VERSION 1

TRAFFIC ENGINEERING / GIS

The City of Yakima, Washington

TRAVEL SPEED STUDY OF URBAN STREETS USING GPS & GIS

GIS / TRAFFIC ENGINEERING, CITY OF YAKIMA, WASHINGTON

Travel Speed Study of Urban Streets Report and Manual

© City of Yakima, Washington
129 North Second Street
Yakima, Washington 98901
Phone 509.576.6602 • Fax 509.575.3021

Table of Contents

Section 1
Project Overview and Purpose of Study 2
Project Description 2
Purpose of Study 3
Study References 3

Section 2
Establishing Databases and Rules for Gathering Data 4
Segmenting the Urban Street and Routes 4
Travel Speed Components 5
Running Time and Free-flow Speed 6
PM Peak Hour Data Collection 7
Stopped Delay and Average Travel Speed 7

Section 3
Using Arcview GIS to Analyze GPS Data 9
GPS System Characteristics 9
GIS Software and Crystal Reports 10
Importing GPS Data into GIS 10
Joining of GPS Shapefiles to Routes 10
Hand Editing of Points 11
Computation of Delay 12
Summary and Detail Reports 13

Section 4
Study Findings
Results of Analysis 17
Table of Travel Speed Summary Data 20
Methodology Observations 22
Recommendations for Future Studies 23

Section

1

Project Overview and Purpose of Study

Average Travel Speed is the basic service measure of urban streets which includes the running time on the street segment and control delay of through movement at signalized intersections. (Highway Capacity Manual, 2000)

PROJECT DESCRIPTION

Managing traffic within our communities is a growing task for local governments. As traffic volumes increase and public financial resources decrease, targeting improvement projects to anticipate growth patterns is critical. Travel Speed Studies are used to determine the level of service for streets, document congestion and quantify the need for street improvements.

The City of Yakima, Washington conducted a Travel Speed Study over 85 miles of arterial streets. The travel speed, running time and delay time were measured for the study area during non-peak and peak hour travel conditions. Data was collected using a global positioning system (GPS) receiver which measured the location and vehicle speed at two-second intervals. Data was analyzed using geographic information system (GIS), specifically ArcView 3.2 and Crystal Reports.

Existing applications for GPS have been developed and are currently in use by the City of Yakima for dispatch of emergency vehicles including police, fire and ambulances. Therefore, the GPS hardware, the spatial data model, the geo-file (relational database) and the procedure for linear referencing of the GPS data was already in place prior to the Travel Speed Study.

PURPOSE OF STUDY

Travel Speed studies are used for a variety of purposes and differ in the level of detail and data collected. The primary purposes of the City of Yakima study are evaluation of the operational level of arterial streets for compliance with the Washington State Growth Management Plan; evaluation of congestion in terms of Level of Service; and to assist in analyzing the Functional Classification of urban streets.

For compliance with the Washington State Growth Management requirements, the Level of Service was measured during the PM peak hour of travel. This study evaluates the impact of delay on the travel speed of through movements between signalized intersections over a street network. Although this study includes very detailed and accurate data on traffic flow, is not intended to be used for analysis of the operation of signal timing patterns or intersection level of service.

REFERENCES FOR STUDY METHODOLOGY

Procedures from the Urban Streets Methodology of the Highway Capacity Manual, 2000 (Transportation Research Board, National Academy of Sciences) were followed for this study, as modified by use of the GPS technology. Methodology for this study was developed using the guidelines published in the “Travel Time Data Collection Handbook”, March 1998 (The Federal Highway Administration Report Number FHWA-PL-98-035).

Additional research of recent studies was also conducted, with particular emphasis on published studies from the Louisiana Transportation Research Center, developed by Quiroga and Bullock. A list of materials used is included in the appendix of this documentation.

Section

2

Establishing Datasets and Rules for Gathering Data

It would seem a very simple task to just go drive and retrieve data. These rules made the processing and evaluation of the data much easier and uniform, as well as ensure the study conforms to standard traffic engineering procedures.

SEGMENTING THE URBAN STREET AND CREATION OF ROUTES

The Yakima study area includes 85 miles urban arterial streets, encompassing over 100 signalized intersections. A total of 80 street segments were defined which span the arterial street system between signalized intersections. A separate study will be conducted on the Yakima CBD core area that includes 40 signalized intersections. Currently, the CBD is in the process of a total signal hardware upgrade and optimization program, replacing fixed time controllers with vehicle and pedestrian actuation.

The street segments were classified with respect to their functional and design characteristics. The Highway Capacity Manual, Exhibit 15-2 was applied to the urban arterial streets within Yakima. All of the streets within this study area are classified either Class III or Class IV Arterial Streets due to their posted speed limits and physical characteristics. The following chart represents an extract of the HCM Exhibit 15-2.

HCM Exhibit 15-2: Urban Street LOS By Class

Urban Street Class	III	IV
Range of Free-flow speeds (FFS)	35 TO 30 MPH	35 TO 25 MPH
Typical FFS	35	30
LOS	Avg Travel Speed (mph)	
A	> 30	> 25
B	> 24 - 30	> 19-25
C	> 18 - 24	> 13 - 19
D	> 14 - 18	> 9 - 13
E	> 10 - 14	> 7 - 9
F	< 10	< 7

Driving routes were also developed for the analyst to collect data. A total of five routes were defined, each encompassing between 13 and 19 individual street segments. Driving routes provided an organization tool to ensure all study segments were driven in a systematic way and the appropriate number of travel runs. The final report aggregates the segments into street corridors for the purpose of analyzing Level of Service.

Use of the GPS to collect data created some specific criteria in developing the driving routes. For simplification of data interpretation, the routes were designed so that no street section was driven more than once. Also, the analyst had to ensure that they did not cross the driving route on the way to or from the data collection run. These simple rules eliminated much of the manual data reduction which otherwise would be necessary to provide “clean” data.

