Bernardin Lochmueller and Associates

MUNICIPALITY OF ANCHORAGE
Traffic Department

Thomas R. Kruse, P.E.
Associate Traffic Engineer

4700 S. Bragaw
P.O. Box 196650
Anchorage, Alaska 99519-6650

Telephone (907) 343-8425
Fax (907) 343-8488
Mobile (907) 317-7072
krusetr@ci.anchorage.ak.us

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ACKNOWLEDGMENTS

This signal timing project and the benefits derived from it were made possible through the cooperative funding and support of the Alaska Department of Transportation and Public Facilities (DOT/PF) and the Municipality of Anchorage Department of Public Works (MOA). These agencies also funded the projects which led up to this undertaking.

The signal timing software used in the project is distributed by the McTrans Center for Microcomputers in Transportation in Gainesville, Florida and the PCTRANS Center of Transportation, University of Kansas, in Lawrence Kansas.

PROJECT SUMMARY

Normal winter weekday timing plans have been developed for SubSystem #8. This SubSystem contains twenty-four signalized intersections including the major arterials of Northern Lights Boulevard, Debarr Road, Lake Otis Parkway, Boniface Parkway, and Bragaw Street. The SubSystem is illustrated in Figure 1.

Two independent timing plans (morning and evening) have been produced, implemented, and evaluated. These timing plans were developed following a process addressing four fundamental signal timing issues: optimum signal phasing, phase-split times meeting level-of-service targets, system cycle length for optimizing coordination, and offsets for maximizing coordination and maintaining a desirable level of platoon progression. The timing plans were developed under the following outline:

- *Submittal of White Paper* outlining recommended steps and procedures to develop the best winter signal timing plan. This paper was reviewed and approved by the MOA.
- *Collection of Start-Up Lost Time and Saturation Flow Rate Data* by ASCG, Inc. following the procedures used previously by the Municipality of Anchorage to determine summer saturation flow rates.
- *Setup of SubSystem Database and Identification of Design Hour Volumes* using the TURNS software.
- *Submittal of White Paper Conclusions* which answered questions raised in the initial white paper. The White Paper Conclusions provided a summary of results and recommended parameters to model winter conditions. This paper was reviewed and approved by the MOA before further work was completed on the development of winter signal timings for SubSystem #8.
- *Development of Optimum System Cycle Lengths* using the SIGNAL85, NOSTOP, PRETRANSYT, and TRANSYT-7F software.
- *Optimization of Intersection Timing* (phase and splits) using the SIGNAL85 software.
- *Development of Optimum Offsets* using the TED, NOSTOP, and TRANSYT-7F software.

Implementation continued with before studies, on-street implementation, and after studies to assess the effectiveness of the new winter signal timing plans:

- *Conduct Before Studies* of speed and delay using travel time runs performed by the MOA Department of Public Works staff, as mentioned in the RFP addendum.

- *Implementation of Signal Timing Plans* by the MOA staff with assistance from BLA/ASCG. The timing plans were provided in a format compatible with the TRACONEX controllers. BLA/ASCG continued by fine tuning the SubSystems sequences, splits, and offsets with guidance and assistance from the MOA staff. Furthermore, recommendations were provided on how to evaluate passage time and minimum gap settings.

- *Conduct After Studies* of speed and delay using travel time runs performed by the MOA. The effectiveness of the new signal timing plans was then addressed using the report process developed in the *Before Study* phase.

