University of Nevada, Reno

**Comparison of Arterial-Level Signal Coordination
Features of Five Selected Software Programs**

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in
Civil and Environmental Engineering

By

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Abstract

Synchro, PTV Vistro, TransModeler, Tru-Traffic, and TranSync are software programs that are part of different software packages that can all be used for traffic signal coordination tasks in countries that use ring-barrier signal controllers. Each program has different functions, features, inputs and outputs. Synchro, Vistro, and TransModeler all require volume inputs to make an analysis while Tru-Traffic and TranSync do not require volumes. These five programs were compared on the basis of their ability to assist the engineer in designing an optimized arterial coordination timing plan, which included automatic optimization, editing and viewing information presented on the time-space diagram, and selecting various timing plans and intersections to show the time-space diagram.

The same arterial was modeled in all five programs and phase sequence and offset default optimization functions were executed separately for Synchro, Vistro, Tru-Traffic and TranSync. The average vehicle travel time and average number of vehicle stops were simulated using TransModeler, a third-party traffic simulation program to ensure results are not biased. Results showed that Synchro and Tru-Traffic had the lowest peak direction travel time through the whole arterial and the least number of stops. The optimization produced by Vistro and TranSync was 1 minute or 10% slower for the peak direction average travel time than Synchro and Tru-Traffic, which were tied. The southbound travel time for the optimization produced by Vistro was very similar to

TranSync, but TranSync had the shortest northbound travel time. The northbound travel time from TranSync was 10% or 1 minute faster than the slowest off-peak (northbound) optimization which was performed by Vistro. TranSync had the greatest number of features for the time-space diagram and timing plan options compared to the other four programs.

This research reviewed the features of each software package so practitioners can make a better educated decision on which program they would like to use. Using the right tool for the task can save project resources (time, budget, etc.) and contribute to efficiently designed timing plans.

Acknowledgments

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I couldn't be where I am today without the practical signal timing experience under Andrew Jayankura, P.E., PTOE, RSP_1 at the Regional Transportation Commission of Washoe County.

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1. **Introduction**

Traffic engineers have several options for software packages, but Synchro is often

chosen because it is the most common and well known. In addition to Synchro, other

less common programs will be fairly evaluated by going through the signal coordination

timing design process with a practical study corridor.

1.1   State of the Practice for Signal Timing Optimization

Signal coordination optimization is a process that traffic signal engineers employ to

improve traffic operations along a street or roadway. Signals in coordinated operation

mean that phase split duration, phase sequence, and offset all have predefined values.

The cycle length must be the same or fraction of a cycle (e.g., half) for all the signals that

will be under the same timing plan. The process of developing coordination timing is

performed different ways across the United States. The common approach is to collect

traffic volumes at intersections and input them into a volume-based software package,

which will make suggestions to the engineer on what phase splits, offsets, sequences,

and cycle length should be. The engineer will then run phase sequence and offset

optimization, then make fine adjustments to the offsets and sequences on the time-

space diagram based on real-world conditions. Extensive time observing the new timing

in operation is not common because volumes were collected.

A less common approach is to not collect traffic volumes and use a non-volume-based software package to change phase splits and sequences based on whether existing splits and sequences are sufficient or not. Then an engineer either optimizes the phase sequence and offset manually with the time-space diagram, or automatically with the program's optimization function. The new timing would then be implemented in the field and engineers would verify timing, observe conditions, and collect GPS travel runs using the software package.

A major difference between these two methods is on which stage of the project consumes more staff resources (time, budget, etc.) More resources are spent collecting and processing volumes for the first method whereas with the second method, more resources are spent observing and making changes in the field. It is important to know the capabilities and features available with both styles of software packages so the engineers can take advantage of the features available to develop the best timing plans. The usability of the programs is also important when the engineer is to make manual adjustments to the optimization output to ensure real-world operations are considered.

The preferred signal coordination software program should be able to assist the engineer in two major parts. The first part is to have enough options to allow the program to automatically produce a high-quality offset and phase sequence optimization of the arterial. The second part is to be able to view and edit different timing plans which straddle different intersections on a time-space diagram.

1.2   Research Goals

Generally, agencies and consultants use either volume dependent programs or non-volume dependent programs. The main goal of this research is to introduce the arterial-level features for both types of programs to illustrate how using both volume-dependent and non-volume dependent programs can be beneficial. Comparing the offset and phase sequence optimization for the five software programs aims help to traffic engineers decide which program they would like to who may not be familiar with what each of the programs have to offer. For the agencies that utilize the automatic optimization features, the phase sequence and offset optimization inputs, options, and results will be compared. If engineers typically do not use the optimization features, this process provides a practical medium to test out features and limitations of the programs. When engineers typically do not automatically optimize the corridors automatically, they use the time-space diagram to make changes manually and this research ranks the time-space diagrams from a usability and features perspective. This research can also help practitioners decide if collecting volume counts at every intersection will accomplish their goal and whether the program offers the features needed to do the required analysis. Knowing which programs can accomplish what the engineers would like them to can save companies time and money because they can be informed of potential deal breakers of the program before they purchase or start a trial for the software package.

1.3   Selection of the Study Corridor

Sparks Boulevard in the City of Sparks, Nevada is a relatively standard suburban corridor with two lanes in each direction that is congested in the peak directions, access controlled, and has a 40 miles per hour (65 kilometers per hour) speed limit. The length of the corridor to study is 4.2 miles (6.75 kilometers) with 9 signals and has varied signal spacing from 700 feet to almost 1 mile (200 meters to 1.6 kilometers). An aerial map of the corridor is shown in Figure 1. The morning peak hour conditions were chosen to study because of the need to find better solutions to manage the traffic at this time period. Two over capacity intersections along the corridor (Baring Blvd and Greg St) would create a good challenge for the programs to optimize. Sparks Blvd has one clustered intersection that consists of two intersections controlled by one controller with overlaps, which will highlight the capabilities of the programs to accommodate special cases.

The average annual daily traffic (AADT) in 2021 was 29,400 vehicles [1]. The corridor is one of three access routes from the rapidly growing private vehicle-oriented development in Spanish Springs to Sparks and continuing on to Reno. Starting from the north, traveling in the peak southbound direction, Sparks Blvd leaves the Spanish Springs area after passing Disc Dr. Reed High School is adjacent to the corridor at the cross street of Baring Blvd, which is a large trip generator that attracts vehicle trips in the AM peak. South of Baring Blvd, the arterial splits into separate northbound and southbound travelways with an irrigation ditch running down the middle. The

intersection with Springland Dr is the clustered intersection. The arterial returns to a

two-way road at Prater Way and continues south to an interchange with the Interstate

80 freeway. Sparks Blvd ends one intersection further south of the freeway at Greg St,

but the roadway continues south to connect Sparks with South Reno.

1.4   Research Scope

Synchro, Vistro, TransModeler, Tru-Traffic, and TranSync are all separate commercially

available programs designed to assist traffic engineers in designing and optimizing traffic

signal timing. These programs have different features and tools, but most traffic

engineers are not familiar with the capabilities of all five programs. This research aims to

provide insights to traffic engineers so they can learn how the most important signal

coordination tasks are performed in each of the programs on an arterial level. Tru-

Traffic and TranSync include field timing diagnostic tools and trajectory collection tools.

Since these features are not available in Synchro, Vistro, and TransModeler, comparing

the field implementation features would not be fair. All the programs offer an

automatic timing optimization function and the ability to viewing and editing timing

plans from a time-space diagram. In this research, the features, options, and

performance of the default optimization function will be compared. Next, the usability

and features embedded in the time-space diagram will be compared. Finally, the ability

to select certain intersections and timing plans along an arterial to open a time-space

diagram will also be compared.

Figure 1: Aerial view of Sparks Blvd

1.5   Contributions

There are six significant contributions of this research. Firstly, using software programs

for coordination timing optimization is the prevalent method and approach, but many

engineers are not aware of emerging and newer software packages. Secondly, the

research provides insights on these software packages, providing valuable guidance for

the engineer to choose the right tool for cost-effective signal coordination timing

design. The third contribution is that this is the first study known to compare older and

newer software packages. The fourth contribution is that this is also the first study to

compare features and performance between volume-based and non-volume-based

software packages. The fifth contribution is that this is the first study to establish a

definitive list of parameters that exist in a clear, useful, and editable time-space

diagram. The sixth and final contribution is that this is the first attempt to use

trajectories to calibrate a simulation model.

2. Literature Review

Existing literature can be separated into three different sections. The first section covers

the main reasons signal timing is optimized and what the expected benefits are.

Secondly, related traffic software program comparison studies will be discussed. Finally,

the website and user manuals of the five commercial programs will be referenced to,

introducing the company, structure of the software package, and arterial-level

optimization features. No articles or reports have been found to differentiate programs

that are volume dependent or do not require volumes as input. In addition, standards

for recommended time-space diagram features, timing plan management, and field

observing features have not been found. This research aims to fill this literature gap.

2.1 Timing Optimization Background

The Traffic Analysis Tools Primer [2] states that features of traffic signal optimization

tools can include capacity calculations, cycle length and split optimization, and the

ability to create coordination plans. Most likely due to the article published in 2004, only

Synchro and Tru-Traffic (formerly known as TS/PP-Draft) are listed as traffic optimization

tools. There was no distinction with Synchro not requiring volume as input and Tru-

Traffic not requiring it. The Traffic Analysis Toolbox Case Studies report mentions that it

is possible to perform signal timing optimization without software, but using a specific

tool for the task yielded in greater time efficiency (Figure 2.) Any tool can provide a way

for staff to test various scenarios and refine them. Other benefits achieved were

reduced delays and stops [3].
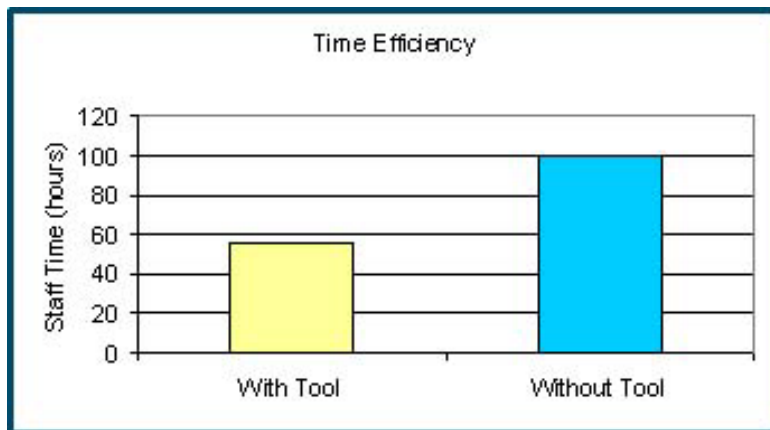
Time Efficiency

Figure 2: Using tools is more time efficient than without [3]

The Signal Timing Manual [4] mentions that to optimize traffic flow conditions at

signalized intersections, phase sequence, offset, phase split, and cycle length can be

adjusted. The signal timing process is usually done using a software program and then

during implementation, judgement will be used to fine-tune mainly offsets, phase splits

in the field. Methods to optimize phase sequence and offsets by hand or with Microsoft

Excel are not the focus of this research.

An overwhelming number of agencies use Synchro because most staff are familiar with

it [5]. Very few agencies use non-volume-based programs for traffic signal optimization

and fewer mention any way of performing fine-tuning and diagnostics as part of the

process. The NCHRP Synthesis 409 discusses necessary volume data for the signal retiming process, for use in a software. The report gives options to obtain turning movement more economically, like collecting data for a short period of time and extrapolating or using an iterative volume balancing software [6]. Neither NCHRP Synthesis 409 nor Signal Timing on a Shoestring (FHWA) mention the option to perform signal timing optimization without turning movement volumes. Signal Timing on a Shoestring even goes further to say, "Regardless of what computer model or manual process the Engineer chooses to use to develop the timing plans, all require network descriptive information and turning movement data [7]." The option to not use volumes was not mentioned in the report.

Existing literature revolves around three major steps in the signal coordination process. The first step is to observe existing conditions which usually involves identifying issues, collecting data, and identifying room for improvement. The second step is to design the timing plans which involves adjusting phase splits and cycle length and then using either an automatic optimization feature or by manually editing the time space diagram to achieve the optimal phase sequence and offset. Another aspect of this step is to analyze an arterial numerically using analytical HCM (Highway Capacity Manual) calculations or simulation methods to experiment with different solutions. The third step is to fine-tune the optimal timing plan both in the program and in the field during implementation.

2.2   Related Comparison Studies

In a report by Andalibian and Tian [8], at the time of publishing in 2012, the most

commonly used optimization programs were TRANSYT-7F, PASSER II. PASSER V, and

Synchro. It was found that programs that optimize the arterial bandwidth produce plans

with fewer stops, such as PASSER II or V. If the primary objective is to reduce network

delay, Synchro is recommended. Ratrout and Reza [9] also performed a case study

comparing the signal timing optimizations between Synchro and TRANSYT-7F. TRANSYT-

7F has more optimization adjustment features compared to Synchro. The case study

involved three intersections in a moderately heavy traffic corridor. Optimization was

performed in each of the two programs and the optimizations were simulated in

PARAMICS. Comparison was done based on queue length and average delay. Cycle

lengths were optimized on an intersection by intersection basis. Therefore, the cycle

lengths were different for each intersection and for each program. Isolated coordination

was running for this case study due to the inconsistent cycle lengths for each

intersection. Phase split optimization was also allowed to be optimized. The

optimization by TRANSYT-7F had a lower queue length and average delay, despite the

optimized cycle length about 10 seconds longer than Synchro. Another comparison of

the optimizations by different programs was done by Benekohal et al. [10]. In this study,

the simulation package CORSIM was used to compare the signal timing optimized

solutions from Synchro, PASSER II, and PASSER IV. Optimizations were intersection

focused (not arterial) and average intersection delay was within 1 second apart from

each other. This study found that at an intersection level, these four programs produced very similar results.

Stevanovic proposed and tested a new way to optimize signal timing using cloud computing and simulation [11]. By leveraging the computing power multiple computers connected to the cloud, Stevanovic claims to be able to optimize network of arterials using simulated scenarios. An advantage of using simulation to develop optimized arterial timing plans is to make use of actuated control early returns and multimodal operations to generate the most advanced optimization. This demonstration makes use of the customizable power of PTV Vissim which is part of the same software package as PTV Vistro.

The time-space diagram is the basis of signal timing optimization. A time-space diagram is a graph with time on the horizontal axis and distance on the vertical access. Time is measured in seconds and distance is measured in feet from a reference point, usually the first intersection on the corridor to be analyzed. Therefore, the slope of the line represents the speed of the vehicle and curved portions represent change in speed such as acceleration [12].

2.3   Program Introduction and Features

Synchro, Vistro, TransModeler, Tru-Traffic, and TranSync are all developed by different

companies, with varying number of customers and familiarity among traffic engineers.

All five programs have a similar timing settings input. However, with regards to traffic

volume input, the programs are divided into two categories: volume based and not

volume based. Synchro, Vistro, and TransModeler belong to the volume-based category,

meaning that inputting traffic volumes of each approach are imperative for the program

to make a traffic analysis. These programs both rely on equations from the Highway

Capacity Manual and use microsimulation to get results. However, TranSync and Tru-

Traffic do not use volume as an input to generate results. Instead, these two programs

maximize the arterial through bandwidth and use GPS trajectories from driving a vehicle

up and down the corridor to get performance outputs. The different features and

optimization options for all five programs are summarized in Table 1.

The costs of these commercial products depend on the number of licenses bought and

whether a private company or public agency using the software. Developers often

provide an education discount. While an approximate license cost is difficult to convey,

in general, Tru-Traffic is the cheapest and TranSync is the most expensive with the other

software packages falling in the middle. Other factors should be considered in the costs

of the licenses such as whether a license is tied to a specific computer, the cost of

technical support, time efficiency using the software, the cost of collecting the volumes,

and method of fine-tuning.

Table 1: Optimization features summary

Features	Synchro	Vistro	TransModeler	TranSync	Tru-Traffic
Volume required	Yes	Yes	Yes	No	No
Sequence optimization	Yes	Yes	No	Yes	Yes
Lock more than one offset	Yes	No	No	Yes	No
Lock sequence	Yes	Yes	N/A	Yes	Yes
Directional weighting	Yes	Yes	No	Yes	Yes
Zones or routes defining	Yes	Yes	Yes	Yes	No

2.3.1   Synchro

Synchro is part of the Synchro Suite which is manufactured by Trafficware, owned by

the multinational Cubic Corporation. Based on responses from an AASHTO report,

Synchro Suite is the most popular traffic analytical/deterministic tool around the United

States [5]. Within Synchro Suite there is Synchro and SimTraffic. Intersection coding is done in Synchro while simulation is done in SimTraffic. Intersection control settings in Synchro can cover most of the most complex phasing and when intersections influence each other [13].

According to the Synchro manual, [14] offset optimization in Synchro is done by varying the offset by user specified intervals until the optimizer finds the solution with the lowest delay. The manual does not specify more information about what kind of delay is minimized and how. The optimizer alternates between treating the intersections as individual intersections and as clusters. This means that Synchro automatically checks for intersections to partition and optimizes the offsets for each partition separately. Figure 3 shows that the user can give a greater weight to the reference phase if desired and that Synchro can also optimize phase sequence.