An ArcView shapefile was created depicting the street segments and driving routes. Links and nodes were established to define each segment. Each segment was typically an arterial street length connecting two signalized intersections. Segment ends were placed in locations which were feasible for driving, with caution used for one-way streets and other physical limitations.

TRAVEL SPEED STUDY COMPONENTS

The two necessary components of a Travel Speed Study are the *Running Time* and the *Stopped Delay* time for each area of interest (street segment). Running time is the travel time necessary to traverse two defined points (usually signalized intersections) and is measured for the best operating condition. These free-flow conditions occur during off-peak periods of time.

Stopped Delay is the time the vehicle is stopped or moving at a very reduced rate of speed either at an intersection or along the travel route. For the purpose of this study a

minimum rate was set to less than 12 miles per hour, measured by the observation that the GPS equipped vehicle had moved less than 12 meters over a 2 second period of time.

The duration of Stopped Delay was observed over a minimum of 6 runs during PM peak hour traffic. The average of the Stopped Delay was added to the Free-flow Running Time. The resulting calculated time was used to determine the Average Travel Speed during PM peak hour traffic conditions. This is the core procedure described in the Highway Capacity Manual for Urban Street Methodology for Planning and Operational analysis.

RUNNING TIME AND FREE-FLOW SPEED

- **Estimated Free-flow Time**

In order to evaluate the field data, an optimized travel time was calculated using the posted speed limit and segment length. The equation for calculating the estimated free-flow travel time (in minutes) is the following:

$$FFe = (60 * (L / 5280)) / speed_limit$$

Where,

FFe = Estimated Free-flow travel time in minutes
L = Length in miles of each street segment
Speed limit = posted speed limit

This estimate is simply the approximate travel time and does not include any delay time at a signalized intersection or other delays. This estimate was used to compare the observed Free-flow speed and Running Time in order to identify any problems with data collection.

- **Running Time Data Collection**

Actual Running Time by street segment was measured by driving each street route during very light traffic conditions (off-peak) or as close to “Free-flow conditions” as possible in the real world. The driver of the GPS-equipped vehicle made the conscience effort to drive at or as near as possible to the posted speed limit. Optimal driving times to observe these conditions were determined to be between 9AM and 10:30AM, Tuesday through Thursday. This methodology is described in Urban Streets “Appendix B: Travel Time Studies for Determining LOS” of the Highway Capacity Manual, 2000.

- **Control Delay During Free-flow Conditions**

For the purpose of establishing the segment Free-flow Speed no delay was included in the running time of the Free-flow calculation. By eliminating any experienced delay from the free-flow calculation, the travel speed was optimized, but relies on actual field data for the base line speed.

- **Calculations for Establishing Free-flow Speed**

Using traditional methodologies, the Free-Flow Speed is often estimated using a variety of input values about the characteristics of the street such as Street Class, segment length and posted speed limit. This study uses direct measurement of the actual Free-flow Speed, as modified using the GPS data. Adjusted Free-flow Speed was derived using the Free-flow Running Time and Adjusted Maximum Delay in the following equations:

$$S_T = T_R$$

$$S_{FF} = 3600(L)/ S_T$$

Where,

S_T = Free-flow Travel time in seconds

S_{FF} = Free-flow Travel Speed

T_R = Running Time in seconds during free-flow conditions

L = Length in miles of each segment

PM PEAK HOUR DATA COLLECTION

- **Peak Hour Driving**

Data collection during PM peak hour conditions required the driver to emulate the stream of through traffic. Where traffic is not congested, the driver should conform to the speed limit. If traffic is blocked in the left lane due to turning movements and the right lane is open, then the driver should move to the right lane. The driver should match vehicle speed with another vehicle and not drive aggressively. The data collection is for through movements and the driver needs to model that behavior. Each segment was driven a minimum of 6 times during peak hour conditions, equally divided by direction. Due to time constraints and planning, only one route was driven each day. A log was kept by the driver to record which day of the week, starting and ending time for the route, direction of travel and any special situations which occurred during the data collection period. Peak hour data collection was conducted primarily Monday through Thursday.

- **Stopped Delay Computations**

One of the critical components of the Travel Speed Study is the calculation of peak period travel delay, known as Control Delay. Traditional traffic engineering procedures specified in the Highway Capacity Manual (HCM) analyze three factors related to Control Delay, including uniform delay, incremental delay and initial queue delay. Uniform delay assumes a stable and uniform arrival of vehicles at an intersection. Incremental delay estimates the more random (non-uniform) arrival of vehicles and conditions of saturated flow. Initial queue delay represents the time period to clear an intersection where vehicles were stopped longer than one signal cycle.

This study relies on field collection of actual delay during PM peak hour conditions. No calculations have been developed or applied for the various types of delay, progression, signal spacing, signal timing or other variables. Therefore, this analysis is for planning level applications.

Use of the GPS equipped vehicle simplified the documentation of delay. A GPS position was generated every two seconds if the vehicle had moved more than 12-meters. In the event that the vehicle was stuck in traffic, no GPS point would be generated until the vehicle moved again at least 12 meters, and the next GPS point would identify the time and velocity of that point. Therefore, delay was calculated and assigned to each GPS point that had been issued longer than 2 seconds from the previous point. Delay was averaged for each of the six runs.

- **Average Travel Speed**

The PM peak hour travel speed was calculated for each street segment and along the entire length of a corridor. As previously discussed, the Running Time was measured during non-peak (Free-flow) travel conditions and delay was calculated for the average of PM peak hour observations. The following formula was used to determine Average Travel Speed:

$$S_A = 3600L/T_R + d$$

S_A = average travel speed
L = segment length (miles)
T_R = total running time on each segment
D = Average control delay during PM Peak traffic

SECTION

3

Using ArcView GIS to analyze GPS data

There are many ways to process and analyze geographic data. ArcView allows you to customize and simplify the steps for analyzing the data gathered.

