FIELD VALIDATION OF MOE's for SIGNALIZED INTERSECTION ANALYSIS

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INTRODUCTION

Purpose

The purpose of this report is to present an independent review of various software packages and methodologies utilized in the analysis of isolated signalized intersections. This review represents the work of the New England Section Institute of Transportation Engineers Technical Committee.

Background

Since the 1985 Highway Capacity Manual (HCM) was introduced, with a dramatically new methodology for analyzing signalized intersections, the field of traffic engineering has seen numerous changes. The original Highway Capacity Software (HCS) has been frequently upgraded to correct programming anomalies. The 1994 HCM represented a further revision, but with basically the same methodology. The latest (1997) HCM also maintained the basic approach, but changed the measures to determine level of service from average stopped delay to average total delay.

Numerous software packages have attempted to emulate the HCS since 1985, and with each of these numerous entries have come several nuances. Depending on the state or municipality, several of these packages can be accepted as an alternative to the HCS. Yet, the differences in results between these software packages can be significant.

The New England Section Institute of Transportation Engineers has recognized this situation, and has recognized two types of discrepancies which need to be investigated: (1) calculated results which differ from the methodology of Chapter 9, and (2) calculated results which differ from actual field measurements of queues and delays. The Technical Committee was charged with the task of investigating this matter. The Committee consists of dozens of participants who have donated thousands of hours to conduct this research, in a true public/private partnership. Committee members come from an array of traffic engineers, including private consultants as well as professionals from the Massachusetts Highway Department, and the Central Transportation Planning Staff.

Scope

This project was limited to the study of isolated signalized intersections, with the recognition that the results could lead to an expanded scope in the future. In this paper, the methodology and results of the HCM were compared to the following analysis tools.

HCS 2.4
HCS 2.4g and 3.1a (Phase II only)
SIDRA
SIGCINEMA
SIGNAL94
Synchro
CINCH94
CINCH88
CIRCULAR 212

In addition to software packages emulating the HCM methodology, some members of The Committee felt that the Critical Sum Method, contained in the 1980 Transportation Research Board Circular 212 and as a planning approach in the 1985/1994 HCM's, was relevant and should be added to the comparison.

The research was separated into two phases with similar approaches, yet different purposes. In Phase I the task was to compare the analysis tools to the HCM solutions to the three example problems in Chapter 9 of the HCM. The question answered by this comparison is, "Do the various packages emulate the HCM methodology?"

The task in Phase II was to compare the same packages and HCM to actual field conditions. This Phase II comparison answers a different question, which is, "Does the basic methodology contained in Chapter 9 of the Highway Capacity Manual accurately describe what's happening in the real world?"

A final note is that this project began before the 1997 HCM update, which modified the basis of level of service from average stopped delay to average total delay. Since the project had begun and the tested software packages had not been updated, the Committee decided to go ahead with average stopped delay comparisons.

PHASE I - COMPARISON OF COMPETING PACKAGES TO THE HCM METHODOLOGY

In this phase of the study, analysis of the three sample problems in Chapter 9 of the 1994 HCM was conducted using the study software packages and methodologies. The results of each are then compared to the results included in Chapter 9. Critical Sum analysis was conducted manually using the Operations Method described in Circular 212. Each analysis was conducted independently by two different traffic engineers and then compared for consistency. A final review of every analysis was then conducted.

The discussions in this section are based on a comparison of average stopped delay and volume-to-capacity ratio (v/c). It should be noted that all packages except SIDRA report weighted average v/c for the intersection. SIDRA reports the highest single v/c for any lane group. For purposes of the comparisons contained in this report, a manual calculation was conducted to convert SIDRA results to a weighted average for the intersection. Following is a description of the Chapter 9 sample problems, and a brief summary of results. A detailed comparison of results is shown in Figures 1-6.

Sample Problem 1

This location is a four-way intersection in a CBD. A two-lane street with 15-foot lanes crosses a four-lane arterial with 11-foot lanes. All left turns are permissive. Signal operations are simple pre-timed, with a 70 second cycle. While traffic volumes are fairly low, the heavy vehicle percentages are high at 5 and 8 percent. No parking is allowed at the intersection.

Delay results from Sample Problem 1 are scattered. The manual calculation in Chapter 9 results in an unreportable delay. CINCH88 and SIDRA show a delay of approximately 22 seconds, Synchro and SIGNAL94 are in the 37-41 second range, and the remaining three packages are above the reportable range.

Volume to capacity values generally correlate well to the Sample Problems. In Sample Problem 1, the Chapter 9 result is 1.01, with five other packages also at 1.01. CINCH88 is at 0.90, SIDRA is at 0.77, and Circular 212 at 0.71.

Sample Problem 2

This intersection includes a one-way local street crossing a four-lane arterial. All lanes are 12 feet wide. Basic operation is two phase, with an eastbound lead phase. There is a permissive left turn movement. The signal operation is a pre-timed, 70-second cycle. Traffic volumes are moderate, with high truck percentages of 5 and 10 percent. Parking is allowed on the one-way, local street.

A tight grouping of calculated delays is evident in Sample Problem 2. The Chapter 9 result is 14.5 seconds, with most of the other packages in the 14-15 second range except for SIDRA at 20.6 seconds.

Volume to capacity results for Sample Problem 2 are tightly grouped. The v/c calculated in Chapter 9 is 0.73 with most packages falling in a range of 0.67 to 0.73.

Sample Problem 3

This intersection is in the CBD, and consists of two major four-lane arterials, with exclusive left turn slots. East-west lanes are 10 feet wide with parking, while north-south lanes are 12 feet wide with no parking. The average cycle length is 90 seconds, with full actuation and lead phases in the north-south approaches. Traffic volumes are heavy with moderate heavy vehicles. Parking is allowed on the eastbound and westbound approaches.

Sample Problem 3 also shows a tight grouping of calculated delays. The Chapter 9 result is 23 seconds, with most packages in the 23-24 second range, and SIDRA just out of the grouping at 20.5 seconds.

Problem 3 also shows a tight grouping of volume to capacity results. The Chapter 9 v/c is 1.01, with most packages in the 0.98 to 1.01 range, and CINCH88 at 0.91, SIDRA at 0.70, and CINCH94 at 1.06.

Phase I Summary Results

The packages examined do a reasonable job emulating the methodology contained in the 1994 HCM, at least in comparison to three sample problems. Generally, the v/c results show a tighter grouping than the calculations of average stopped delay.

HCM Sample Problem 1

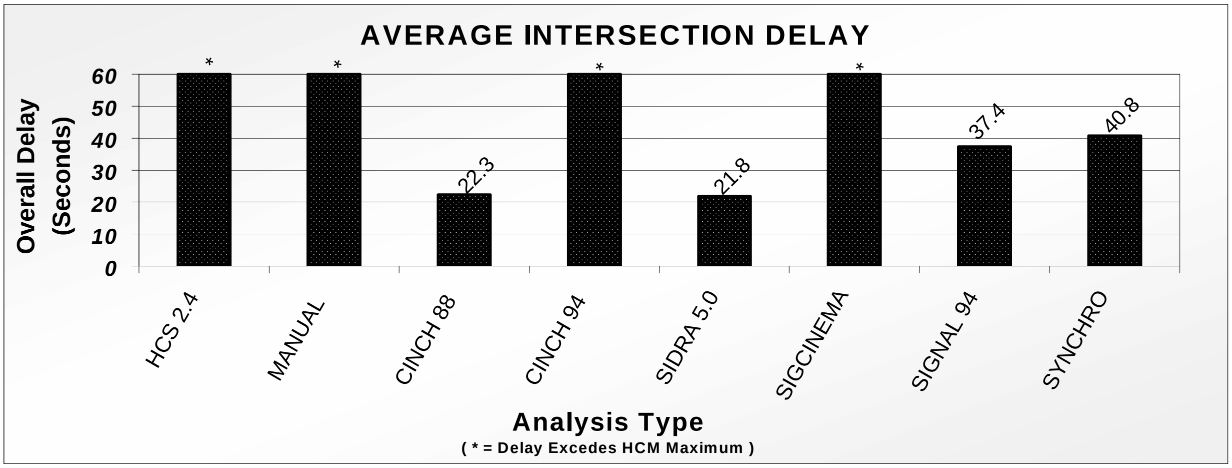

Figure 1 - Average Stopped Delay

The Manual (HCM) result calculated is unreportable as it exceeds the HCM maximum. A wide variation is evident, with CINCH88 and SIDRA resulting in delays of approximately 22 seconds, Signal94 resulting in 37 seconds, Synchro resulting in 41 seconds, and all others showing unreportable results.