2.3.2   PTV Vistro

PTV Vistro is a volume and network geometry-based traffic modeling tool which is similar to Synchro. PTV is based in Germany and its main product, Vissim is used around the world for detailed microsimulation projects. Vistro was developed primarily for the North American market to provide easier analysis for ring-barrier intersections compared to PTV Vissim. Vistro can model signalized, unsignalized intersections, and

roundabouts using HCM methodology. Simulation is performed with Vissim and Vistro

networks are able to be imported relatively easily into Vissim [15].
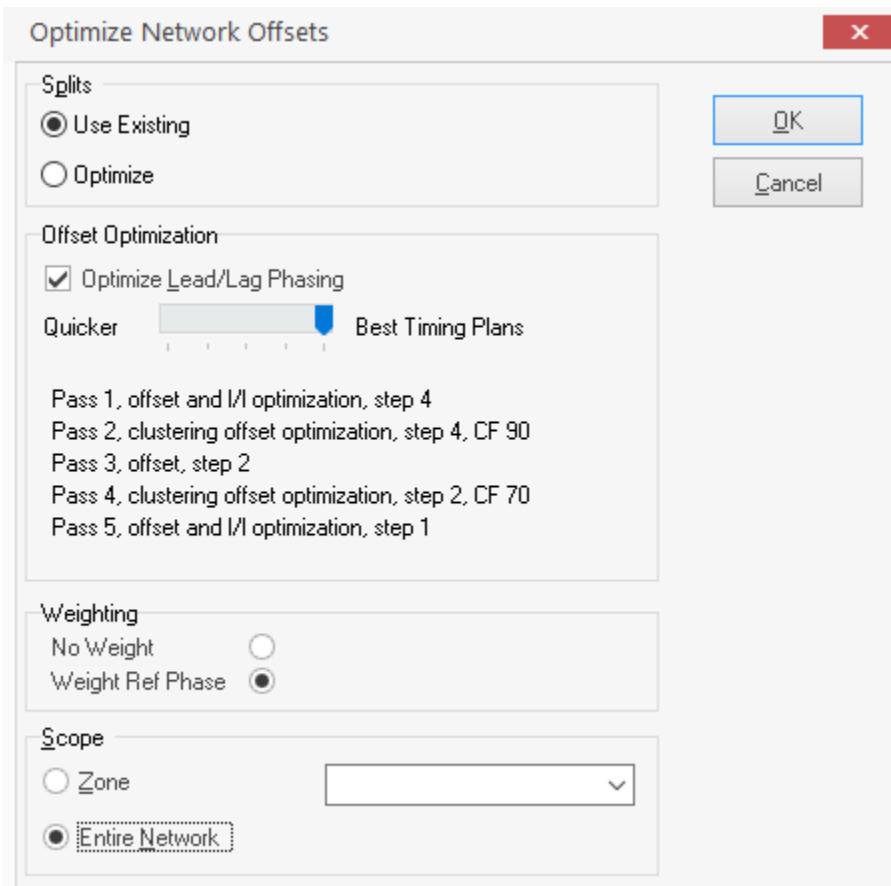
Figure 3: Synchro optimization options

According the Vistro manual, [16] network optimization uses a platoon dispersion model

to reduce the delay and number of stops between intersections. The objective is to

change the signal timing so that vehicles can go through several consecutive signals on

green. Vistro can have several "signal groups" within one arterial, so different groups of

signals can be optimized separately if needed. The user must create a route which can

go around corners and the signals will be optimized to travel along that route. There are

two different network optimization algorithms to choose from in Vistro: Genetic and Hill

Climbing. Genetic is the default method where the objective function has a weighted

sum of delay and number of stops, which is to be minimized. The user can change the

number of iterations, population size, number of generations without improvement,

and minimum improvement. The Hill Climbing method uses the same objective function

but the user can only specify the number of starting solutions. Figure 4 shows the

network optimization parameters, including the option to optimize phase sequence. The

user can specify priorities for various routes, as seen in Figure 5.

Figure 4: Vistro optimization options

Figure 5: Route priorities view

2.3.3   TransModeler

TransModeler SE is a volume and network geometry-based traffic modeling and microsimulation software. It is developed by Caliper, an American based transportation software company. TransModeler SE is one program that does both timing/geometry coding and simulation. TransModeler provides arterial signal optimization using both analytical and simulation methods [17].

According to the TransModeler manual, [18] offset optimization starts with the Kell Method, which aims to produce approximately equal bandwidth in each direction [7]. Then a simulation is run to produce arrival profiles and signal actuations which are used as inputs for the optimization function. The objective function is to reduce the Performance Index which is based on average control delay, average queue length, arrival on green, and average number of stops and the user can specify weights to all these parameters (Figure 6) to develop arrival on green percentages and performance

indexes. The offsets with the greatest opportunity for improvement for the arrival on green percentage is selected to be rerun and repeated the number of user specified iterations. No record of phase sequence optimization is found in the manual. The user can specify weights of performance index factors as shown below. Because TransModeler uses simulation for optimization, it takes longer but is expected to have better results.
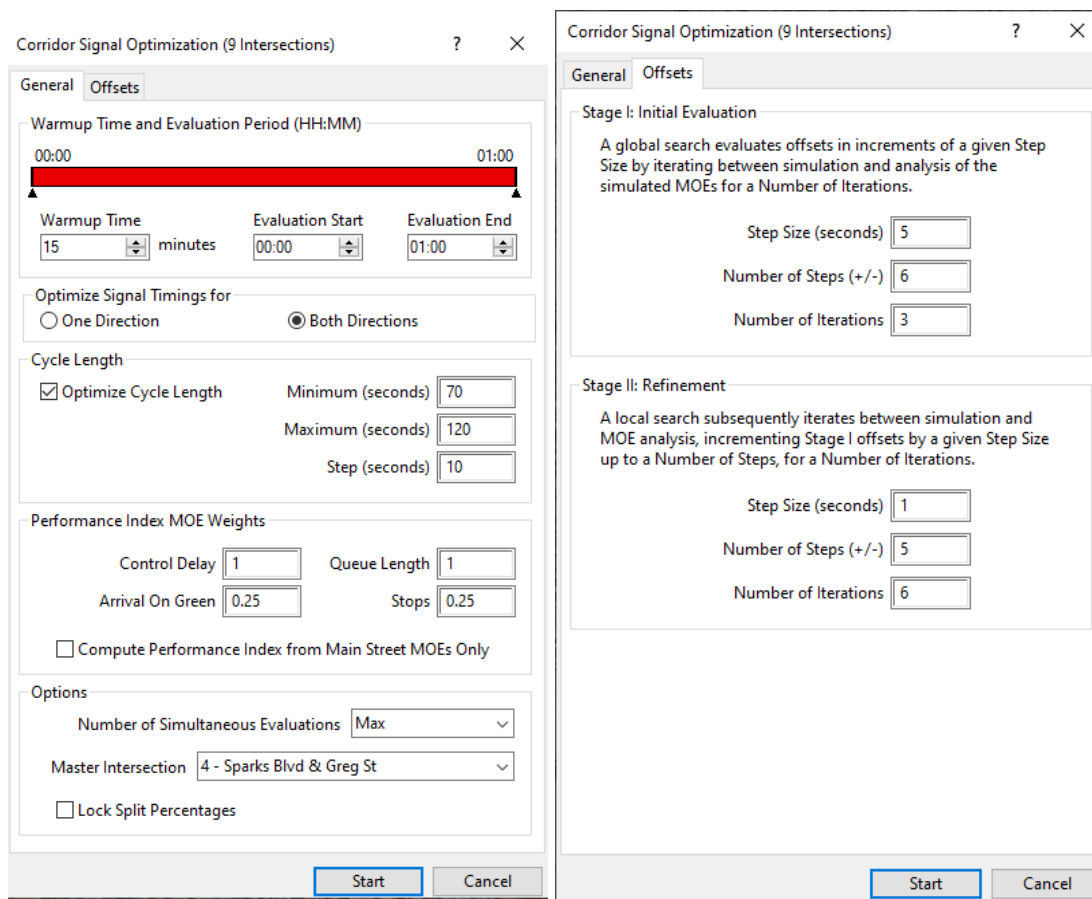
Figure 6: Optimization options in TransModeler

Intersection control settings offered with TransModeler are standard and very similar

with Synchro and PTV Vistro. One difference is with how volume is displayed; the

default visibility of which direction's traffic volume is being edited is reduced. The

display of the volumes is in a matrix-like format opposed to all in one row. Volumes of a

right turn channelized movement must be edited in a different window.

2.3.4   Tru-Traffic

Tru-Traffic is also a signal timing focused program but does not require volume inputs to

generate timing optimization. Even though volumes can be inputted into the program,

volumes are not used in any way to generate the time-space diagram. Number of lanes

and saturation flow rates can be inputted, but just like volumes, these parameters are

not used in timing optimization [19]. These parameters are used when displaying

platoon-flow diagrams and for exporting to UTDF (Universal Traffic Data Format) files.

Signals are placed on a satellite map and existing timing is put in. Timing is adjusted by

changing phase splits and viewing the time-space diagram to make phase sequence and

offset adjustments. Real time floating car travel runs and diagnostics are done by a

laptop in the passenger seat with a USB GPS receiver. Video needs to be collected

separately and synced up to a user recorded screen (not a program feature) in a video

editing software [20].

According to the Tru-Traffic manual [19], offset and phase sequence optimization is attempted to get good progression in both directions. The method used is "Half-Cycle Multiples" where the middle of green for each intersection is roughly aligned, attempting to form the widest bandwidth in both directions. Figure 7 and Figure 8 show that phase sequence optimization, priority for directions, and priority for different modes of transportation is possible. Travel time and delay reports can be automatically generated using GPS trajectories gathered while driving along the corridor.
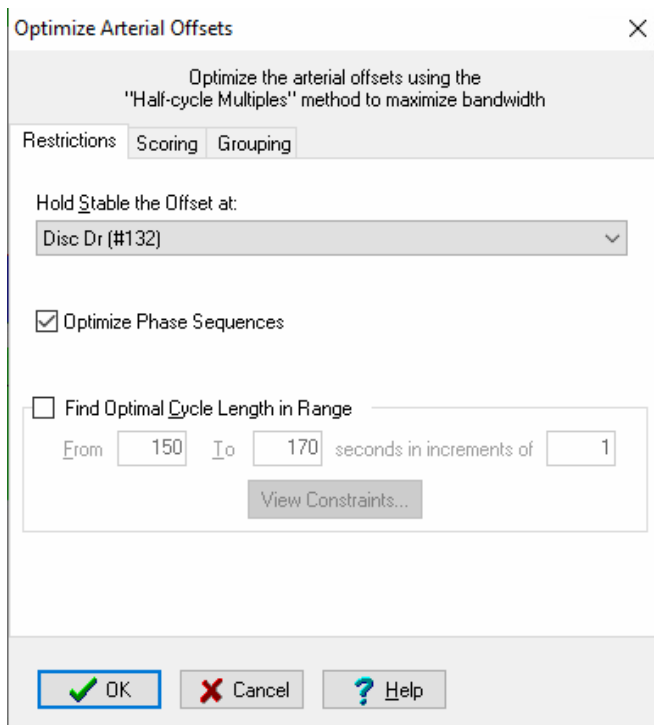
Figure 7: Options include holding an offset stable and sequence optimizing
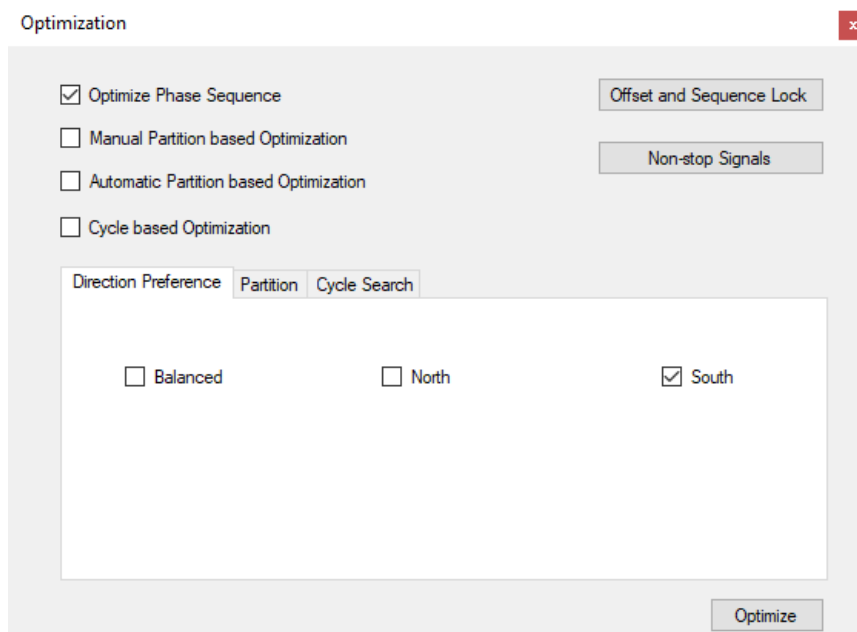
Figure 8: Directional weighting and multimodal options are available

2.3.5   TranSync

TranSync is a signal timing focused desktop and mobile device software package that

does not use volume as an input. The user inputs signalized intersections on an internet

map which are then geolocated. Arterial timing is optimized by changing the phase

sequences and offsets to achieve the maximum two-way bandwidth between signals.

Timing is then fine-tuned in the field with the mobile app acting as a diagnostic tool [21].

TranSync-D (desktop) can import trajectories from GPS files which can be recorded on

an Apple mobile device running TranSync-M (mobile) or from connected vehicle data.

Measures of effectiveness such as travel time, number of stops, greens per red, and

more can be automatically generated.

According to the TranSync manual [22], optimization is done by maximizing green

bandwidths in both directions. The program also offers automatic partitioning of the

arterial and optimizing separate groups of signals. Figure 9 and Figure 10 show the

optimization settings which include phase sequence, partition options, cycle, and

directional preference.

Figure 9: Direction preference for optimization settings
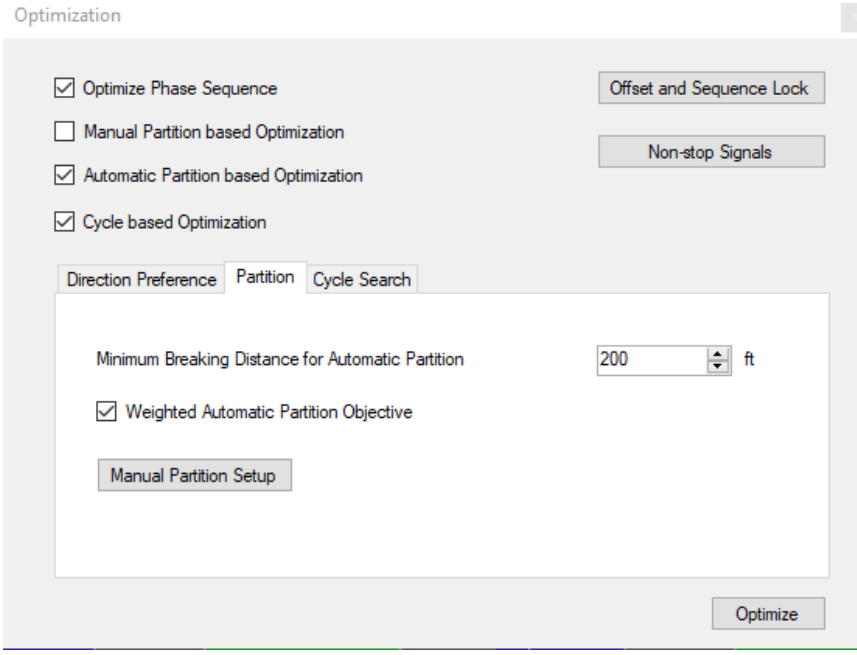
Figure 10: Partition optimization settings

A summary of features relating to arterial optimization was shown in Table 1. More

detailed information is located in the results section.

3.   Methodology

The methodology behind this research consists of two parts. The first part is to prepare

and optimize the study corridor. The second part is to compare the time-space diagrams

and their associated features.