GPS SYSTEM CHARACTERISTICS

GPS data is being gathered using a Sierra Wireless MP200 CDPD modem with GPS option. These modems are being used for the City of Yakima's Public Safety Departments. A lot of the data gathering technology was already in place prior to this study. The modem and antenna to equip the vehicle cost approximately $1,100. The GPS data is being transmitted back to a central Automated Vehicle Location (AVL) server.

The use of AVL in our Public Safety vehicles spurred the idea of using the same technology for a traffic speed study. The ability to have less people and a less manual process of gathering the data makes gathering data a much more accurate and safer.

A two second interval was used for gathering vehicle positions. This interval was selected to keep data gathered to a minimum, while still maintaining a very accurate vehicle positions and times. The time interval is easily configured on the GPS unit by sending a Trimble ASCII Interface Protocol (TAIP) message. An example setting a two second interval for this device follows:

>DPV0002000000120000<

This sets a 2 second interval and 12-meter distance for each Position and Velocity Solution message. This setting ensures that a position will not be sent unless the vehicle has moved 12 meters or more and 2 seconds has elapsed. The 12-meter configuration is set as a basic threshold of movement. It is set slightly higher than the amount the unit might "bounce" if standing still, thereby sending unnecessary positions from the same location.

GIS SOFTWARE INCLUDING CRYSTAL REPORTS

Environmental Systems Research Institute (ESRI) ArcView 3.2a was used for managing and displaying the GPS points and selected route data sets. The City of Yakima maintains a very robust set of GIS data and applications that have been developed over the last 15 years. A well-documented and geo-coded street centerline file is constantly maintained for emergency service purposes and is used for various transportation applications as well.

Seagate's Crystal Reports was used to display the results of the speed study.

IMPORTING GPS DATA INTO GIS

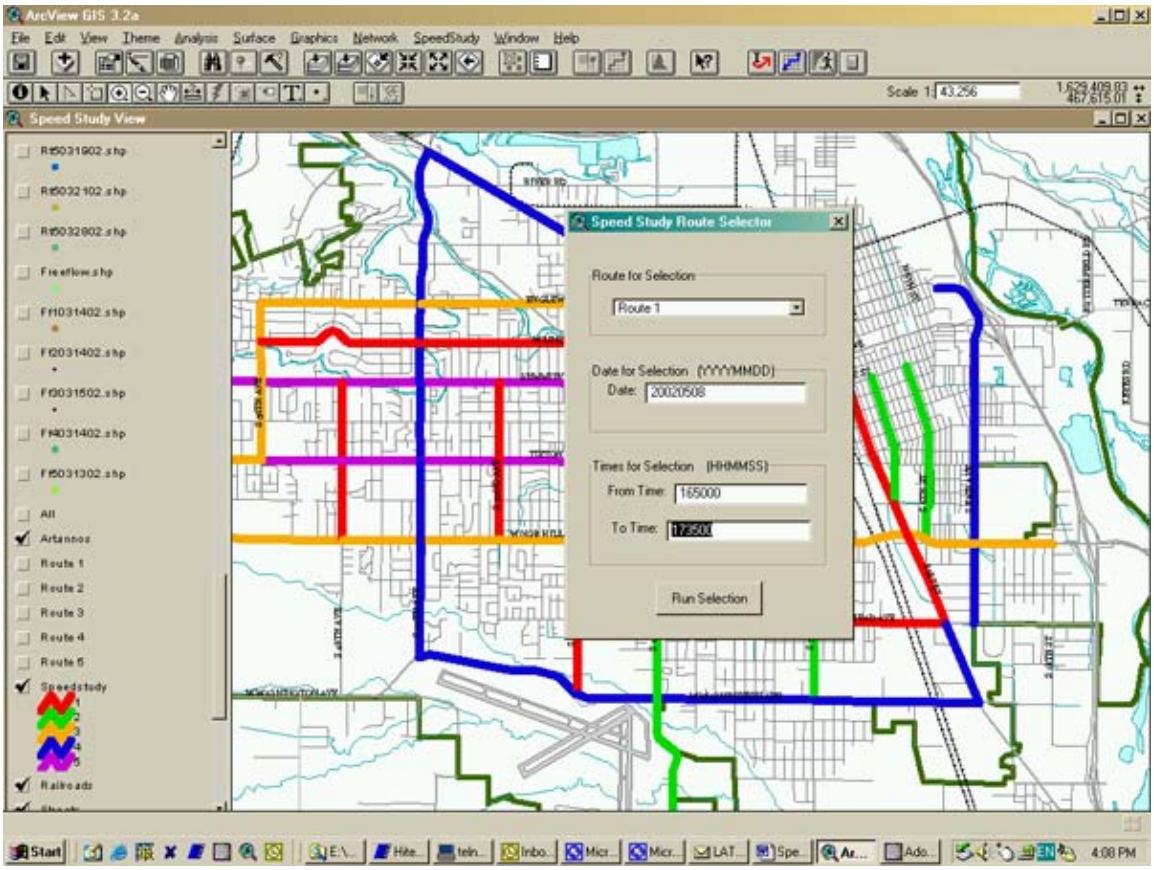
A script was written in ArcView Avenue to import the position reports from the field and create a table of position and time information critical to this analysis. The data is imported in latitude and longitude and then projected into stateplane coordinate system. The table includes fields for unit, position ID, heading, GPS speed, date, time, and delay.

Delay is calculated based on any time longer than the normal 2-second interval between position reports. If a gap of data is found, a major difference in distance between points, the delay is discounted. Data gaps may occur when buildings, trees, or other objects blocking clear satellite view obscure the GPS antenna. Due the topography there may be some areas where reception is more difficult. There can also be time spans where the "dilution of precision" is not suitable.

