.0	5.0	0.0	23.0	85.0
3 32nd Ave at 38	4.5	4.1	3.4	5.0	17.0	518.0	481.0	311.0	437.0	1747.0	13.0	16.0	8.0	10.0	47.0	55.0
4 32nd Ave at 34	8.5	7.9	4.2	6.2	26.8	737.0	692.0	330.0	398.0	2157.0	22.0	21.0	9.0	10.0	62.0	55.0
5 32nd Ave at 31	9.6	4.6	2.6	1.9	18.6	861.0	604.0	181.0	140.0	1786.0	23.0	21.0	5.0	3.0	52.0	74.0
6 32nd Ave at Cc	11.8	12.6	7.4	10.7	42.5	906.0	860.0	565.0	751.0	3082.0	30.0	27.0	16.0	20.0	93.0	102.0
7 32nd Ave at 24	5.6	4.0	1.7	0.0	11.4	671.0	573.0	164.0	0.0	1408.0	19.0	19.0	4.0	0.0	42.0	82.0
8 32nd Ave at 20	8.1	9.2	3.4	5.5	26.2	736.0	870.0	255.0	363.0	2224.0	23.0	22.0	6.0	8.0	59.0	76.0
Zone 151	51.4	46.2	23.6	31.3	152.4	5008.0	4711.0	1891.0	2353.0	13963.0	149.0	143.0	53.0	58.0	403.0	574.0

12b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	2.3	1.7	0.0	2.1	6.1	272.0	280.0	0.0	306.0	858.0	53.9	31.1	0.0	30.3	115.3	46.0
2 32nd Ave at 29	1.4	1.3	0.7	0.0	3.4	187.0	132.0	180.0	0.0	499.0	66.4	52.4	17.8	0.0	136.6	92.0
3 32nd Ave at 38	4.9	3.8	4.7	5.8	19.2	566.0	458.0	368.0	484.0	1876.0	58.5	81.7	29.9	36.4	206.5	58.0
4 32nd Ave at 34	10.2	6.9	2.8	3.3	23.2	804.0	660.0	300.0	403.0	2167.0	118.1	84.2	22.1	8.6	233.0	64.0
5 32nd Ave at 31	8.9	4.9	2.2	1.4	17.4	722.0	458.0	223.0	169.0	1572.0	110.0	119.2	13.9	9.1	252.2	76.0
6 32nd Ave at Cc	13.6	8.9	6.2	7.3	36.0	950.0	698.0	493.0	711.0	2852.0	149.8	87.7	49.3	17.5	304.3	100.0
7 32nd Ave at 24	5.5	3.5	1.4	0.0	10.4	478.0	356.0	231.0	0.0	1065.0	111.0	96.1	10.7	0.0	217.8	82.0
8 32nd Ave at 20	8.7	6.9	2.1	4.0	21.7	650.0	603.0	232.0	335.0	1820.0	119.2	67.8	15.1	20.2	222.3	81.0
Zone 151	55.5	37.9	20.1	23.9	137.4	4629.0	3645.0	2027.0	2408.0	12709.0	786.9	620.2	158.8	122.1	1688.0	599.0

13b

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.5	0.8	0.0	1.4	3.7	252.0	184.0	0.0	218.0	654.0	9.0	5.0	0.0	6.0	20.0	39.0
2 32nd Ave at 29	1.2	1.7	0.6	0.0	3.5	276.0	270.0	70.0	0.0	616.0	7.0	8.0	5.0	0.0	20.0	72.0
3 32nd Ave at 38	4.2	3.0	4.1	4.5	15.8	477.0	373.0	332.0	424.0	1606.0	12.0	13.0	9.0	9.0	43.0	42.0
4 32nd Ave at 34	9.0	9.5	5.2	10.8	34.6	754.0	618.0	350.0	519.0	2241.0	23.0	21.0	9.0	15.0	68.0	45.0
5 32nd Ave at 31	10.0	5.2	2.2	2.8	20.2	882.0	652.0	169.0	212.0	1915.0	24.0	22.0	4.0	5.0	55.0	68.0
6 32nd Ave at Cc	10.6	9.7	5.1	8.9	34.3	833.0	753.0	415.0	694.0	2695.0	27.0	24.0	11.0	18.0	80.0	89.0
7 32nd Ave at 24	5.5	3.6	1.3	0.0	10.4	641.0	565.0	126.0	0.0	1332.0	19.0	18.0	3.0	0.0	40.0	77.0
8 32nd Ave at 20	5.0	5.4	2.0	2.2	14.6	634.0	701.0	164.0	172.0	1671.0	19.0	17.0	4.0	4.0	44.0	86.0
Zone 151	47.0	38.9	20.5	30.7	137.1	4749.0	4116.0	1626.0	2239.0	12730.0	140.0	128.0	45.0	57.0	370.0	518.0

14b

****AGGREGATE PERIODS** (= Sum of Volume/Timing Plan Case * Hours of Operation)**

MON - THURS

AM PERIOD (630 AM to 1100 AM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	2.4	1.9	0.0	3.4	7.8	465.8	454.5	0.0	684.0	1604.3	62.3	41.2	0.0	37.8	141.3
2 32nd Ave at 29	2.0	2.4	1.1	0.0	5.5	488.3	393.8	319.5	0.0	1201.5	70.7	72.2	26.1	0.0	169.0
3 32nd Ave at 38	4.3	4.6	2.4	4.4	15.6	868.5	843.8	389.3	679.5	2781.0	65.3	121.3	16.9	30.6	234.0
4 32nd Ave at 34	6.9	6.2	3.6	4.4	21.1	1059.8	978.8	558.0	668.3	3264.8	106.4	79.9	26.8	29.7	242.8
5 32nd Ave at 31	13.2	4.3	2.3	1.3	21.1	1509.8	645.8	297.0	177.8	2630.3	101.7	137.0	10.4	5.2	254.3
6 32nd Ave at Cc	13.0	13.3	9.3	9.7	45.3	1417.5	1496.3	1131.8	1050.8	5096.3	133.0	117.9	92.7	62.8	406.4
7 32nd Ave at 24	7.2	5.9	1.0	0.0	14.1	859.5	906.8	135.0	0.0	1901.3	91.4	126.2	3.6	0.0	221.2
8 32nd Ave at 20	4.8	7.0	2.8	4.6	19.2	769.5	1134.0	432.0	645.8	2981.3	83.7	82.6	18.0	24.1	208.4
Zone 151	53.8	45.7	22.4	27.7	149.6	7438.5	6853.5	3262.5	3906.0	21460.5	714.4	778.3	194.4	190.1	1877.2

MID-DAY PERIOD (1100 AM to 245 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	4.6	3.2	0.0	3.9	11.8	814.5	756.8	0.0	655.5	2226.8	32.3	19.5	0.0	15.8	67.5
2 32nd Ave at 29	2.8	5.2	1.6	0.0	9.6	761.3	1006.5	221.3	0.0	1989.0	19.5	25.5	8.3	0.0	53.3
3 32nd Ave at 38	8.0	7.9	6.9	9.2	32.1	1186.5	1193.3	817.5	1071.0	4268.3	29.3	39.0	19.5	23.3	111.0
4 32nd Ave at 34	16.1	14.1	9.1	10.7	49.9	1744.5	1644.0	798.8	966.0	5153.3	51.0	48.8	21.8	21.8	143.3
5 32nd Ave at 31	24.2	9.5	6.0	4.7	44.4	2420.3	1458.0	495.8	417.8	4791.8	62.3	53.3	12.0	9.8	137.3
6 32nd Ave at Cc	27.0	23.5	15.5	19.8	85.8	2355.8	1986.0	1441.5	1642.5	7425.8	75.8	63.0	36.0	42.8	217.5
7 32nd Ave at 24	13.3	9.4	3.5	0.0	26.1	1641.8	1505.3	384.8	0.0	3531.8	48.0	49.5	9.8	0.0	107.3
8 32nd Ave at 20	13.6	14.8	4.5	6.9	39.8	1746.8	1973.3	444.0	649.5	4813.5	52.5	48.0	9.8	13.5	123.8
Zone 151	109.7	87.6	47.1	55.3	299.7	12671.3	11523.0	4603.5	5402.3	34200.0	370.5	346.5	117.0	126.8	960.8