3.1   Default Optimization

To compare the signal offset and sequence optimization from each of the five programs,

the study corridor was modeled in each of the five programs. The first program to model

the corridor in was Synchro because the four other programs are able to import Synchro

models to accelerate model development. Since the import process is usually not

perfect, adjustments were needed or in some cases, complete remodeling. After the

geometry, speeds, and existing signal timing were correctly modeled in each of the five

programs, the next step was calibration. Only one software model was required to be

calibrated because only one simulation modeled is needed to compare the

optimizations. To be the least biased as possible toward the optimization solutions from

Synchro, Vistro, and TranSync, TransModeler was chosen as the third-party simulation

program. Since Synchro has its own simulation program (SimTraffic), it would not be fair

to test Synchro's arterial optimization with SimTraffic because the two programs are

made by the same company. The optimization of PTV Vistro could be tested with PTV

Vissim, but that might be biased towards PTV Vistro's optimization. Tru-Traffic and

TranSync do not have their own simulation programs within their software packages, so

it is easy to use a third-party simulation program. To calibrate the model, the number of

trips for all the origin-destination (O-D) pairs were adjusted until travel times, queues,

and number of stops were close to existing field conditions. The resulting O-D trips were

converted into intersection volume counts and these counts were inputted into the

volume-dependent programs which are Synchro and Vistro. Now, optimization was able

to be run for all five programs. The same arterial was modeled into all five of the

programs so that each program's optimization function could be executed. The resulting

offsets and phase sequences for each of the programs were inputted into separate

TransModeler scenarios to simulate independently of each other. The process to model,

optimize, and compare each of the program's optimized timing is shown in Figure 11.
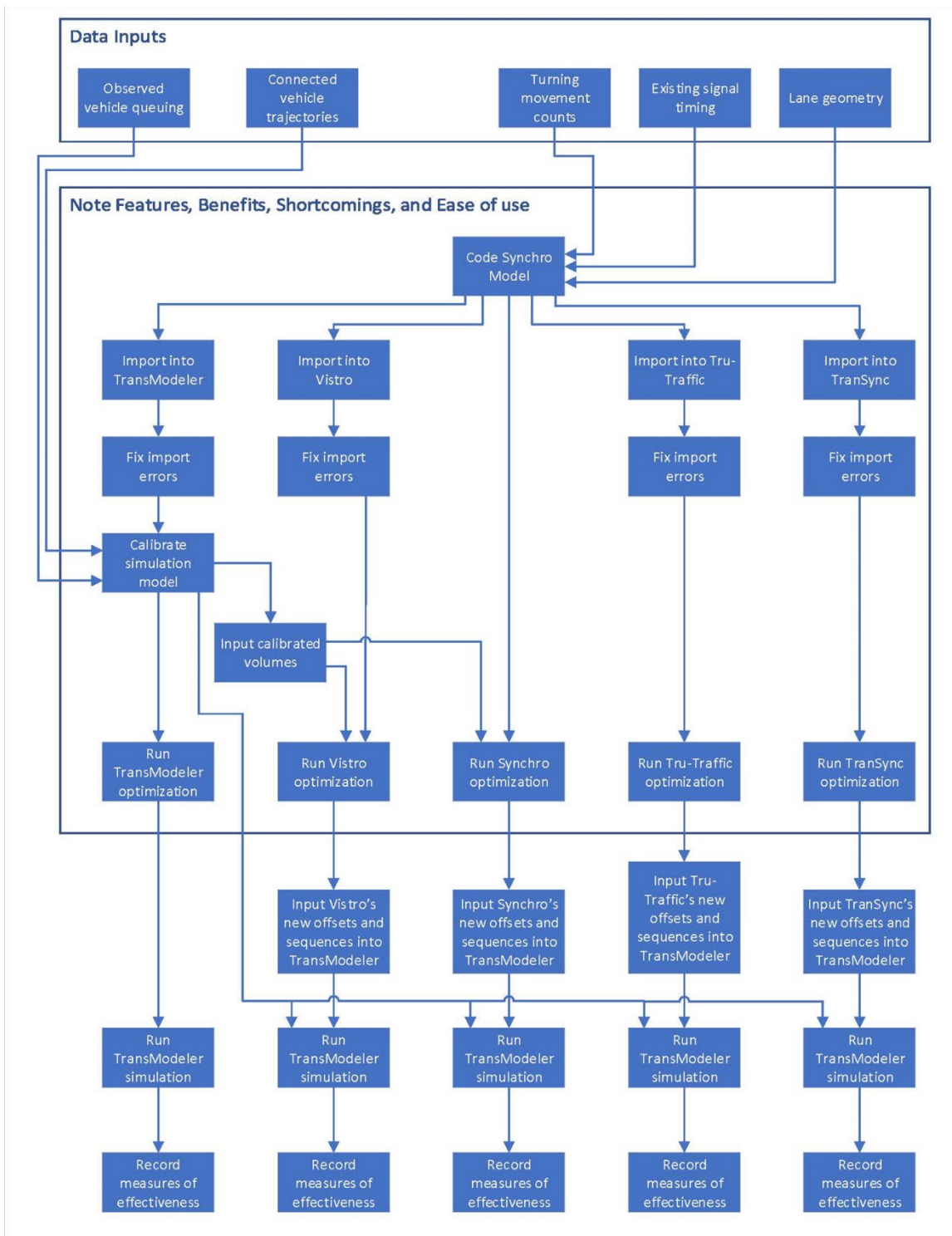
Figure 11: Optimization process flow chart

3.1.1   Model Synchro

First, an arterial needed to be selected for evaluation. While a fictional corridor could be

used to learn how to use the programs and optimize the timing, the full experience of

using the programs would not be possible. The ideal corridor would have underlying

problems associated with it, such as traffic congestion. Traffic volume counts and signal

timing settings are also important to be able to have access to. Based on these factors,

Sparks Boulevard in Sparks, Nevada was chosen.

The next step was to code Sparks Blvd into Synchro. Geometry features of the roadway

was gathered and transferred manually from the included aerial imagery background

maps in Synchro. Manual geometry coding involves looking on aerial imagery to see

how many lanes go in which direction, medians, turning lane storage length, and other

features that define the footprint of the corridor.

Since Synchro requires traffic volume for each movement, a combination of counts

taken from 2010 and 2019 were used to estimate the traffic volume. All intersections

had 2010 counts but only the southern half of the intersections had 2019 counts. Counts

were extrapolated based on the input of the downstream volume and adjusted for

growth based on the 2010 and 2019 counts. Volumes were then balanced throughout

the whole corridor.

Existing signal timing parameters were obtained from the Washoe County Master Model

which is a TranSync file that has all the timing plans of all the coordinated signals in the

region. The existing coordinated signal timing for the morning peak plan was then

verified with the most up-to-date timing from the central traffic management system

from the City of Sparks. To keep track of all the timing produced throughout this

research, a separate TranSync file with just Sparks Blvd would act as a database. This

database has the existing timing and stores each of the optimizations outputted from

the five total programs. Geometry, phasing, signal timing and other parameters were

coded into Synchro. Volumes and existing signal coordination timings were inputted as

well. Volumes are balanced using the volume balancing overlay in Synchro.

3.1.2   Export Synchro and Import into Other Programs

Synchro was exported into the Universal Traffic Data Format as a *.csv file. This file was

then imported into each of the four remaining programs. This saved time and the

import process was relatively accurate with the exception of the unique geometry

involved with Springland Dr.

3.1.3   Model Calibration

Model Calibration is technically not required if the goal is simply to compare the

optimizations of each of the software packages. An optimization can be performed on

any corridor whether observed or fictional volumes and geometry are inputted. But to

make the results useful and realistic, model calibration was performed for Sparks Blvd.

Field visits to the corridor during the study period of 7:00 a.m. to 8:00 a.m. assisted in

verifying geometry, signal timing, and finding out what expected travel times, delay, and

queues were. Model calibration was done primarily in the third-party simulation

software package, TransModeler. When simply inputting turning movements into

TransModeler, only a handful of trips traversed the whole nine intersection corridor.

This is because at every intersection, there is a chance the vehicle that just went

through the previous intersection will turn left or right at the next intersection.

3.1.3.1   Volumes to O-D Matrix

Instead of using turning movement volumes, complete trips were inputted using an

origin-destination (O-D) matrix. TransModeler is the only program studied for this

research that has such capability. Estimated base volumes from Excel and Synchro were

inputted into TransModeler and verified. TransModeler can take turning movement

counts and turn them into an O-D matrix. The matrix will need adjustments to better

model the number of vehicles making longer trips on the corridor. One major advantage

to using O-D trips instead on intersection by intersection turning counts is volume

balancing between intersections is no longer necessary. When adding trips to the O-D

matrix, the turns the trip makes while traversing the network is automatically coding the

number of through and turns at each intersection the trip goes through. Figure 12

shows the O-D matrix and when the user clicks on a certain O-D pair; the route is

automatically highlighted to easily visualize where the trip is going.

Matrix1 - Trip Matrix - Count								— □ ×
	1	2	3	6	7	8	9	21	Sum
1	--	15.00	400.00	12.00	437.00	20.00	61.00	78.00	1214.00
2	74.00	--	10.00	2.00	150.00	4.00	11.00	39.00	516.00
3	300.00	5.00	--	4.00	200.00	10.00	22.00	10.00	629.00
6	13.00	8.00	5.00	--	20.00	60.00	60.00	20.00	338.00
7	218.00	20.00	435.00	15.00	--	33.00	76.00	50.00	1073.00
8	6.00	4.00	2.00	26.00	17.00	--	70.00	3.00	519.00
9	75.00	25.00	25.00	100.00	190.00	150.00	--	150.00	1026.00
20	100.00	25.00	30.00	20.00	200.00	43.00	100.00	2.00	914.00
29	10.00	1.00	5.00	2.00	30.00	2.00	6.00	28.00	113.00
41	7.00	4.00	10.00	3.00	71.00	7.00	15.00	14.00	176.00
65	59.00	7.00	23.00	6.00	160.00	12.00	28.00	31.00	399.00
99	15.00	9.00	5.00	11.00	39.00	24.00	55.00	8.00	334.00
100	30.00	20.00	4.00	6.00	100.00	15.00	35.00	50.00	403.00
101	37.00	305.00	14.00	9.00	101.00	22.00	50.00	19.00	612.00
108	6.00	4.00	2.00	13.00	100.00	350.00	65.00	100.00	667.00
Sum	1002.00	483.00	1031.00	305.00	1951.00	887.00	708.00	703.00	9788.00

Figure 12: O-D matrix and associated path in TransModeler

3.1.3.2 Trajectories

Trajectories were collected from connected vehicle data. To have access to more

trajectories, connected vehicle data for the corridor was extracted from Wejo. Wejo is a

data service that compiles and redistributes connected vehicle trips. Wejo offers anonymous connected vehicle trajectories which provide complete origin-destination trips of vehicles traveling throughout a selected region. A supplemental software program called STEP (Systematic Trajectory Extraction Program) was developed at University of Nevada, Reno can automatically extract connected vehicle trips and place them on a time-space diagram passing through requested signals. Figure 13 shows one time period of trajectories on the TSD. The user can scroll to the left to see trajectories earlier in the AM period or to the right to see later time periods. One can also zoom in to better see the queue lengths and get a more detailed view including the instantaneous speed and time at which the data point was collected. The benefit of using connected vehicle trajectories instead of GPS trips collected by the engineer is that a greater number of trips from any origin and destination are available to analyze. Collecting the number of trips used in this research (87) would take weeks of valuable engineer's time. Numerous trips can be referenced when calibrating the TransModeler simulation without going into the field to collect as many travel runs. Observations of side street traffic and traffic patterns were also made in person at Sparks Blvd.
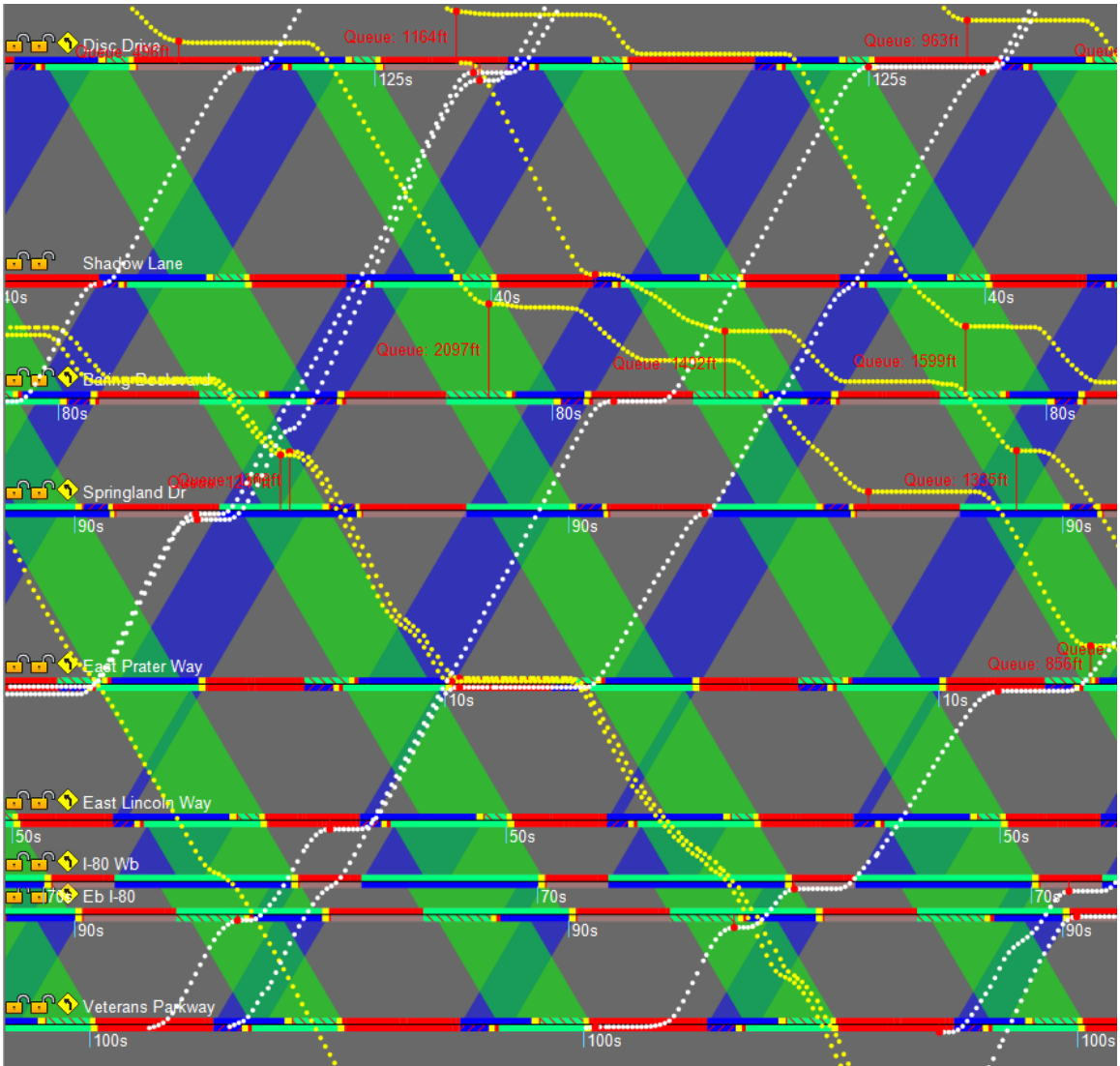
Figure 13: Connected vehicle trajectories on a TSD

Trajectories revealed several patterns which were used to adjust O-D trips in the

TransModeler model. Trajectories were extracted from trips made on March 9th and 10th

2022 from 7:00 a.m. until 8:00 a.m. To capture arterial change in demand, the trip

statistics were divided into four categories separated every 15 minutes. Southbound

trips were the focus of the timing plans and have by far more volume than northbound

trips. Average trip statistics for each interval can be found in Table 2 for southbound

trips while northbound trips are in Table 3. Southbound trips were well represented in

the connected vehicle data with 11-16 trips per 15-minute time interval. However,

northbound trips had a small sample size of 1-4 trips per 15-minute interval because not

many vehicles are moving from Greg St. to Disc Dr. in the morning. Major observations

to emulated in TransModeler are summarized in Table 2 and Table 3.

Table 2: Southbound Trip Statistics

Time Interval	Average Travel Time (min)	Average Number of Stops
7:00 – 7:15 a.m.	6.4	0.8
7:15 – 7:30 a.m.	11.3	5.4
7:30 – 7:45 a.m.	12.3	5.9
7:45 – 8:00 a.m.	11.0	5.0

Table 3: Northbound Trip Statistics

Time Interval	Average Travel Time (min)	Average Number of Stops
7:00 – 7:15 a.m.	8.3	2.7
7:15 – 7:30 a.m.	9.8	5
7:30 – 7:45 a.m.	8.7	3.0
7:45 – 8:00 a.m.	8.5	3.3

The first time interval is from 7:00 a.m. to 7:15 a.m. The selected trajectory within the time interval started at 7:02 a.m. and lasted until 7:08 a.m., resulting in a travel time of 6 minutes. The average speed was 42 mph and there was 1 stop. Since the speed limit for the corridor is 40 mph, it was common to see vehicles speeding. Figure 14 shows the vehicle trajectory for the selected trip to emulate in TransModeler. Table 4 lists the stops and other notes for the trajectory.

The second time interval is from 7:15 a.m. to 7:30 a.m. The selected trajectory within the time interval started at 7:22 a.m. and lasted until 7:31 a.m., resulting in a travel time of 9 minutes. The average speed was 26 mph and there were 3 stops. Figure 15 shows the vehicle trajectory for the selected trip to emulate in TransModeler. Table 5 lists the stops and other notes for the trajectory.

The third time interval is from 7:30 a.m. to 7:45 a.m. The selected trajectory within the time interval started at 7:31 a.m. and lasted until 7:45 a.m., resulting in a travel time of 14 minutes. The average speed was 18 mph and there were 6 stops. Figure 16 shows the vehicle trajectory for the selected trip to emulate in TransModeler. Table 6 lists the stops and other notes for the trajectory.