JOINING OF GPS SHAPE FILES TO ROUTES (BEGINNING AND END TIME)

Another Avenue script is used to apply the data to each designated route. A simple dialog requests the route, date and time span to be extracted and analyzed.

Route Selection Dialog for Selection of GPS points

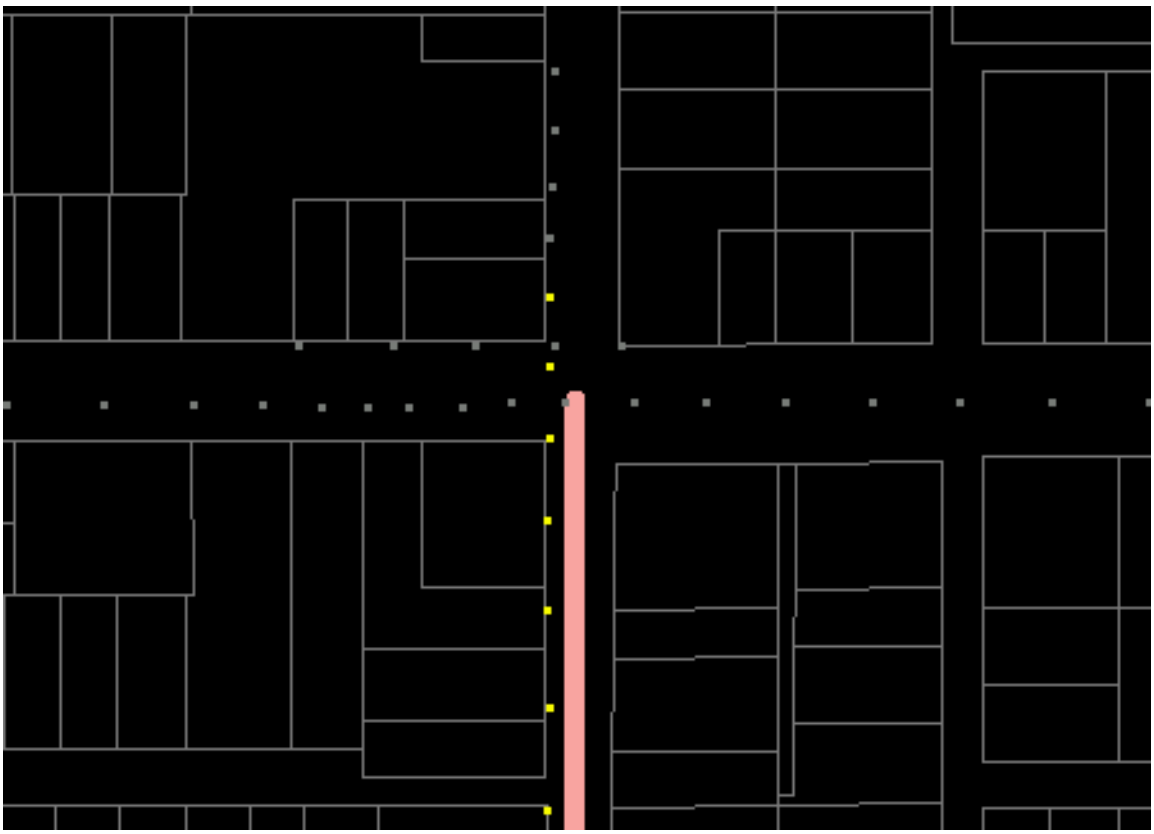


This creates a shapefile that has the GPS data as well as the spatially joined linear data for the requested route. Several trips in each direction are taken for each route. This routine performs data reduction and spatial joining of all necessary tables.

HAND EDITING OF POINTS (TOLERANCE & UNREALISTIC POINTS)

Reduction of GPS points for the speed study is mostly automated, but does require inspection of the end points of each segment. This ensures that only appropriate points are considered. The automated process allows points within the given time constraint and within 150 feet are selected. Since all route segments are not contiguous, the non-contiguous ends must be inspected to eliminate extraneous points for the selected day. A visual inspection of the data was required to make sure that only the points necessary were included in the study. The graphic below shows yellow GPS collection points to be potentially used in the study. The pink line is the study route that will be spatially joined to the GPS points. Obviously, the uppermost yellow point should be eliminated from the days study group.

Screen of GPS points (shown in yellow) matched to Street Segment



COMPUTATION OF DELAY

GPS collection was done using a two second interval between each collection point. This allowed for a dense enough collection of point data eliminated a stream-lined data reduction. The computation of delay was derived from the setting of the two second interval and the distance between successive points. An additional 2 seconds was allowed between points without calculating any delay time. An amount of time exceeding this would calculate a delay time as long as the distance between points was less the 150 feet. The 150 feet allowance was for possible gaps in GPS data the would also be gaps in time. Closely spaced points with over 4 seconds of time are actual vehicle congested conditions indicating delay.