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	8.3	5.2	0.0	8.1	21.6	1356.3	1170.0	0.0	1374.3	3900.5	100.5	55.6	0.0	56.4	212.5
2 32nd Ave at 29	5.8	7.5	2.9	0.0	16.1	1398.0	1367.5	521.0	0.0	3286.5	100.6	87.8	37.1	0.0	225.5
3 32nd Ave at 38	15.6	13.4	10.8	15.7	55.6	2379.0	2045.3	1303.3	1778.5	7506.0	106.9	136.9	50.3	62.3	356.3
4 32nd Ave at 34	28.1	22.8	12.4	16.9	80.2	3080.5	2819.0	1293.8	1659.8	8853.0	191.0	149.8	44.0	37.1	421.8
5 32nd Ave at 31	39.2	14.9	8.6	6.0	68.8	3899.3	2171.3	823.3	638.5	7532.3	195.1	197.8	28.3	20.3	382.8
6 32nd Ave at Cc	43.7	39.1	23.4	35.1	141.3	3787.0	3399.3	2226.5	2969.0	12381.8	251.0	179.9	96.1	78.4	604.4
7 32nd Ave at 24	22.9	15.4	5.7	0.0	43.9	2658.8	2305.8	722.8	0.0	5687.3	179.6	166.3	22.5	0.0	368.4
8 32nd Ave at 20	23.7	25.4	9.9	15.6	74.6	2797.5	3203.3	1024.3	1480.5	8505.5	192.6	137.8	29.6	42.4	402.4
Zone 151	187.3	143.8	73.7	97.4	502.1	21356.3	18481.3	7914.8	9900.5	57652.8	1317.4	1110.6	307.9	296.7	3032.6

FRI

AM PERIOD (630 AM to 1030 AM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	2.1	1.8	0.0	3.0	6.9	395.8	402.0	0.0	612.5	1410.3	59.8	39.7	0.0	36.3	135.8
2 32nd Ave at 29	1.7	2.1	1.0	0.0	4.8	404.3	323.8	299.0	0.0	1027.0	68.7	70.7	25.1	0.0	164.5
3 32nd Ave at 38	3.7	4.1	2.1	3.9	13.9	754.0	754.3	340.8	609.0	2458.0	62.8	118.3	15.9	29.1	226.0
4 32nd Ave at 34	6.0	5.5	3.2	3.9	18.5	920.8	859.3	508.0	597.8	2885.8	102.4	76.4	25.8	28.2	232.8
5 32nd Ave at 31	11.5	3.8	2.0	1.1	18.5	1325.8	553.3	266.0	154.8	2299.8	97.2	133.5	9.9	4.7	245.3
6 32nd Ave at Cc	11.6	11.9	8.5	8.6	40.6	1259.0	1347.3	1037.3	938.8	4582.3	128.0	113.4	90.2	59.8	391.4
7 32nd Ave at 24	6.3	5.2	0.8	0.0	12.3	739.5	795.8	115.5	0.0	1650.8	87.9	122.7	3.1	0.0	213.7
8 32nd Ave at 20	4.2	6.2	2.6	4.2	17.2	662.0	990.5	398.0	586.8	2637.3	80.2	79.1	17.5	23.1	199.9
Zone 151	47.0	40.7	20.3	24.7	132.7	6461.0	6026.0	2964.5	3499.5	18951.0	686.9	753.8	187.4	181.1	1809.2

MID-DAY PERIOD (1030 AM to 245 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	
1 32nd Ave at 29	8.3	5.4	0.0	6.8	20.5	1190.0	1198.5	0.0	981.8	3370.3	46.8	29.8	0.0	25.5	102.0	
2 32nd Ave at 29	4.5	8.3	2.9	0.0	15.7	1139.0	1525.8	335.8	0.0	3000.5	29.8	38.3	17.0	0.0	85.0	
3 32nd Ave at 38	15.1	14.1	13.5	17.3	60.0	1878.5	1797.8	1245.3	1649.0	6570.5	46.8	59.5	29.8	38.3	174.3	
4 32nd Ave at 34	31.8	29.7	17.8	22.9	102.2	2813.5	2635.0	1321.8	1585.3	8355.5	85.0	80.8	38.3	38.3	242.3	
5 32nd Ave at 31	41.1	19.3	10.9	8.3	79.6	3757.0	2584.0	777.8	633.3	7752.0	102.0	89.3	21.3	12.8	225.3	
6 32nd Ave at Cc	49.3	40.2	31.4	35.4	156.3	3795.3	3132.3	2520.3	2775.3	12223.0	123.3	97.8	68.0	72.3	361.3	
7 32nd Ave at 24	21.1	13.9	6.1	0.0	41.1	2484.8	2171.8	573.8	0.0	5240.3	72.3	68.0	12.8	0.0	153.0	
8 32nd Ave at 20	25.3	26.7	8.0	12.2	72.3	2856.0	3034.5	671.5	939.3	7501.3	85.0	76.5	17.0	21.3	199.8	
Zone 151	196.4	157.5	90.7	103.0	547.6	19924.0	18079.5	7446.0	8563.8	54013.3	590.8	539.8	204.0	208.3	1542.8	

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	11.4	7.8	0.0	10.5	29.8	1652.5	1550.0	0.0	1618.8	4821.3	138.8	82.7	0.0	79.5	301.0
2 32nd Ave at 29	7.1	10.1	3.9	0.0	21.1	1560.0	1668.0	663.0	0.0	3891.0	148.2	128.0	48.9	0.0	325.1
3 32nd Ave at 38	22.8	19.5	18.9	25.3	86.6	2953.8	2586.0	1772.8	2398.8	9711.3	149.9	202.5	79.8	98.7	530.9
4 32nd Ave at 34	45.0	36.5	18.7	24.6	124.8	4131.5	3668.3	1721.8	2178.5	11700.0	287.7	222.9	69.9	50.1	630.5
5 32nd Ave at 31	51.8	24.2	12.6	8.9	97.5	4741.3	3025.3	1084.0	842.5	9693.0	283.0	287.6	41.6	27.9	640.1
6 32nd Ave at Cc	64.6	54.3	35.7	45.6	200.2	5082.5	4255.5	3027.0	3823.8	16188.8	372.9	248.2	144.5	98.8	864.4
7 32nd Ave at 24	29.8	20.1	7.8	0.0	57.7	3285.3	2771.3	946.8	0.0	7003.3	264.5	237.9	32.2	0.0	534.7
8 32nd Ave at 20	38.2	38.4	12.6	21.3	110.4	3730.0	4089.3	1190.5	1741.8	10751.5	288.9	193.9	43.4	59.4	585.5
Zone 151	270.7	210.9	110.2	136.4	728.2	27136.8	23613.5	10405.8	12604.0	73760.0	1933.8	1603.6	460.4	414.4	4412.2

SAT

OFF PERIOD (830 AM to 600 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	13.1	7.8	0.0	12.1	33.1	2246.0	1742.5	0.0	1969.0	5957.5	81.5	47.0	0.0	52.5	181.0
2 32nd Ave at 29	9.9	15.1	5.4	0.0	30.5	2446.5	2495.0	637.5	0.0	5579.0	62.0	71.0	41.5	0.0	174.5
3 32nd Ave at 38	34.6	25.8	32.5	36.5	129.4	4108.0	3328.5	2778.0	3571.0	13785.5	102.5	115.0	74.0	76.5	368.0
4 32nd Ave at 34	72.8	74.8	41.8	82.4	271.8	6351.0	5318.0	2935.5	4221.0	18825.5	193.0	176.5	75.5	118.5	563.5
5 32nd Ave at 31	84.4	42.4	48.8	22.4	168.1	7641.5	5466.0	1474.5	1720.5	16302.5	205.5	186.5	35.0	40.5	467.5
6 32nd Ave at Cc	90.4	81.0	45.0	74.0	290.4	7229.5	6415.0	3808.0	5829.0	23281.5	233.5	204.0	100.0	151.5	689.0
7 32nd Ave at 24	46.0	30.7	10.9	0.0	87.6	5457.5	4817.5	1090.5	0.0	11365.5	161.0	154.0	26.5	0.0	341.5
8 32nd Ave at 20	42.7	45.9	16.4	19.8	124.8	5455.5	6065.5	1420.0	1604.0	14545.0	164.0	147.0	33.5	36.0	380.5
Zone 151	393.9	323.7	170.9	247.2	1135.6	40935.5	35648.0	14144.0	18914.5	109642.0	1203.0	1101.0	386.0	475.5	3165.5
															4690.0

ZONE 151 - FINAL MOE (VOLUME / TIMING PLAN CASES)