The fourth time interval is from 7:45 a.m. to 8:00 a.m. The selected trajectory within the time interval started at 7:45 a.m. and lasted until 7:58 a.m., resulting in a travel time of 13 minutes. The average speed was 19 mph and there were 6 stops. Figure 17 shows the

vehicle trajectory for the selected trip to emulate in TransModeler. Table 7 lists the

stops and other notes for the trajectory.
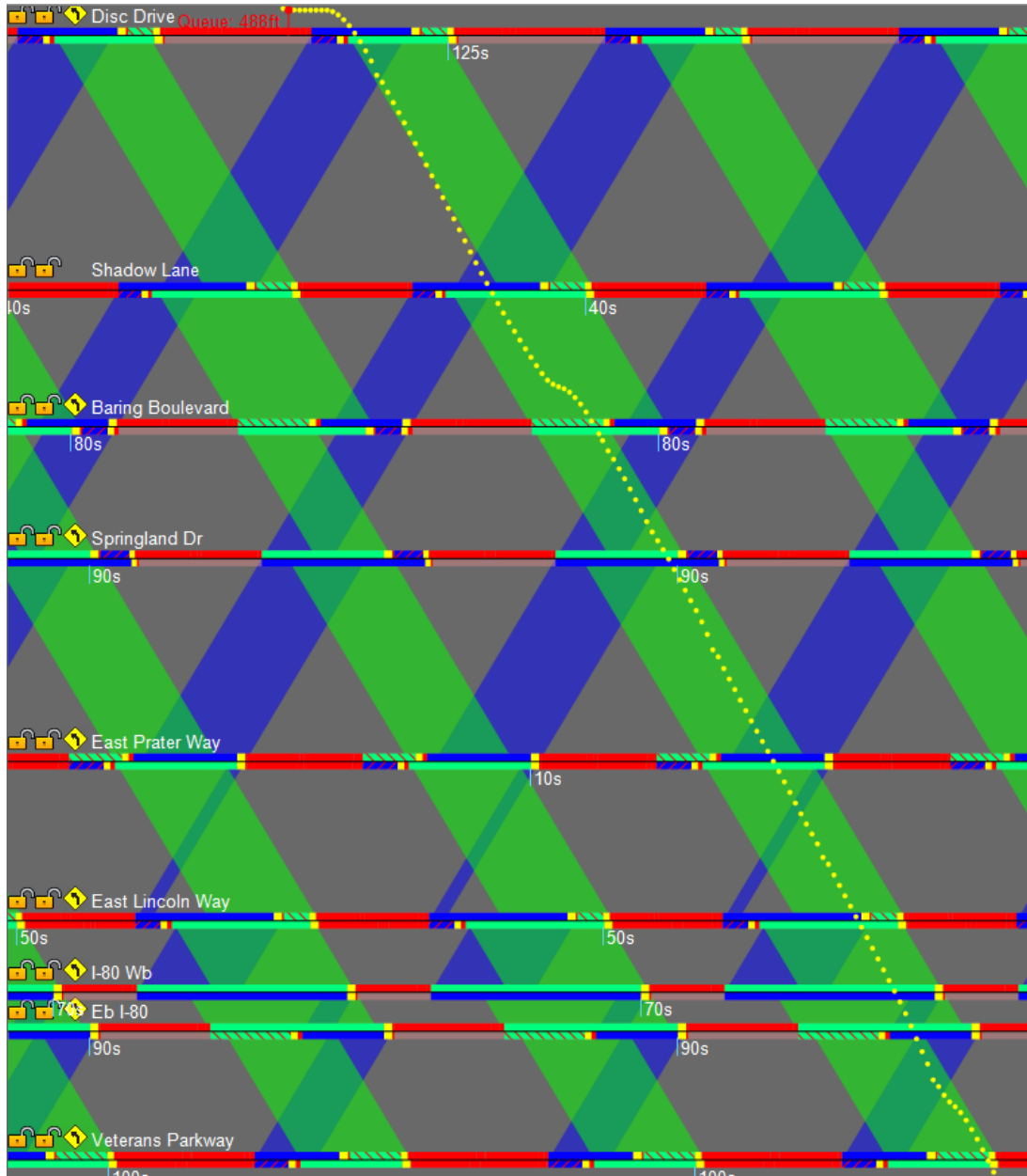
Figure 14: Southbound off-peak trajectory on a time-space diagram

Table 4: Representative southbound off-peak trip

Intersection	Time	Notes
Disc Dr	7:02	Trip starts
Baring	7:04	Slow down- not stop
Greg	7:07	Slight slow down
Greg	7:08	End of trip
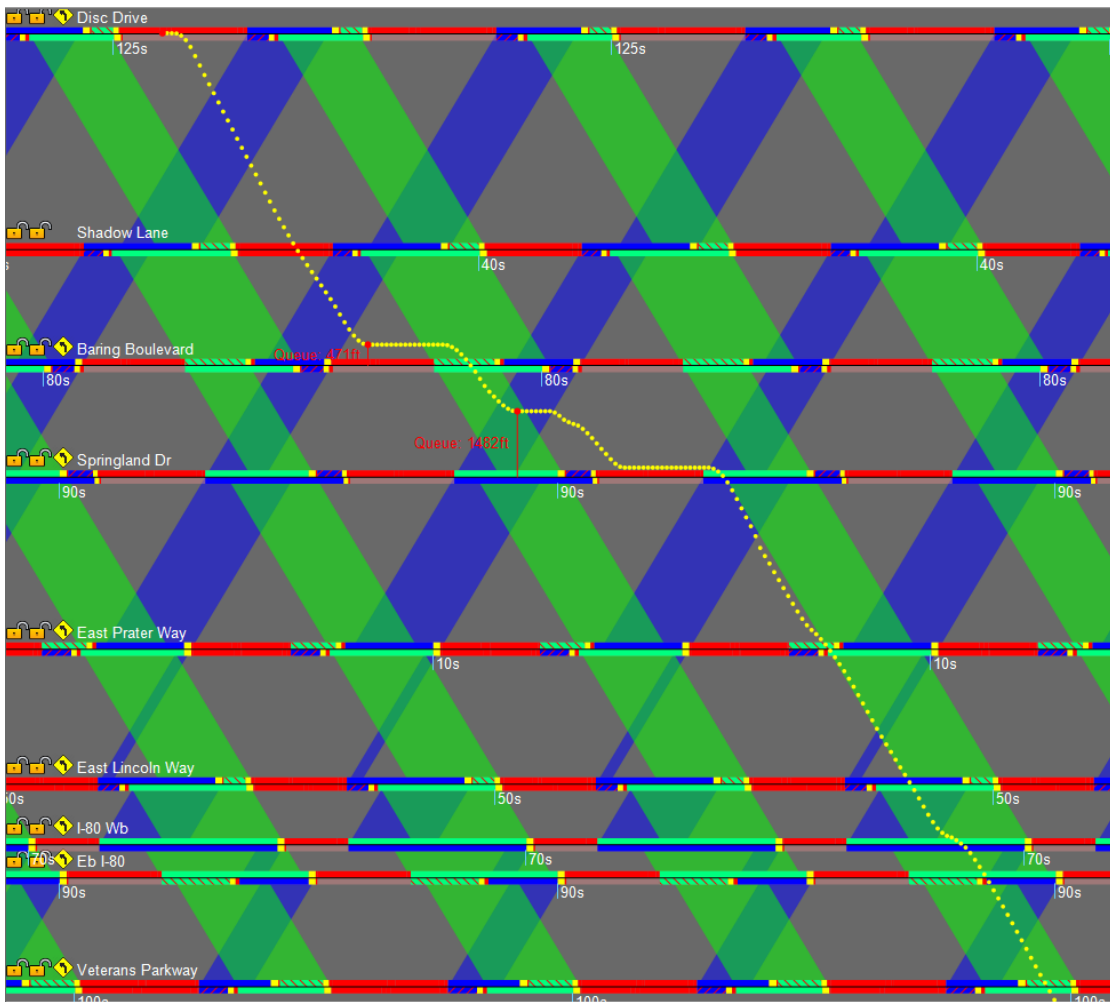
Figure 15: Southbound early-peak trajectory on a time-space diagram

Table 5: Representative southbound early-peak trip

Intersection	Time	Notes
Disc	7:22	Trip starts
Baring	7:24	1st stop- close to intersection
Springland	7:26	2nd stop- 1500 ft queue length (halfway after baring)
Springland	7:27	3rd stop – long stop close to intersection
Prater	7:29	Prater early return allows vehicle to go through with slight slow down
WB I-80	7:31	Slight slow down
Greg	7:31	End of trip
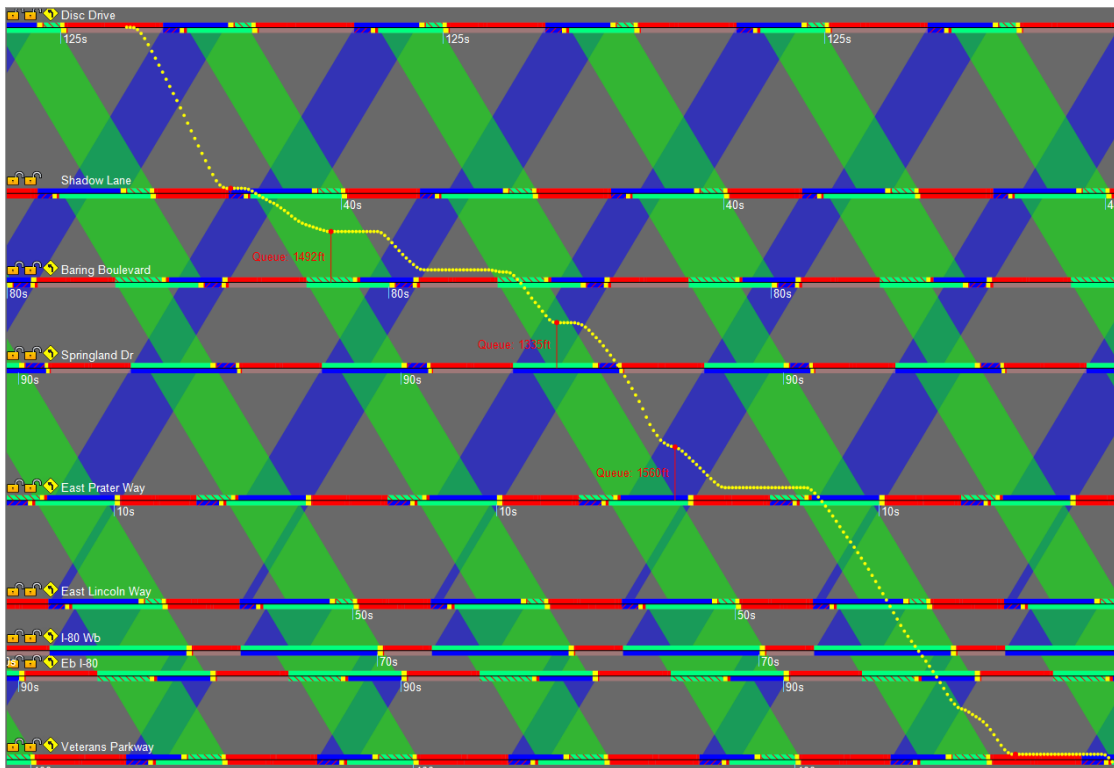
Figure 16: Southbound mid-peak trajectory on a time-space diagram

Table 6: Representative southbound mid-peak trip notes

Intersection	Time	Notes
Disc	7:31	Trip starts
Baring	7:33	1st stop- 1600 ft queue length (2/3 before Baring
Baring	7:35	2nd stop – close to intersection
Springland	7:37	3rd stop – 1335 ft queue length (halfway before Springland)
Prater	7:38	4th stop (short) – 1560 ft queue length (1/3 before Prater)
Prater	7:39	5th stop – close to intersection
Greg	7:42	Slow moving vehicles starting at 2/3 distance to Greg
Greg	7:43	6th stop – close to intersection
Greg	7:45	End of trip
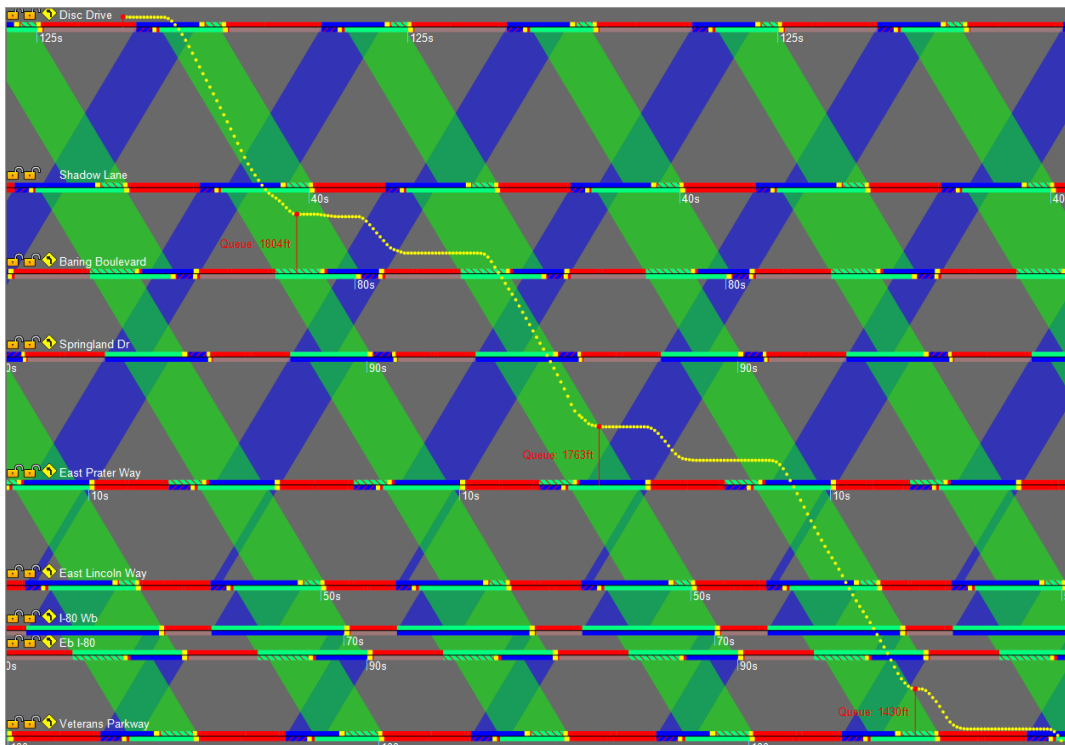
Figure 17: Southbound late-peak trajectory on a time-space diagram

Table 7: Representative southbound late-peak trip notes

Intersection	Time	Notes
Disc	7:45	Trip starts
Baring	7:47	1st stop- 1804 ft queue length (3/4 distance before Baring)
Baring	7:48	2nd stop – (1/4 distance before Baring)
Prater	7:51	3rd stop – 1763 ft queue length (halfway before Prater)
Prater	7:52	4th stop – (1/4 before Prater)
Greg	7:56	5th stop – queue length 2/3 distance to Greg
Greg	7:57	6th stop – close to intersection
Greg	7:58	End of trip

3.1.3.3 Trip Adjustment

After analyzing the trajectories, the next step was to manually adjust the number of trips in the O-D matrix so that Sparks Blvd has approximately the same queue lengths and locations of stops as in real life. This is done by a time-intensive process that involves running a simulation (built into TransModeler) and visually inspecting the queue length at several time of the morning simulation. If one O-D matrix resulted in too short of a travel time compared to the Wejo trajectories at a specified time interval, either the number of trips was reduced in an area that had shorter queues than expected or the percentage of overall trips for the time period was reduced. Editing both main street trips and side street trips is required to achieve the approximate amount of early return to green for the main street.

3.1.3.4 O-D Matrix to Turning Movement Counts

After manually adjusting the O-D trip matrix to result in a good representation of real-world conditions in TransModeler, it is time to copy the trips into Synchro and Vistro in order to run optimization with those programs. TransModeler has an automatic tool that can transform an O-D trip matrix to intersection by intersection turning movement counts. A turning movement file is generated by TransModeler where it is then converted into a universal format that Synchro and Vistro can read. This file is then imported into Synchro and Vistro and then optimization is ready to be run in both of these programs.

3.1.3.5 Calibration Results

Due to the nature of morning peak traffic, it fluctuates within one hour. Based on field

observations and Wejo data, Figure 18 shows the distribution of the hourly volume that

was decided on. The peak congestion period is from 7:30 a.m. until 7:45 a.m. and the

last 15-minute interval is still heavy but recovering from the short peak.