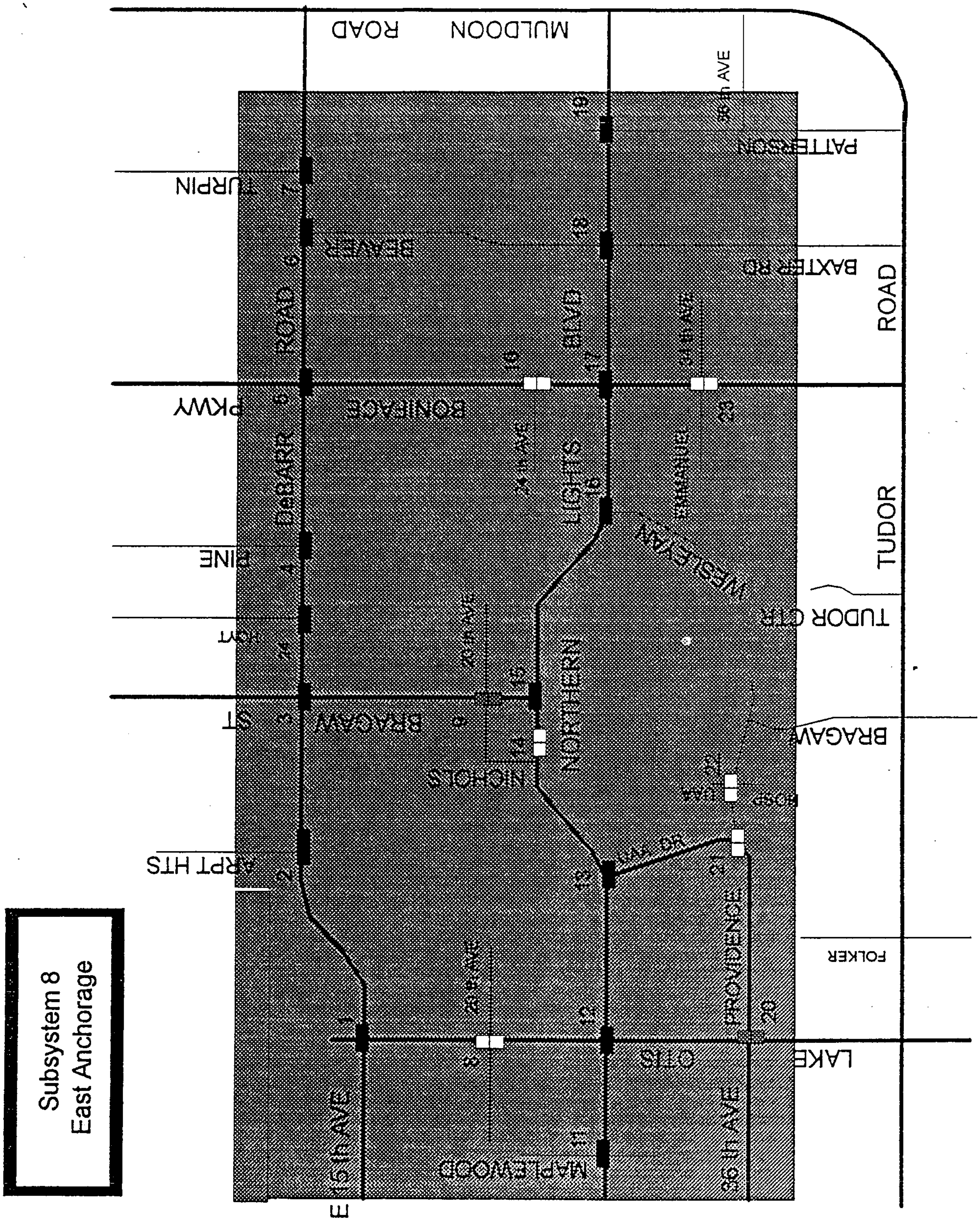

FIGURE 1
SubSystem #8 East Anchorage Traffic Signal System

JANUARY 1995 WHITE PAPER

Winter is regarded as the coldest season of the year. Most American cities experience this season's typical inclement weather - cold temperatures, ice, and snow - intermittently, for about 90-days during the calendar months of December, January, and February. These inclement weather periods are interspersed with intervals of warmer temperatures allowing melting and runoff of frozen precipitation.

However, winter time conditions in the Municipality of Anchorage last significantly longer than most communities in the United States. A typical winter in Anchorage begins about October 15 and ends around April 15, for a period of 180-days. Unlike other American communities, the Municipality does not experience many intervals of warmer temperatures, which results in significant accumulations of snow and ice. In addition, Anchorage's location at 61^{o} North Latitude means shorter days, longer periods of darkness, and less opportunity for sunshine and its warming affects.

The Anchorage community recognizes the need for a good, efficient transportation system. However, the extended winter time conditions this area experiences impact this goal. Thus, the State of Alaska and the Municipality of Anchorage has developed and enhanced the transportation system to include winter time elements. For example, roadway lane widths are generally greater than those in other American communities to accommodate reductions created by snow and ice accumulations. Pavement design often incorporates a flexible system to discourage the destructive effects of freeze-thaw actions. In addition, most Anchorage roadway facilities are well-lighted to accommodate the periods of darkness that extend into morning and evening peak travel periods.

Until now, the Municipality made few adjustments to traffic operations (e.g., traffic signals, speed zone control, etc.) to account for winter time weather and improve travel conditions during this 180-day period. As part of the Anchorage Signal System Upgrade study, sponsored by the State of Alaska Department of Transportation and Public Facilities, the Municipality requested the signal system be studied to determine if winter time procedures can be developed and implemented to improve the efficiency of traffic operations.

The following white paper, developed by Bernardin, Lochmueller & Associates, Inc., Strong Concepts, Inc., and ASCG Incorporated, recommends a study for developing winter time signal timing procedures for use in Anchorage. The following includes a brief overview of winter signal timing practices in other locations; an approach for modifying the current signal timing plan process with winter time variables; and methods for developing the winter time variables.

Other Adverse Weather Analysis Practices

The acknowledged source for analyzing traffic operations is the current edition of the *Highway Capacity Manual*. In the manual, it cites there have been relatively few efforts to quantify the effects of adverse weather on capacity. In the current edition of the *Highway Capacity Manual*, some measure of the weather impact is presented from studies on two freeways with automated data collection systems. One freeway, Interstate 35W in Minneapolis, was studied for effectsä for both rain and snow. The study cited that "when precipitation falls as snow, the impact (on capacity) is even greater (than rain): an additional 2.8 percent decrease in capacity for each 0.01 inch per hour of snow (water equivalent) beyond the initial "trace (of snow)" decrease ofä 8 percent."[1]

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[1] *Highway Capacity Manual* (1985). Special Report 209, Transportation Research Board, Washington, DC. Page 2-16.

The manual concludes its discussion on adverse weather by stating that the analysis procedures do not specifically account for inclement weather conditions. However, the manual does recommend that in some areas, where such conditions are prevalent, some adjustments to the analysis variables may be necessary to account for adverse weather conditions.

The primary variable dictating the quantity of capacity in an intersection is the saturation flow rate. "The saturation flow rate is the flow in vehicles per hour which could be accommodated assuming that the green phase was always available to the approach (i.e., that the green time-to-capacity (g/C) is 1.00)."[2] Capacity analysis computations begin with selection of an "ideal" saturation flow rates, and adjustments made for a variety of prevailing conditions that are not "ideal." These adjustments include:

- lane width
- heavy vehicles in the traffic stream (e.g., trucks, recreational vehicles)
- approach grade
- existence of a parking lane and parking activity in that lane
- blocking effect of local buses stopping within the intersection area
- area type (e.g., central business districts or other areas)
- effects of left- and/or right-turning traffic

Limited research has been conducted on winter time saturation flow rates as suggested in the *Highway Capacity Manual.* Most notable efforts include recommendations and guidelines suggested in the *Canadian Capacity Guide for Signalized Intersections,* by Stan S. Teply, P. Eng., of the University of Alberta and research studies summarized in *Flow Rates at Signalized Intersections Under Cold Winter Conditions,* by Jan L. Botha, of San Jose State University and Thomas R. Kruse of Purdue University (now Municipality of Anchorage employee).

The *Canadian Capacity Guide for Signalized Intersections* makes significant recommendations for analyzing traffic operations in adverse winter weather climates. The guide suggest three separate categories of weather conditions for capacity analyses:

- Summer - Temperatures above 14°F (-10°C) on dry roads, or above 32°F(0°C) on wet roads (no ice);
- Winter - Temperatures from -22°F(-30°C) to 14°F(-10°C) with dry pavement or well sanded hard-packed snow and exhaust fumes obstructing close range visibility; and
- Extreme - Visibility significantly reduced, air below -22°F(-30°C), snowfall, blizzard, freezing rain at any temperature, or slippery roads.

For summer conditions, no adjustments are recommended to saturation flow rates in analyzing traffic operations. During winter conditions, the guide includes adjustment factors and identified saturation flow rates for various design standards and pedestrian activity. These adjustment factors and identified rates are between 7 and 15 percent below the "ideal" saturation flow rate (with the appropriate adjustment factors listed on page 2).

Rates and adjustment factors are not suggested for extreme conditions. These recommendations are consistent with the practice of designing for "normal" traffic conditions; not extreme events that occur infrequently.

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[2]Ibid, Page 9-11.