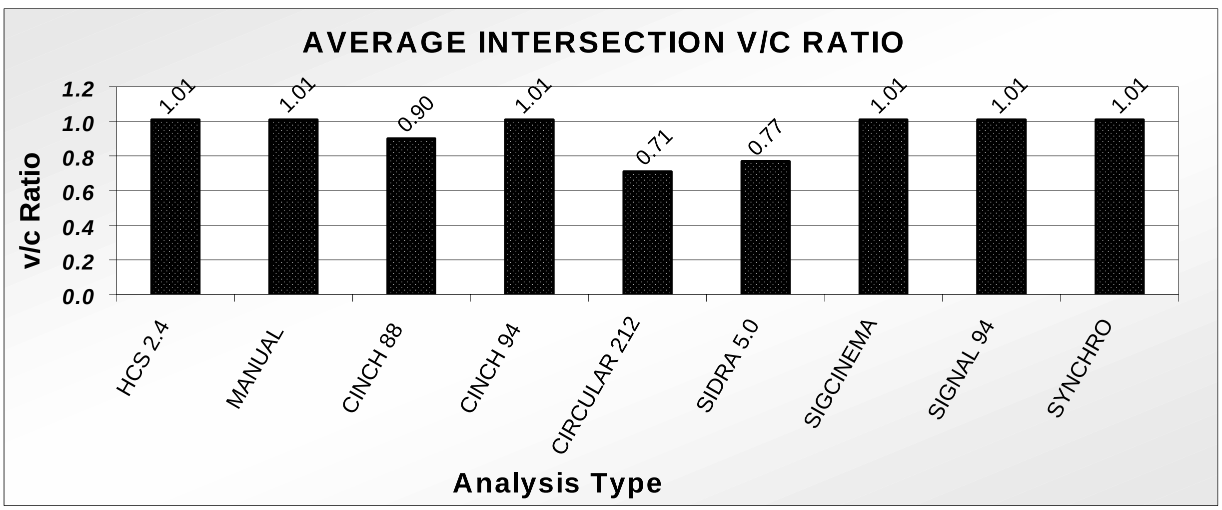

Figure 2 - Volume-to-Capacity Ratio

The Highway Capacity Manual Volume-to-Capacity (v/c) ratio is 1.01. The v/c's range from 0.70 and 0.90 for Circular 212, SIDRA 5.0 and CINCH. All others are grouped at a ratio of 1.01.

HCM Sample Problem 2

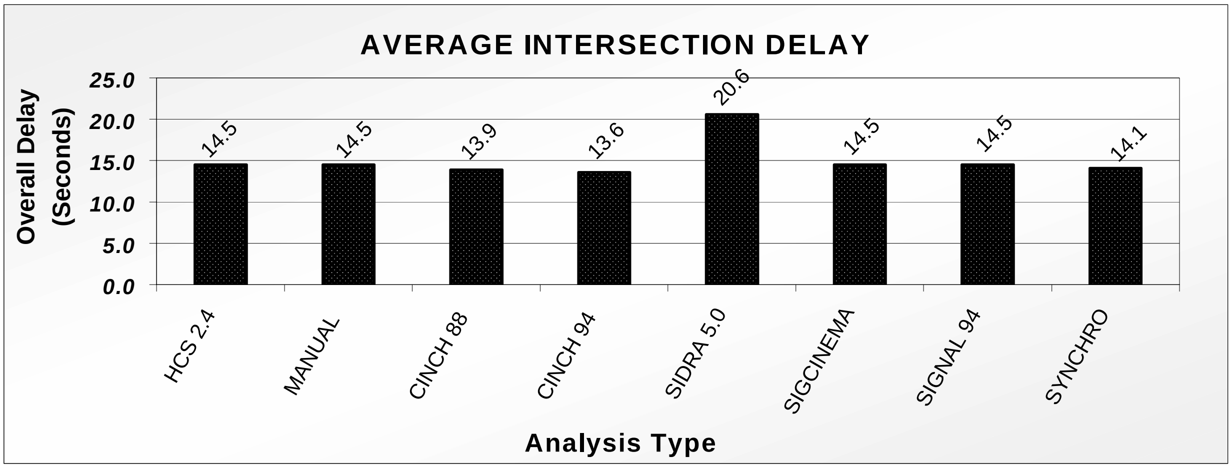

Figure 3 - Average Stopped Delay

The result for the manual calculation is 14.5 seconds of average delay. A tight grouping is evident, with all values between 13.6 and 15 seconds, except SIDRA, which results in delay of 21 seconds.

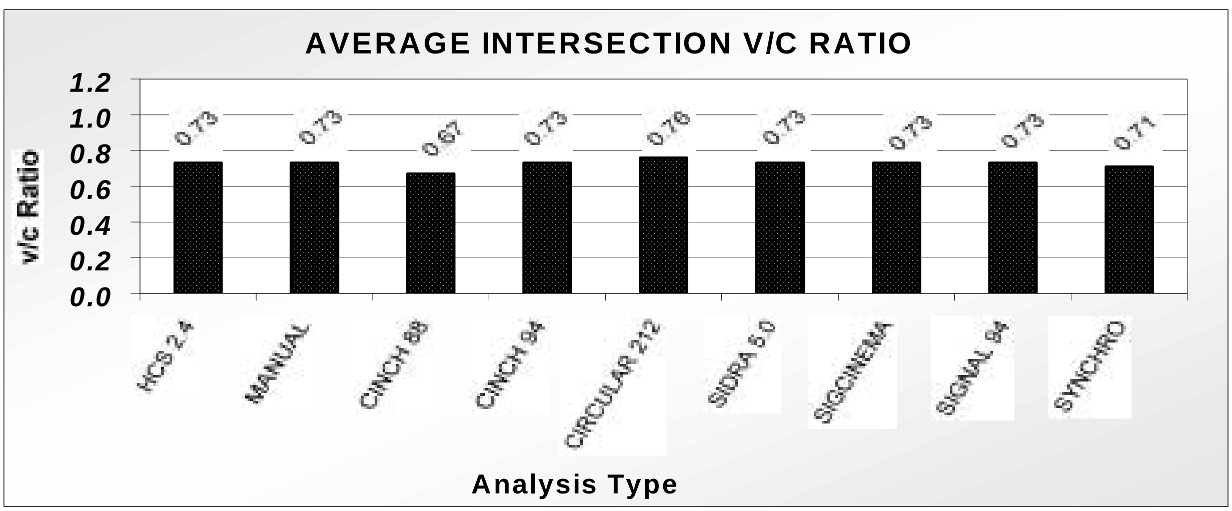

Figure 4 - Volume-to-Capacity Ratio

The manual result is a v/c ratio of 0.73. The remainder of the values fall in the 0.67 to 0.73 range. Results for this sample problem were fairly uniform.

HCM Sample Problem 3

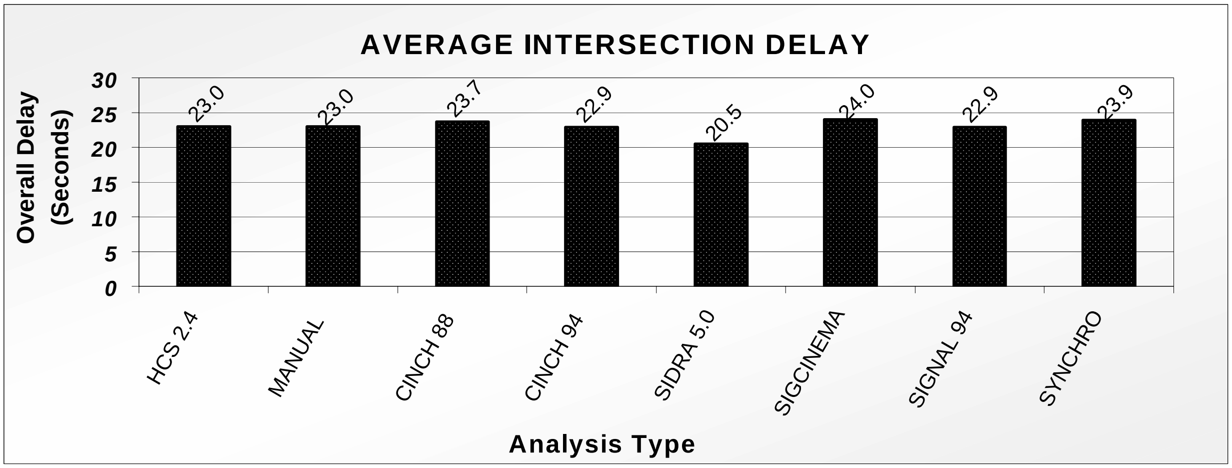

Figure 5 - Average Stopped Delay

The manual calculations result in an average intersection delay of 23 seconds. Most values fall within the 23 to 24 seconds, with SIDRA just outside that range at approximately 21 seconds.

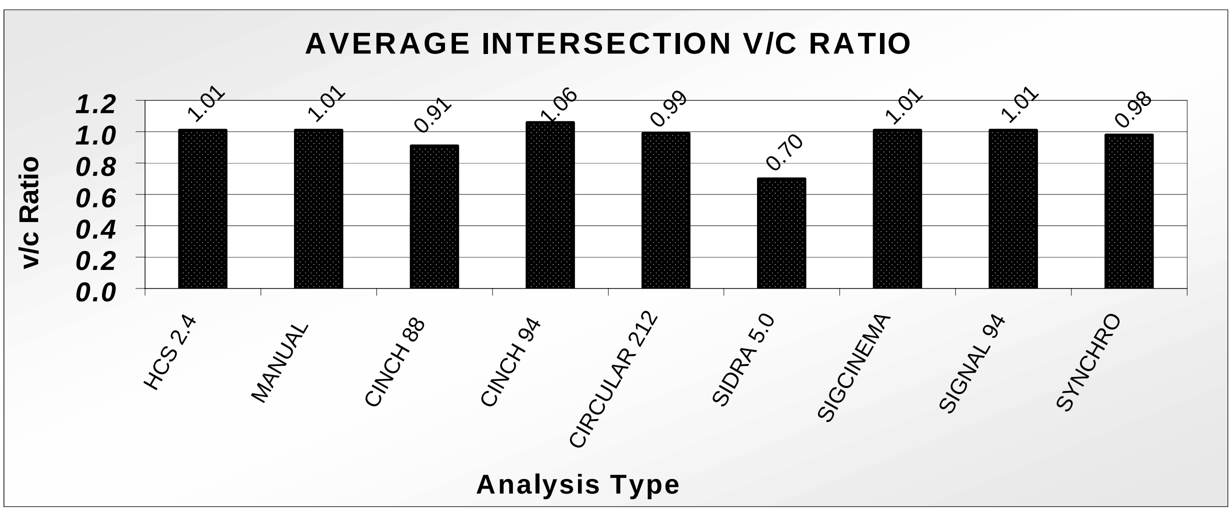

Figure 6 - Volume-to-Capacity Ratio

The v/c ratio for the manual calculations is 1.01. Values fall in the range of 0.91 to 1.01, except for SIDRA which is at 0.70.