Table 8 compares the real-world and theoretical average travel time and number of

stops, to show that the model is close to real life.
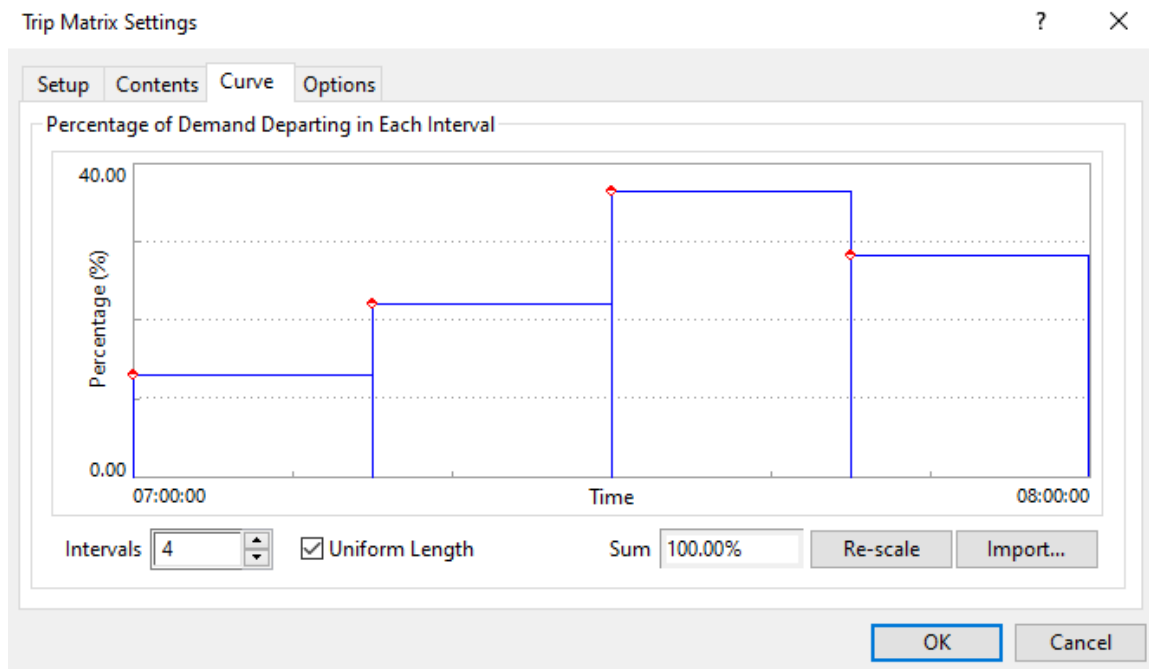
Figure 18: 15-minute simulated volume intervals

Table 8: Real-world and Calibrated travel time and number of stops

Connected Vehicle Trajectories (Real-world)				
Existing	**Northbound**		**Southbound**	
Time Interval	**Travel Time (min)**	**Stops**	**Travel Time (min)**	**Stops**
7:00 – 7:15 a.m.	8.3	2.7	6.4	0.8
7:15 – 7:30 a.m.	9.8	5.0	11.3	5.4
7:30 – 7:45 a.m.	8.7	3.0	12.3	5.9
7:45 – 8:00 a.m.	8.5	3.3	11.0	5.0
Calibrated Model (TransModeler)				
	Northbound		**Southbound**	
Time Interval	**Travel Time (min)**	**Stops**	**Travel Time (min)**	**Stops**
7:00 – 7:15 a.m.	8.4	2.8	7.9	1.4
7:15 – 7:30 a.m.	9.9	3.4	11.3	3.4
7:30 – 7:45 a.m.	9.8	3.4	12.6	4.4
7:45 – 8:00 a.m.	9.5	3.1	11.5	3.5

3.1.4   Optimization Options

After all the imported models were checked and verified for accuracy, optimization was run. The optimization settings were kept as close to default as possible, resulting in the following directional favorability settings for optimization:

- Synchro: weight the reference phase (southbound)

- PTV Vistro: 67% southbound favorability, 33% northbound favorability

- TransModeler (bonus): automatic direction favoring

- Tru-Traffic: 67% southbound favorability, 33% northbound favorability

- TranSync: southbound favorability

The default objective functions that were auto populated in the optimization window were used for this test. These objective functions and weights are default and were used:

- Synchro: no additional options

- PTV Vistro: Genetic

  o Delay weight: 1

  o Number of stops weight: 0.02

  o Maximum number of iterations: 100

  o Population size: 20

  o Number of generations without improvement: 50

  o Minimum improvement: 1%

- TransModeler (bonus):

  o Control delay weight: 1

  o Queue length weight: 1

  o Arrival on green weight: 0.25

- Stops weight: 0.25

- Tru-Traffic:

    - 100% cars (same travel speed as corridor)

    - Excess directional asymmetry: -1

    - Partial arterial bandwidth: 1

    - Bandwidth trimmed from -1 to 0

- TranSync: default (no measure of effectiveness options because no volume input)

3.1.5 Optimize and Compare Timings

The sequence and offset optimization procedures were executed for each program except TransModeler because TransModeler cannot optimize the phase sequence. TransModeler was to be a bonus optimization because there is a chance that TransModeler's optimization gets simulated more logically using the same program. To see the differences in optimization solutions easier, the offset of the southernmost intersection was held constant at its original value of 100 seconds, when the program allowed for this offset lock. If the only way to lock an offset is to set the intersection as a master intersection, then the offset would be automatically set to zero. In this case, all offsets were increased by 100 seconds. The optimized phase sequence and offset for each program was then inputted into different timing files of TransModeler. The timing files (*.tms) acted as scenarios would in Synchro and the selectable timing files were set up as follows:

1. Existing Conditions

2. Synchro Optimization

3. PTV Vistro Genetic Optimization

4. TransModeler Optimization (bonus)

5. Tru-Traffic Optimization

6. TranSync Optimization

Now the optimizations need to be objectively compared with each other. New optimized timing was inputted manually into the TranSync database made specifically for this project. Having all the timings in one format and one file makes it easier to copy over the timing to all the TransModeler timing files, which would then be simulated. This was done using TransModeler and the average travel time and average number of stops were recorded for vehicles going through all nine signals. Any turns onto and off the corridor will not be considered. Simulation in TransModeler was run from 7:00 a.m. to 8:00 a.m. with a 15-minute warm up time. Three simulation iterations were batched together to improve the consistency of the results.

3.2 Time-space Diagram evaluation

The process of modeling a real-world corridor with each of the programs resulted in becoming very familiar with the of the five programs. Since the goal was to have the most accurate model of a semi-complex arterial in each of the programs, the features,

benefits, shortcomings, and ease of use of editing and generating time-space diagrams

became evident. Because existing guidelines were not found for suggested information

to display and edit on a time-space diagram, a list was generated that included all the

signal coordination parameters. All the possible parameters to display and change on a

TSD are as follows. Some practical features such as viewing a flow diagram or diagram

resizing are also included.

- Display intersection name (printed next to the horizontal bar)

- Change offset

- Display offset value (e.g., 0)

- Display offset reference phase (e.g., phase 2)

- Display offset reference point (e.g., beginning of green)

- Display phase split

- Display phase sequence (e.g., which phase is leading for northbound left)

- Change phase sequence

- Display durations of bandwidths

- Flow diagram option

- Resize and zoom in

Whether or not the time-space diagrams show or are able to edit this information is the

basis on comparing the TSDs.

4. Results and Discussion

With Sparks Blvd coded into each of the five programs, the default optimization was executed. To compare the quality of arterial coordination, the average travel time and average number of stops were extracted from TransModeler simulation models. Corridor Travel Time reports were generated for each scenario to output the average travel time through the corridor. To extract the average number of stops, a matrix of all the origin-destination average number of stops was generated for the simulation results. The values for the O-D pair that corresponded to a full trip on the corridor with no turns were extracted from the matrix. Figure 19 shows this process. After optimization was ran, time-space diagrams are viewed, and features were compared.
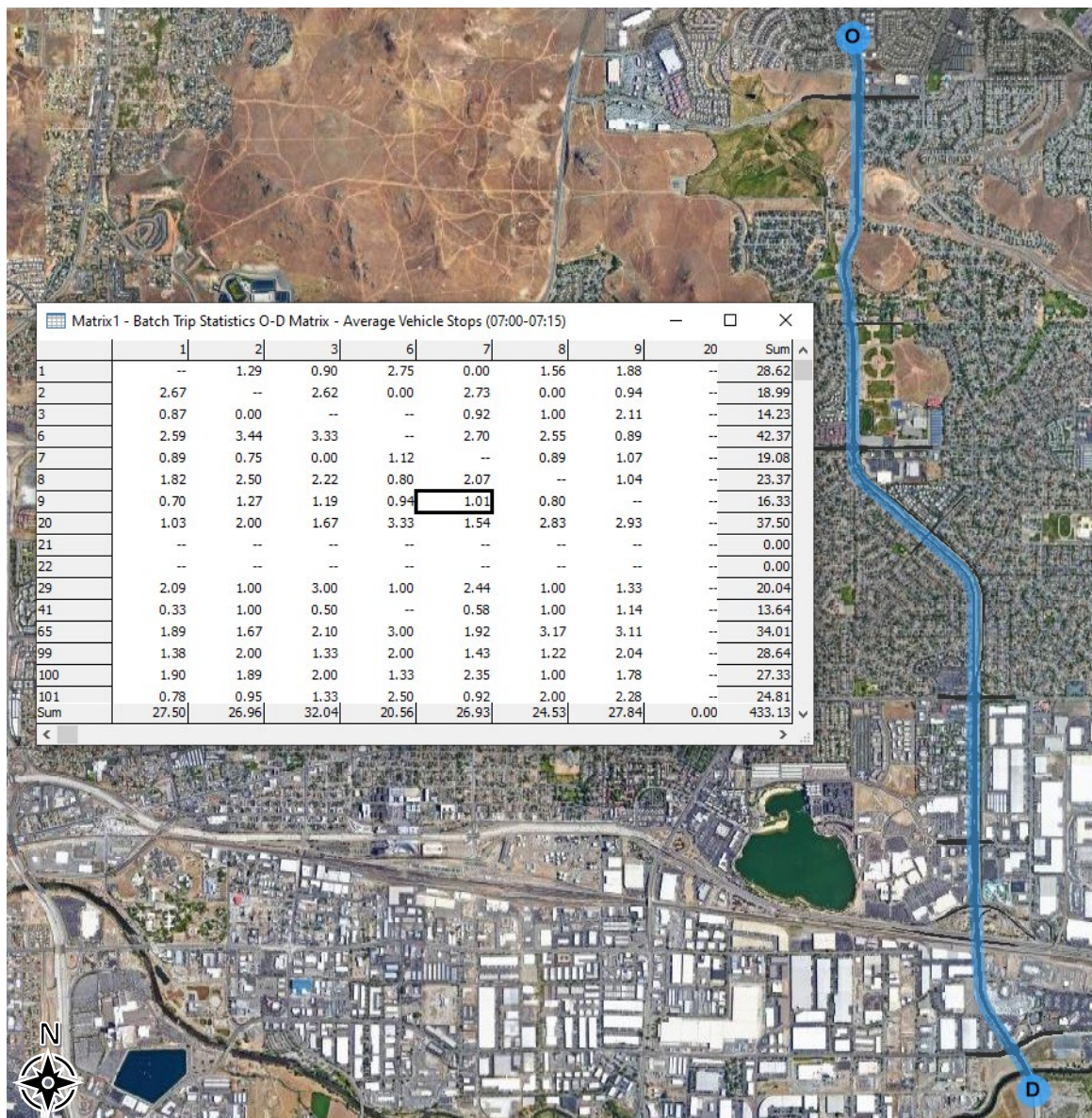
Figure 19: Average number of stops output

Table 9 shows the comparative results of the programs tested. A five-point scale is used

to demonstrate the performance of the programs. A (1) indicates the program did not

achieve desired results for each of the five categories. A (3) indicates the program was

able to perform the task, however not to a high degree of satisfaction. A (5) indicates

the program excelled at the given task. This table is partially based on the author's

experience using the programs and the objective analysis performed by the research.

Therefore, this table should not be a definitive ranking. According to this ranking,

TranSync overall performed the best.

Table 9: Useful arterial-level features

	Synchro	Vistro	TransModeler	Tru-Traffic	TranSync
Optimization Performance	5	3	2	5	4
Optimization Options	4	5	2	4	4
Time-space Diagram	3	3	1	4	5
Timing Plan Management and Options	4	4	3	2	5
Offset and sequence lock	3	3	3	4	5
Total	19	18	11	19	23

4.1   Optimization Performance Comparison

Synchro, Vistro, Tru-Traffic, and TranSync all completed the optimization within a few

seconds. TransModeler, because it uses simulation results to run its optimization

iterations, took about 20 minutes to optimize offsets only. In the simulated hour,

approximately 125 vehicles are generated for southbound runs and 55 vehicles for

northbound runs that pass through all nine intersections.

These results can be ranked from shortest travel time and lowest number of stops to

longest travel time and highest number of stops. Table 10 shows that Synchro and Tru-

Traffic tie with first place when considering northbound and southbound are treated

equally. Third place is TranSync, fourth is Vistro, and finally is TransModeler. This

ranking shows that the prevalence of Synchro among practicing engineers in validated

because of its good optimization result. But considering volumes are not needed to

import into Tru-Traffic, for a similar optimization performance, a significant amount of

time and money can be saved. TranSync is not very far behind and does not require

volume either. Vistro is an interesting case because the optimization could be placing a

higher priority on minor movements travel time or number of stops instead of arterial

travel time and number of stops. TransModeler produced the least desirable

optimization because it could not optimize phase sequence, illustrating the importance

of phase sequence optimization. Taking the average of the four 15-minute time intervals

is a simple way to rank the optimizations, but Table 11 shows a full breakdown of the

simulation results. Reports were generated for the full hour with intervals separated every 15 minutes. TransModeler reports and stop matrices are found in Appendix A.

Table 10: Optimization results (1-hour average)

Scenario	Northbound			Southbound		
	Travel Time (min)	Stops	Rank	Travel Time (min)	Stops	Rank
Synchro	9.6	3.3	3	10	2.48	1
Vistro	10	4.38	4	10.9	3.43	3
TransModeler	10.7	5.03	5	11.3	4.09	5
Tru-Traffic	9.4	2.81	2	10.3	2.47	2
TranSync	8.9	1.85	1	11	3.53	4

Table 11: Optimization results (15-minute interval)

Existing	Northbound		Southbound	
Time Interval	Travel Time (min)	Stops	Travel Time (min)	Stops
7:00 – 7:15 a.m.	8.4	2.81	7.9	1.43
7:15 – 7:30 a.m.	9.9	3.39	11.3	3.36
7:30 – 7:45 a.m.	9.8	3.37	12.6	4.37
7:45 – 8:00 a.m.	9.5	3.06	11.5	3.52

Synchro	Northbound		Southbound	
Time Interval	Travel Time (min)	Stops	Travel Time (min)	Stops
7:00 – 7:15 a.m.	8.8	3.30	7.3	0.76
7:15 – 7:30 a.m.	10.1	3.69	10.5	2.69
7:30 – 7:45 a.m.	10.0	3.39	11.6	3.62
7:45 – 8:00 a.m.	9.6	2.80	10.7	2.86

Vistro	Northbound		Southbound	
Time Interval	Travel Time (min)	Stops	Travel Time (min)	Stops
7:00 – 7:15 a.m.	9.0	3.00	7.8	1.34
7:15 – 7:30 a.m.	10.8	4.52	11.1	3.30
7:30 – 7:45 a.m.	11.3	5.52	12.7	4.63
7:45 – 8:00 a.m.	10.7	4.47	12.1	4.43

Tru-Traffic	Northbound		Southbound	
Time Interval	Travel Time (min)	Stops	Travel Time (min)	Stops
7:00 – 7:15 a.m.	7.7	1.96	7.4	0.71
7:15 – 7:30 a.m.	10.3	3.48	11.0	2.88
7:30 – 7:45 a.m.	10.2	3.2	11.8	3.27
7:45 – 8:00 a.m.	9.5	2.6	11.0	3.00

TranSync	Northbound		Southbound	
Time Interval	Travel Time (min)	Stops	Travel Time (min)	Stops
7:00 – 7:15 a.m.	7.9	1.07	7.6	1.01
7:15 – 7:30 a.m.	9.3	2.15	11.4	3.67
7:30 – 7:45 a.m.	9.1	2.16	12.6	4.62
7:45 – 8:00 a.m.	9.3	2.00	12.3	4.80

4.2   Offset and Phase Sequence Locking

An important consideration when optimizing groups of signals is offset and phase

sequence limitations. Offset limitations occur when one or more coordinated arterials

intersect the study arterial. The engineer might not want to optimize the offset for this

intersecting arterial because the timing may have already been optimized and

implemented on the other corridor. Phasing sequence limitations may consist of one or

more intersections that cannot have their phase sequence optimized because dual

leading left turns for the main street conflict geometrically with each other, thus must

stay lead-lag. The abilities of each of the programs to lock offsets and phase sequences

is shown in Table 12.

For Synchro, the user can "lock timings" for intersections meaning that offset and phase

sequence will not be changed during optimization. If the user would like to lock one

offset at an intersection, the user can lock the timing, but the sequence will not be allowed to optimize. With timing unlocked, the user can check or uncheck the "allow lead/lag optimize" box for the phase(s) the user would or would not like to optimize sequence for.

Table 12: Lock offset and sequence summary

	Lock Offset	Lock Sequence	Both
Synchro	1 master intersection = 0	Multiple	Yes
Vistro	1 master intersection = 0	Multiple	Yes
TransModeler	1 master intersection = 0	No sequence optimization	N/A
Tru-Traffic	Hold 1 offset stable	Multiple	Yes
TranSync	Multiple	Multiple	Yes

4.3   Time-space Diagram Features Comparison

This section will discuss time-space diagram features and timing plans management for each of the five programs. Each TSD will be evaluated whether each of the possible signal coordination parameters are visible and editable on each TSD.

4.3.1   Synchro

Synchro's TSD has a good amount of information that is displayed and editable. The

intersection name is frequently hidden when viewing the whole TSD. It is possible to see

the offset, but it depends on the scale of the TSD and could be covered up. The window

resizing limitations make it difficult to print or see all signals in one window. The teal

horizontal lines are dummy nodes that make the arterial better match the geometry

conditions in the real-world. No other program showed these auxiliary lines. Figure 20

shows Synchro's TSD which had to be compiled from two screenshots.