In the Botha and Kruse paper, headway data was collected under subfreezing conditions, with ice, snow, or frost present. Additional analysis indicated saturation flow rates were found to be substantially lower than those suggested in the *Highway Capacity Manual*. The study recommends "reducing the flow rates 20 percent"[3] to account for adverse weather conditions. Other conclusions reached in the study included:

- Lane widths, reduced by snow or ice, did not significantly contribute to reduced saturation flow rates.
- Saturation flow rates were higher with a presence of only frost or ice film than those streets with packed snow or ice cover.
- Measured saturation flow rates were reduced by as much as 27 percent at some locations due to winter conditions.
- Summer saturation flow rates were less than the *Highway Capacity Manual*, but consistent with adjustments for metropolitan area sizes.

The paper summarized data collected as part of a study to determine the effect of ice at intersections on the optimal signal timing for urban arterials. Data was collected at intersections throughout Fairbanks, Alaska in weather ranging from 31°F(-0.5°C) to -6°F(-21°C). The paper's author judged whether there was sufficient snow, ice cover , or an ice or frost film to significantly influence vehicle operation and the flow rate. No data was collected during extreme conditions, such as periods of high wind, heavy snowfall, heavy ice or fog, or temperatures below -10°F(-30°C).

Although the saturation flow rate reductions suggested in the Canadian guide and the Botha and Kruse paper are consistent, the data cannot be directly compared. The Canadian approach uses different conventions for the definition and adjustments of basic saturation flow rates and lost times. In addition, the range of temperatures for which the data are valid also differs from the Fairbanks conditions. The Canadian approach treats dry pavement above 14°F (-10°C) as summer conditions. Data were not obtain under these conditions in Fairbanks.

Consultant Observation and Theories

Research by Bernardin, Lochmueller & Associates, Inc. (BLA) on this topic has concluded that the recommendations in the current edition of the *Highway Capacity Manual*, suggestions from the *Canadian Capacity Guide for Signalized Intersections*, and the Botha and Kruse research are the only presently available and applicable studies to developing winter timing signal timing procedures in Anchorage. After careful review of this data, BLA developed the following observations and theories for the procedures.

Definitions of "Winter Time"

The Canadian study concludes three winter time driving conditions exist in northern climates: summer, winter, and extreme. The Botha and Kruse research support this assumption. BLA concludes these three conditions exist, too, based upon observations of climate conditions in the Anchorage area.

[3] Botha, J.L., and Kruse, T.R, *Flow Rates at Signalized Intersections Under Cold Winter Conditions*, American Society of Civil Engineers *Journal of Transportation Engineering*, Vol. 118, No. 3, May/June 1992, p. 439.

Discussions with Municipal staff suggest the ability to implement signal timing plans is better linked to a time - between two assumed dates - than a climate condition. Climate conditions are only best predictable for a 48- to 72-hour period. This implies difficulty in determining when and how long a winter plan should be implemented, and more importantly, when "normal" timing plans are returned. Finally, the cumbersome activities involved with implementation may mean that by the time a plan is fully activated, the winter weather may have passed, and it is time to return to "normal" operations. Therefore, BLA believes it is difficult to develop "on-demand" coordinated timing plans for winter, especially extreme, conditions.

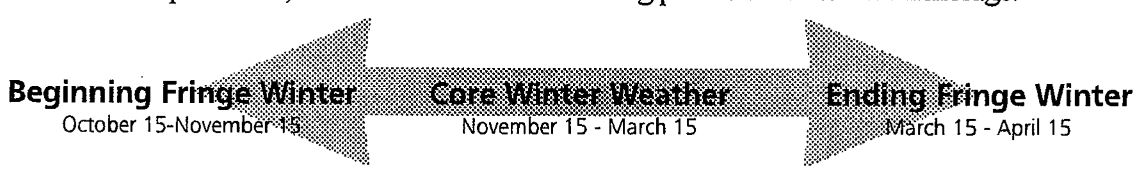
BLA does believe Anchorage's prolonged winter time warrants a coordinated timing plan for the season. This belief is based upon comments from MOA staff and the BLA's observations of climate and roadway conditions for extended periods in Anchorage:

- Roadways, particularly collectors and residential streets, are covered with snow and/or ice;
- Major arterials experience reduced lane widths from side snow and covered pavement markings; and
- A need for traffic efficiency to minimize poor air quality during the winter season.

Given these observations, BLA recommends a "general" timing plan for "normal" winter travel conditions (the "winter" category identified above). As recommended in the Canadian guide, and supported by the Botha and Kruse research, we do not suggest developing timing plans for the "Extreme" winter conditions. BLA does provide recommendations later in this paper on allowing the entire system to run free when these conditions, as defined by the Municipal Traffic Engineering staff, occur within the Municipality.

If winter is to be defined chronologically, then when is Winter Time?
In the beginning paragraphs to this paper, BLA identified a 180-day period as "winter" in Anchorage. This period begins October 15 and ends April 15, and the above three factors exist for the majority or duration of this time.

As a matter of procedure, BLA has defined the following phases of winter in Anchorage:



The "winter" period was subdivided into these categories to reflect the differences in weather and travel conditions over the course of the season. During the initial and final 30-days of the season, icy and snow conditions are prevalent throughout the Municipality. However, temperatures tend to warm from time-to-time, allowing snow and ice to melt, providing driving surfaces close to summer time conditions. Thus, BLA believes it may not be necessary to implement the winter timing plans during all or some of the initial and final 30-day periods. It is recommended that roadway conditions be monitored and if warranted, implement the winter timing plans.

Otherwise, BLA recommends implementing the winter timing plans by the "Core Winter Weather" season. Often, this occurs by November 15 and lasts for a 120-day period ending on March 15. During these times, the above three factors are present for the entire period, and a formal coordinated winter timing plan, based upon studied saturation flow rates can be developed. The November 15 and April 15 dates were selected arbitrarily by BLA; and subject to change following discussions with Municipal staff.

Again, BLA recommends that the roadway conditions be monitored from year-to-year for when the winter timing plans should be implemented, or discontinued. BLA also recommends that once the winter timing plans are implemented, the summer timing plans are not again implemented until the end of the "Core Winter Weather" season, or March 15. Likewise, if the decision is made to discontinue the timing plans prior to March 15, then the summer timing plans will remain implemented until the following winter season.

Timing Parameters, Core Winter

Based on the literature review and discussions with Municipality Staff, BLA has identified cycle, split, and offset to be the parameters for potential change during the core winter. The goal for the adjusted winter timing plans is to equalize delay for critical movements and to coordinate travel between intersections.

Cycle and Split

Several variables are considered in the determination of split and cycle. Two variables which are affected by winter conditions are saturation flow rate and startup lost time.

Saturation flow rates will be determined for winter conditions through studies conducted by ASCG. Studies will be conducted at the same locations where the Municipality has previously conducted studies during the summer. Based on a comparison of winter and summer data, a new adjustment factor will be developed:

f_{si} = adjustment factor for snow and ice conditions experienced in core winter.