1a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.2	0.3	0.0	1.5	2.0	43.0	52.0	0.0	183.0	278.0	20.9	13.7	0.0	16.8	51.4	23.0
2 32nd Ave at 29	0.2	0.4	0.4	0.0	1.0	16.0	13.0	116.0	0.0	145.0	25.4	29.0	10.4	0.0	64.8	30.0
3 32nd Ave at 38	0.6	1.3	0.9	1.5	4.3	114.0	217.0	90.0	167.0	588.0	22.2	43.4	6.4	12.0	84.0	23.0
4 32nd Ave at 34	0.9	0.9	1.6	1.6	5.0	130.0	135.0	176.0	181.0	622.0	36.3	26.1	12.2	12.0	86.6	33.0
5 32nd Ave at 31	0.3	0.4	0.6	0.2	1.5	39.0	38.0	76.0	33.0	186.0	31.3	49.1	4.1	1.4	85.9	21.0
6 32nd Ave at Cc	1.7	2.0	4.3	2.5	10.5	175.0	206.0	411.0	247.0	1039.0	36.7	36.2	40.5	23.4	136.8	75.0
7 32nd Ave at 24	0.2	0.4	0.1	0.0	0.7	8.0	38.0	28.0	0.0	74.0	27.7	46.1	0.8	0.0	74.6	16.0
8 32nd Ave at 20	0.3	1.1	1.2	1.7	4.3	57.0	176.0	150.0	181.0	564.0	22.5	30.4	8.8	10.3	72.0	52.0
Zone 151	4.4	6.8	9.1	9.0	29.3	582.0	875.0	1047.0	992.0	3496.0	223.0	274.0	83.2	75.9	656.1	273.0

2a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.8	0.5	0.0	1.3	2.6	137.0	136.0	0.0	201.0	474.0	5.0	4.0	0.0	5.0	14.0	27.0
2 32nd Ave at 29	0.6	1.1	0.5	0.0	2.2	181.0	211.0	64.0	0.0	456.0	5.0	6.0	3.0	0.0	14.0	56.0
3 32nd Ave at 38	1.7	2.7	0.9	1.6	6.9	262.0	450.0	99.0	155.0	966.0	7.0	12.0	2.0	4.0	25.0	26.0
4 32nd Ave at 34	1.4	1.3	2.9	3.1	8.7	194.0	166.0	268.0	193.0	821.0	8.0	6.0	6.0	5.0	25.0	39.0
5 32nd Ave at 31	0.6	0.1	1.0	0.6	2.3	88.0	60.0	88.0	62.0	298.0	5.0	6.0	2.0	1.0	14.0	22.0
6 32nd Ave at Cc	2.5	2.6	8.8	3.2	17.1	257.0	228.0	590.0	318.0	1393.0	10.0	9.0	16.0	7.0	42.0	74.0
7 32nd Ave at 24	0.3	0.7	0.2	0.0	1.2	47.0	256.0	23.0	0.0	326.0	4.0	9.0	0.0	0.0	13.0	13.0
8 32nd Ave at 20	0.2	1.8	1.9	2.7	6.6	45.0	335.0	171.0	229.0	780.0	4.0	9.0	4.0	5.0	22.0	45.0
Zone 151	8.1	10.9	16.1	12.5	47.6	1211.0	1842.0	1303.0	1158.0	5514.0	48.0	61.0	33.0	27.0	169.0	302.0

3a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.6	0.4	0.0	0.9	1.9	123.0	93.0	0.0	145.0	361.0	5.0	2.0	0.0	3.0	10.0	22.0
2 32nd Ave at 29	0.5	0.5	0.2	0.0	1.2	152.0	128.0	42.0	0.0	322.0	4.0	3.0	2.0	0.0	9.0	49.0
3 32nd Ave at 38	1.4	1.9	0.9	1.3	5.6	202.0	285.0	98.0	132.0	717.0	5.0	8.0	2.0	3.0	18.0	16.0
4 32nd Ave at 34	1.2	0.9	1.1	1.9	5.0	138.0	118.0	109.0	163.0	528.0	6.0	5.0	2.0	4.0	17.0	30.0
5 32nd Ave at 31	0.5	0.3	0.6	0.4	1.8	91.0	90.0	65.0	48.0	294.0	5.0	6.0	1.0	1.0	13.0	24.0
6 32nd Ave at Cc	2.1	1.5	2.7	2.6	8.9	205.0	143.0	241.0	239.0	828.0	8.0	6.0	6.0	6.0	26.0	37.0
7 32nd Ave at 24	0.5	0.7	0.5	0.0	1.7	82.0	223.0	48.0	0.0	353.0	5.0	7.0	1.0	0.0	13.0	13.0
8 32nd Ave at 20	0.3	1.3	0.6	1.1	3.3	103.0	214.0	68.0	113.0	498.0	5.0	6.0	1.0	2.0	14.0	34.0
Zone 151	7.2	7.2	6.6	8.3	29.3	1096.0	1294.0	671.0	840.0	3901.0	43.0	43.0	15.0	19.0	120.0	225.0

4a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.6	0.1	0.0	0.9	1.7	119.0	38.0	0.0	153.0	310.0	5.0	2.0	0.0	4.0	11.0	27.0
2 32nd Ave at 29	0.1	0.3	0.3	0.0	0.7	14.0	82.0	41.0	0.0	137.0	2.0	3.0	2.0	0.0	7.0	17.0
3 32nd Ave at 38	1.8	0.4	1.3	1.7	5.1	206.0	70.0	101.0	137.0	514.0	6.0	4.0	2.0	3.0	15.0	20.0
4 32nd Ave at 34	0.8	1.7	1.4	2.3	6.3	127.0	281.0	109.0	168.0	685.0	6.0	7.0	3.0	4.0	20.0	25.0
5 32nd Ave at 31	0.6	0.3	0.8	0.5	2.2	120.0	72.0	63.0	47.0	302.0	5.0	6.0	1.0	1.0	13.0	10.0
6 32nd Ave at Cc	1.5	1.9	3.4	3.2	10.1	179.0	266.0	243.0	242.0	930.0	8.0	8.0	7.0	6.0	29.0	29.0
7 32nd Ave at 24	0.6	0.3	0.6	0.0	1.5	162.0	51.0	47.0	0.0	260.0	5.0	5.0	1.0	0.0	11.0	19.0
8 32nd Ave at 20	0.7	0.8	0.9	1.8	4.1	85.0	147.0	70.0	120.0	422.0	5.0	5.0	2.0	3.0	15.0	61.0
Zone 151	6.8	5.8	8.7	10.5	31.7	1012.0	1007.0	674.0	867.0	3560.0	42.0	40.0	18.0	21.0	121.0	208.0

5a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.1	0.1	0.0	1.6	2.8	198.0	36.0	0.0	226.0	460.0	8.0	3.0	0.0	6.0	17.0	42.0
2 32nd Ave at 29	0.1	1.1	0.6	0.0	1.8	26.0	280.0	74.0	0.0	380.0	4.0	7.0	3.0	0.0	14.0	35.0
3 32nd Ave at 38	3.3	1.2	4.9	6.1	15.5	396.0	190.0	293.0	346.0	1225.0	10.0	9.0	8.0	9.0	36.0	35.0
4 32nd Ave at 34	2.3	4.6	5.7	7.5	20.1	299.0	637.0	286.0	316.0	1538.0	11.0	16.0	9.0	10.0	46.0	28.0
5 32nd Ave at 31	1.3	1.0	2.9	2.1	7.2	289.0	248.0	168.0	137.0	842.0	10.0	13.0	5.0	3.0	31.0	25.0
6 32nd Ave at Cc	5.5	5.5	8.9	7.8	27.6	492.0	600.0	548.0	529.0	2169.0	19.0	17.0	16.0	15.0	67.0	60.0
7 32nd Ave at 24	1.0	0.7	1.9	0.0	3.7	346.0	108.0	135.0	0.0	589.0	11.0	9.0	3.0	0.0	23.0	33.0
8 32nd Ave at 20	2.0	2.1	2.0	3.0	9.1	230.0	354.0	142.0	200.0	926.0	11.0	10.0	3.0	5.0	29.0	93.0
Zone 151	16.6	16.2	26.9	28.1	87.8	2276.0	2453.0	1646.0	1754.0	8129.0	84.0	84.0	47.0	48.0	263.0	351.0

6a

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.9	0.1	0.0	0.9	1.9	177.0	41.0	0.0	143.0	361.0	7.0	3.0	0.0	3.0	13.0	34.0
2 32nd Ave at 29	0.1	0.5	0.3	0.0	0.9	20.0	131.0	41.0	0.0	192.0	3.0	4.0	2.0	0.0	9.0	27.0
3 32nd Ave at 38	2.1	0.7	3.2	3.6	9.6	248.0	111.0	211.0	266.0	836.0	6.0	6.0	6.0	6.0	24.0	28.0
4 32nd Ave at 34	1.3	2.2	2.6	3.7	9.7	202.0	372.0	167.0	233.0	974.0	8.0	10.0	5.0	6.0	29.0	29.0
5 32nd Ave at 31	0.9	0.4	1.5	1.2	4.0	191.0	95.0	103.0	91.0	480.0	7.0	8.0	3.0	2.0	20.0	15.0
6 32nd Ave at Cc	3.4	3.8	4.3	5.3	16.8	337.0	466.0	299.0	379.0	1481.0	13.0	13.0	8.0	10.0	44.0	42.0
7 32nd Ave at 24	1.1	0.4	1.4	0.0	2.9	258.0	64.0	104.0	0.0	426.0	8.0	7.0	2.0	0.0	17.0	34.0
8 32nd Ave at 20	1.6	1.8	1.2	2.3	6.9	179.0	306.0	93.0	158.0	736.0	9.0	9.0	2.0	3.0	23.0	95.0
Zone 151	11.5	9.9	14.3	17.0	52.7	1612.0	1586.0	1018.0	1270.0	5486.0	61.0	60.0	28.0	30.0	179.0	304.0