The following snippet of AVENUE code is used to calculate delay, duration and distance between each point. The time values from the database are actually numbers which are calculated into seconds. The are stored and compared to their previous point values.

```
' Convert time to seconds
begTime = mgVTab.ReturnValue(timeFld,sumrec)
begHours = (begTime / 10000).truncate
begMinutes = (begTime / 100).truncate - (begHours * 100)
begSeconds = begTime - (begHours * 10000) - (begMinutes * 100)
begTimeinSeconds = (begHours * 3600) + (begMinutes * 60) + begSeconds
durSeconds = begTimeinSeconds - prevTime
if (prevPoint.Distance(thePoint) < 150) then
  if ((durSeconds > 4) and (durSeconds < 200))then
     iDelay = durSeconds - 2
  else
     iDelay = 0
  end
end
' when the number of seconds is high, it is just a beginning point for the day
if (durSeconds > 300) then
  durSeconds = 0
end
shpFTab.SetValueNumber( secondsField, rec, durSeconds )
shpFTab.SetValueNumber( delayField, rec, iDelay )
prevTime = begTimeinSeconds
prevPoint = thePoint
```

SUMMARY AND DETAIL REPORTS

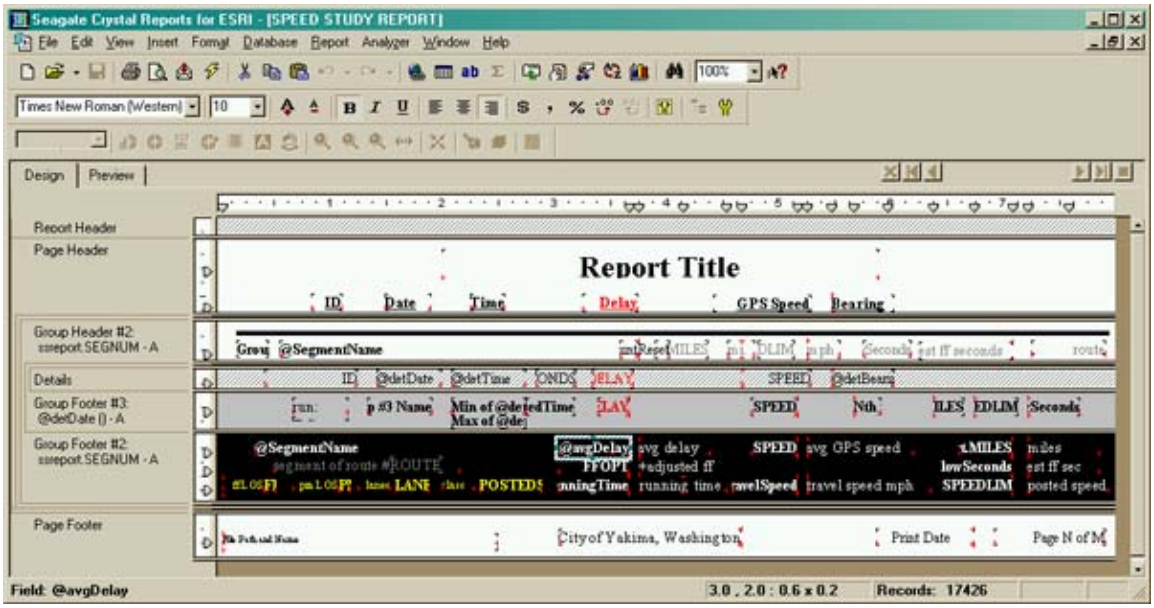
Crystal Reports was used to take the Free-flow and Speed Study merged data files and create a variety of detail and summary reports. Crystal was ideal for creating these reports because of the ability to have many break points and groups of data. Formatting of the GPS data for reporting purposes was essential for analyzing the study findings.

All of the GPS data was considered and summarized to some degree. Since the study used a 2 second GPS interval, no data reduction was necessary beyond the route editing, described previously, in this document. The GPS data was sorted by driving route, street segment, direction (or bearing) of the run, date, and by time. A total of 6 data runs were provided for each of the 80 street segments in order to summarize and average information.

Several key data items on the report were computed using macros within Crystal Reports. Some of the calculations required that a running totals or averages be available. The travel time (in seconds) for each study segment was calculated using a macro within Crystal. Likewise, stopped delay for each data run was calculated and then averaged by street segment.

Below is a sample of the formatting screen of Crystal Reports that identifies fields and data displayed for the Speed Study Report.