The factor will be used in the standard formula for saturation flow rate:[4]

$$S = S_o N f_W f_{HV} f_g f_p f_{bb} f_a f_{RT} f_{LT} f_{si}$$

The result will be a reduced saturation flow rate which accounts for weather related road conditions in addition to other prevailing conditions, such as number of lanes, grade, and trucks.

Flow rates will be developed for three categories of roadway:

- Major street, through movement
- Major street, left turn movement
- Minor street, through movement

Snow removal generally keeps through lanes on the major street clear. Minor cross streets and left turn lanes are frequently covered with packed snow. This leads to the potential for varying factors (f_{si}) for each of the three categories. Studies will be conducted at the locations listed in Appendix A.

[4]Highway Capacity Manual (1985). Special Report 209, Transportation Research Board, Washington, D.C., Page 9-12

Startup lost times will be developed from the data collected in the saturation flow rate study. These times are expected to be longer because of the traction problems experienced by motorists on snow and ice. The additional startup lost time will be added to accepted values of lost time for use at all intersections. SIGNAL85 accepts one lost time value for each intersection; that lost time is used on all approaches.

Offset
Travel time between intersections is one of the variables considered in the determination of appropriate offset. Speed changes due to winter conditions (narrow lanes, slick or moist pavement, poor visibility) will necessitate a change in offset. Changes to cycle and split identified above would also result in revisions to offset.

In order to identify speed changes, the Municipality has conducted travel time runs during winter conditions, excluding severe situations. Several runs will be made during the am and pm peak periods. The average speeds will be used to develop new offsets.

Timing Parameters, Severe Winter
Severe winter conditions occur during storms and in the period immediately thereafter. This condition is characterized by :

- Heavy snowfall.
- Extremely slow speeds between intersections.
- Very long startup times for stopped vehicles.
- Peak traffic spread over a longer period.
- Loss of channelization until snow plows arrive.
- Motorists run the red light more, knowing cross street has a long startup time .

The project scope did not include activities for addressing changes in this condition. However, in the process of developing procedures for normal winter plans, several ideas were discussed regarding the severe winter condition. Those ideas are shared in this part of the paper in the interest of fostering further exploration of possible changes during a severe event.

Numerous problems occur at signals during these events for various reasons. Some of the problems occur because motorists are unable to get to detectors which are covered with snow. Others are due to inappropriate signal timing parameters dependent on the speed of vehicles. A few are due to traffic volumes which are different than those which are normally expected for a given time of day.

Because of the many uncertainties associated with these problems the following severe event philosophy is proposed:

- Operate signals in an uncoordinated fully actuated mode accept in areas where signals are closely spaced and in the downtown CBD - severe event pattern.
- Manually select the time of day at which to begin and end the severe event pattern. This would be through a time-of-day (TOD) program which is called at the beginning of the event.
- Adjust certain phase timing parameters when the winter timing database is loaded in November.

BLA has not found any literature regarding these problems. The following ideas should only be implemented on a limited basis with a careful observation and evaluation of the impact of each change. The primary changes are to phase timing parameters.

Recall

Because left turn lanes may not be accessible until plowed, it may be desirable to put some left turn arrows on minimum or maximum recall. This can be done through a TOD program. The use of minimum or maximum recall should be based on knowledge of expected traffic for the time of day .

Minimum Green

If traffic can get to the detectors, minor cross street and left turn minimums should remain low. As long as a vehicle is on the stop line detector, the phase will stay green. However, if recall is used, as noted above, it may be desirable to increase the minimum. Main street minimums can remain low because they can be varied through seconds/actuations. It is assumed that traffic will always cross one of the back loops for main street.

Seconds/Actuation

This parameter is used only on mainline approaches where the detectors are located several hundred feet from the stop line. It increases the amount of minimum time for each vehicle that crosses the detector. During coordinated operation, the parameter is disabled. Since the parameter will usually only be used during a snow event, a severe event value can be entered when the winter database is loaded into the system in November The value should be high to account for the increased startup time needed when vehicle traction is poor and approach speeds are low. The goal should be to have a minimum time long enough to get all vehicles between stop line and detector moving. Once vehicles start crossing the detector, the passage time should be long enough to keep the phase green.

Passage

The passage parameter is normally set as the travel time from the detector to the stop line. For minor cross streets and left turn lanes this is zero because the loops are at the stop line. Therefore, no change in passage is anticipated for these two situations. However, passage is also used to measure the gap, or headway, between vehicles. If slow speeds result in gaps greater than the passage time, causing the green to end prematurely, then the passage time should be increased to the typical gap. However, passage should be kept as low as possible in order to not cause inefficiency during normal winter conditions. Passage must be changed when loading the winter database.

For main street approaches, passage time at slow speeds will be a large value which is also used to measure gaps between vehicles. This could possibly result in very inefficient intersection operation with the main street green on longer than desirable. Volume density features should be used to avoid this.

Volume Density: minimum gap, time before reduction, time to reduce

During coordinated operations the volume density features are disabled. Therefore, severe winter values can be installed in most situations without affecting normal operation. A reasonable gap should be chosen; it will probably be a little larger than the summer value. The time before reduction and time to reduce values must be chosen to ensure that reduction does not occur before the traffic between the stop line and detector clears the intersection. Also, it should occur before the maximum.

Maximum
During severe events typical cycle lengths may be longer. Maximum values, particularly for left turns and cross street, may need to be increased. These will have to be changed when the normal winter database is loaded. The values may need to be a compromise between normal and severe event requirements.

Timing Parameters Remaining Unchanged

Yellow and all red
There has been more research on the yellow and all red parameters than any of the other phase timing parameters; see Appendix B. Despite this effort, there still remains much disagreement on the timing of these parameters, particularly the all red.

Anchorage traffic signals generally have long yellows (4-5 seconds) and always have an all red (1-3 seconds). The motorists have been accustomed to seeing long yellows and respond accordingly. Consequently, many motorists appear to use the yellow as green knowing that they can clear the intersection during the all red. Some enter the intersection on the red.

Any change in these parameters should be done using the standard formulae found in traffic engineering literature. If a change were made for winter conditions, it would be based on a reduced speed. Using a reduced speed would result in shorter yellows and longer all reds. The total of yellow and all red would decrease as assumed speed is reduced.

Because of the driver expectation in Anchorage, BLA does not recommend changing yellow and all red for winter conditions. In order to protect the Municipality from liability, it is important that these parameters be determined using accepted practice.