7a

Travel Time (Veh-Hr)					Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.9	0.1	0.0	0.9	1.9	177.0	41.0	0.0	143.0	361.0	7.0	3.0	0.0	3.0	13.0	34.0
2 32nd Ave at 29	0.1	0.5	0.3	0.0	0.9	20.0	131.0	41.0	0.0	192.0	3.0	4.0	2.0	0.0	9.0	27.0
3 32nd Ave at 38	2.1	0.7	3.2	3.6	9.6	248.0	111.0	211.0	266.0	836.0	6.0	6.0	6.0	6.0	24.0	28.0
4 32nd Ave at 34	1.3	2.2	2.6	3.7	9.7	202.0	372.0	167.0	233.0	974.0	8.0	10.0	5.0	6.0	29.0	29.0
5 32nd Ave at 31	0.9	0.4	1.5	1.2	4.0	191.0	95.0	103.0	91.0	480.0	7.0	8.0	3.0	2.0	20.0	15.0
6 32nd Ave at Cc	3.4	3.8	4.3	5.3	16.8	337.0	466.0	299.0	379.0	1481.0	13.0	13.0	8.0	10.0	44.0	42.0
7 32nd Ave at 24	1.1	0.4	1.4	0.0	2.9	258.0	64.0	104.0	0.0	426.0	8.0	7.0	2.0	0.0	17.0	34.0
8 32nd Ave at 20	1.6	1.8	1.2	2.3	6.9	179.0	306.0	93.0	158.0	736.0	9.0	9.0	2.0	3.0	23.0	95.0
Zone 151	11.5	9.9	14.3	17.0	52.7	1612.0	1586.0	1018.0	1270.0	5486.0	61.0	60.0	28.0	30.0	179.0	304.0

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.1	0.2	0.0	1.9	3.3	197.0	84.0	0.0	240.0	521.0	8.0	4.0	0.0	6.0	18.0	33.0
2 32nd Ave at 29	0.2	1.5	0.8	0.0	2.4	40.0	285.0	78.0	0.0	403.0	4.0	8.0	4.0	0.0	16.0	46.0
3 32nd Ave at 38	4.3	2.2	5.6	6.3	18.4	426.0	258.0	297.0	372.0	1353.0	11.0	11.0	9.0	10.0	41.0	22.0
4 32nd Ave at 34	2.8	5.0	5.1	6.4	19.3	279.0	551.0	300.0	348.0	1478.0	12.0	16.0	8.0	9.0	45.0	12.0
5 32nd Ave at 31	0.7	0.7	2.9	2.0	6.4	102.0	195.0	155.0	121.0	573.0	8.0	12.0	4.0	3.0	27.0	17.0
6 32nd Ave at Cc	5.7	7.9	8.2	10.1	31.9	532.0	646.0	474.0	604.0	2256.0	19.0	20.0	14.0	17.0	70.0	51.0
7 32nd Ave at 24	1.1	1.0	2.3	0.0	4.3	329.0	181.0	150.0	0.0	660.0	11.0	11.0	4.0	0.0	26.0	31.0
8 32nd Ave at 20	0.7	2.9	3.7	6.4	13.7	103.0	404.0	225.0	317.0	1049.0	9.0	12.0	6.0	8.0	35.0	45.0
Zone 151	16.6	21.5	28.6	33.1	99.9	2008.0	2604.0	1679.0	2002.0	8293.0	82.0	94.0	49.0	53.0	278.0	257.0
9a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	0.9	0.8	0.0	2.0	3.7	149.0	157.0	0.0	286.0	592.0	47.5	22.3	0.0	26.1	95.9	47.0
2 32nd Ave at 29	0.6	0.5	0.7	0.0	1.8	69.0	43.0	185.0	0.0	297.0	53.1	40.1	16.7	0.0	109.9	41.0
3 32nd Ave at 38	4.3	2.4	5.0	6.6	18.3	425.0	266.0	389.0	445.0	1525.0	47.3	67.5	29.2	36.1	180.1	23.0
4 32nd Ave at 34	4.6	3.8	2.9	3.8	15.1	372.0	507.0	273.0	407.0	1559.0	93.4	57.5	20.3	8.8	180.0	15.0
5 32nd Ave at 31	1.4	1.6	2.6	1.5	7.1	122.0	146.0	217.0	148.0	633.0	82.2	96.2	14.0	8.3	200.7	17.0
6 32nd Ave at Cc	7.3	6.2	6.7	10.1	30.3	494.0	448.0	437.0	638.0	2017.0	104.7	68.2	45.3	18.2	236.4	62.0
7 32nd Ave at 24	1.1	1.7	1.9	0.0	4.7	48.0	193.0	227.0	0.0	468.0	84.6	76.1	11.0	0.0	171.7	32.0
8 32nd Ave at 20	2.6	3.3	2.2	4.2	12.3	238.0	364.0	212.0	304.0	1118.0	83.7	56.0	14.3	19.7	173.7	48.0
Zone 151	22.8	20.3	22.0	28.2	93.3	1917.0	2124.0	1940.0	2228.0	8209.0	596.5	483.9	150.8	117.2	1348.4	285.0
10a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.1	0.2	0.0	1.9	3.3	197.0	84.0	0.0	240.0	521.0	8.0	4.0	0.0	6.0	18.0	33.0
2 32nd Ave at 29	0.2	1.5	0.8	0.0	2.4	40.0	287.0	76.0	0.0	403.0	4.0	8.0	4.0	0.0	16.0	47.0
3 32nd Ave at 38	4.3	2.2	5.6	6.2	18.3	427.0	259.0	296.0	373.0	1355.0	11.0	11.0	9.0	10.0	41.0	21.0
4 32nd Ave at 34	2.8	5.0	5.1	6.4	19.3	278.0	549.0	299.0	349.0	1475.0	12.0	16.0	8.0	9.0	45.0	12.0
5 32nd Ave at 31	0.7	0.7	2.9	2.0	6.4	103.0	195.0	156.0	121.0	575.0	8.0	12.0	4.0	3.0	27.0	17.0
6 32nd Ave at Cc	5.7	7.9	8.1	10.1	31.7	532.0	636.0	474.0	603.0	2245.0	19.0	20.0	14.0	17.0	70.0	50.0
7 32nd Ave at 24	1.1	1.0	2.3	0.0	4.3	327.0	180.0	150.0	0.0	657.0	11.0	11.0	4.0	0.0	26.0	31.0
8 32nd Ave at 20	0.9	3.2	3.5	5.5	13.1	117.0	421.0	220.0	311.0	1069.0	10.0	12.0	5.0	8.0	35.0	45.0
Zone 151	16.8	21.8	28.2	32.2	98.9	2021.0	2611.0	1671.0	1997.0	8300.0	83.0	94.0	48.0	53.0	278.0	256.0
11a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.3	0.2	0.0	2.1	3.5	236.0	51.0	0.0	278.0	565.0	10.0	4.0	0.0	7.0	21.0	55.0
2 32nd Ave at 29	0.2	1.3	0.6	0.0	2.1	35.0	345.0	86.0	0.0	466.0	4.0	9.0	4.0	0.0	17.0	45.0
3 32nd Ave at 38	4.2	1.7	7.5	9.6	22.9	507.0	229.0	334.0	408.0	1478.0	12.0	11.0	11.0	13.0	47.0	37.0
4 32nd Ave at 34	3.2	5.8	9.9	14.2	33.2	366.0	783.0	332.0	370.0	1851.0	14.0	20.0	13.0	15.0	62.0	49.0
5 32nd Ave at 31	1.5	1.5	3.7	2.6	9.3	362.0	335.0	194.0	163.0	1054.0	12.0	16.0	6.0	4.0	38.0	27.0
6 32nd Ave at Cc	6.9	7.1	12.2	11.0	37.2	604.0	718.0	638.0	687.0	2647.0	23.0	21.0	20.0	19.0	83.0	73.0
7 32nd Ave at 24	1.2	0.8	2.3	0.0	4.4	425.0	132.0	163.0	0.0	720.0	13.0	11.0	4.0	0.0	28.0	40.0
8 32nd Ave at 20	2.7	3.3	2.3	3.5	11.8	318.0	481.0	166.0	238.0	1203.0	14.0	13.0	4.0	6.0	37.0	102.0
Zone 151	21.2	21.6	38.5	43.0	124.5	2853.0	3074.0	1913.0	2144.0	9984.0	102.0	105.0	62.0	64.0	333.0	428.0
12a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.3	0.2	0.0	2.1	3.5	236.0	51.0	0.0	278.0	565.0	10.0	4.0	0.0	7.0	21.0	55.0
2 32nd Ave at 29	0.2	1.3	0.7	0.0	2.2	35.0	339.0	86.0	0.0	460.0	4.0	9.0	4.0	0.0	17.0	45.0
3 32nd Ave at 38	4.2	1.7	7.6	9.6	23.1	507.0	229.0	334.0	408.0	1478.0	12.0	11.0	11.0	13.0	47.0	37.0
4 32nd Ave at 34	3.2	5.8	9.9	14.2	33.2	367.0	783.0	333.0	370.0	1853.0	14.0	20.0	13.0	15.0	62.0	49.0
5 32nd Ave at 31	1.5	1.5	3.7	2.6	9.3	362.0	335.0	194.0	163.0	1054.0	12.0	16.0	6.0	4.0	38.0	27.0
6 32nd Ave at Cc	6.9	7.1	12.2	11.0	37.2	604.0	716.0	638.0	687.0	2645.0	23.0	21.0	20.0	19.0	83.0	73.0
7 32nd Ave at 24	1.2	0.8	2.3	0.0	4.4	425.0	131.0	163.0	0.0	719.0	13.0	11.0	4.0	0.0	28.0	40.0
8 32nd Ave at 20	2.7	3.3	2.3	3.5	11.8	318.0	483.0	166.0	238.0	1205.0	14.0	13.0	4.0	6.0	37.0	102.0
Zone 151	21.2	21.6	38.8	43.0	124.7	2854.0	3067.0	1914.0	2144.0	9979.0	102.0	105.0	62.0	64.0	333.0	428.0
13a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.6	0.5	0.0	2.6	4.7	263.0	114.0	0.0	308.0	685.0	11.0	5.0	0.0	8.0	24.0	44.0
2 32nd Ave at 29	0.2	2.1	1.0	0.0	3.3	46.0	366.0	92.0	0.0	504.0	5.0	10.0	5.0	0.0	20.0	45.0
3 32nd Ave at 38	5.9	2.8	10.6	10.2	29.6	584.0	323.0	339.0	468.0	1714.0	15.0	14.0	13.0	14.0	56.0	20.0
4 32nd Ave at 34	4.1	7.3	7.4	9.7	28.5	364.0	742.0	360.0	425.0	1891.0	16.0	21.0	11.0	13.0	61.0	14.0
5 32nd Ave at 31	0.9	1.2	3.9	2.5	8.6	109.0	260.0	192.0	152.0	713.0	10.0	15.0	6.0	4.0	35.0	19.0
6 32nd Ave at Cc	7.8	11.1	11.0	14.8	44.7	686.0	819.0	590.0	760.0	2855.0	24.0	26.0	18.0	23.0	91.0	69.0
7 32nd Ave at 24	1.1	1.5	3.0	0.0	5.6	404.0	241.0	190.0	0.0	835.0	13.0	14.0	5.0	0.0	32.0	39.0
8 32nd Ave at 20	2.1	5.2	4.6	9.1	21.0	269.0	622.0	276.0	395.0	1562.0	14.0	17.0	7.0	11.0	49.0	54.0
Zone 151	23.7	31.8	41.5	48.9	145.9	2725.0	3487.0	2039.0	2508.0	10759.0	108.0	122.0	65.0	73.0	368.0	304.0
14a	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.4	1.2	0.0	2.6	5.2	202.0	191.0	0.0	350.0	743.0	53.8	27.5	0.0	31.1	112.4	55.0
2 32nd Ave at 29	0.8	0.7	0.9	0.0	2.4	89.0	63.0	199.0	0.0	351.0	63.3	48.0	18.5	0.0	129.8	54.0
3 32nd Ave at 38	5.1	3.0	8.1	16.8	33.0	492.0	309.0	527.0	835.0	2163.0	53.8	77.5	38.8	64.0	234.1	22.0
4 32nd Ave at 34	6.5	5.2	3.8	3.8	19.3	469.0	613.0	335.0	431.0	1848.0	108.7	70.2	25.3	9.2	213.4	18.0
5 32nd Ave at 31	2.0	2.5	4.2	1.8	10.5	155.0	200.0	273.0	176.0	804.0	96.9	114.6	19.5	9.8	240.8	19.0
6 32nd Ave at Cc	9.8	7.8	8.0	10.1	35.7	622.0	527.0	502.0	794.0	2445.0	124.4	81.2	51.9	20.4	277.9	77.0
7 32nd Ave at 24	1.4	2.6	2.3	0.0	6.3	54.0	254.0	271.0	0.0	579.0	99.9	93.3	13.7	0.0	206.9	37.0
8 32nd Ave at 20	4.1	4.7	2.7	5.7	17.2	308.0	482.0	238.0	358.0	1386.0	101.9	67.5	16.2	24.9	210.5	55.0
Zone 151	31.1	27.7	30.0	40.8	129.6	2391.0	2639.0	2345.0	2944.0	10319.0	702.7	579.8	183.9	159.3	1625.7	337.0