PHASE II - COMPARISON OF HCM METHODOLOGY TO FIELD CONDITIONS

In this phase of the research, analysis results of study software packages and methodologies are compared to measures of effectiveness (MOE's) collected in the field. Data were collected at seven isolated signalized intersections. An isolated intersection is defined as one not affected by operation of an adjacent location. In addition, an attempt was made to select locations of varying characteristics (e.g., pre-timed vs. actuated, saturated vs. non-saturated, exclusive left turn lanes vs. shared lanes, protected vs. permitted turns). The data collected at two of the locations were later rejected due to unforeseen conditions, such as severe weather and a special event that created unusual blockages. The remaining five intersections were used as the basis of comparisons for this study, and are described in Figures 7-11.

A discussion of research methodologies and results follows.

Methodology

The methodology and assumptions for data collection and analysis, and limitations to field data are described in this section.

1. Data collection included input values and MOE's. Recommended procedures found in ITE and TRB publications were followed where possible. A list of data collected at each intersection is listed below.

   Turning movement counts were conducted by lane for a full hour, recording interim values every fifteen minutes. Pedestrian volumes were also noted where applicable.

   Heavy vehicles were counted for a full hour, recording values every fifteen minutes.

   At pre-timed locations, signal timing and phasing were collected. At actuated locations, each phase was sampled during the hour.

   Geometric features and lane use were collected.

   Saturation flow data were collected on each lane for a minimum of fifteen minutes per lane during the hour.

   Average vehicle delay was measured for a minimum of fifteen minutes per lane during the hour.

   Queues were inventoried for a minimum of fifteen minutes per lane during the hour.

2. Analysis was conducted using the tools provided by each software package included in the comparisons. Two analysis cases were conducted for each intersection; one using the default saturation flow rate of 1900 pcphgpl, and one using the field measured saturation flow rate. Critical Sum analysis was conducted manually using the Operations Method described in Circular 212. Each analysis was conducted independently by two different traffic engineers and then compared for consistency. A final review of every analysis was then conducted.

3. Limitations of this study must be acknowledged. One is that some of the data were collected for only 15 minutes and assumed to represent conditions over the hour counted. In most cases, however, the collection of saturation flow rate, average delay and queue information were coordinated for each lane.

The other limitation was that saturation flow data could not be collected on each lane, simply because not all lanes were saturated. Rather than just using the default value of 1900 for ideal conditions, the values measured for similar lanes were assigned. For example, on adjacent through lanes, a measured value for one lane would be assigned to the other if only one was saturated.

Intersection A - Middlesex Turnpike and Burlington Mall Road in Burlington, MA.

Middlesex Turnpike at Mall Road and Second Avenue in Burlington, Massachusetts is a four-way signalized intersection. Middlesex Turnpike runs primarily north to south, while Mall Road comprises the easterly leg of the intersection and Second Avenue comprises the westerly leg. The Middlesex Turnpike northbound approach consists of one 12 foot wide exclusive left-turn lane, two 12 foot wide through lanes, and one 12 foot wide exclusive right-turn lane. The Middlesex Turnpike southbound approach consists of one 12 foot exclusive left-turn lane, one through lane, and one shared through/right-turn lane. The Second Avenue eastbound approach consists of one 11 foot wide shared left-turn/through lane, and one 12 foot wide uncontrolled, or "free", right-turn lane. The Mall Road westbound approach consists of one 11 foot wide exclusive left-turn lane, one 12 foot wide shared through/right-turn lane, and one 12 foot wide exclusive right-turn lane. There are no pedestrian provisions at this intersection and no pedestrians were present during field data collection.

The intersection currently operates with an actuated four-phase cycle with an average length of 88 seconds. The Middlesex Turnpike left-turns operate protected while the Mall Road and Second Avenue approaches run via split phasing.

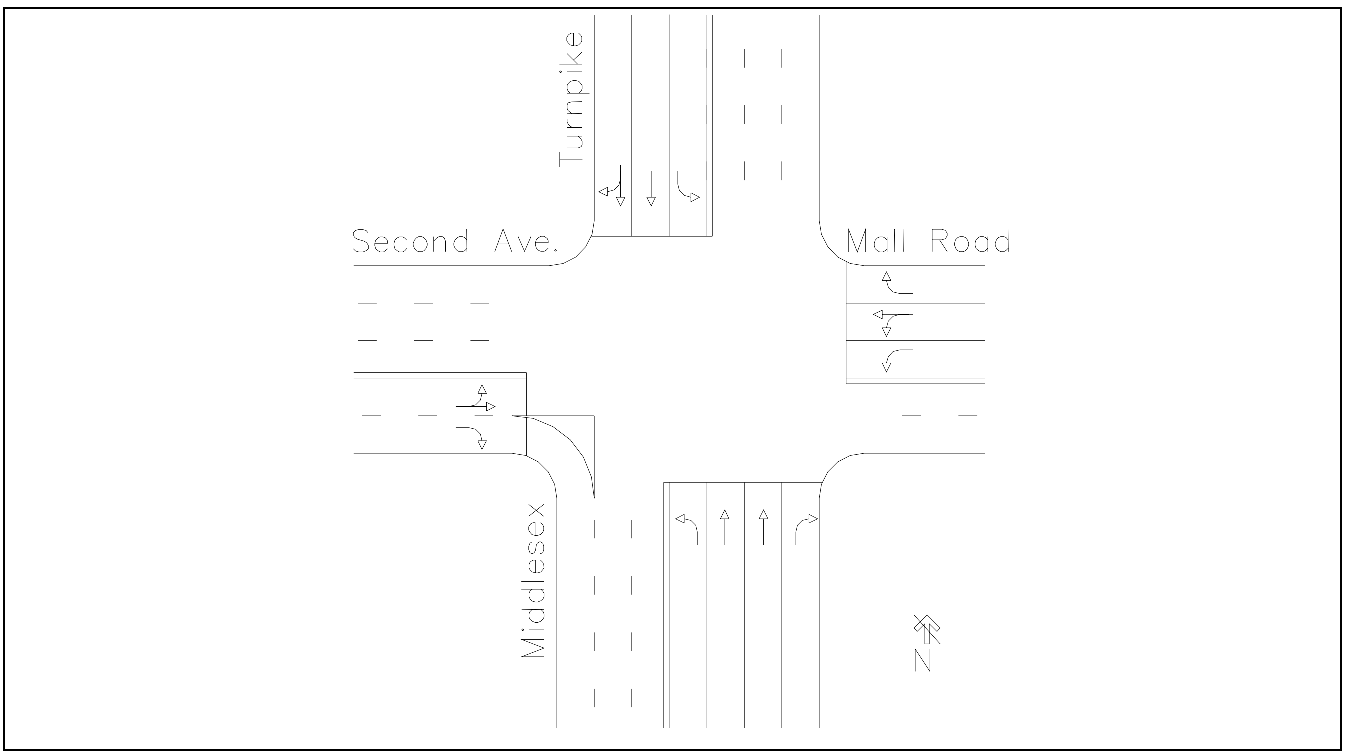

Figure 7 - Intersection A - Middlesex Turnpike and Burlington Mall Road

Intersection B - Route 60 and Ferry Street in Malden, MA

Route 60 at Ferry Street in Malden, Massachusetts is a four-way signalized intersection. Route 60 runs primarily east to west, while Ferry Street runs north to south. The Route 60 eastbound approach consists of one 10 foot wide exclusive left-turn lane, one 12 foot wide through lane, and one 12 foot wide shared through/right-turn lane. The Route 60 westbound approach also consists of one 10 foot wide exclusive left-turn lane, one 12 foot wide through lane, and one 12 foot wide shared through/right-turn lane. The Ferry Street northbound approach consists of one 11 foot wide shared left-turn/through lane and one 10 foot wide shared through/right-turn lane. The Ferry Street southbound approach consists of one 10.5 foot wide shared left-turn/through lane and one 10 foot wide right-turn lane.

The intersection currently operates as a pre-timed three-phase cycle length of 65 seconds. The Route 60 eastbound and westbound left-turns operate permissive only, while the Ferry Street northbound approach operates as a lead.

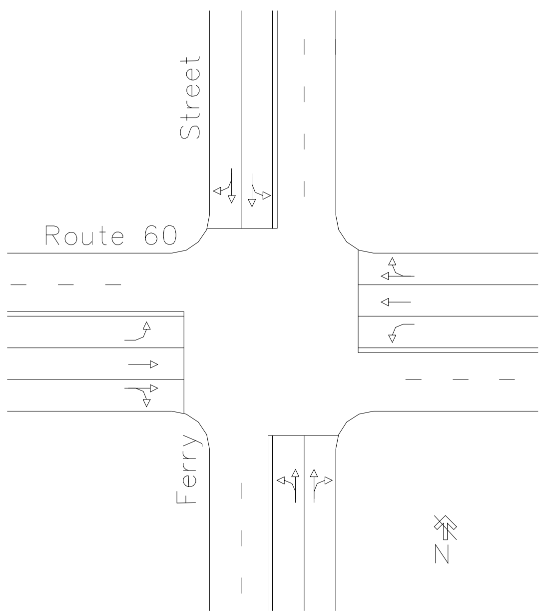

Figure 8 - Intersection B - Route 60 and Ferry Street

Intersection C - Route 99 and Route 60 in Malden, MA

Route 99 at Eastern Avenue in Malden, Massachusetts is a four-way signalized intersection. Route 99 runs primarily north to south, while Eastern Avenue runs primarily east to west. The Route 99 northbound approach consists of one 12 foot wide shared left-turn/through lane and one 12 foot wide shared through/right-turn lane. The Route 99 southbound approach consists of one 11.5 foot wide shared left-turn/through lane and one 12 foot wide shared through/right-turn lane. The Eastern Avenue eastbound approach consists of one 11.5 foot wide exclusive left-turn lane and one 11.5 foot wide shared through/right-turn lane. The Eastern Avenue westbound approach consists one 12.5 foot wide general purpose lane.