- ❑ Display intersection name

- ✓ Change offset

- ✓ Display offset

- ❑ Display offset reference phase

- ❑ Display offset reference point

- ❑ Display phase split

- ✓ Display phase sequence

- ✓ Change phase sequence

- ✓ Display durations of bandwidths

- ✓ Flow diagram

- ❑ Resize and zoom in
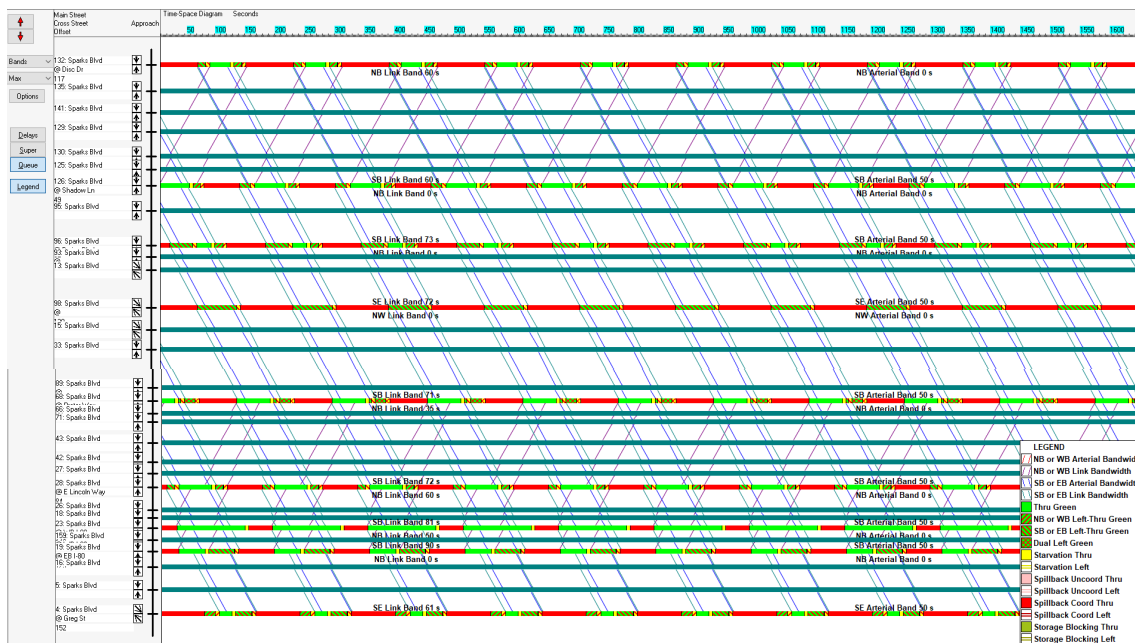
Figure 20: Synchro TSD

4.3.2   Vistro

Vistro's time-space diagram is average in terms of readability and editability among the

five programs. Compared to Synchro, it is more resizable which can make the offset

more visible. With Vistro, the user cannot change the phase sequence on the TSD but it

was possible on Synchro. None of the programs could show both bandwidths at the

clustered intersection of Springland/O'Callaghan Dr. Syncho and Vistro came very close

and they are both missing the northbound bandwidth at this intersection. The protected

left phasing at the intersections is visible in Vistro, but it is not the easiest to read. Figure

21 shows Vistro's TSD.

- ✓ Display intersection name
- ✓ Change offset

- ✓ Display offset

- ❑ Display offset reference phase

- ❑ Display offset reference point

- ❑ Display phase split

- ✓ Display phase sequence

- ❑ Change phase sequence

- ❑ Display durations of bandwidths

- ✓ Flow diagram

- ✓ Resize and zoom in
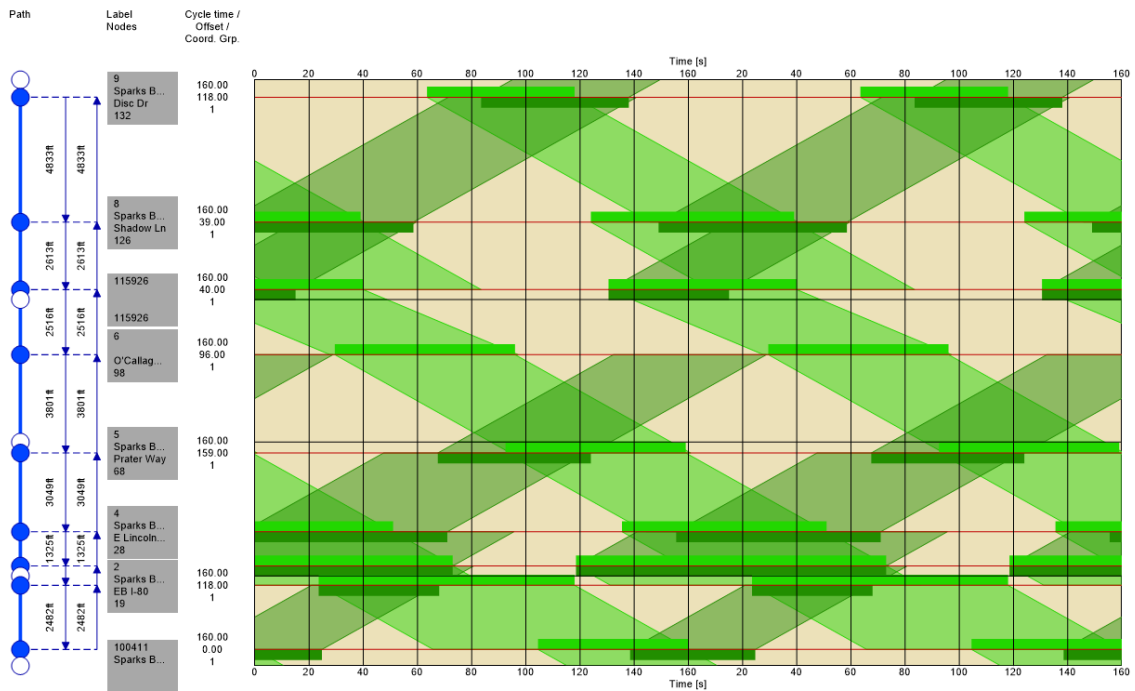
Figure 21: Vistro TSD

4.3.3   TransModeler

TransModeler's TSD needs to be improved to be on par with the other programs. An important finding for TransModeler's TSD is that it does not show offsets and/or reference phases correctly. A separate test was carried out where the offset, phase sequence, reference phase and reference point were set identical for two intersections. The reference points should be in a vertical line, but TSD did not show the offset references to be in a vertical line and were shifted by non-constant amounts. This is highly likely to be a bug in the program. Moving past the relatively major alignment bug, there is almost no information provided on the TSD. Figure 22 shows TransModeler's TSD.

- ❑ Display intersection name
- ❑ Change offset
- ❑ Display offset
- ❑ Display offset reference phase
- ❑ Display offset reference point
- ❑ Display phase split
- ✓ Display phase sequence
- ❑ Change phase sequence
- ❑ Display duration of bandwidths
- ✓ Flow diagram
- ❑ Resize and zoom in

For bandwidths, due to the cluster intersection the program was not able to continue

the flows on the TSD past the intersection in both directions. Another nuance of the TSD

is that the orientation of the top of the diagram is dependent on the direction the path

is drawn to select the signals to display on the TSD. In order to get the top of the TSD as

the northernmost intersection, the path on the map has to be drawn from the

southernmost intersection to the northernmost. This path needs to be drawn every time

the user would like to view the TSD.
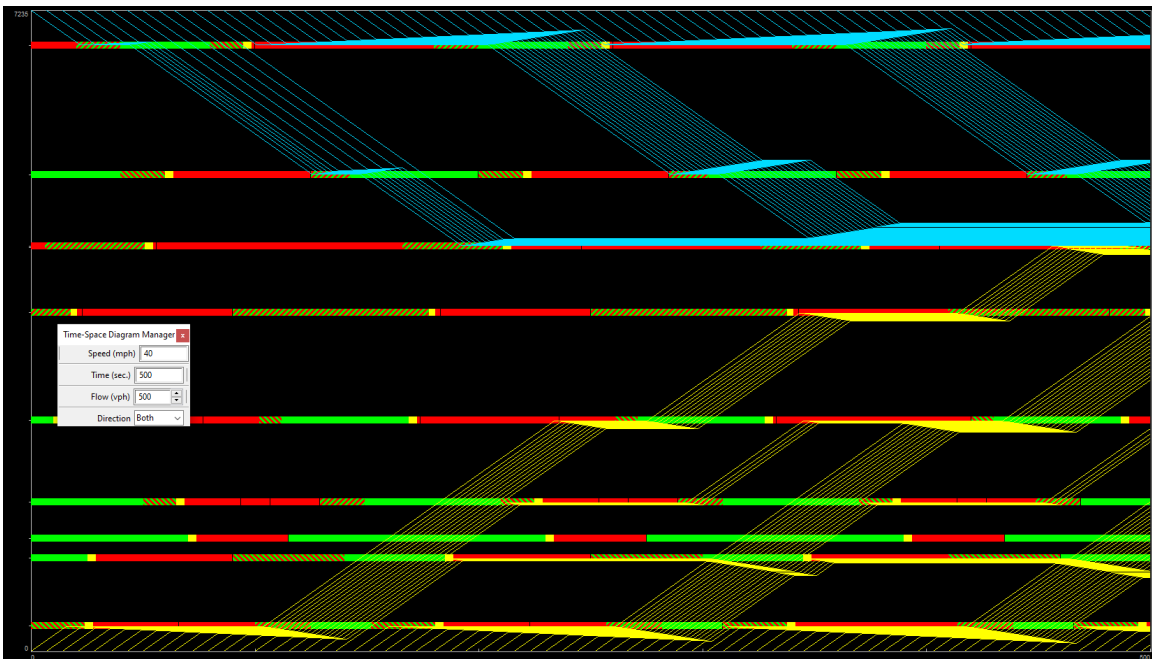
Figure 22: TransModeler TSD

4.3.4   Tru-Traffic

Tru-Traffic's TSD has numerous options to customize exactly how the user would like to

show their bands. A slight nuance is that the arterial bands move from side to side

instead of always up and down like all the other programs. A nice feature of the TSD is

that the user can double click on the vertical line representing an intersection to view

the timing editing window. To be able to show the TSD, the clustered intersection

needed to be converted into a single intersection. The signal operations are the same,

just side street movements and overlaps are not modeled as they are in the field. The

phase split can be seen by looking at the little arrows at each intersection on the TSD.

Figure 23 shows Tru-Traffic's TSD.

- ✓ Display intersection name

- ✓ Change offset

- ✓ Display offset

- ✓ Display offset reference phase

- ✓ Display offset reference point

- ✓ Display phase split

- ✓ Display phase sequence

- ❑ Change phase sequence

- ✓ Display durations of bandwidths

- ❑ Flow diagram

- ✓ Resize and zoom in
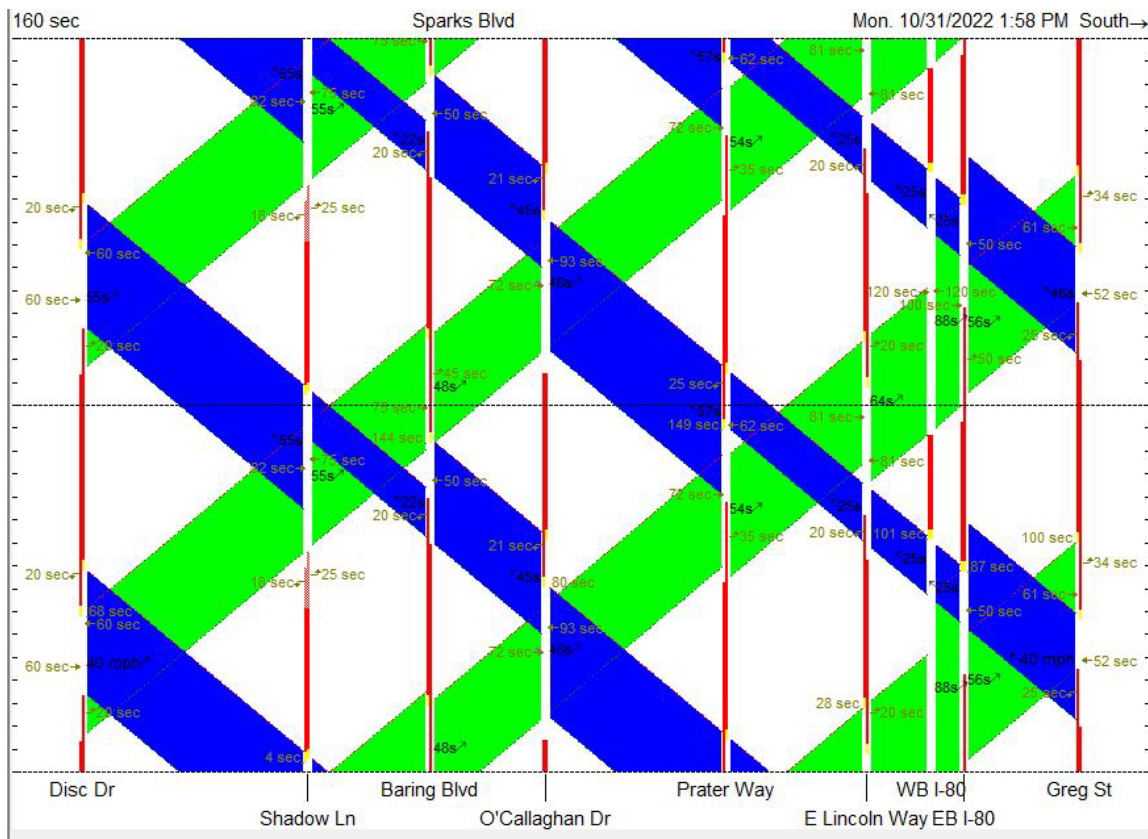
Figure 23: Tru-Traffic TSD

4.3.5   TranSync

TranSync's TSD has the most features to view and edit on a TSD. All parameters of signal coordination are shown, and offset and phase sequence can be edited. The phase sequence is shown very clearly and can also be changed on the TSD. To show bands in both directions, a dummy northbound phase at the clustered intersection (which is supported in TranSync) was placed to have both a northbound and southbound phase for the intersection that the subsystem went through. The phase split can be seen either by hovering the mouse over the phase or on the right-hand side panel. Figure 24 shows TranSync's TSD.

- ✓ Display intersection name

- ✓ Change offset

- ✓ Display offset

- ✓ Display offset reference phase

- ✓ Display offset reference point

- ✓ Display phase split

- ✓ Display phase sequence

- ✓ Change phase sequence

- ✓ Display durations of bandwidths

- ❑ Flow diagram

- ✓ Resize and zoom in
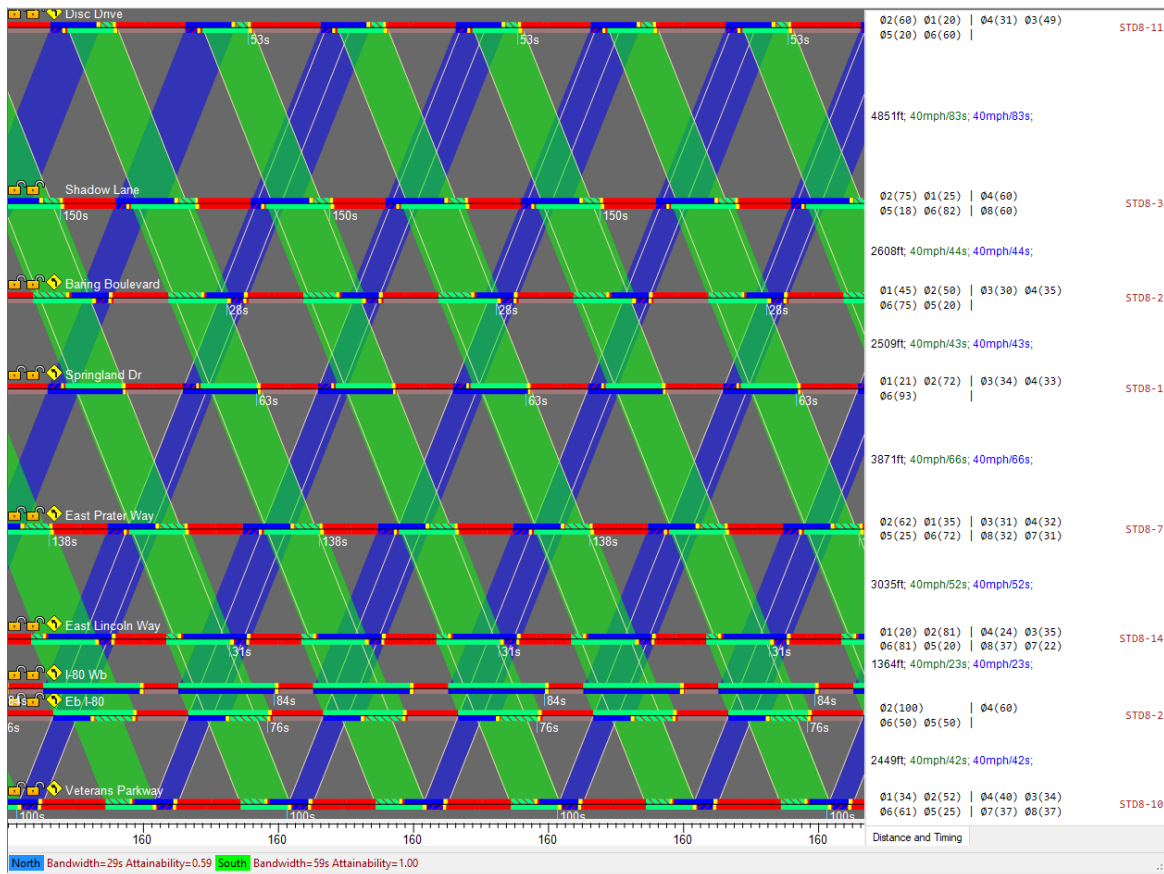
Figure 24: TranSync TSD

4.4   Timing Plan Management

Timing plans need to be managed in two ways: viewing and editing timing for different

time-of-day patterns, and selecting which intersections are to be included at a specific

time of day. The ability for signal timing programs to manage different time-of-day

timing plans varies. In general, all programs include ways to store different timings in

the same network file. However, features relating to displaying the time-space diagram

and optimizing for only certain intersections in the network was handled differently in

the programs.