Winter Timing Procedures
Detailed procedures have been developed for conducting the saturation flow rate/startup lost time studies. The studies and analysis of data will be done using the following guidelines:

- Use the same methodology as that used for the summer rates to avoid data collection bias.
- ASCG will conduct field surveys
- BLA will analyze the data.
- MOA Staff will provide quality control by observing data collection and reviewing analysis to avoid systematic errors and bias.
- Attempt to use same equipment for data collection.

Timing plans for Subsystem #8 will be developed for the AM and PM peak periods:

- Existing timing plans are assumed to be appropriate.
- Winter saturation flow rates and startup lost times will be used in SIGNAL85 to modify cycle and split.
- Speeds from winter travel time runs will be used to modify offsets.
- Before and after studies will be conducted.

FEBRUARY 1995 WHITE PAPER CONCLUSIONS

The following section answers questions raised in the initial January 1995 white paper (pervious section) and summarizes results from field studies conducted by the MOA and ASCG, Incorporated.

Timing Parameters, Core Winter

Based on literature review and discussions with Municipality Staff, BLA has identified cycle, split, offset, and possibly passage time to be the parameters for potential change during the core winter. The specific parameters proposed for adjustments are saturation flow rate, startup lost time, and design speed. The goal for the adjusted winter timing plans is to equalize delay for critical movements and to coordinate travel between intersections.

Cycle and Split

Several variables are considered in the determination of split and cycle. Two variables which are affected by winter conditions are saturation flow rate and startup lost time.

Saturation flow rates have been determined for winter conditions through studies conducted by ASCG, Inc. Studies have been conducted at the same locations where the Municipality has previously conducted studies during the summer. Based on a comparison of winter and summer data, the new adjustment factor (f_{si}) has been developed for snow and ice conditions experienced in core winter.

The factor will be used in the standard formula for saturation flow rate:[5]

$$S = S_o N f_W f_{HV} f_g f_p f_{bb} f_a f_{RT} f_{LT} f_{si}$$

The result will be a reduced saturation flow rate which accounts for weather related road conditions in addition to other prevailing conditions, such as number of lanes, grade, and heavy vehicles.

An f_{si} factor has been developed for four categories:

- Major street, through movement
- Major street, left turn movement
- Minor street, through movement
- Upgrades >2%

Table 1 contains the recommended f_{si} for each of the four categories based on field observations of eight major street through movements, four major street left turn movements, and two minor street through movements. Analysis sheets and summary of results for each location can be found in Appendix C.

Table 1

Recommended Saturation Flow Rate Adjustment Factors (f_{si})

Major Street Left Turn Movements	Major Street Through Movements	Minor Street Through Movements	Upgrades Greater than 2%
0.87	0.89	0.85	0.85

[5]Highway Capacity Manual (1985). Special Report 209, Transportation Research Board, Washington, D.C., Page 9-12

Because of the deviations in f_{si} from case to case, TEAPAC simulations were performed to determine what allowance there is in the saturation flow adjustment factor before a significant change occurs in signal timing strategies. Results are summarized in Table 2. See Appendix C for further details.

Table 2

f_{si} Allowable Deviations Before Significant Changes in Signal Timing Strategies Occur

Major Street Left Turn Movements	Major Street Through Movements	Minor Street Through Movements	Upgrades Greater than 2%
+/- 0.02	+/- 0.02	+/- 0.05	+/- 0.02

Startup lost times were analyzed from the data collected in the saturation flow rate study. These times were expected to be longer because of the traction problems experienced by motorists on snow and ice. The results, detailed in Appendix D, were quite the opposite. In fact, the startup lost times were either less than or equal to the summer startup lost time. Although different than expected, theoretically this is what happens since the startup lost time is a function of the saturation flow rate after the fourth vehicle. As such, all the additional startup lost time is taken up by the assumed saturation headway at the start-up of the first four vehicles and accounted for in the longer overall saturation headway. Therefore, the lost time factor used in SIGNAL85 will be recommended at its current value of 4.0 seconds.

Offset

Travel time between intersections used to determine offset. Speed changes due to winter conditions (narrow lanes, slick or moist pavement, poor visibility) will necessitate a change in offset. Changes to cycle and split identified above will also result in revisions to offset.

To identify speed changes, the Municipality has conducted travel time runs during winter conditions, excluding severe situations. Four runs were made during the am and pm peak periods. The average speeds will be used to develop new offsets.

The following page contains a summary of the winter design speeds for SubSystem #8 based on analysis of each travel time run. The analysis involved looking at each individual travel time run to determine cruising speed between intersections. Worksheets can be found in Appendix E.

Passage

The passage is normally set as the travel time from the detector to the nearest point of conflicting traffic. For minor cross streets and left turn lanes the passage time should be set for a short duration of one or two seconds because the loops are at the stop line. Therefore, a review of the existing passage times was to be made. However, on approaches where volume density is used the passage time sets the maximum gap allowed for vehicles to travel from the detector to the nearest point of conflicting traffic and the minimum gap is the lower limit to which the extendible portion or terminating gap may be decreased. The winter database was developed using saturation flow rates appropriate with the conditions. Therefore, the minimum gap was determined using these saturation flow rates. A program was developed by BLA for the Municipality of Anchorage to calculate the passage times and minimum gaps under winter conditions. Also taken into account is dilemma zone protection. The program is to be provided to the Municipality to use at there own discretion.

SubSystem #8: Winter Design Speed Summaries and Conclusions

The following are winter design speeds chosen for SubSystem #8 based on travel time analysis and consideration of average speed and standard deviation during each peak. Contrary to previous "summer" signal timing analysis, speeds will be changed in accordance with each peak period analysis.