15a	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)			
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.5	0.5	0.0	2.2	4.2	244.0	111.0	0.0	266.0	621.0	10.0	5.0	0.0	7.0	22.0	41.0
2 32nd Ave at 29	0.2	1.9	0.8	0.0	3.0	42.0	370.0	84.0	0.0	496.0	4.0	9.0	4.0	0.0	17.0	71.0
3 32nd Ave at 38	4.8	3.3	7.2	7.4	22.7	498.0	371.0	342.0	424.0	1635.0	13.0	14.0	11.0	11.0	49.0	22.0
4 32nd Ave at 34	3.7	6.4	6.9	7.7	24.8	341.0	636.0	358.0	404.0	1739.0	14.0	18.0	11.0	11.0	54.0	17.0
5 32nd Ave at 31	1.2	1.8	3.7	2.7	9.5	126.0	327.0	196.0	158.0	807.0	10.0	16.0	6.0	4.0	36.0	22.0
6 32nd Ave at Cc	7.8	8.9	11.3	10.8	38.9	679.0	706.0	643.0	687.0	2715.0	25.0	22.0	19.0	19.0	85.0	58.0
7 32nd Ave at 24	1.0	1.4	2.5	0.0	4.9	344.0	214.0	156.0	0.0	714.0	12.0	12.0	4.0	0.0	28.0	33.0
8 32nd Ave at 20	1.1	3.0	2.7	4.2	11.0	139.0	435.0	162.0	236.0	972.0	11.0	13.0	4.0	6.0	34.0	47.0

Zone 151 21.4 27.3 35.2 35.0 **118.8** 2413.0 3170.0 1941.0 2175.0 **9699.0** 99.0 109.0 59.0 58.0 **325.0** **311.0**

16a	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)			
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.2	0.1	0.0	1.8	3.1	213.0	20.0	0.0	241.0	474.0	9.0	3.0	0.0	6.0	18.0	39.0
2 32nd Ave at 29	0.2	1.2	0.8	0.0	2.1	35.0	301.0	74.0	0.0	410.0	4.0	8.0	5.0	0.0	17.0	47.0
3 32nd Ave at 38	4.4	1.7	9.1	11.6	26.9	504.0	244.0	383.0	439.0	1570.0	13.0	11.0	13.0	15.0	52.0	67.0
4 32nd Ave at 34	5.7	10.4	6.2	13.4	35.8	487.0	830.0	363.0	519.0	2199.0	18.0	23.0	10.0	17.0	68.0	54.0
5 32nd Ave at 31	0.9	1.5	3.2	4.5	10.1	108.0	301.0	187.0	228.0	824.0	10.0	16.0	5.0	6.0	37.0	18.0
6 32nd Ave at Cc	5.8	7.7	9.5	16.4	39.3	540.0	743.0	455.0	712.0	2450.0	21.0	22.0	15.0	24.0	82.0	49.0
7 32nd Ave at 24	1.3	1.5	2.0	0.0	4.8	353.0	286.0	142.0	0.0	781.0	13.0	14.0	3.0	0.0	30.0	48.0
8 32nd Ave at 20	0.8	2.8	2.8	3.1	9.6	111.0	447.0	174.0	179.0	911.0	11.0	13.0	4.0	5.0	33.0	100.0

Zone 151 20.4 26.9 33.7 50.7 **131.8** 2351.0 3172.0 1778.0 2318.0 **9619.0** 99.0 110.0 55.0 73.0 **337.0** **422.0**