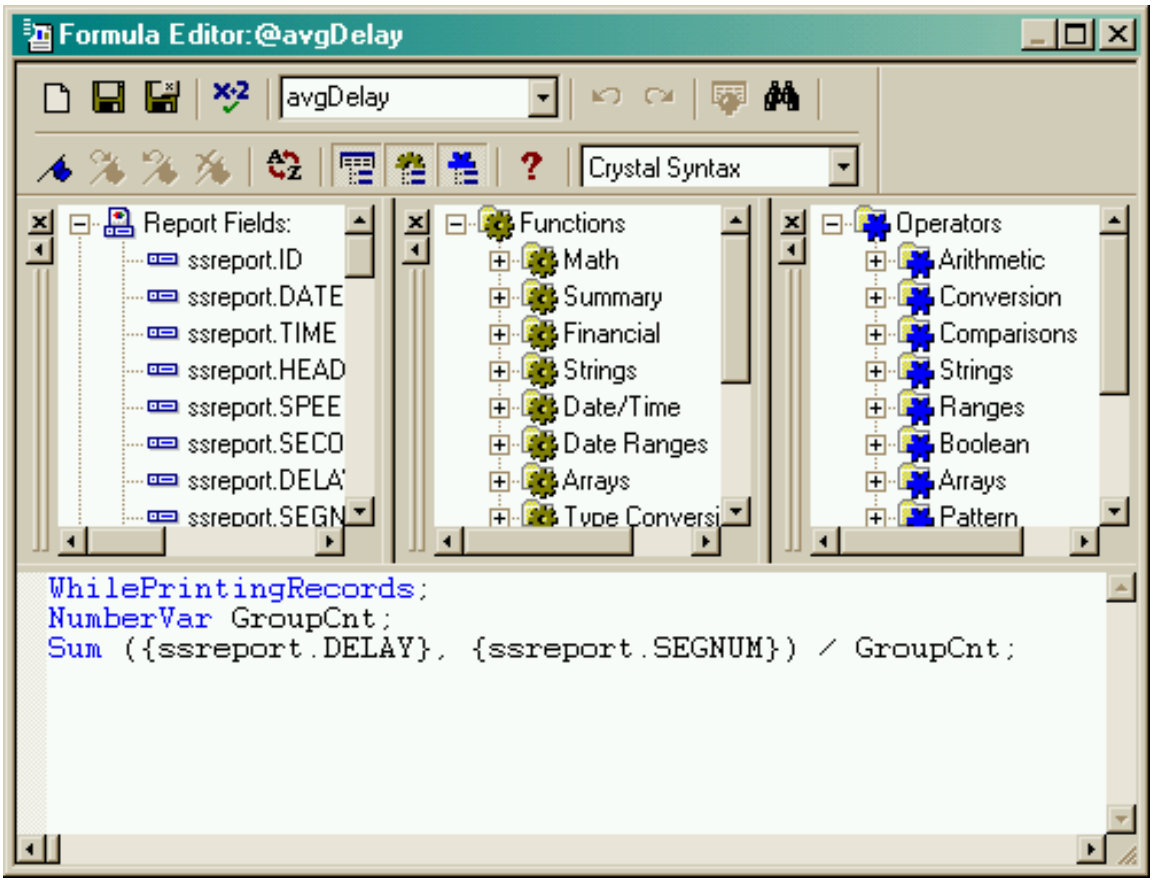
Crystal Reports Formatting Screen



A number of reporting fields were used to generate the data reports from Crystal Report software. Items calculated within this Crystal Report include average delay; average GPS speed; length of travel time in seconds for each run; and travel speed.

As previously noted, Crystal Report worked extremely well as a reporting tool and for analysis of the GPS data. One particularly nice feature of Crystal Reports is the Formula Editor, which facilitates the operation of data calculations by various fields. The data collected from the GPS equipped vehicle includes an array of very complex data points. Analysis of this data is dependent upon a well-designed report, with computational fields for comparative purposes.

Crystal Reports Formula Editor



Sample of Travel Speed Study Report

SPEED STUDY REPORT

ID	Date	Time		Delay		GPS Speed	Bearing			
6	On 3rd St from Walnut St to Nob Hill Blvd				0.83 mi.	30 mph		100 est ff seconds		route #2
run: 1	3/13/2002	5:03:37PM 5:06:11PM	154	52		27.22	N	0.83	30	100
run: 2	3/25/2002	5:20:15PM 5:22:11PM	116	21		27.74	S	0.83	30	100
run: 3	3/26/2002	5:06:09PM 5:08:15PM	126	30		28.70	N	0.83	30	100
run: 4	4/1/2002	5:03:59PM 5:06:53PM	174	68		27.57	N	0.83	30	100
run: 5	4/15/2002	5:18:25PM 5:20:49PM	144	42		28.47	S	0.83	30	100
run: 6	4/16/2002	5:14:01PM 5:16:11PM	130	20		26.64	S	0.83	30	100
On 3rd St from Walnut St to Nob Hill Blvd segment of route #2				39 avg delay 108 +adjusted ff		27.70 avg GPS speed			0.83 miles 100 est ff sec	
am LOS A	pm LOS B	lanes 5	class IV	147 running time		20.36 travel speed mph			30 posted speed	

The study findings were tabulated in a Crystal Reports summary, as shown above. The report included data for average delay, travel speed and resulting level of service by street segment. The grey area lists all of the runs done for each segment. The red numbers indicate delay. The black area shows the final tabulation of all runs for the above street segment. The yellow text is the resulting level of service and street classification information.

SECTION

4

Study Findings

The Travel Speed Study provides an important foundation for assessment of the capacity and characteristics of the City of Yakima Urban Arterial Street network. GPS technology enhanced the study.

RESULTS OF ANALYSIS

Travel speed during the weekday PM Peak hour in Yakima is significantly diminished from the non-peak periods. A number of arterial street segments were identified which currently operate at Level of Service (LOS) D or E during the PM Peak period. Other street segments operate at a low LOS C that will create limited growth potential as traffic volumes increase in the future.

Delay, as measured for each arterial street segment, provides a variable which can be compared for analysis purposes in order to evaluate relative importance of street deficiencies. While the Travel Speed Study identified a number of arterial street segments which experience peak hour delay, most of the arterial streets have adequate capacity to maintain an acceptable level of service during the peak hour period. The following street segments were identified with peak hour travel speed deficiencies:

- 16th Avenue from Fruitvale Boulevard to Nob Hill Boulevard
- 1st Street from Walnut Street to Nob Hill Boulevard
- Nob Hill Boulevard 18th Street to 10rd Avenue
- 40th Avenue from Fruitvale Boulevard to Nob Hill Boulevard
- 3rd Avenue from Walnut Street to Nob Hill Boulevard
- Summitview Avenue from 32nd Avenue to 40th Avenue
- Tieton Drive from 16th Avenue to 21st Avenue
- 56th Avenue Englewood to Summitview
- 72nd Avenue from Tieton Drive to Nob Hill Boulevard.

The maps in the appendix and the following summary table illustrate the findings of this study .