The intersection currently operates with a three-phase cycle length of 77.5 seconds. The Eastern Avenue eastbound approach operates as a lead. The Route 99 left-turns operate permissive only.

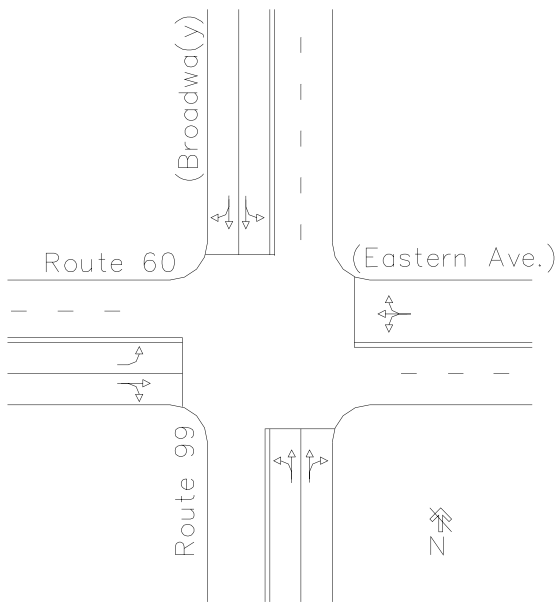

Figure 9 - Intersection C - Route 99 and Route 60

Intersection D - Route 1A and Revere Street in Revere, MA

Route 1A at Revere Street in Revere, Massachusetts is a four-way signalized intersection. Route 1A runs primarily north to south, while Revere Street runs primarily east to west. The Route 1A northbound approach consists of one 11 foot wide exclusive left-turn lane, one 12 foot wide through lane, and one 12 foot wide shared through/right-turn lane. The Route 1A southbound approach consists of one 11 foot exclusive left-turn lane, one through lane, and one shared through/right-turn lane. The Revere Street eastbound approach consists of one 10 foot wide exclusive left-turn lane and one 12 foot shared through/right-turn lane. The Revere Street westbound approach consists of one 10 foot wide exclusive left-turn lane and one 11 foot shared through/right-turn lane. There are pedestrian push buttons at this intersection, but no pedestrians were present during field data collection.

The intersection currently operates as a fully actuated six-phase cycle with an average length of 135 seconds. The Route 1A left turns operate protected only then the Route 1A northbound approach operates as a lead. The Revere Street left turns also operate protected only and then the Revere Street eastbound approach operates as a lead.

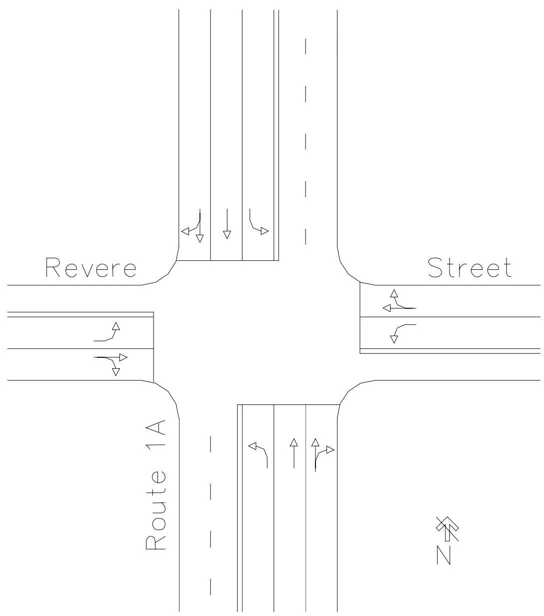

Figure 10 - Intersection D - Route 1A and Revere Street

Intersection E - Route 20 and School Street in Weston, MA

Route 20 at School Street in Weston, Massachusetts is a four-way signalized intersection. Route 20 runs primarily east to west while School Street runs primarily north to south. The Route 20 eastbound approach consists of one 12 foot wide shared left-turn/through lane and one 12 foot wide exclusive right-turn lane. The Route 20 westbound approach consists of one 12 foot wide shared left-turn/through lane and one 13 foot wide shared through/right-turn lane. The School Street northbound approach consists of one 13 foot wide general purpose lane. The School Street southbound approach consists of one 13.5 foot wide general purpose lane.

The intersection currently operates with a three-phase cycle length of 128 seconds. The Route 20 left-turns operate as permissive only, while the School Street approaches operate via split phasing.

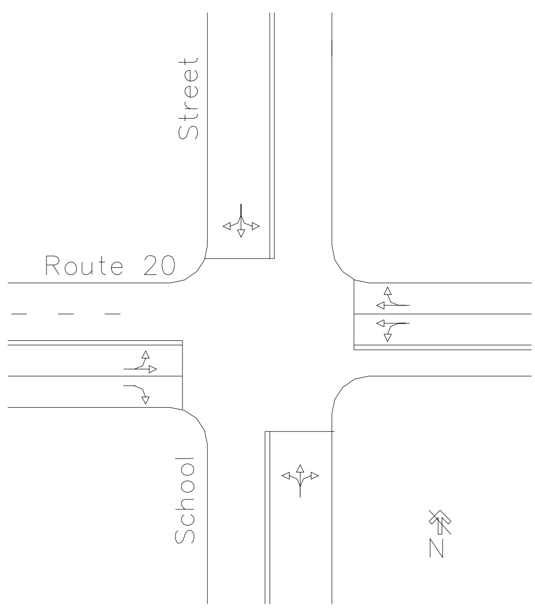

Figure 11 - Intersection E - Route 20 and School Street

Results

Analyses results are summarized for average stopped delay, volume to capacity ratio (v/c), and queues, each set being analyzed once using default ideal saturation flow rates and once using field measured saturation flow rates. Comparisons of average stopped delay, volume-to-capacity ratio and queues are summarized in detail in Figures 12-26. A brief summary of trends follows.

1. Average Stopped Delay

With the exception of one intersection, calculated values generally do not compare well to field measured values. Only at intersection D, where the field measured average stopped delay was 93.1 seconds, do three of the packages match within - 3 to +8 percent. The remaining packages, however, indicate that values are too high to report.

At the other four intersections, the closest match is at +23 percent, and many values are so different that a comparison is not meaningful.

2. Volume-to-Capacity Ratio/Level of Service

A subjective comparison is made in this section. At each location, experienced traffic engineers taking part in the data collection estimated level of service based on observations of traffic operations. The estimates, made before revelation of calculation results, are compared to calculated level of service (LOS). In addition, Critical Sum calculations from TRB Circular 212 are included for comparison of level of service and v/c.

More consistency is evident in the comparison of v/c's than was evident in the comparison of average stopped delay. Three locations show a tight grouping of v/c results, with Intersections B and C showing greater variation.

The LOS comparison shows the most consistency, with the calculated values always corresponding to the observations.

3. Queues

For the five intersections analyzed, the best program for queue measurement was clearly Synchro, which gave the most accurate results for four out of five locations. The other four models – SIDRA, SIGNAL94, CINCH88 and CINCH94 were all closely grouped in terms of relative accuracy, with little significant difference in overall performance on queues.

Some caution should be used in evaluating the queue results, because some models assess queues differently. CINCH88 calculates a Webster queue, occurring at the beginning of green. The other models are based on a "back of queue" analysis which measures the extension of the queue during the green phase.

Phase II Summary Results

Table 1 (default and field measured saturation flow calculations, respectively) provides a summary of the average stopped delay results for the combined data for all of the intersections. In Table 1, an examination of the computerized packages reveals that the average error for all locations (using default saturation flow rate) ranges from 71 percent (CINCH88) to 117 percent (CINCH94). There appear to be three groupings of average error. CINCH88, Synchro and SIGCINEMA are in the 71 to 81 percent range. SIDRA, HCS and SIGNAL94 range from 88 to 99 percent. The last group would include manual calculations and CINCH94 at 114 and 117 percent, respectively.

Table 1 Phase II Summary Results - Delays

	Average Error From Measured Delay	
Analysis Method	1990 Default Saturation	Measured/Adjusted Saturation
HCS	90%	53%
SIDRA 5.0	88%	64%
SIGCINEMA	99%	52%
SIGNAL94	81%	43%
SYNCHRO	75%	58%
CINCH94	117%	52%
CINCH88	71%	40%
MANUAL (HCM)	114%	67%

Table 1, again considering computerized packages, shows that with field measured saturation flow rates, the average error for all locations ranging from 40 percent (CINCH88) to 64 percent (SIDRA). There are also groupings in this case. The first group includes CINCH88, Synchro and SIGCINEMA ranging between 40 and 43 percent. SIGNAL94, CINCH94 and HCS range from 53 to 54 percent average error. SIDRA and the manual results are at 64 and 67 percent, respectively.

It should be noted that in each case the percentages are artificially low because intersection analyses that result in unreportable results have been omitted from the overall average calculations. If a reasonable estimate of these values had been included, the average errors would have been greater.

Calculations of average stopped delay do not seem to replicate actual field measured conditions with any degree of consistency. Only at Intersection D did three of the packages (SIDRA, SIGNAL94 and CINCH88) closely match a field measured delay of approximately 93.1 seconds. None of the other packages, however, could report results. The next closest matches at the remaining intersections ranged from 24% to over 100%. Calculations based on field measured saturation flow rates generally produced slightly closer comparisons to the field measured delay.