17a	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)			
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All
1 32nd Ave at 29	1.2	0.1	0.0	1.8	3.1	213.0	20.0	0.0	241.0	474.0	9.0	3.0	0.0	6.0	18.0	39.0
2 32nd Ave at 29	0.2	1.2	0.8	0.0	2.1	35.0	301.0	74.0	0.0	410.0	4.0	8.0	5.0	0.0	17.0	47.0
3 32nd Ave at 38	4.4	1.7	9.1	11.6	26.9	504.0	244.0	383.0	439.0	1570.0	13.0	11.0	13.0	15.0	52.0	67.0
4 32nd Ave at 34	5.7	10.4	6.2	13.4	35.8	487.0	830.0	363.0	519.0	2199.0	18.0	23.0	10.0	17.0	68.0	54.0
5 32nd Ave at 31	0.9	1.5	3.2	4.5	10.1	108.0	301.0	187.0	228.0	824.0	10.0	16.0	5.0	6.0	37.0	18.0
6 32nd Ave at Cc	5.8	7.7	9.5	16.4	39.3	540.0	743.0	455.0	712.0	2450.0	21.0	22.0	15.0	24.0	82.0	49.0
7 32nd Ave at 24	1.3	1.5	2.0	0.0	4.8	353.0	286.0	142.0	0.0	781.0	13.0	14.0	3.0	0.0	30.0	48.0
8 32nd Ave at 20	0.8	2.8	2.8	3.1	9.6	111.0	447.0	174.0	179.0	911.0	11.0	13.0	4.0	5.0	33.0	100.0

Zone 151 20.4 26.9 33.7 50.7 **131.8** 2351.0 3172.0 1778.0 2318.0 **9619.0** 99.0 110.0 55.0 73.0 **337.0** **422.0**

****AGGREGATE PERIODS** (= Sum of Volume/Timing Plan Case * Hours of Operation)****MON - THURS****AM PERIOD (630 AM to 1100 AM)**

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	
1 32nd Ave at 29	2.0	1.4	0.0	5.3	8.8	395.0	319.8	0.0	746.5	1461.3	54.3	32.9	0.0	42.1	129.3	
2 32nd Ave at 29	1.4	2.1	1.5	0.0	5.0	350.3	343.8	342.0	0.0	1036.0	60.1	66.3	26.1	0.0	152.4	
3 32nd Ave at 38	5.0	6.7	4.3	6.6	22.6	750.0	1080.3	426.8	672.3	2929.3	57.9	105.8	17.8	31.8	213.3	
4 32nd Ave at 34	4.6	4.5	6.6	8.5	24.1	613.5	658.5	664.3	779.5	2715.8	88.1	66.0	30.9	34.3	219.2	
5 32nd Ave at 31	2.0	1.4	2.9	1.6	7.9	319.3	284.5	319.3	189.0	1112.0	75.1	113.2	11.0	5.3	204.6	
6 32nd Ave at Cc	8.5	8.2	17.2	12.0	45.8	862.5	852.3	1512.8	1112.8	4340.3	93.9	89.2	99.0	62.1	344.1	
7 32nd Ave at 24	1.7	2.3	1.4	0.0	5.3	252.3	555.8	169.3	0.0	977.3	67.7	109.2	3.9	0.0	180.7	
8 32nd Ave at 20	1.6	5.2	4.4	6.9	18.1	348.0	883.8	496.8	677.0	2405.5	57.3	76.1	21.4	26.9	181.5	
Zone 151	26.8	31.8	38.2	40.8	137.6	3890.8	4978.5	3931.0	4177.0	16977.3	554.3	658.5	209.9	202.3	1625.0	

MID-DAY PERIOD (1100 AM to 245 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	3.8	0.4	0.0	5.0	9.2	711.0	142.5	0.0	723.0	1576.5	28.5	11.3	0.0	18.0	57.8
2 32nd Ave at 29	0.5	3.2	1.7	0.0	5.4	88.5	826.5	228.0	0.0	1143.0	13.5	21.8	9.8	0.0	45.0
3 32nd Ave at 38	10.7	3.8	15.9	19.0	49.3	1263.0	594.0	975.8	1177.5	4010.3	31.5	29.3	27.0	29.3	117.0
4 32nd Ave at 34	7.1	13.6	16.7	22.4	59.8	975.8	1991.3	894.0	1060.5	4921.5	36.8	51.0	27.8	31.5	147.0
5 32nd Ave at 31	4.2	2.8	8.7	6.5	22.2	936.8	700.5	532.5	444.8	2614.5	33.0	41.3	15.8	9.8	99.8
6 32nd Ave at Cc	17.4	18.1	26.4	25.4	87.3	1612.5	2049.0	1681.5	1758.8	7101.8	62.3	57.8	48.0	48.8	216.8
7 32nd Ave at 24	4.0	2.1	6.4	0.0	12.5	1165.5	339.0	459.8	0.0	1964.3	36.8	30.8	9.8	0.0	77.3
8 32nd Ave at 20	6.9	7.3	6.2	10.3	30.8	786.0	1255.5	459.0	687.0	3187.5	38.3	36.0	9.8	15.8	99.8
Zone 151	54.6	51.3	82.0	88.7	276.6	7539.0	7898.3	5230.5	5851.5	26519.3	280.5	279.0	147.8	153.0	860.3

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)					Fuel Consumption (Gal)					Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	
1 32nd Ave at 29	6.1	2.5	0.0	10.5	19.1	1103.3	649.3	0.0	1477.0	3229.5	96.9	44.9	0.0	59.6	201.4	
2 32nd Ave at 29	2.2	5.8	3.7	0.0	11.7	511.3	1146.3	570.8	0.0	2228.3	87.4	80.6	37.9	0.0	205.9	
3 32nd Ave at 38	21.6	12.9	24.0	29.1	87.7	2309.8	1653.0	1575.8	1956.3	7494.8	105.6	133.9	66.0	80.6	386.1	
4 32nd Ave at 34	16.4	21.6	20.6	28.1	86.7	1628.5	2667.8	1472.3	1957.3	7725.8	167.8	132.4	53.9	47.5	401.5	
5 32nd Ave at 31	5.6	4.7	13.1	8.6	32.0	770.0	958.0	883.8	654.0	3265.8	140.3	171.3	31.0	21.4	363.9	
6 32nd Ave at Cc	29.9	33.3	39.3	47.9	150.4	2626.0	2855.0	2577.8	3148.0	11206.8	206.4	159.3	114.1	86.2	566.0	
7 32nd Ave at 24	6.1	6.3	9.9	0.0	22.3	1288.5	1215.8	825.3	0.0	3329.5	150.8	144.1	27.3	0.0	322.1	
8 32nd Ave at 20	6.8	15.2	14.5	25.6	62.1	895.5	2122.0	1066.0	1575.5	5659.0	145.1	119.5	37.4	53.1	355.1	
Zone 151	94.7	102.3	125.1	149.8	472.0	11132.8	13267.0	8971.5	10768.0	44139.3	1100.1	985.9	367.5	348.4	2801.9	

FRI**AM PERIOD (630 AM to 1030 AM)**

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	1.7	1.4	0.0	4.9	7.9	335.5	300.8	0.0	670.0	1306.3	51.8	31.9	0.0	40.1	123.8
2 32nd Ave at 29	1.4	2.0	1.3	0.0	4.6	343.3	302.8	321.5	0.0	967.5	59.1	64.8	25.1	0.0	148.9
3 32nd Ave at 38	4.1	6.5	3.7	5.7	20.1	647.0	1045.3	376.3	603.8	2672.3	54.9	103.8	16.8	30.3	205.8
4 32nd Ave at 34	4.2	3.6	5.8	7.3	21.0	550.0	518.0	609.8	695.5	2373.3	85.1	62.5	29.4	32.3	209.2
5 32nd Ave at 31	1.6	1.3	2.5	1.3	6.7	259.3	248.5	287.8	165.5	961.0	72.6	110.2	10.5	4.8	198.1
6 32nd Ave at Cc	7.8	7.2	15.5	10.3	40.8	773.0	719.3	1391.3	991.8	3875.3	89.9	85.2	95.5	59.1	329.6
7 32nd Ave at 24	1.4	2.1	1.1	0.0	4.6	171.3	530.3	145.8	0.0	847.3	65.2	106.7	3.4	0.0	175.2
8 32nd Ave at 20	1.2	4.8	3.9	6.0	16.0	305.5	810.3	461.8	617.0	2194.5	54.8	73.6	20.4	25.4	174.0
Zone 151	23.4	28.9	33.8	35.6	121.8	3384.8	4475.0	3594.0	3743.5	15197.3	533.3	638.5	200.9	191.8	1564.5