Travel Speed Study Data Summary

Arterial Street	Segment	Street Class	Length (mi.)	AVG PM Delay (s)	PM Travel Speed (MPH)	PM LOS	N or W delay	E or S delay
16th Ave	Tieton Dr to Nob Hill Blvd	III	0.50	62	15.03	D	55.6	69
16th Ave	Lincoln Ave to Summitview	III	0.25	22	16.97	D	30	13.3
16th Ave	Fruitvale Blvd to Lincoln Ave	III	0.63	44	19.65	C	45.7	41.7
16th Ave	Summitview to Yakima Ave	III	0.18	13	20.23	C	17.6	9
16th Ave	Yakima Ave to Tieton Dr	III	0.32	10	25.61	B	12.3	7
16th Ave	Nob Hill Blvd to Washington	III	0.99	38	25.62	B	58.6	16.3
16th Ave	Washington to Ahtanum Rd	III	0.95	18	27.81	B	14.3	22.3
16th Ave Average				**30**	**21.56**	**C**		
1st St	Arlington St to Nob Hill Blvd	III	0.21	18	18.85	C	5.75	42
1st St	Nob Hill Blvd to Mead Ave	III	0.61	25	23.22	C	9.25	57
1st St	Walnut St to Arlington St	III	0.81	31	23.69	C	26.25	41
1st St	Home Depot to Washington	III	0.23	7	27.13	B	0	10.25
1st St	Mead Ave to Home Depot Dr	III	0.31	4	28.35	B	11	0
1st St Average				**17**	**24.25**	**B**		
24th Ave	Nob Hill Blvd to Washington	IV	0.97	26	28.99	A	53	12
24th Ave Average				**26**	**28.99**	**A**		
32nd Ave	Summitview to Tieton Dr	IV	0.50	23	15.94	C	22	23.75
32nd Ave	Tieton Dr to Nob Hill Blvd	IV	0.50	17	21.92	B	13	18.5
32nd Ave Average				**20**	**18.93**	**C**		
3rd Ave	Walnut St to Nob Hill Blvd	IV	0.91	69	18.26	C	34.7	104
3rd Ave	Nob Hill Blvd to Viola Ave	IV	0.25	16	20.71	B	26	0
3rd Ave	Mead Ave to Washington	IV	0.50	18	23.40	B	21	15.3
3rd Ave	Viola Ave to Mead Ave	IV	0.25	7	26.02	A	8	6
3rd Ave Average				**28**	**22.10**	**C**		
3rd St	Walnut St to Nob Hill Blvd	IV	0.83	39	20.36	B	50	27.7
3rd St Average				**39**	**20.36**	**B**		
40th Ave	Lincoln to Summitview	III	0.25	26	16.62	D	4.5	69.5
40th Ave	Tieton Dr to Nob Hill Blvd	III	0.50	40	19.22	C	60	0
40th Ave	Nob Hill Blvd to Washington	III	0.74	58	19.33	C	43	88.5
40th Ave	Fruitvale Blvd to River Rd	III	0.23	12	20.64	C	3.5	29
40th Ave	Summitview to Tieton Dr	III	0.50	30	20.71	C	36	17.5
40th Ave	River Rd to Englewood Ave	III	0.76	12	28.65	B	12.25	11
40th Ave	Englewood Ave to Lincoln	III	0.25	5	29.28	B	3.4	6.5
40th Ave Average				**26**	**22.06**	**C**		
48th Ave	Summitview to Tieton Dr	IV	0.50	17	21.08	B	20.25	11
48th Ave	Tieton Dr to Nob Hill Blvd	IV	0.50	14	22.51	B	16.5	8
48th Ave Average				**16**	**21.80**	**B**		
56th Ave	Englewood to Summitview	IV	0.25	49	15.65	D	35.7	61.3
56th Ave	Summitview to Tieton Dr	IV	0.50	24	20.45	B	31	17
56th Ave Average				**37**	**18.05**	**C**		
64th Ave	Tieton Dr to Nob Hill Blvd	III	0.49	17	27.41	B	22	12

Arterial Street	Segment	Street Class	LENGTH (mi.)	AVG PM Delay (s)	PM Travel Speed (MPH)	PM LOS	N or W delay	E or S delay
64th Ave	Nob Hill Blvd to Washington	III	1.01	14	32.00	A	4.6	22.7
64th Ave Average				**16**	**29.71**	**B**		
6th St	Walnut St to Nob Hill Blvd	IV	1.13	29	25.63	A	37	21
6th St Average				**29**	**25.63**	**A**		
72nd Ave	Tieton Dr to Nob Hill Blvd	IV	0.50	41	17.13	C	52.3	29.6
72nd Ave	Summitview to Tieton Dr	IV	0.50	18	20.81	B	2.6	32.6
72nd Ave	Nob Hill Blvd to Washington	IV	1.01	26	25.31	A	40.3	10.6
72nd Ave Average				**28**	**21.08**	**B**		
Englewood Ave	16th Ave to 40th Ave	IV	1.50	32	22.43	B	47	17.6
Englewood Ave	40th Ave to 56th Ave	IV	1.01	22	24.03	B	13.7	30
Englewood Ave Average				**27**	**23.23**	**B**		
Fair Ave	Pacific Ave to Nob Hill Blvd	IV	0.50	42	19.54	B	46	40.25
Fair Ave	Nob Hill Blvd to Mead Ave	IV	0.51	18	21.43	B	37.5	7.5
Fair Ave	Lincoln Ave to Pacific	IV	1.30	14	27.61	A	13	14.25
Fair Ave Average				**25**	**22.86**	**B**		
Fruitvale Blvd	5th Ave to 16th Ave	III	0.57	26	22.25	B	42.5	17
Fruitvale Blvd	16th Ave to 40th Ave	III	1.61	36	27.53	A	32	38
Fruitvale Blvd Average				**31**	**24.89**	**B**		
Lincoln Ave	5th Ave to 16th Ave	IV	0.49	23	20.05	B	34.25	1.5
Lincoln Ave	16th Ave to 40th Ave	IV	1.50	43	22.44	B	40.75	46.5
Lincoln Ave	40th Ave to 56th Ave	IV	1.06	14	25.10	A	17.75	6.5
Lincoln Ave Average				**27**	**22.53**	**C**		
Mead Ave	3rd Ave to 16th Ave	IV	0.99	27	23.67	B	38	21
Mead Ave	1st St to 3rd Ave	IV	0.84	28	25.13	A	18.5	32.75
Mead Ave Average				**28**	**24.40**	**B**		
Nob Hill Blvd	18th St to Fair Ave	III	0.51	115	10.76	E	21.6	206
Nob Hill Blvd	1st St to 3rd Ave	IV	0.60	57	16.48	C	50.3	63.7
Nob Hill Blvd	3rd Ave to 10th Ave	IV	0.50	34	17.71	C	39.6	28.3
Nob Hill Blvd	Fair Ave to 1st St	III	0.44	36	17.89	D	44.7	27
Nob Hill Blvd	16th Ave to 24th Ave	IV	0.50	28	20.24	B	19	36
Nob Hill Blvd	40th Ave to 48th Ave	IV	0.49	20	21.66	C	24.3	16
Nob Hill Blvd	64th Ave to 72nd Ave	III	0.49	10	24.84	B	6.7	12.7
Nob Hill Blvd	24th Ave to 32nd Ave	III	0.50	12	25.85	A	7	16.7
Nob Hill Blvd	10th Ave to 16th Ave	III	0.49	2	25.99	A	0	4.3
Nob Hill Blvd	32nd Ave to 40th Ave	III	0.50	4	28.14	A	7.3	0
Nob Hill Blvd	48th Ave to 64th Ave	III	1.03	5	31.68	A	7.6	2.6
Nob Hill Blvd Average				**29**	**21.93**	**C**		
Summitview Ave	32nd Ave to 40th Ave	IV	0.50	30	18.89	C	54.7	4.7
Summitview Ave	10th Ave to 16th Ave	IV	0.32	18	19.08	B	30.7	5.3
Summitview Ave	40th Ave to 56th Ave	III	1.02	37	24.85	B	12	62.7
Summitview Ave	16th Ave to 32nd Ave	IV	1.00	8	25.82	A	0	15.3
Summitview Ave	56th Ave to 72nd Ave	III	1.03	26	26.29	B	28.3	23.7