NORTHERN LIGHTS BOULEVARD

(Posted Speed 40 mph)

Westbound	Am Peak (mph)	PM Peak (mph)
Patterson to Baxter	30	35
Baxter to Boniface	30	35
Boniface to Wesleyan	30	35
Wesleyan to Bragaw	32	36
Bragaw to UAA	31	37
UAA to Lake Otis	31	33
Lake Otis to Maplewood	30	30
Eastbound		
Maplewood to Lake Otis	30	25
Lake Otis to UAA	32	30
UAA to Bragaw	35	35
Bragaw to Wesleyan	35	37
Wesleyan to Boniface	33	35
Boniface to Baxter	32	32
Baxter to Patterson	32	32

DEBARR ROAD

(Posted Speed 40 mph)

Westbound	Am Peak (mph)	PM Peak (mph)
Turpin to Beaver	30	32
Beaver to Boniface	32	33
Boniface to Pine	33	33
Pine to Hoyt	32	33
Hoyt to Bragaw	30	30
Bragaw to Airport Hghts	30	33
Airport Hghts to Lake Otis	30	33
Eastbound		
Lake Otis to Airport Hghts	35	33
Airport Hghts to Bragaw	35	33
Bragaw to Hoyt	35	33
Hoyt to Pine	37	33
Pine to Boniface	37	33
Boniface to Beaver	37	33
Beaver to Turpin	35	33

LAKE OTIS PARKWAY

(Posted Speed 35/40 mph)

Northbound	Am Peak (mph)	PM Peak (mph)
Tudor to 36th	33	33
36th to Northern Lights	35	30
Northern Lights to 24th	33	30
24th to 15th/Debarr	31	30
Southbound		
15th/Debarr to 24th	30	32
24th to Northern Lights	32	32
Northern Lights to 36th	33	33
36th to Tudor	34	31

BONIFACE PARKWAY

(Posted Speed 45 mph)

Northbound	Am Peak (mph)	PM Peak (mph)
Tudor to 34th	40	40
34th to Northern Lights	37	37
Northern Lights to 24th	37	38
24th to Debarr	42	42
Southbound		
Debarr to 24th	40	39
24th to Northern Lights	37	37
Northern Lights to 34th	41	38
34th to Tudor	41	38

BRAGAW STREET

(Posted Speed 35 mph)

Northbound	Am Peak (mph)	PM Peak (mph)
Northern Lights to 20th	30	30
20th to Debarr	32	30
Debarr to Penland	32	30

Southbound	Am Peak (mph)	PM Peak (mph)
Penland to Debarr	32	32
Debarr to 20th	32	32
20th to Northern Lights	30	30

SIGNAL TIMINGS METHODOLOGIES

Intersection Identification
All intersections to be studied were identified on the SubSystem diagram provided by the MOA (see Figure 1). A control file, S8CFDESC (see Appendix F) was created which identified the eight intersections and established standard names to be used by all the selected TEAPAC programs. The intersections were numbered from 1 to 24 in accordance with the numbering scheme assigned to them by the MOA.

Intersection #14 was excluded from TEAPAC analyses. This intersection is a signalized pedestrian crossing along Northern Lights Boulevard between UAA Drive and Bragaw Street. Based upon MOA Traffic Engineering practices, pedestrian signals are not included in coordinated SubSystem signal plans. There are too many implications for including pedestrian signals in the timing plan, especially related to persons with disabilities. Therefore, intersection #14 will not be incorporate into the TEAPAC analyses.

Intersection Design Hour Volumes
The MOA provided BLA with winter time turn movement data for all twenty-three signalized intersections in various formats (VAXX, TLS,, & manual counts) and durations (full week, single day, and Tuesday-Thursday only). All data was assembled and entered as a TEAPAC database. After entry, the database was accessed with TURNS, a TEAPAC component program.

It would not be efficient to manually input every single day of the turn movement data provided by the MOA for analysis. Therefore, a manual evaluation of the count data was performed by inspecting the occupancy and volume graphs, available from VAXX (system detector) data. The highest intersection volume (assumed to be near the 30th highest volume) was used to identify which day of count to use. BLA concluded that Thursday data appropriate for analysis purposes.

A control file, S8CFTURN (see Appendix F), was created to stack all the individual turn movement count files (see Appendix F for individual naming conventions) into one file, S8TURNS, to be used by TEAPAC. A separate control file, S8CFTNPK, was used to tabulate, plot, and analyze these counts in detail. A common peak hour was identified for analysis purposes. Table 3 summarizes the peaks at each intersection and the derived system peak.

The control file, S8CFTNPK (see Appendix F), was modified to analyze the system peak period volumes in detail and to create the volume file used for the remainder of the analysis. These volume files were called S8VOLx, where "x" represents the peak period, 1-4, in accordance with the MOA standards where:

- "1" = Offpeak
- "2" = Midday Peak
- "3" = Morning (AM) Peak
- "4" = Evening (PM) Peak

For this SubSystem, timing plans are only being developed for the AM and PM peak periods; therefore, "x" will either be equal to 3 or 4 as indicated above.

Table 3
Peak Hour Summary
SubSystem #8: East Anchorage

INT	DESCRIPTION	AM PEAK	PM PEAK
1	15th & Lake Otis	7:45	17:00
2	Debarr & Airport Heights	7:45	16:45
3	Debarr & Bragaw	7:30	16:45
4	Debarr & Pine	7:30	17:00
5	Debarr & Boniface	7:30	17:00
6	Debarr & Beaver	7:15	17:00
7	Debarr & Turpin	7:15	17:00
8	20th & Lake Otis	7:30	16:30
9	20th & Bragaw	7:30	16:30
10	24th & Boniface	7:30	17:00
11	Northern Lights & Maplewood	7:15	16:30
12	Northern Lights & Lake Otis	7:45	16:30
13	Northern Lights & UAA	7:15	16:45
15	Northern Lights & Bragaw	7:30	17:15
16	Northern Lights & Wesleyan	7:15	17:00
17	Northern Lights & Boniface	7:30	17:15
18	Northern Lights & Baxter	7:15	17:15
19	Northern Lights & Patterson	7:15	17:15
20	36th & Lake Otis	7:45	16:45
21	Providence & University	7:30	16:30
22	Providence & Alumni	7:30	16:30
23	34th & Boniface	7:30	17:00
24	Debarr & Hoyt	7:30	17:00
APPROXIMATE SYSTEM PEAK		**7:30**	**17:00**

Entering volumes from one intersection were compared with exiting volumes from its upstream intersection to validate the design hour volumes. If discrepancies in volumes were identified, potential reasons for this occurrence were examined (e.g., unsignalized cross streets, places of employment, or retail centers). The data was classified corrupt and another turn movement count was requested for the intersection in question if the volume discrepancy could not be resolved. In the case of SubSystem #8, no volume discrepancies were found.

Intersection Geometrics and Signal Timing Parameters

Geometric and signal timing data were assembled and entered into TEAPAC's SIGNAL85 program, using the control file, S8CFS85 (see Appendix F). The result was the creation of a base file, S8BASE. All data necessary for SIGNAL85 was entered, including:

- lane widths,
- distances between intersections
- arrival types, priority movements
- type of control (actuated vs. pretimed)
- minimum phase durations (PED clearance)
- number of lanes
- existing phasing
- clearance requirements
- lost time
- permissive movements.

In addition, the control file changed the ideal saturation flow rates to 1900 vphpl. This change was discussed and approved by the MOA to be consistent with their studies and to correspond with the change which will be occurring in the 1994 Highway Capacity Manual Update.