MID-DAY PERIOD (1030 AM to 245 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)						Fuel Consumption (Gal)						Dilemma Zone (No.)	
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	All		
1 32nd Ave at 29	5.5	0.7	0.0	8.8	15.0	1003.0	216.8	0.0	1181.5	2401.3	42.5	17.0	0.0	29.8	89.3	233.8		
2 32nd Ave at 29	0.7	5.5	2.7	0.0	9.0	148.8	1461.8	365.5	0.0	1976.0	17.0	38.3	17.0	0.0	72.3	191.3		
3 32nd Ave at 38	17.8	7.1	32.0	40.8	97.6	2154.8	973.3	1419.5	1734.0	6281.5	51.0	46.8	46.8	55.3	199.8	157.3		
4 32nd Ave at 34	13.8	24.7	42.1	60.6	141.1	1556.3	3327.8	1411.8	1572.5	7868.3	59.5	85.0	55.3	63.8	263.5	208.3		
5 32nd Ave at 31	6.4	6.4	15.9	10.9	39.6	1538.5	1423.8	824.5	692.8	4479.5	51.0	68.0	25.5	17.0	161.5	114.8		
6 32nd Ave at Cc	29.3	30.2	51.8	46.9	158.1	2567.0	3050.0	2711.5	2919.8	11248.3	97.8	89.3	85.0	80.8	352.8	310.3		
7 32nd Ave at 24	5.3	3.5	9.9	0.0	18.6	1806.3	560.3	692.8	0.0	3059.3	55.3	46.8	17.0	0.0	119.0	170.0		
8 32nd Ave at 20	11.5	13.9	9.7	15.0	50.2	1351.5	2045.8	705.5	1011.5	5114.3	59.5	55.3	17.0	25.5	157.3	433.5		
Zone 151	90.3	92.0	164.0	182.9	529.1	12126.0	13059.3	8131.0	9112.0	42428.3	433.5	446.3	263.5	272.0	1415.3	1819.0		

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)		
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All
1 32nd Ave at 29	8.4	4.0	0.0	13.5	25.9	1394.3	815.0	0.0	1816.3	4025.5	136.9	66.4	0.0	84.2	287.5
2 32nd Ave at 29	3.0	7.8	4.7	0.0	15.5	620.3	1482.3	715.3	0.0	2817.8	134.3	119.0	50.1	0.0	303.4
3 32nd Ave at 38	27.5	16.8	42.0	59.0	145.4	2935.5	2089.5	2188.5	3104.8	10318.3	146.9	192.9	107.4	156.5	603.7
4 32nd Ave at 34	24.9	30.9	30.8	38.8	125.4	2221.5	3565.5	1908.0	2355.5	10050.5	248.5	194.6	82.0	62.5	587.6
5 32nd Ave at 31	8.2	9.0	20.0	11.9	49.1	1063.8	1416.0	1220.0	894.3	4594.0	213.3	260.8	54.6	31.2	559.9
6 32nd Ave at Cc	44.4	44.9	53.3	60.7	203.3	3533.3	3575.5	3312.3	4072.0	14493.0	308.0	226.9	160.8	111.9	807.6
7 32nd Ave at 24	7.0	9.9	13.3	0.0	30.2	1489.5	1549.8	1114.0	0.0	4153.3	225.3	217.3	39.5	0.0	482.1
8 32nd Ave at 20	14.2	22.9	16.7	32.0	85.8	1531.3	2918.0	1242.0	1841.3	7532.5	229.8	176.1	46.9	73.8	526.6
Zone 151	137.7	146.2	180.8	215.9	680.7	14789.3	17411.5	11700.0	14084.0	57984.8	1643.0	1453.9	541.3	520.1	4158.3

SAT**OFF PERIOD (830 AM to 600 PM)**

	Travel Time (Veh-Hr)				Total Stops (No.)				Fuel Consumption (Gal)				Dilemma Zone (No.)			
	EB	WB	NB	SB	All	EB	WB	NB	SB	All	EB	WB	NB	SB	All	
1 32nd Ave at 29	10.7	1.3	0.0	15.8	27.8	1911.0	287.0	0.0	2171.0	4369.0	80.0	27.5	0.0	54.0	161.5	358.0
2 32nd Ave at 29	1.8	10.2	6.7	0.0	18.7	436.0	2655.0	671.0	0.0	3762.0	38.0	69.5	41.5	0.0	149.0	430.5
3 32nd Ave at 38	37.5	15.7	72.4	91.5	217.1	4324.0	2278.0	3218.5	3724.0	13544.5	111.0	98.5	105.0	121.5	436.0	537.5
4 32nd Ave at 34	44.8	80.4	53.3	107.1	285.6	3995.5	6883.5	3079.0	4270.0	18228.0	148.5	190.0	85.5	138.0	562.0	450.5
5 32nd Ave at 31	8.9	12.5	27.1	34.8	83.3	1280.5	2569.0	1628.0	1849.5	7325.0	90.0	137.5	43.5	47.5	318.5	187.5
6 32nd Ave at Cc	50.7	63.4	82.7	128.7	325.5	4723.0	6244.0	4248.0	6016.5	21231.5	183.5	185.5	135.0	196.5	700.5	670.0
7 32nd Ave at 24	11.2	12.2	17.6	0.0	41.0	3072.0	2387.0	1244.5	0.0	6703.5	112.5	118.5	26.5	0.0	257.5	398.5
8 32nd Ave at 20	9.2	24.0	23.4	27.6	84.3	1225.0	3874.0	1499.0	1666.0	8264.0	98.5	112.0	33.5	44.5	288.5	873.5
Zone 151	174.9	219.8	283.1	405.5	1083.3	20967.0	27177.5	15586.0	19697.0	83427.5	862.0	939.0	470.5	602.0	2873.5	3705.5

ZONE 151 - FINAL MOE "BEFORE/AFTER" COMPARISON (AGGREGATEDTIME PERIODS)

Change from Existing (Positive Value Equals Reduction (or Benefit))

MON - THURS

AM PERIOD (630 AM to 1100 AM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	0.4	0.5	0.0	-1.9	-1.0	70.8	134.8	0.0	-62.5	143.0	8.0	8.3	0.0	-4.3	12.0	21.3
2 32nd Ave at 29	0.5	0.3	-0.3	0.0	0.5	138.0	50.0	-22.5	0.0	165.5	10.6	6.0	0.0	0.0	16.6	77.0
3 32nd Ave at 38	-0.7	-2.2	-1.9	-2.2	-7.1	118.5	-236.5	-37.5	7.3	-148.3	7.4	15.5	-0.9	-1.2	20.8	118.8
4 32nd Ave at 34	2.3	1.7	-3.0	-4.1	-3.1	446.3	320.3	-106.3	-111.3	549.0	18.3	13.9	-4.1	-4.6	23.6	64.0
5 32nd Ave at 31	11.2	2.9	-0.6	-0.3	13.2	1190.5	361.3	-22.3	-11.3	1518.3	26.6	23.8	-0.6	-0.1	49.7	83.3
6 32nd Ave at Cc	4.5	5.1	-7.9	-2.2	-0.5	555.0	644.0	-381.0	-62.0	756.0	39.1	28.8	-6.3	0.7	62.3	31.3
7 32nd Ave at 24	5.5	3.6	-0.4	0.0	8.7	607.3	351.0	-34.3	0.0	924.0	23.7	17.0	-0.3	0.0	40.5	101.3
8 32nd Ave at 20	3.2	1.8	-1.6	-2.3	1.2	421.5	250.3	-64.8	-31.3	575.8	26.5	6.5	-3.4	-2.8	26.9	55.8
Zone 151	27.0	13.8	-15.7	-13.1	12.0	3547.8	1875.0	-668.5	-271.0	4483.3	160.1	119.8	-15.5	-12.2	252.2	552.5

MID-DAY PERIOD (1100 AM to 245 PM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	0.9	2.8	0.0	-1.1	2.5	103.5	614.3	0.0	-67.5	650.3	3.8	8.3	0.0	-2.3	9.8	-10.5
2 32nd Ave at 29	2.3	2.0	0.0	0.0	4.3	672.8	180.0	-6.8	0.0	846.0	6.0	3.8	-1.5	0.0	8.3	139.5
3 32nd Ave at 38	-2.6	4.2	-8.9	-9.8	-17.1	-76.5	599.3	-158.3	-106.5	258.0	-2.3	9.8	-7.5	-6.0	-6.0	57.0
4 32nd Ave at 34	9.0	0.5	-7.7	-11.7	-9.9	768.8	-347.3	-95.3	-94.5	231.8	14.3	-2.3	-6.0	-9.8	-3.8	72.8
5 32nd Ave at 31	20.0	6.7	-2.7	-1.8	22.2	1483.5	757.5	-36.8	-27.0	2177.3	29.3	12.0	-3.8	0.0	37.5	144.0
6 32nd Ave at Cc	9.6	5.5	-10.9	-5.6	-1.4	743.3	-63.0	-240.0	-116.3	324.0	13.5	5.3	-12.0	-6.0	0.8	61.5
7 32nd Ave at 24	9.3	7.3	-3.0	0.0	13.6	476.3	1166.3	-75.0	0.0	1567.5	11.3	18.8	0.0	0.0	30.0	76.5
8 32nd Ave at 20	6.7	7.4	-1.8	-3.4	8.9	960.8	717.8	-15.0	-37.5	1626.0	14.3	12.0	0.0	-2.3	24.0	-96.0
Zone 151	55.0	36.4	-34.9	-33.4	23.1	5132.3	3624.8	-627.0	-449.3	7680.8	90.0	67.5	-30.8	-26.3	100.5	444.8