4.4.1   Synchro

Various scenarios in Synchro 11 allow the user to change between different volume and

timing settings easily without having to change files. This makes it easier to have several

timing plans for one intersection in one file. The time space diagram can be generated

by clicking on any one of the links on the arterial. If the user does not want to evaluate

all signals along the arterial, zones can be defined by assigning a coordination zone to

any number of intersections to treat as one group. Optimization can be done for the

whole network or by zone. Figure 25 shows some sample scenarios that represent

different timing plans.
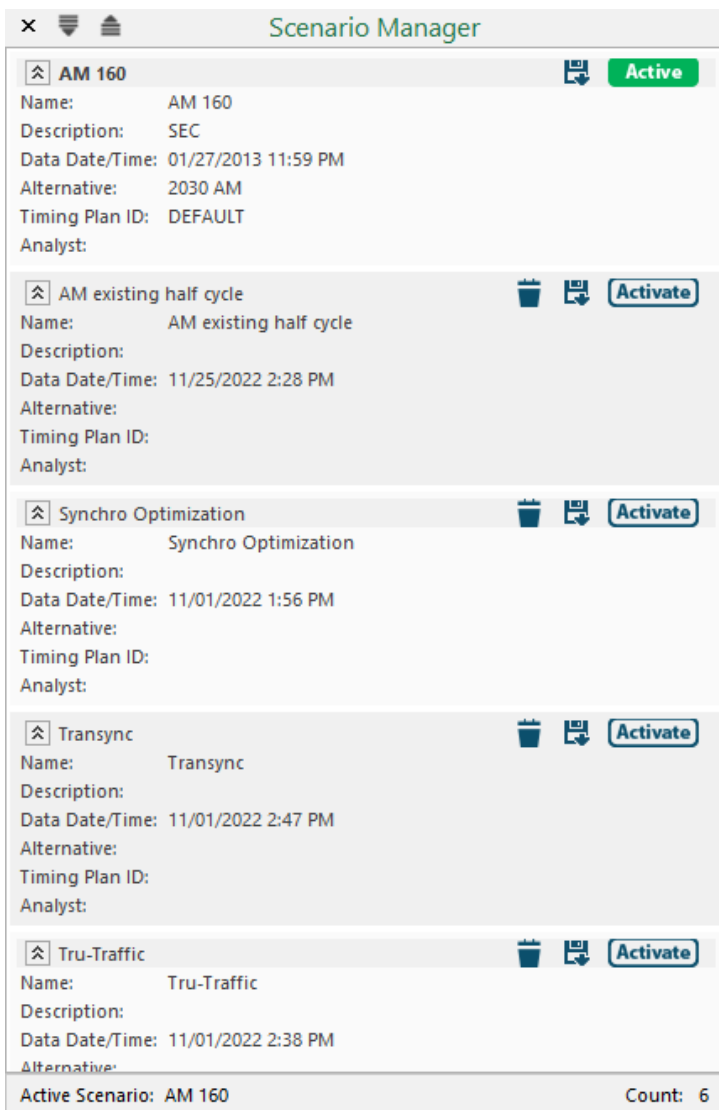
Figure 25: Synchro scenarios

4.4.2   Vistro

Vistro also uses scenarios to change between volume and timing settings. However,

geometric changes are also unique to each scenario. This means that when an

intersection lane is changed or intersection is deleted, for example, it affects only the

current working scenario. Different paths can be defined in Vistro and can pass through

any number of signals in the network. Figure 26 shows some sample scenarios.
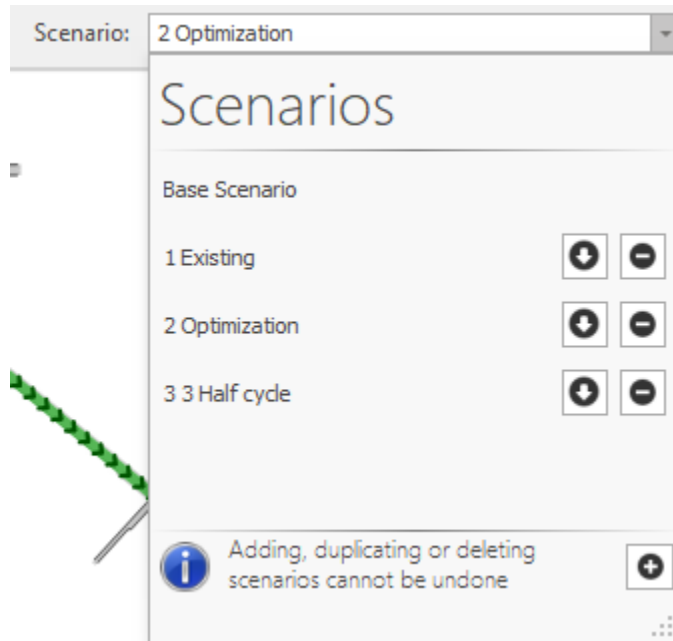
Figure 26: Vistro scenarios

4.4.3   TransModeler

To change timing plans in TransModeler, such as an AM plan to a midday plan, one must

swap out a "timings file" (.tms) with another one in the working folder Windows

Explorer directory. This process does not take a significantly much more time compared

to Synchro and Vistro. Creating a time-space diagram for only some signals is possible

because a path must first be drawn through the desired signals before the TSD can be

opened. Figure 27 shows where timing files are inputted and swapped out.
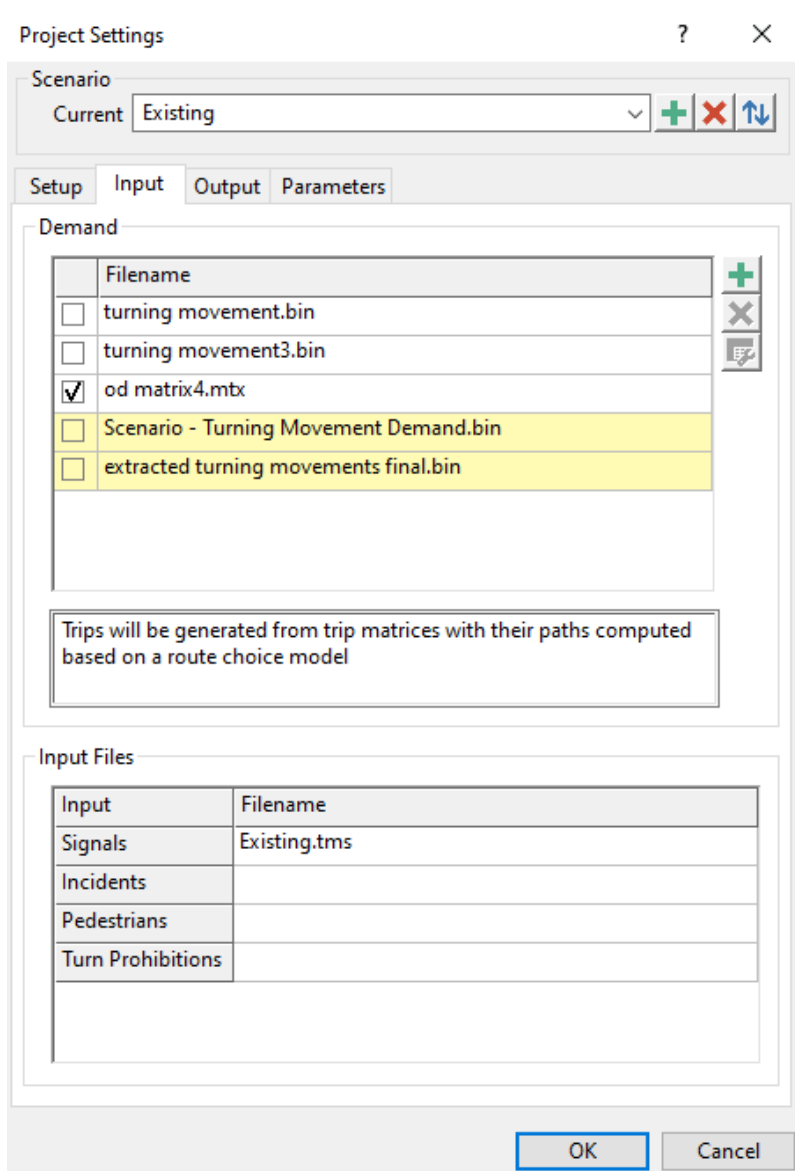
Figure 27: TransModeler timing file input

4.4.4   Tru-Traffic

Changing timing plans in Tru-Traffic is similar to Synchro and Vistro in the way that the user can select different timing plans to edit and view TSDs in one file. However, changes in the study intersections for different timing plans are reflected in all the timing plans. This means that if for the AM plan, one intersection is not in coordination

and it is for the rest of the plans, the excluded intersection will be included on the TSD.

The alternative is that the intersection is deleted which will be reflected for all the

timing plans. Figure 28 shows a sample selection of timing plans.
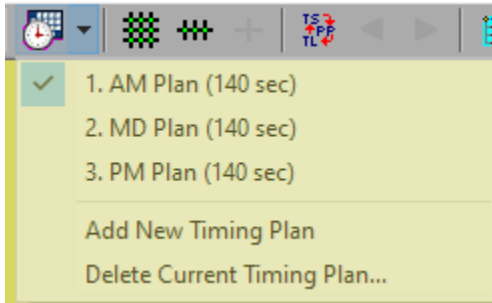
Figure 28: Tru-Traffic timing plans

4.4.5   TranSync

For TranSync, timing plans are available to select from the signal timing editing window.

"Subsystems" are created which allows various groups of intersections to be linked then

view the TSD and perform an optimization. Subsystems are saved and can be accessed

by clicking on one of the ends of the arterial. Figure 29 and Figure 30 show the timing

plan options in TranSync.
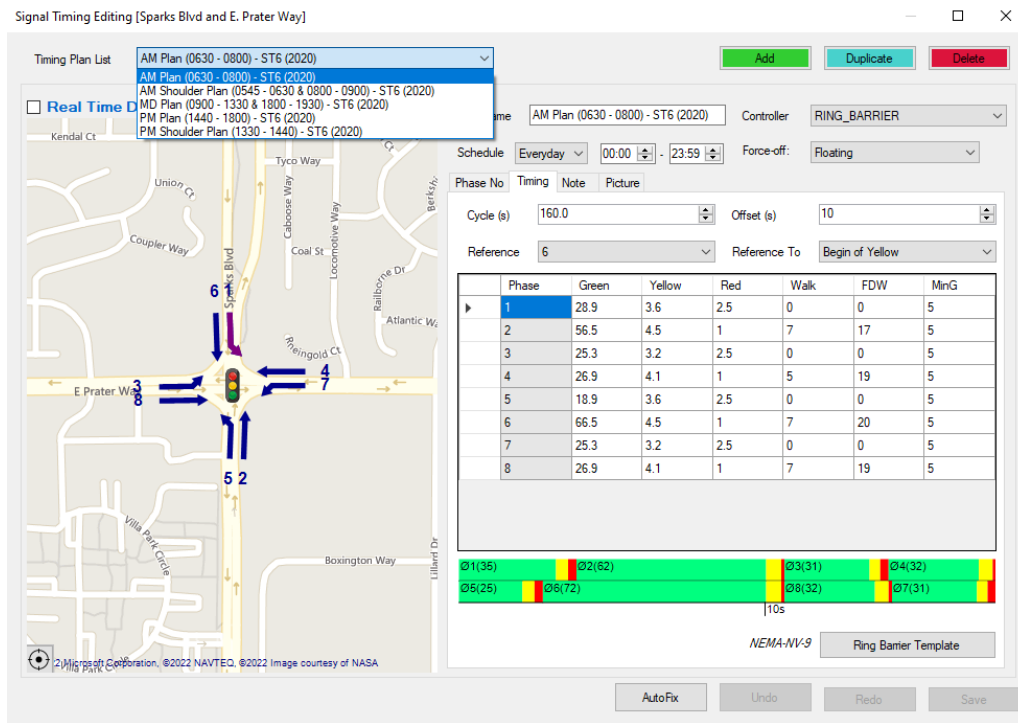
Figure 29: TranSync timing plans
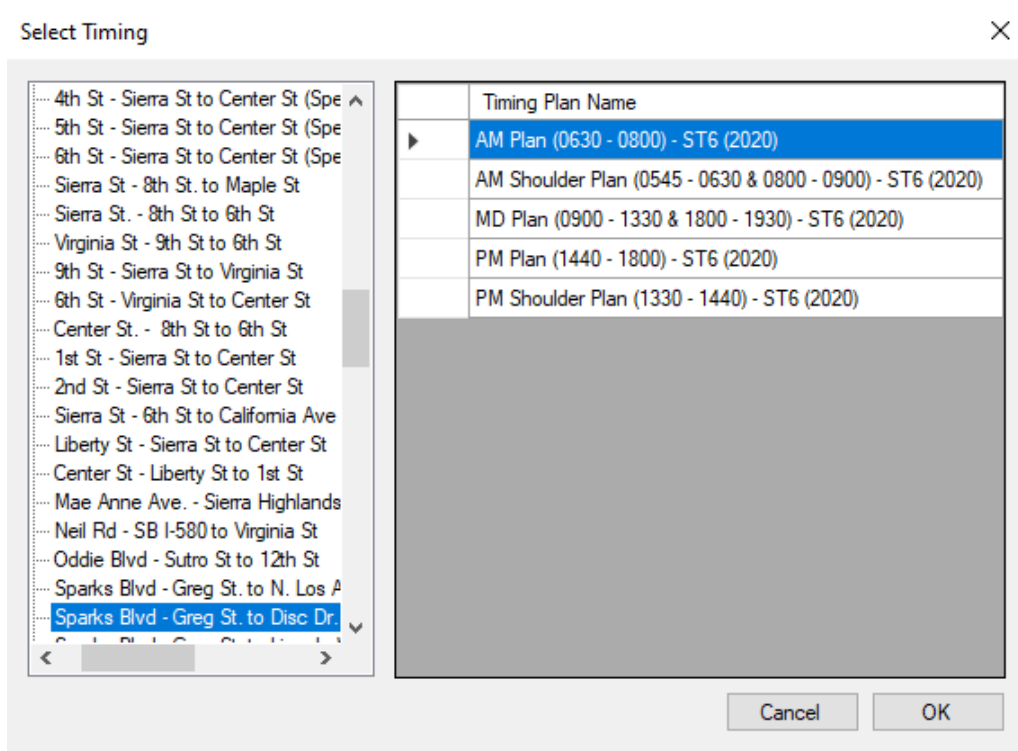
Figure 30: Subsystem selection in TranSync

5. Conclusion

This research objectively compared five software programs on their ability to perform two main tasks: run offset and phase sequence optimization, view the time-space diagram, edit, and view timing plans. The goal was to evaluate the programs without bias by modeling a typical suburban corridor in Sparks, Nevada with some unique phasing and geometric features and to use a third-party simulation software to compare the optimizations.

Synchro and Tru-Traffic produced the optimization with the lowest travel time and lowest number of stops. The time-space diagram of TranSync is the easiest to read and the user could view and edit the most coordination parameters on it. TranSync had the most options for locking offsets and phase sequences during optimization. TranSync had the most flexibly when choosing various groups of intersections to open a time-space diagram while all programs had various methods of storing timing plans.

The applicability and transferability of this research extends beyond Sparks Blvd. The methodology can be used for many types of traffic software comparisons because it involves using one master simulation model and inputting the optimized values from other programs. A limitation of this research is the applicability of the optimized travel times and number of stops ranking. Since every corridor has different geometry and stop spacing, the results may be different. However, Sparks Blvd was chosen because it had a selection of standard and unique features and any nuances in the program's

abilities would be apparent. Therefore, it is reasonable to assume that Synchro, Tru-

Traffic, and TranSync can optimize corridors to an acceptable level in a variety of

scenarios. The time-space diagram editing and usability methodology is very widely

applicable and transferrable because TSDs from different programs have varying

parameters that are able to be changed and viewed by the user. The more coordination

parameters shown and can be edited, the more usable the TSD is.

Future research using these software packages can be expanded in a couple different

directions. One path is to look at some of the local optimization features such as phase

split and cycle length optimization with Synchro, Vistro, and TransModeler. One of the

major draws to PTV Vistro is the ability to easily import a Vistro file into PTV Vissim. It

would be very helpful to test out that process is to see how much more useful a fully-

fledged Vissim model for everyday simulation is. Another area to explore is to compare

optimization results from a different time of day. Only the morning peak plan was

simulated in this research, but a balanced midday plan would be beneficial to compare

because the directional priority specification would be a simpler 50/50 split.

6. References

[1]   Nevada Department of Transportation, "Traffic Records Information Access (TRINA)," 2021. [Online]. Available: https://www.dot.nv.gov/doing-business/about-ndot/ndot-divisions/planning/traffic-information. [Accessed 9 November 2022].

[2]   J. A. Lindley, "Traffic Analysis Toolbox Volume I: Traffic Analysis Tools Primer," FHWA, McLean, VA, 2004.

[3]   Federal Highway Administration, "Traffic Analysis Toolbox Case Studies – Benefits and Applications," 3 May 2022. [Online]. Available: https://ops.fhwa.dot.gov/publications/fhwahop06005/chap_5.htm#5-3.