The validity of the SIGNAL85 data was field checked during the first week of October 1994. All discrepancies between the data MOA provided and what is existing "on-street" were reported to MOA and subsequently corrected in the SIGNAL85 database. It was found that the intersection of Boniface Parkway and Northern Lights Boulevard had east and west right turn only lanes which had not been identified on the data sheets MOA provided.

A winter timing file, S8yyFACT, where yy = "AM" for the morning peak hour factors and yy = "PM" for the evening peak hour factors, was created using TED. This file was used to overwrite the base file (S8BASE) whose parameters reflected summer conditions. The winter timing file included such information as winter travel speeds between intersections and an adjustment factor (f_{si}) which would be applied to the saturation flow rate to simulate slick conditions. The contents of each file can be found in Appendix F.

The speed between each of the intersections was determined using the travel time studies conducted by the MOA. Unlike other SubSystem timing plans, MOA Traffic Engineering recommended that different speeds should be entered for both the AM peak and the PM peak. A 70/30 directional distribution along Debarr Road and Northern Lights Boulevard during the morning and evening peak periods prompted this recommendation. This distribution resulted in a 5 mph difference in speeds along a section of roadway between the peak periods in some cases.

The free flow speed was obtained from the travel time graphs and entered into a Microsoft Excel Spreadsheet for analysis (see Appendix F). The average speed over each of the time periods was then entered into the winter parameter adjustment file, S8yyFACT.

Control file, S8CFS85A (see Appendix F), was developed to perform an optimization of each signalized intersection. This included a full optimization of the phasing and cycle lengths in order to get the best level of service for each of the intersections critical movements. Results of this analysis is presented later in this report.

The next phase of the analysis requires system progression and cycle analyses using NOSTOP/TEAPAC and TRANSYT-7F. Since each of these programs requires split percentages, a preliminary cycle length needed to be assumed. It was determined that the optimum cycle length is most likely to lie within the range of 120-140 seconds; therefore, a cycle length of 130 seconds was assumed. Control file, S8CFTIME (see Appendix F), was written to optimize phase and timing for each intersection and write the results to a timing file S8TIMx. The "x" represents the time period analyzed (see page 14). The information saved in this file includes the intersection name, green time, yellow time, sequence, offset (always 0 - SIGNAL85 cannot optimize offsets), cycle length, and winter time saturation flow rates calculated by SIGNAL85. The main street split was noted for later use in a NOSTOP analysis for each time period.

System Progression/Cycle Analysis Using NOSTOP
Each of the arterials (Debarr Road, Northern Lights Boulevard, Lake Otis Parkway, Boniface Parkway, and Bragaw Street) were analyzed by NOSTOP for each time period using the splits noted from the SIGNAL85 analysis run. Progressive efficiency versus a varying cycle length was plotted and used for comparison to the cycle ranges SIGNAL85 determined could produce the best level of service. Results of this analysis is presented later in this report (see Summary of Signal Timing Analyses).

System Cycle Analysis Using TRANSYT-7F
TRANSYT-7F was used for further analysis of the optimum cycle length. Control file, S8CFPRTR (see Appendix F) was written to import all necessary information into PRETRANSYT. This includes the volumes from TURNS, geometrics and signal parameters from SIGNAL85, and signal sequences and splits created by SIGNAL85. The program was executed using the EXPORT command in PRETRANSYT and a cycle evaluation was run to be compared with SIGNAL85 and NOSTOP results. At the conclusion of this process, a system cycle length was chosen for each of the analysis periods.

Final Timings
Once a system cycle length was chosen, SIGNAL85 was rerun with the chosen cycle length to determine final sequences and splits. This was executed setting the S8CFS85A control file cycle length to the chosen cycle length and importing into SIGNAL85 for analysis. Again, the mainline splits were noted and input into NOSTOP to determine initial offsets for the chosen cycle length. The offsets chosen by NOSTOP were placed into the S8TIMx file using TED for subsequent use by PRETRANSYT in performing the final system offset optimization with TRANSYT-7F. Studies[6 & 7] have shown TRANSYT-7F will generate offsets that yield better arterial progression if the starting point for the programs optimization is a reasonable progression plan.

The Platoon Progression Diagram (PPD) option, available through TRANSYT-7F, was run to simulate theoretical vehicle progression through the system. Using these plots, trouble spots were identified for field review. Notations were made on the PPD diagrams and brought back to the MOA for adjustments.

Upon completion of each of the four timing plans, the timings were entered in to an Excel spreadsheet in the format requested by MOA. These timing sheets (along with 24" x 36" time-space diagrams fro each of the five primary arterials) were subsequently submitted, reviewed, and approved by MOA. The Coordination Data (CRD) and Time of Day (TOD) timings can be found in the "SubSystem #8 Timing Plans" section of this report.

TEAPAC Signal Timing Process
The TEAPAC signal timing process and use of control files has been described throughout this chapter. Figures 2 and 3 illustrate this process used to determine the winter signal timings for SubSystem #8

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6 <u>City-Wide Traffic Signal System Timing Project</u>, DeKalb, Illinois, January 1992.
7 <u>1995 HCM, PASSER, and TRANSYT in Harmony</u>, PCTRANS, Winter 1994