Volume-to-capacity results were more consistent when comparing the study software packages to each other, although little differences is evident between calculations using default vs. field measured saturation flow rates. The comparison of calculated level of service to engineers' estimates based on observations was consistently close.

Comparison of calculated queues to field measured values were uneven. Synchro was the better performer at four of the five locations. CINCH88 produced a good match at Intersection A and B, while SIGNAL94 was close at Intersection C. None of the packages compared closely to the measured value at Intersection D.

Intersection A – Middlesex Turnpike at Burlington Mall Road

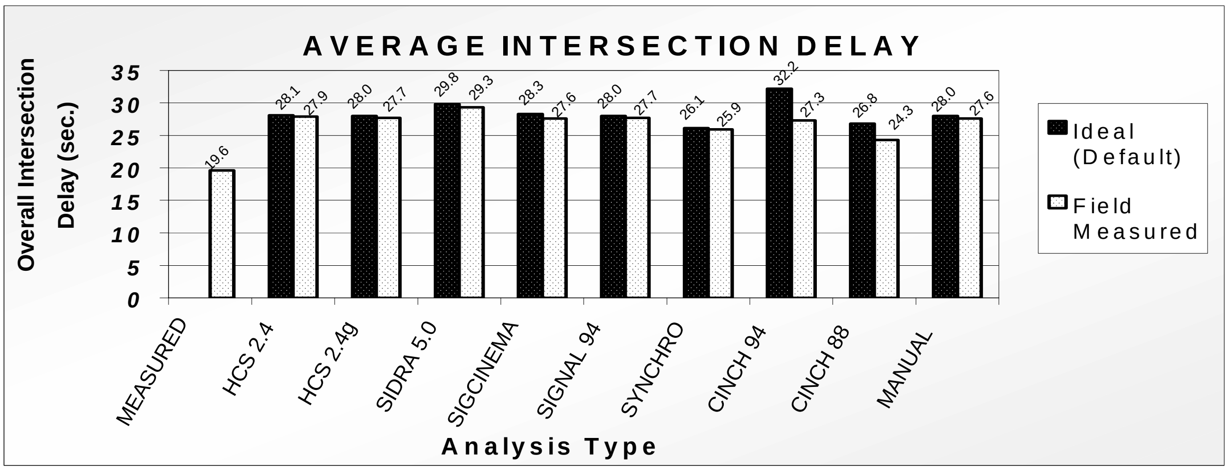

Figure 12 - Average Stopped Delay

The field measured overall average delay for the intersection was 19.6 seconds. The range of values for default ideal saturation flow calculations is 26.1 to 32.2 seconds, with the closest being Synchro (26.1, +33%) and CINCH88 (26.8, +37%). The values furthest from the measured delay are CINCH94 (32.2, +64%) and SIDRA (29.8, +52%).

An examination of measured saturation flow calculations shows a range of 24.3 to 29.3 seconds. The closest results are from CINCH88 (24.3, +24%) and Synchro (25.9, +32%). The furthest results come from SIDRA (29.3, +49%) and HCS (27.9, +42%).

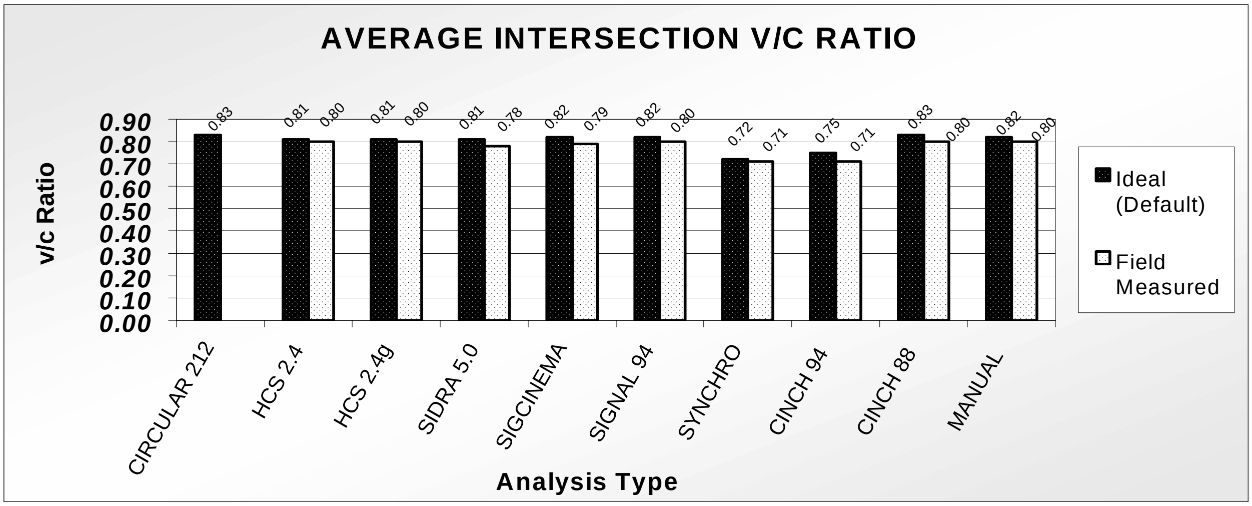

Figure 13 - Volume-to-Capacity Ratio

The engineers' estimate of LOS was C/D, which would imply a v/c of 0.78 to 0.83. Calculations using default saturation flow rates fall mostly within a tightly packed range between 0.81 and 0.83 is evidenced by most of the packages. Only Synchro (0.72) and CINCH94 (0.75) fall out of this range. Resulting level of service is in the C/D to D range for all packages, which matched the engineers' observed estimate of LOS C/D.

Calculations using measured saturation flow rates are equally clustered between 0.80 and 0.82, except for Synchro (0.71) and CINCH94 (0.71). All calculations indicate LOS C/D to D.

Circular 212 calculations, independent of saturation flow rate, result in a v/c of 0.83, and also within the observed range and a LOS C/D.

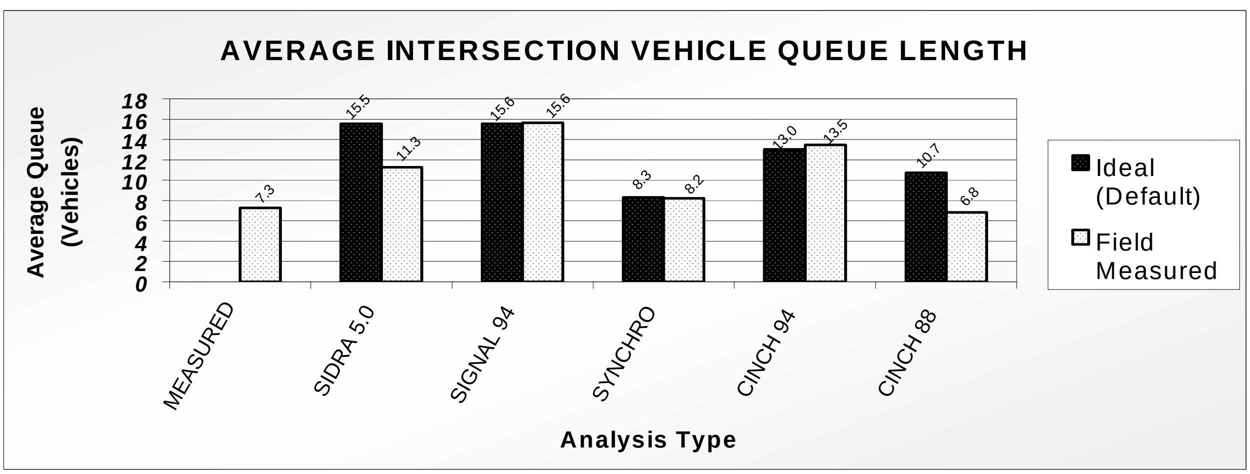

Figure 14 - Average Vehicle Queue Lengths

The average measured field queue for the intersection is 7.3 vehicles. Synchro and CINCH88 are the closest to the actual field measured value. The average intersection queue lengths for CINCH94, SIDRA 5.0 and Signal 94 are about double the measured values.

Intersection B – Route 60 at Ferry Street

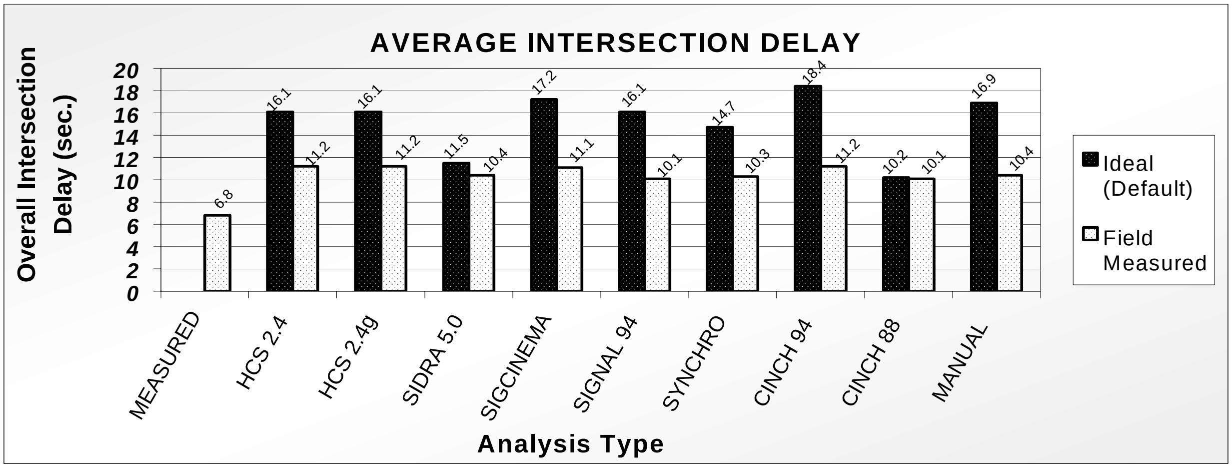

Figure 15 - Average Stopped Delay

The field measured overall average intersection delay was 6.8 seconds. The range of values for default saturation flow calculations is 10.2 to 18.4 seconds. The closest calculated values come from CINCH88 (10.2, +50%) and SIDRA (11.5, +68%). The furthest values come from HCS (16.1, +137%), SIGCINEMA (17.2, +153%), and CINCH94 (18.4, 171%).