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	2.1	2.7	0.0	-2.4	2.4	253.0	520.8	0.0	-102.8	671.0	3.6	10.8	0.0	-3.3	11.1	14.3
2 32nd Ave at 29	3.6	1.6	-0.8	0.0	4.4	886.8	221.3	-49.8	0.0	1058.3	13.3	7.1	-0.8	0.0	19.6	173.8
3 32nd Ave at 38	-6.0	0.4	-13.2	-13.4	-32.1	69.3	392.3	-272.5	-177.8	11.3	1.3	3.0	-15.8	-18.4	-29.9	202.3
4 32nd Ave at 34	11.7	1.2	-8.3	-11.3	-6.6	1452.0	151.3	-178.5	-297.5	1127.3	23.3	17.4	-9.9	-10.4	20.4	222.0
5 32nd Ave at 31	33.6	10.2	-4.5	-2.5	36.8	3129.3	1213.3	-60.5	-15.5	4266.5	54.9	26.5	-2.8	-1.1	77.5	256.0
6 32nd Ave at Cc	13.9	5.8	-15.9	-12.9	-9.1	1161.0	544.3	-351.3	-179.0	1175.0	44.6	19.6	-18.0	-7.8	38.4	171.3
7 32nd Ave at 24	16.8	9.1	-4.3	0.0	21.6	1370.3	1090.0	-102.5	0.0	2357.8	28.9	22.1	-4.8	0.0	46.3	182.3
8 32nd Ave at 20	16.8	10.3	-4.6	-10.0	12.5	1902.0	1081.3	-41.8	-95.0	2846.5	47.5	18.3	-7.8	-10.8	47.3	118.0
Zone 151	92.6	41.4	-51.5	-52.4	30.1	10223.5	5214.3	-1056.8	-867.5	13513.5	217.3	124.8	-59.6	-51.7	230.7	1339.8

FRI

AM PERIOD (630 AM to 1030 AM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	0.4	0.4	0.0	-1.8	-1.0	60.3	101.3	0.0	-57.5	104.0	8.0	7.8	0.0	-3.8	12.0	22.3
2 32nd Ave at 29	0.3	0.2	-0.3	0.0	0.2	61.0	21.0	-22.5	0.0	59.5	9.6	6.0	0.0	0.0	15.6	61.0
3 32nd Ave at 38	-0.4	-2.4	-1.6	-1.8	-6.2	107.0	-291.0	-35.5	5.3	-214.3	7.9	14.5	-0.9	-1.2	20.3	108.8
4 32nd Ave at 34	1.8	1.9	-2.6	-3.5	-2.5	370.8	341.3	-101.8	-97.8	512.5	17.3	13.9	-3.6	-4.1	23.6	53.0
5 32nd Ave at 31	9.9	2.5	-0.5	-0.2	11.7	1066.5	304.8	-21.8	-10.8	1338.8	24.6	23.3	-0.6	-0.1	47.2	68.8
6 32nd Ave at Cc	3.8	4.7	-6.9	-1.7	-0.2	486.0	628.0	-354.0	-53.0	707.0	38.1	28.3	-5.3	0.7	61.8	19.8
7 32nd Ave at 24	4.9	3.1	-0.3	0.0	7.7	568.3	265.5	-30.3	0.0	803.5	22.7	16.0	-0.3	0.0	38.5	94.3
8 32nd Ave at 20	3.0	1.4	-1.3	-1.8	1.2	356.5	180.3	-63.8	-30.3	442.8	25.5	5.5	-2.9	-2.3	25.9	61.3
Zone 151	23.6	11.7	-13.5	-10.9	10.9	3076.3	1551.0	-629.5	-244.0	3753.8	153.6	115.3	-13.5	-10.7	244.7	489.0

MID-DAY PERIOD (1030 AM to 245 PM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	2.8	4.7	0.0	-2.0	5.5	187.0	981.8	0.0	-199.8	969.0	4.3	12.8	0.0	-4.3	12.8	-42.5
2 32nd Ave at 29	3.7	2.8	0.2	0.0	6.7	990.3	64.0	-29.8	0.0	1024.5	12.8	0.0	0.0	0.0	12.8	178.5
3 32nd Ave at 38	-2.7	7.1	-18.5	-23.5	-37.6	-276.3	824.5	-174.3	-85.0	289.0	-4.3	12.8	-17.0	-17.0	-25.5	59.5
4 32nd Ave at 34	18.0	4.9	-24.2	-37.6	-38.9	1257.3	-692.8	-90.0	12.8	487.3	25.5	-4.3	-17.0	-25.5	-21.3	8.5
5 32nd Ave at 31	34.6	12.9	-5.0	-2.6	39.9	2218.5	1160.3	-46.8	-59.5	3272.5	51.0	21.3	-4.3	-4.3	63.8	195.5
6 32nd Ave at Cc	20.0	10.1	-20.3	-11.5	-1.8	1228.3	82.3	-191.3	-144.5	974.8	25.5	8.5	-17.0	-8.5	8.5	63.8
7 32nd Ave at 24	15.8	10.4	-3.8	0.0	22.4	688.5	1611.5	-119.0	0.0	2181.0	17.0	21.3	-4.3	0.0	34.0	127.5
8 32nd Ave at 20	13.8	12.8	-1.7	-2.8	22.1	1504.5	988.8	-44.0	-72.3	2387.0	25.5	21.3	0.0	-4.3	42.5	-106.3
Zone 151	106.1	65.6	-73.3	-79.9	18.5	7798.0	5020.3	-685.0	-548.3	11585.0	157.3	93.5	-59.5	-63.8	127.5	484.5

PM PERIOD (245 PM to 1000 PM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)				All	Fuel Consumption (Gal)				All	Dilemma Zoi
	EB	WB	NB	SB		EB	WB	NB	SB		EB	WB	NB	SB		
1 32nd Ave at 29	3.0	3.8	0.0	-2.9	3.8	258.3	735.0	0.0	-197.5	795.8	1.9	16.3	0.0	-4.7	13.6	-8.0
2 32nd Ave at 29	4.1	2.3	-0.7	0.0	5.6	939.8	185.8	-52.3	0.0	1073.3	13.9	9.0	-1.2	0.0	21.7	189.5
3 32nd Ave at 38	-4.7	2.7	-23.1	-33.7	-58.8	18.3	496.5	-415.8	-706.0	-607.0	3.0	9.6	-27.6	-57.8	-72.8	204.0
4 32nd Ave at 34	20.1	5.6	-12.1	-14.2	-0.6	1910.0	102.8	-186.3	-177.0	1649.5	39.2	28.3	-12.1	-12.4	42.9	221.0
5 32nd Ave at 31	43.6	15.2	-7.4	-2.9	48.4	3677.5	1609.3	-136.0	-51.8	5099.0	69.7	26.8	-13.1	-3.2	80.2	291.5
6 32nd Ave at Cc	20.2	9.4	-17.6	-15.1	-3.1	1549.3	680.0	-285.3	-248.3	1695.8	65.0	21.4	-16.3	-13.1	56.9	156.0
7 32nd Ave at 24	22.7	10.2	-5.5	0.0	27.5	1795.8	1221.5	-167.3	0.0	2850.0	39.2	20.7	-7.3	0.0	52.6	236.8
8 32nd Ave at 20	24.0	15.4	-4.2	-10.7	24.6	2198.8	1171.3	-51.5	-99.5	3219.0	59.0	17.8	-3.4	-14.5	58.9	104.5
Zone 151	133.0	64.7	-70.7	-79.6	47.5	12347.5	6202.0	-1294.3	-1480.0	15775.3	290.9	149.7	-80.9	-105.7	253.9	1395.3

SAT

OFF PERIOD (830 AM to 600 PM)

	Travel Time (Veh-Hr)				All	Total Stops (No.)	
--	----------------------	--	--	--	-----	-------------------	--