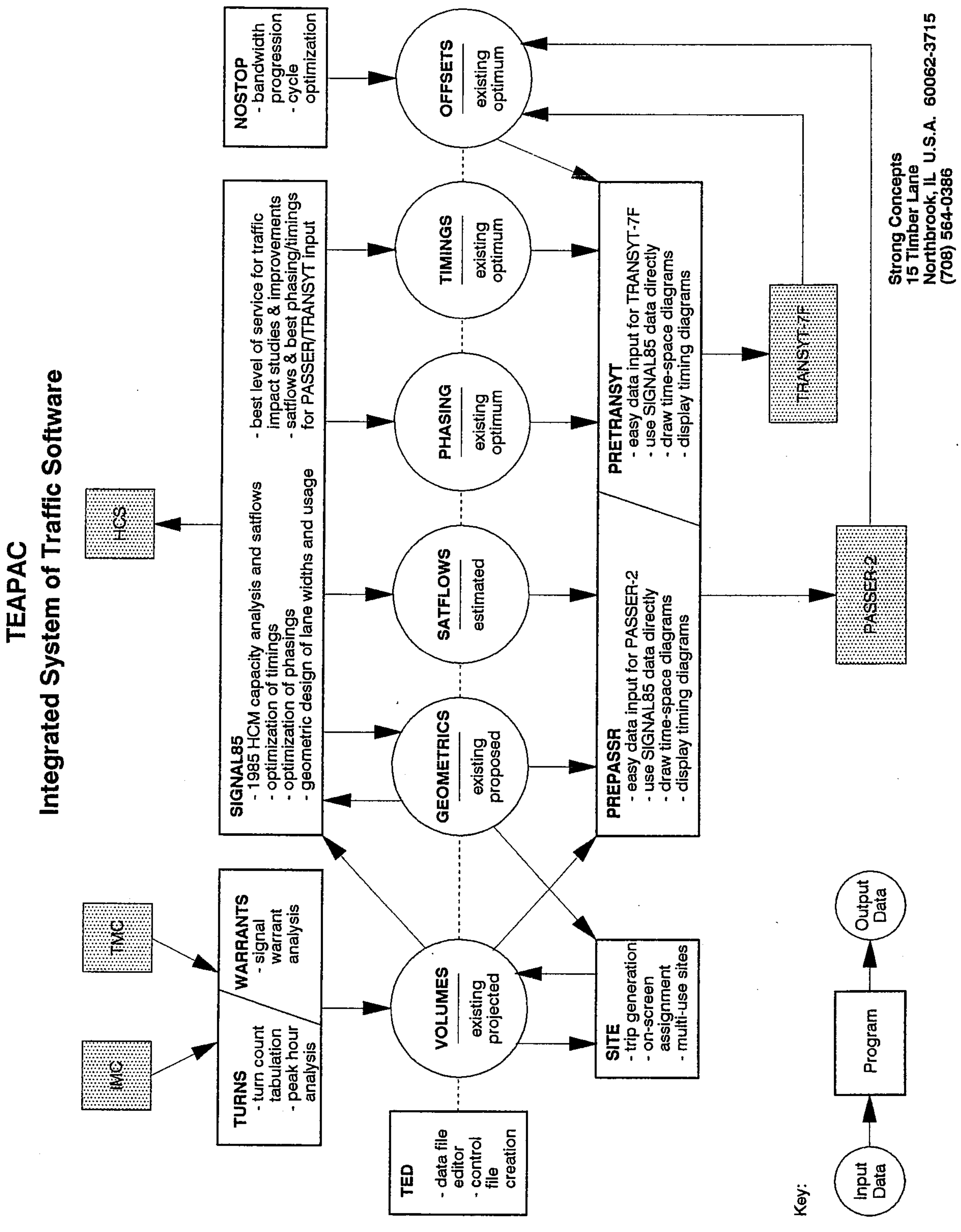

FIGURE 2
General TEAPAC Signal Timing Process

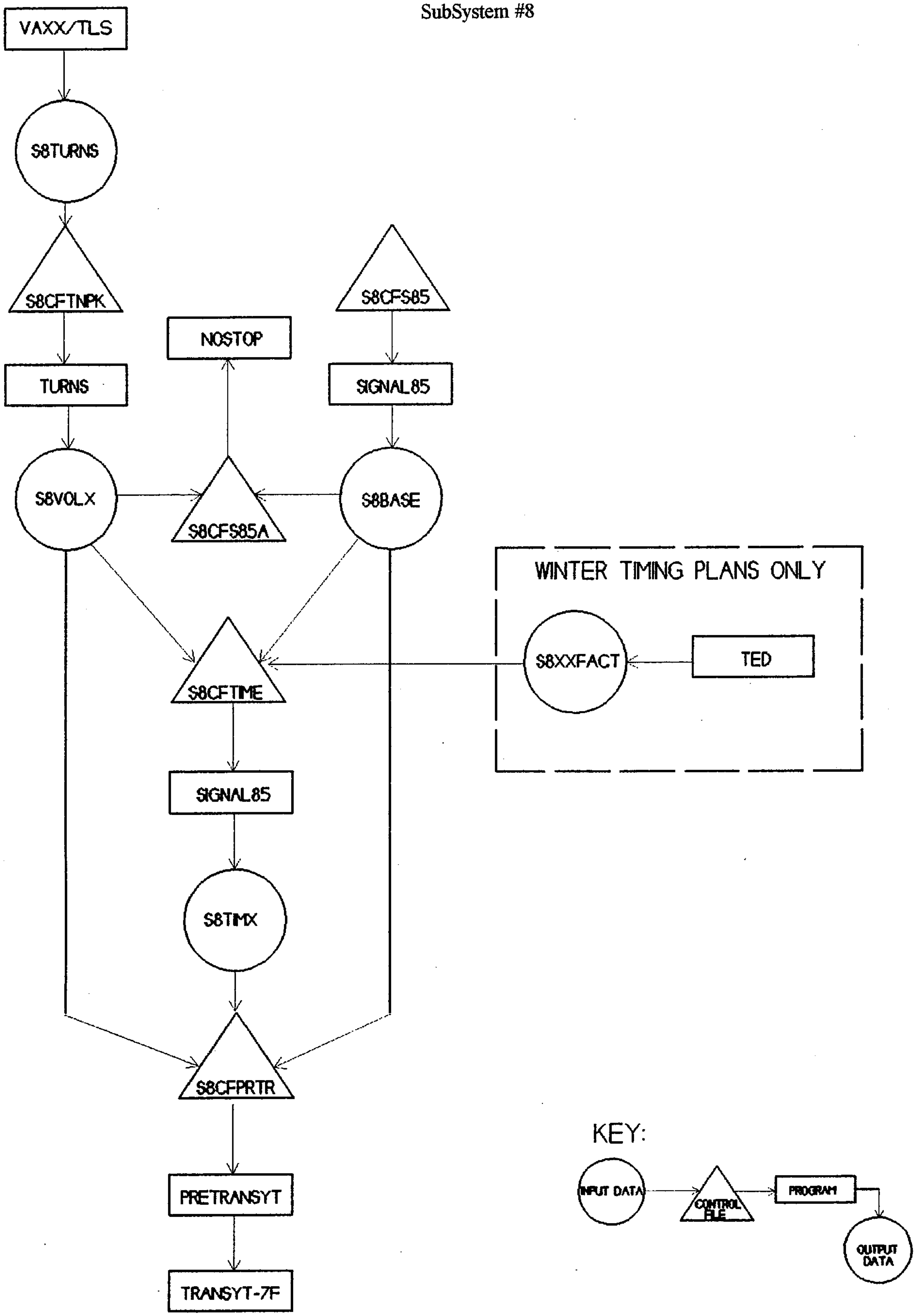

FIGURE 3
Specific TEAPAC Signal Timing Process Using Control Files