Calculations conducted using field measured saturation flow rates shows values from 10.0 (+47%) to 11.2 (+65%) seconds, a range that is not significant enough to break down and analyze.

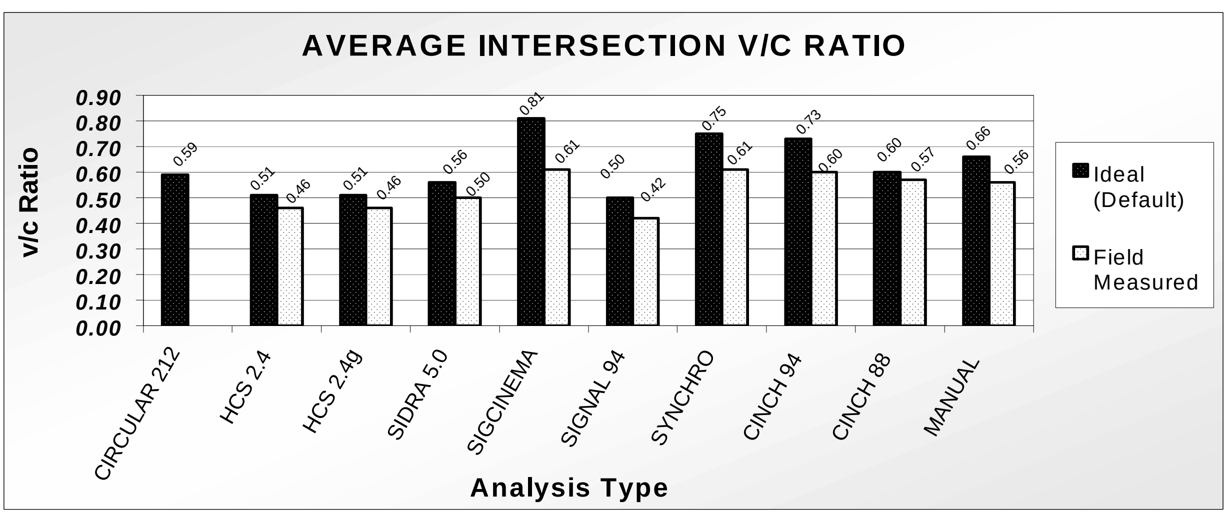

Figure 16 - Volume-to-Capacity Ratio

Level of service was estimated at B/C by engineers' observations. The range of values calculated using default saturation flow rates varies widely between 0.51 - 0.81. All level of service calculations are in the B/C range.

Calculations using measured saturation flow rates also vary widely from 0.42 to 0.61. Level of service is B for all packages.

Circular 212 calculations result in a v/c of 0.59, and a LOS B/C.

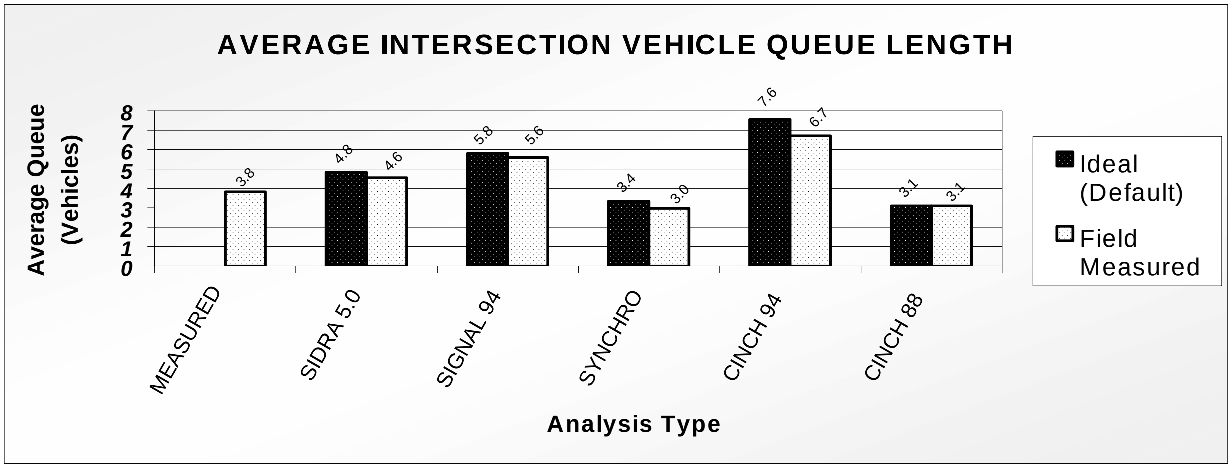

Figure 17 - Average Vehicle Queue Lengths

For the five packages which calculated queue lengths, Synchro, CINCH88, and SIDRA were within 1 vehicle of measured values, while SIGNAL94 and CINCH94 were 2 to 4 vehicles longer than measured queues.

Intersection C – Broadway (Route 99) at Eastern Avenue (Route 60)

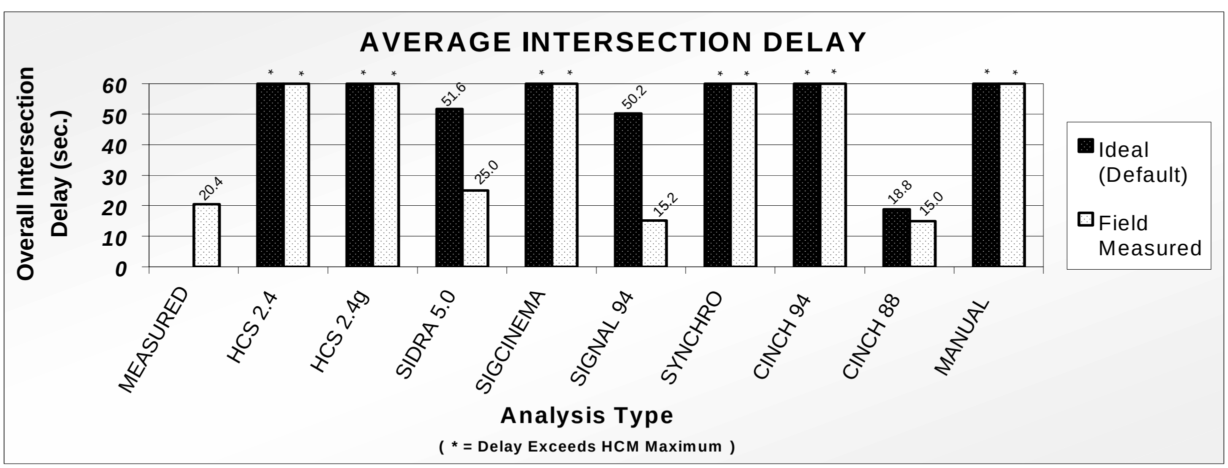

Figure 18 - Average Stopped Delay

The field measured overall average intersection delay was 20.4 seconds. The range of values calculated using default saturation flow calculations is 18.8 to 51.6 seconds. The closest of these values was 18.8 seconds (-8%), using CINCH88. The furthest calculated values came from SIDRA (51.6, +153%) and SIGNAL94 (50.2, +146%).

Using measured saturation flow values, the range of calculated delays was 14.8 seconds to unreported values. The software packages that had the closest results were SIDRA (25.0, +23%) and CINCH88 (15.0, -24%). Five packages reported values too high to report.

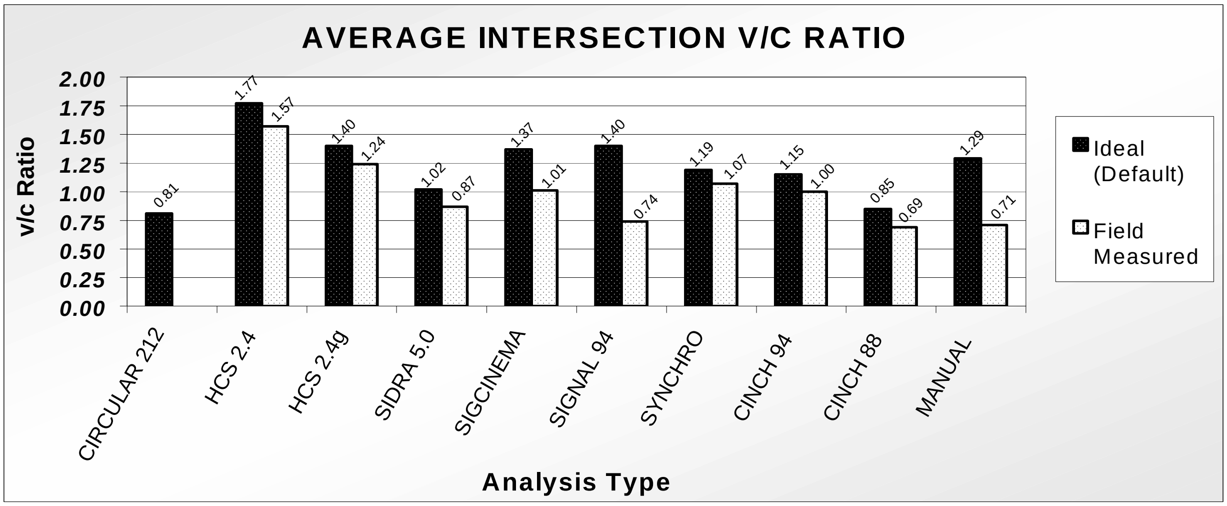

Figure 19 - Volume-to-Capacity Ratio

The engineers' observation was a LOS D. A wide range of v/c's and LOS results from the calculations using default saturation flow rates. CINCH88 results in a v/c of 0.85, and LOS C, while HCS results in a v/c of 1.77 and LOS F. The only other package that results in a LOS D is Synchro, with a v/c of 1.07. All others indicate LOS E-F.