Arterial Street	Segment	Street Class	LENGTH (mi.)	AVG PM Delay (s)	PM Travel Speed (MPH)	PM LOS	N or W delay	E or S delay
Tieton Dr	16th Ave to 21st Ave	IV	0.25	18	18.43	C	6.7	29.3
Tieton Dr	40th Ave to 44th Ave	IV	0.25	14	20.71	B	0	28
Tieton Dr	32nd Ave to 40th Ave	IV	0.50	25	20.77	B	40	10
Tieton Dr	44th Ave to 48th Ave	IV	0.25	9	22.14	B	17.3	0
Tieton Dr	11th Ave to 16th Ave	IV	0.41	15	22.31	B	21.7	8.7
Tieton Dr	48th Ave to 56th Ave	IV	0.51	16	24.57	B	11	21
Tieton Dr	56th Ave to 72nd Ave	IV	1.01	23	26.65	A	24.7	20.3
Tieton Dr	5th Ave to 11th Ave	IV	0.45	2	27.98	A	4.3	0
Tieton Dr	21st Ave to 32nd Ave	IV	0.75	8	29.09	A	15.3	0
Tieton Dr Average				**14**	**23.63**	**B**		
Washington Ave	Cornell Ave to 16th Ave	III	0.49	16	25.80	B	24.5	0
Washington Ave	3rd Ave to 10th Ave	III	0.25	5	25.97	B	0	14.5
Washington Ave	1st St to 3rd Ave	III	1.05	26	27.67	B	23.5	32
Washington Ave	10th Ave to Cornell Ave	III	0.25	6	28.52	B	8.25	0
Washington Ave	16th Ave to 24th Ave	III	0.52	1	31.79	A	0.75	0
Washington Ave	24th Ave to 40th Ave	III	1.06	2	32.85	A	2.5	1.5
Washington Ave Average				**9**	**28.77**	**B**		

METHODOLOGY OBSERVATIONS

The application of GPS technology for collection of a Travel Speed Study provided excellent results. The data was reliable and accurate. The collection process for the study was far simpler than the traditional data collection method which usually involves two technicians, two stop watches and various field data collection sheets. Analyzing the data was facilitated by the use of GIS and the automation provided through the Crystal Report format.

On the other hand, there are some limitations to this format for traffic engineering applications. First and foremost, use of the GPS technology requires some complex programming to process and analyze the data. The City of Yakima has a well-developed GIS system which already integrates some GPS technology in the emergency dispatching process. This facilitated the application of GPS technology to the Traffic Engineering program. Likewise, the initial cost of equipping the project for GPS was already expended for dispatching purposes .The total cost to equip this study was approximately $1000 for the GPS receiver to be installed on the vehicle.

The use of GPS for this study automated the real-time capture of data during the Travel Speed Study and provided a means to quantify delay experienced by the vehicle. The component of

Stopped Delay during each of the PM Peak hour data runs is an essential variable which GPS and GIS technology automated very efficiently.

As previously stated, this study is not intended for determining signal timings or other site-specific engineering or operational applications. Travel speed studies do not account for characteristics of a street such as on-street parking, driveways, two-way center turn lanes or many other variables. Peak hour travel speed does provide the basis for analyzing the basic mobility on the street for the through movement. The results of this study will be combined with other components in determining where capacity and other improvements may be necessary in the future.

RECOMMENDATIONS FOR FUTURE STUDIES USING GPS AND GIS

This study was very successful in the integration of GPS and GIS technology to the Travel Speed Study methodology. A pilot study was conducted prior to commencing of the actual study and many of the data collection and GIS components of the study were refined. However, in retrospect, there remain some elements that might be modified in future studies.

Given the scale of this study (80 street segments, 85 miles total of study area) GPS data could have been received at 1-second intervals (rather than 2-second) without needing to deal with significant data reduction. More data points and greater frequency may have yielded better representation of Stopped Delay and other data components.

Although Avenue and Crystal Reports provided an excellent resource for formatting data, Visual Basic may have provided a more simple approach to the formatting of data.