Calculations using measured saturation flow rates also indicate a wide range of values, from CINCH88 (0.69, LOS B) to HCS (1.57, LOS F). The remaining packages show LOS in the C - D range.

Circular 212 results in a v/c ratio of 0.81, and LOS C/D.

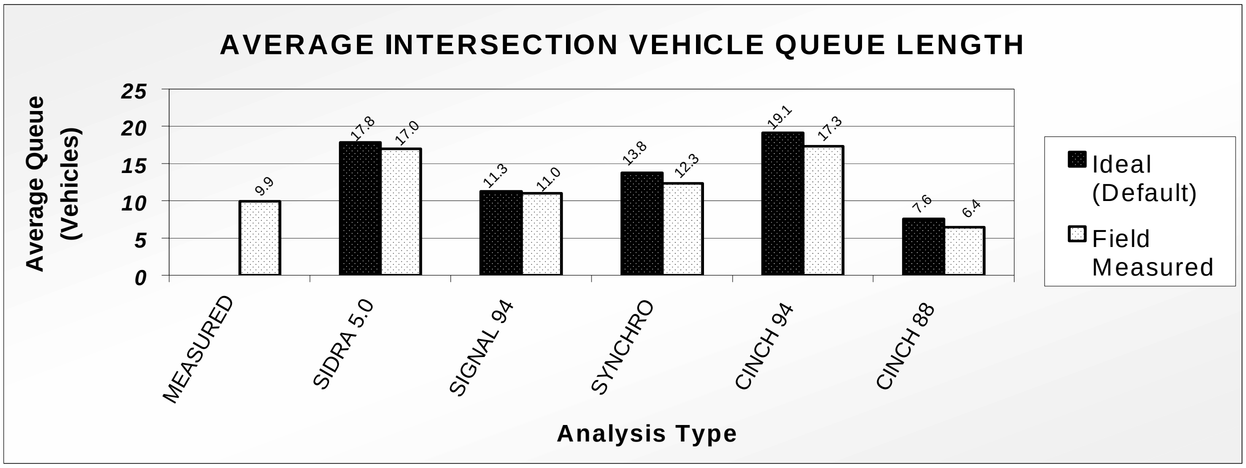

Figure 20 - Average Vehicle Queue Lengths

CINCH88 was the only package which calculated a queue less than the measured value of 9.9 vehicles. SIGNAL94 and Synchro were fairly close, exceeding the measured 9.9 queue by 1 to 3 vehicle lengths. SIDRA and CINCH94 estimated the longest queue, in the range of 7 to 10 vehicle lengths higher than the measured queue.

Intersection D – Route 1A at Revere Street

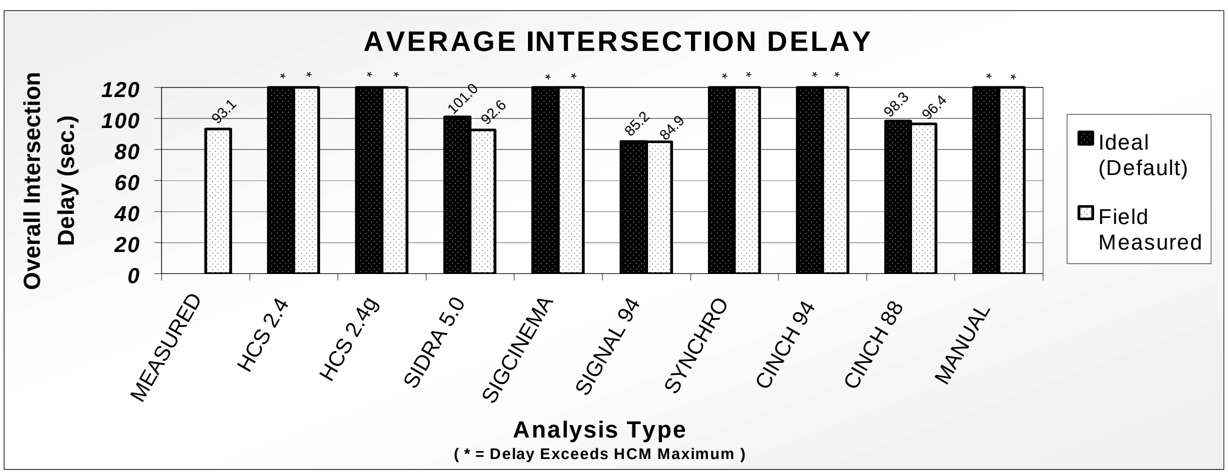

Figure 21 - Average Stopped Delay

Overall average intersection delay was field measured as 93.1 seconds. Using default ideal saturation flow rates, all but three of the packages indicated calculations too high to report. Those reported were SIGNAL94 (85.2, -8%), CINCH88 (98.3, +6%) and SIDRA (101.0, +8%).

Calculations using measured saturation flow rates were reported for the same three packages that showed results using default saturation flow rates. They are SIGNAL94 (84.9, -9%), SIDRA (92.6, -1%) and CINCH88 (96.4, +3.5%).

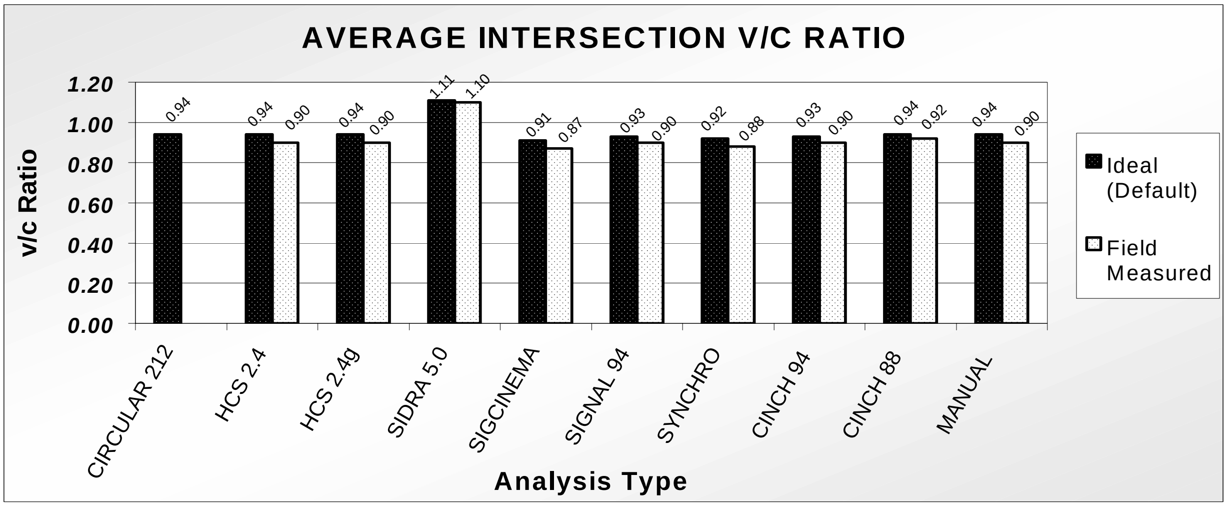

Figure 22 - Volume-to-Capacity Ratio

The engineers' observation was LOS E. All default saturation flow rate calculations are at LOS F, and v/c's show little variation (0.91 - 0.94), except SIDRA, which calculates v/c at 1.11.

Calculations using measured saturation flow rates are also very close, with v/c's ranging from 0.87 - 0.92, except SIDRA, which calculates v/c at 1.10. All packages indicate a LOS F.

Circular 212 results indicate LOS E and a v/c of 0.94.

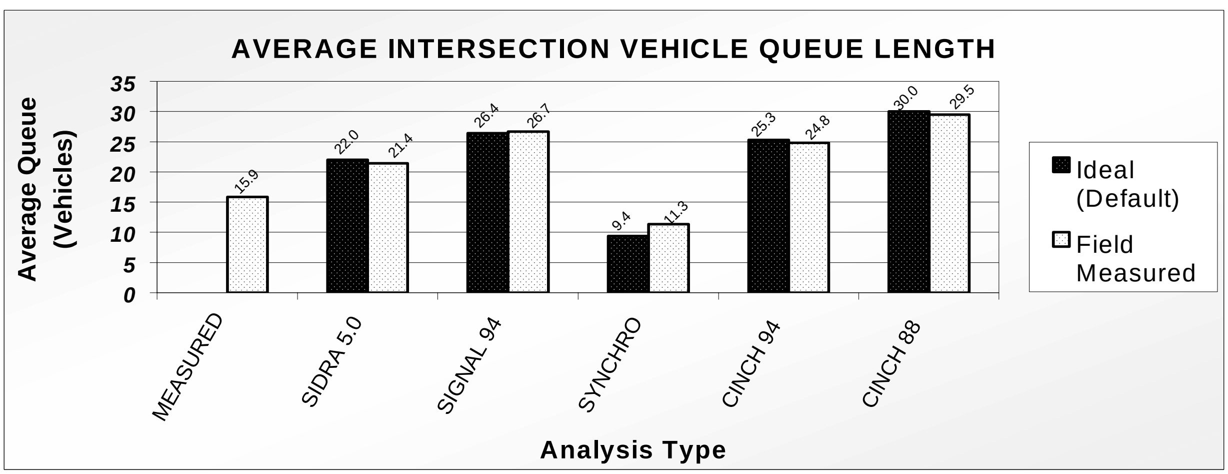

Figure 23 - Average Vehicle Queue Length

Synchro provides a queue length shorter than measured, while the other four models project longer queues. SIDRA is about 40% higher than measured, while CINCH94 and SIGNAL94 are 56% to 68% higher. CINCH88 estimated the longest queues, up to 89% longer than measured.

Intersection E – Route 20 at School Street

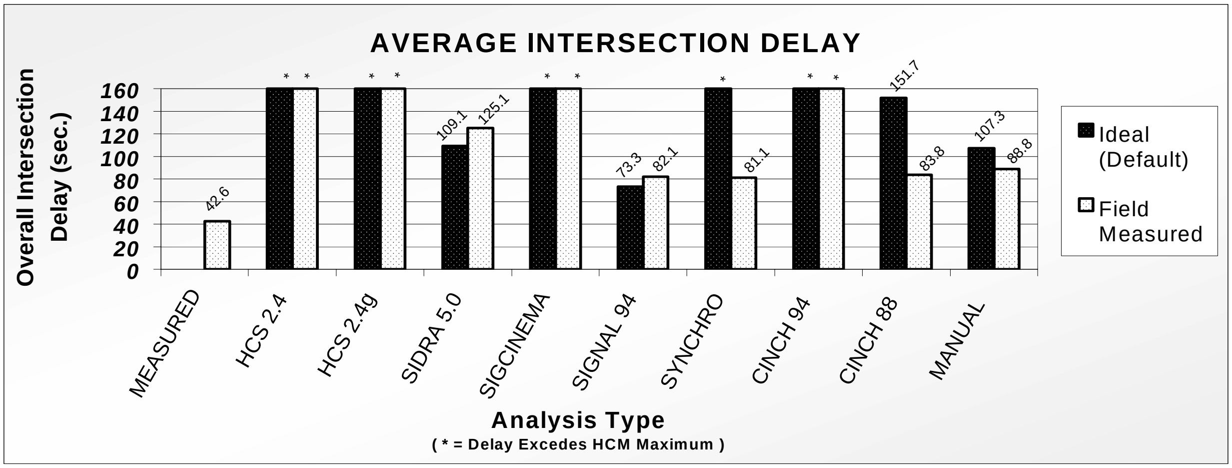

Figure 24 - Average Stopped Delay

The field measured overall average intersection stopped delay was 42.6 seconds. The range of calculated values using default ideal saturation flow was from 73.3 seconds to 151.7 seconds. The entire range is so much higher than the measured value that comparisons are not meaningful.

Calculations using field measured saturation flow rates ranged form 81.1 seconds to 125.1 seconds. These values are also too high to make a meaningful comparison.

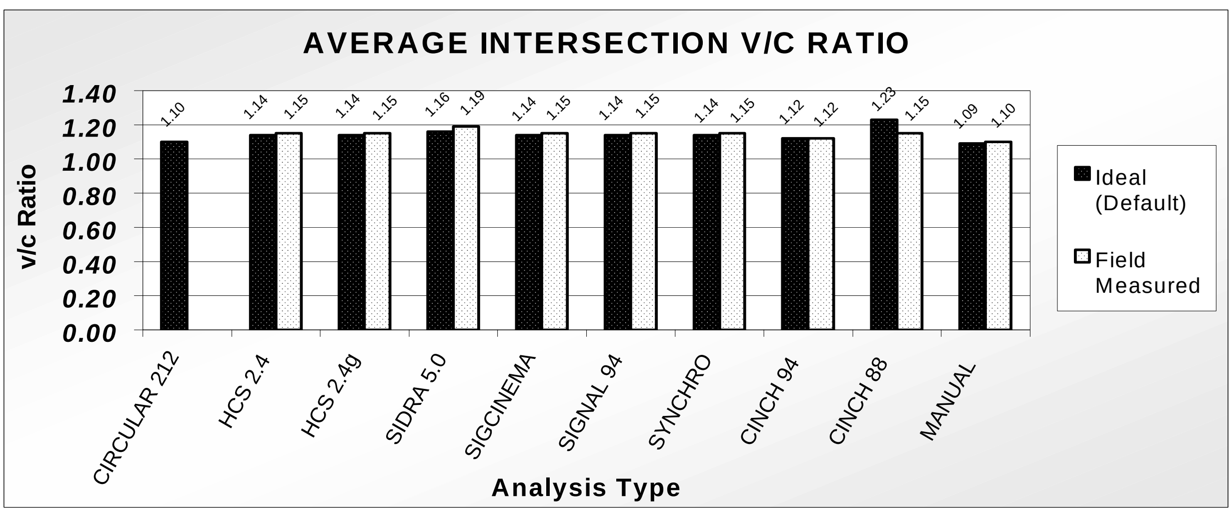

Figure 25 - Volume-to-Capacity Ratio

The engineers' observation was LOS F. All calculations, either using default or measured saturation flow rate indicate LOS F. Volume to capacity ratios also show little spread, ranging from 1.12 to 1.23 for default saturation flow calculations, and from 1.07 to 1.19 for measured saturation flow calculations. Circular 212 calculations result in a v/c of 1.10 and LOS F.

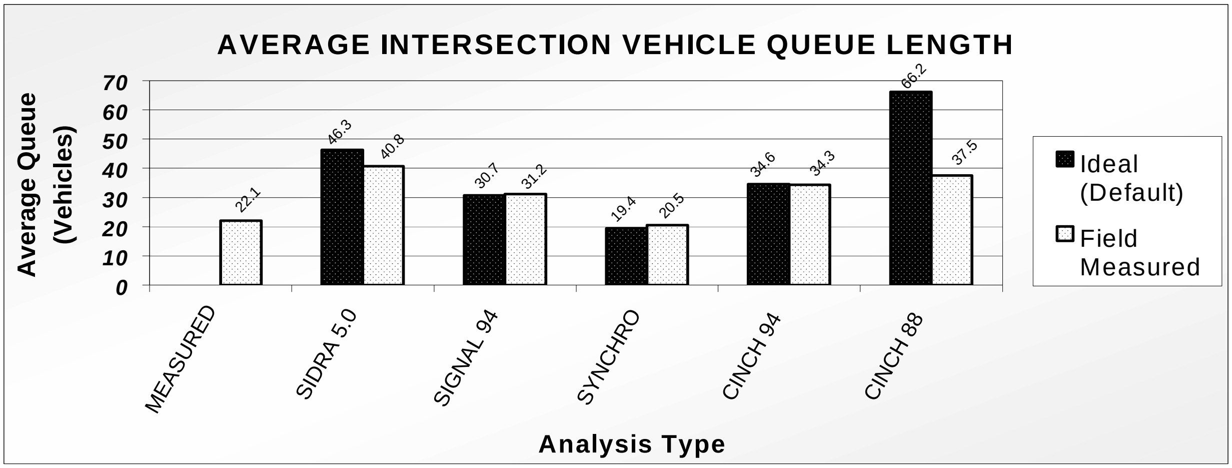

Figure 26 - Average Vehicle Queue Length

Synchro provides the closest queue estimate to measured, although it provides only the queue after two cycles and states the "queue may be longer." SIGNAL94 and CINCH94 exceed measured queues by 40% to 55%. SIDRA queues are almost double the measured queues, while CINCH88 shows considerable variation for the 1900 default case, with an error of 200% while the field measured case has a 70% error.

SUMMARY

The results presented study indicate that the examined software packages exhibit the following trends:

- They do not accurately replicate field measured average stopped delay.
- Calculations of volume-to-capacity ratio do show some groupings, but not an overall consistency.
- Only Synchro consistently calculated queues close to field measured values.
- Level of Service results were consistent and matched the subjective judgements of observing traffic engineers.
- Inclusion of field measured saturation flow rates generally improved the results.

As stated in the Scope of this study, all calculations were conducted using methodologies that pre-dated the 1997 update of the HCM. As such, all delays have been reported in terms of average stopped delay. While outside the scope of this project, the five intersections for which field data were collected have been analyzed using the 1997 HCM methodology, which reports total delay as the level of service MOE. The results are disappointing for those looking for a "new and improved" package. Version 3.1a (March 1999 patch) gave quite similar v/c results as version 2.4g, for three of the five locations studied. The high overall v/c's produced by version 2.4 were reduced to values closer to the other models, comparable to SIDRA and slightly below Synchro and CINCH94. For location D, Version 3.1a returned a v/c of zero, and in one instance produced a blank value for LOS and delay. Overall, the results of version 3.1a do not represent a clear case for its superiority to version 2.4g.

Recommendations

The results do, however, show trends that cannot be ignored. While some success was obtained in the comparison of level of service and, to a lesser degree volume-to-capacity ratio, the models do a poor job with comparisons to queue length and average stopped delay. There can be several reasons for the disappointing comparisons. Do the algorithms for delay, v/c and queue determination need to be addressed? Do the intersections chosen for this study contain anomalies that challenge the methodologies beyond the norm? No definitive conclusions can be drawn from a data pool of five intersections and the limitations described in this report.

Recommendations for further study include the following:

- Include more intersections with saturated lanes with permissive turns.
- Analyze more CBD intersections with parking and pedestrian activity.
- Standardize procedures for data collection and analysis so that continuation of these efforts can produce cumulative results.
- Collect more data and evaluate the results independently.

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ENDNOTES

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