[4]   Transportation Research Board, "Signal Timing Manual, 2nd Ed.," Transportation Research Board, Washington D.C., 2015.

[5]   American Association of State Highway and Transportation Officials, "Committee on Traffic Engineering," 3 October 2017. [Online]. Available: https://traffic.transportation.org/wp-content/uploads/sites/26/2017/04/Traffic-Signal-Software-All-10-3-17.pdf.

[6]   M. R. Morris, N. J. Pedersen and R. E. Skinner, "NCHRP Synthesis 409: Traffic Signal Retiming Practices in the United States," Transportation Research Board, Washington, D.C., 2010.

[7]   Federal Highway Adminstraion, "Signal Timing on a Shoestring," 3 May 2022. [Online]. Available: https://ops.fhwa.dot.gov/publications/signal_timing/03.htm. [Accessed 6 November 2022].

[8]   R. Andalibian and Z. Tian, "Signal Timing and Coordination Stragegies Under Varying Traffic Demands," Nevada Department of Transportation, Carson City, 2012.

[9]   N. Ratrout and I. Reza, "Comparison of optimal signal plans by Synchro & TRANSYT-7F using PARAMICS – A case study," *Procedia Computer Science,* pp. 373-379, 2014.

[10] Y. M. Elzohairy, R. F. Benekohal and J. E. Saak, "Comparison of Delays from HCM, Synchro, PASSER II, PASSER IV and CORSIM for an Urban Arterial," The Illinois Department of Transportation, Urbana, 2001.

[11] A. Stevanovic, "Retime: PTV Vissim – A demonstration of a novel way to optimize traffic signals in complex urban networks," PTV Group, 17 December 2020. [Online]. Available: https://company.ptvgroup.com/en-us/retime. [Accessed 10 November 2022].

[12] University of Idaho, "Time-Space Diagrams," [Online]. Available: https://www.webpages.uidaho.edu/niatt_labmanual/chapters/trafficflowtheory/theoryandconcepts/TimeSpaceDiagram.htm.

[13] Oregon DOT, "Analysis Procedures Manual: Appendix 12/13A – Software and Settings for Intersection Analysis," September 2019. [Online]. Available: https://www.oregon.gov/ODOT/Planning/Documents/APMv2_App12-13A.pdf.

[14] Cubic ITS, Inc, "Synchro Manual," Cubic ITS, Inc, Sugarland, TX, 2020.

[15] PTV Group, "PTV Vistro," [Online]. Available: https://www.ptvgroup.com/en/solutionsproducts/ptv-vistro/.

[16] PTV Planung Transport Verkehr GmbH, "User Manual," PTV Planung Transport Verkehr GmbH, Karlsruhe, 2022.

[17] Caliper Corporation, "TransModeler Overview," [Online]. Available: https://www.caliper.com/transmodeler/default.htm.

[18] Caliper Corporation, "TransModeler Manual," Caliper Corporation, Newton, MA, 2021.

[19] G. L. Bullock, "Tru-Traffic User's Manual," 2015.

[20] Tru-Traffic Software LLC, 5 December 2019. [Online]. Available: http://www.tsppd.com/.

[21] Trans-Intelligence, "TranSync Suite," [Online]. Available: http://trans-intelligence.com/transync.html.

[22] Trans Intelligence, LLC., "TranSync-D User Manual," 2012.

Appendix A: Simulation Output Reports and Matrices

Simulation 1: Existing calibrated model

Project: Master simulation model
Scenario: Existing
Run(s):   Batch (3 runs)
Simulated: Various
Time: 07:00:00 - 08:00:00
Interval: 15 min
Selection: --

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	9.0	8.1
7:00 AM	2	9.0	8.4
7:00 AM	3	9.0	8.7
7:15 AM	1	18.0	10.1
7:15 AM	2	18.0	9.7
7:15 AM	3	18.0	9.8
7:30 AM	1	17.0	9.7
7:30 AM	2	17.0	9.8
7:30 AM	3	17.0	9.9
7:45 AM	1	5.0	9.6
7:45 AM	2	5.0	9.6
7:45 AM	3	6.0	9.3
7:00 AM	Avg	9.0	8.4
7:15 AM	Avg	18.0	9.9
7:30 AM	Avg	17.0	9.8
7:45 AM	Avg	5.3	9.5

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	23.0	7.7
7:00 AM	2	22.0	8.3
7:00 AM	3	22.0	7.7
7:15 AM	1	45.0	11.1
7:15 AM	2	45.0	11.1
7:15 AM	3	46.0	11.6
7:30 AM	1	42.0	12.8
7:30 AM	2	43.0	12.5
7:30 AM	3	42.0	12.6
7:45 AM	1	12.0	10.9
7:45 AM	2	9.0	11.4
7:45 AM	3	8.0	12.2
7:00 AM	Avg	22.3	7.9
7:15 AM	Avg	45.3	11.3
7:30 AM	Avg	42.3	12.6
7:45 AM	Avg	9.7	11.5

Existing Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	20	Sum
1	--	2.00	0.87	2.17	0.00	2.40	2.54	--	40.18
2	1.47	--	2.67	2.00	1.44	--	1.67	--	19.32
3	0.89	1.50	--	1.33	0.88	3.50	2.89	--	25.22
6	2.37	3.22	3.00	--	2.67	2.07	0.89	--	34.57
7	0.96	2.00	0.00	3.86	--	3.11	2.81	--	42.59
8	0.82	2.00	1.89	0.60	0.87	--	1.23	--	16.17
9	0.93	1.81	2.00	0.88	1.43	0.71	--	--	18.29
20	1.12	1.33	1.78	3.14	1.40	3.10	3.26	--	39.12
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.58	--	3.00	1.50	2.67	3.00	2.33	--	27.62
41	0.44	1.00	1.18	2.00	0.45	2.00	1.71	--	20.94
65	1.93	1.00	2.73	2.00	2.16	1.20	1.44	--	26.73
99	1.67	1.40	2.00	1.83	1.78	1.67	2.08	--	28.23
100	2.33	1.89	4.00	1.00	2.45	1.33	1.67	--	28.86
101	0.89	0.94	1.50	1.80	0.71	1.33	2.16	--	22.81
Sum	24.03	30.21	33.10	27.02	26.26	30.81	29.74	0.00	471.16

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	20	Sum
1	--	2.67	0.83	3.83	0.00	3.50	3.71	--	45.08
2	2.19	--	3.21	0.67	2.44	1.33	1.75	--	21.55
3	0.86	2.25	--	3.00	0.86	3.00	3.17	--	41.12
6	4.06	4.42	3.80	--	4.55	2.69	0.72	--	53.27
7	0.93	2.33	0.00	3.43	--	3.39	3.39	--	45.44
8	2.24	2.00	2.28	1.78	2.44	--	2.21	--	28.72
9	2.95	3.10	3.46	0.91	3.36	1.83	--	--	33.20
20	1.60	1.83	1.89	3.46	1.78	2.91	2.87	--	38.64
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.87	0.50	4.00	--	3.06	1.00	2.20	--	27.27
41	0.95	1.00	1.97	0.50	1.35	1.14	1.80	--	19.84
65	2.17	0.88	2.90	1.67	2.21	1.67	2.22	--	27.39
99	1.93	1.89	2.00	2.00	2.24	1.83	2.31	--	30.72
100	2.61	2.22	3.75	1.67	3.00	1.89	1.89	--	42.62
101	1.68	0.90	2.31	2.00	2.00	1.74	2.69	--	30.33
Sum	40.24	34.85	48.45	27.00	43.80	35.01	35.78	0.00	609.19

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	20	Sum
1	--	2.42	0.86	3.40	0.00	3.50	3.60	--	51.76
2	2.49	--	3.08	1.33	2.80	1.33	1.52	--	25.36
3	0.85	2.75	--	4.00	0.84	3.25	3.19	--	39.52
6	4.08	4.53	5.40	--	4.54	3.27	0.63	--	55.54
7	0.93	2.67	0.00	2.92	--	3.47	3.37	--	45.23
8	3.57	2.67	4.06	1.50	3.62	--	2.14	--	34.98
9	3.89	3.87	4.53	0.84	4.37	2.41	--	--	44.96
20	1.81	2.11	1.91	2.93	1.85	3.14	2.96	--	44.31
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	3.41	2.00	3.67	1.50	3.35	1.50	2.33	--	34.80
41	1.52	0.33	2.33	1.67	1.99	1.17	1.50	--	23.23
65	2.43	0.67	3.05	1.80	2.39	1.60	1.69	--	25.93
99	2.42	2.17	3.20	2.00	2.62	1.89	2.23	--	37.41
100	2.76	3.31	3.67	1.67	3.52	1.89	2.06	--	41.03
101	2.56	0.93	3.08	1.86	2.72	1.63	2.38	--	32.86
Sum	46.24	45.28	53.64	30.80	49.76	38.00	35.29	0.00	689.91

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	20	Sum
1	--	2.43	0.84	2.00	0.00	2.33	3.14	--	35.82
2	2.22	--	3.33	2.00	2.42	0.67	1.45	--	24.60
3	0.86	1.00	--	1.00	0.87	3.40	3.00	--	27.63
6	3.50	4.17	4.00	--	4.15	2.52	0.71	--	50.47
7	0.95	2.83	0.00	3.40	--	3.00	3.06	--	36.93
8	2.50	2.00	3.33	1.20	3.50	--	2.14	--	26.69
9	3.06	3.40	3.60	0.89	3.52	2.02	--	--	35.47
20	1.59	1.67	1.96	2.50	1.73	2.33	2.29	--	33.23
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	3.14	1.00	4.33	2.00	2.91	--	1.67	--	30.20
41	1.00	0.67	2.14	1.00	1.42	1.33	1.00	--	20.79
65	2.00	1.00	3.15	2.00	2.00	1.29	0.86	--	23.00
99	2.17	1.83	3.00	2.17	2.32	1.67	2.42	--	30.75
100	2.44	2.80	2.50	1.67	2.36	1.43	1.89	--	26.94
101	2.58	0.90	2.83	2.33	2.37	1.50	2.50	--	30.60
Sum	36.61	39.77	45.28	27.20	42.23	30.62	29.60	0.00	551.00

Simulation 2: Synchro Optimization

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	9.0	8.8
7:00 AM	2	9.0	8.7
7:00 AM	3	9.0	8.8
7:15 AM	1	18.0	10.0
7:15 AM	2	18.0	9.9
7:15 AM	3	18.0	10.5
7:30 AM	1	17.0	10.2
7:30 AM	2	17.0	10.1
7:30 AM	3	17.0	9.6
7:45 AM	1	4.0	9.9
7:45 AM	2	6.0	9.4
7:45 AM	3	5.0	9.4
7:00 AM	Avg	9.0	8.8
7:15 AM	Avg	18.0	10.1
7:30 AM	Avg	17.0	10.0
7:45 AM	Avg	5.0	9.6

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	22.0	7.3
7:00 AM	2	22.0	7.3
7:00 AM	3	22.0	7.3
7:15 AM	1	45.0	10.5
7:15 AM	2	45.0	10.3
7:15 AM	3	46.0	10.7
7:30 AM	1	42.0	11.5
7:30 AM	2	42.0	11.5
7:30 AM	3	42.0	11.7
7:45 AM	1	12.0	10.3
7:45 AM	2	14.0	10.4
7:45 AM	3	11.0	11.3
7:00 AM	Avg	22.0	7.3
7:15 AM	Avg	45.3	10.5
7:30 AM	Avg	42.0	11.6
7:45 AM	Avg	12.3	10.7

Synchro Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	20	Sum
1	--	1.17	0.87	1.33	0.00	1.44	1.38	--	23.61
2	1.28	--	2.29	0.50	1.26	1.00	1.00	--	17.46
3	0.90	2.50	--	0.67	0.87	1.25	1.56	--	23.07
6	1.63	3.44	2.00	--	1.75	1.81	0.89	--	33.84
7	0.96	1.20	0.00	2.14	--	3.00	3.30	--	32.34
8	2.73	2.33	3.40	0.75	2.21	--	1.14	--	26.43
9	0.60	1.71	2.05	0.97	0.76	0.75	--	--	14.36
20	1.22	3.00	1.78	4.29	1.57	3.82	4.37	--	50.22
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.09	--	2.00	--	2.22	1.00	2.67	--	20.42
41	0.55	1.00	1.27	2.33	0.64	1.33	2.33	--	19.52
65	1.39	2.00	1.73	3.00	1.61	3.40	4.11	--	34.17
99	1.33	2.00	2.00	1.50	1.57	1.10	2.88	--	23.14
100	2.11	2.00	2.50	1.33	2.14	1.00	2.33	--	28.71
101	0.67	0.94	1.50	1.75	0.68	2.20	2.56	--	23.30
Sum	24.41	32.07	29.14	22.51	24.31	28.17	35.58	0.00	447.10

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	20	Sum
1	--	1.07	0.83	1.91	0.00	2.06	3.10	--	29.52
2	1.25	--	2.38	1.50	1.37	1.33	2.44	--	24.90
3	0.85	1.00	--	2.67	0.87	2.20	3.28	--	33.78
6	3.04	3.44	4.00	--	3.38	2.59	0.72	--	42.20
7	0.90	2.22	0.00	3.67	--	3.17	3.69	--	42.79
8	2.38	3.33	3.56	1.11	2.59	--	1.30	--	31.44
9	2.39	2.70	3.07	0.93	2.69	1.56	--	--	28.53
20	1.50	2.17	1.76	3.36	1.75	2.95	3.51	--	41.84
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.09	--	3.20	2.00	2.37	2.00	2.80	--	29.17
41	0.74	1.00	1.58	2.33	0.97	2.00	2.92	--	24.52
65	2.13	2.17	2.29	3.67	2.13	3.17	4.17	--	45.81
99	1.69	1.71	2.80	2.27	2.04	1.94	2.90	--	31.96
100	2.28	2.83	3.00	2.00	2.13	1.56	2.67	--	35.92
101	1.44	0.92	2.23	2.14	1.73	1.89	2.64	--	35.28
Sum	32.60	36.31	43.04	31.57	36.13	35.30	41.38	0.00	600.56

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	20	Sum
1	--	1.00	0.86	2.20	0.00	1.83	2.55	--	26.12
2	1.43	--	2.79	2.50	1.54	1.67	2.29	--	24.00
3	0.84	1.75	--	2.00	0.85	2.00	2.78	--	28.86
6	3.61	3.75	4.60	--	4.01	3.04	0.73	--	47.82
7	0.82	2.33	0.00	2.92	--	2.89	3.39	--	37.33
8	3.14	3.33	3.82	0.89	3.56	--	1.26	--	33.50
9	3.07	3.27	3.69	0.94	3.62	1.86	--	--	35.73
20	1.69	2.18	1.76	3.08	1.81	3.29	3.71	--	46.43
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.81	0.00	3.25	2.00	2.72	2.50	2.83	--	28.70
41	1.14	1.00	1.67	2.00	1.57	1.80	2.83	--	27.73
65	2.58	2.00	2.56	4.00	2.58	3.67	3.75	--	47.43
99	2.00	2.00	2.67	2.33	2.45	2.00	2.71	--	39.11
100	2.47	3.31	4.00	1.60	2.98	1.78	2.41	--	39.72
101	2.26	0.88	2.83	2.22	2.29	2.00	2.65	--	35.80
Sum	41.85	40.82	46.65	32.65	45.08	38.14	37.57	0.00	637.57

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	20	Sum
1	--	1.11	0.84	2.00	0.00	2.00	2.18	--	21.58
2	1.50	--	2.00	1.50	1.23	1.00	2.06	--	18.61
3	0.83	0.67	--	1.00	0.85	2.00	2.80	--	23.52
6	3.07	2.29	--	--	3.53	2.03	0.67	--	34.93
7	0.91	2.33	0.00	3.00	--	2.67	2.80	--	37.54
8	2.55	3.33	3.33	1.00	3.09	--	1.23	--	26.75
9	2.32	2.73	3.29	0.89	2.86	1.71	--	--	30.85
20	1.55	2.25	1.75	1.67	1.72	2.60	3.22	--	39.22
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.60	1.00	3.33	3.00	2.00	3.00	4.00	--	31.52
41	1.27	1.00	1.32	--	1.32	1.67	2.67	--	23.47
65	2.14	2.00	2.64	3.00	2.33	3.33	3.67	--	44.91
99	2.14	2.20	3.00	2.17	2.12	2.00	2.68	--	38.20
100	2.38	3.00	--	2.00	2.38	1.67	2.20	--	31.66
101	1.64	0.91	2.33	2.25	2.09	2.00	2.53	--	31.94
Sum	36.51	34.49	36.34	26.94	39.37	34.75	36.10	0.00	552.23

Simulation 3: Vistro Optimization

Project: Master simulation model
Scenario: Vistro Optimization
Run(s): Batch (3 runs)
Simulated: Various
Time: 07:00:00 - 08:00:00
Interval: 15 min
Selection: --

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	10.0	9.1
7:00 AM	2	9.0	8.9
7:00 AM	3	9.0	9.1
7:15 AM	1	18.0	11.1
7:15 AM	2	18.0	11.0
7:15 AM	3	18.0	10.2
7:30 AM	1	17.0	11.5
7:30 AM	2	16.0	11.3
7:30 AM	3	17.0	11.2
7:45 AM	1	6.0	10.8
7:45 AM	2	5.0	11.2
7:45 AM	3	6.0	10.1
7:00 AM	Avg	9.3	9.0
7:15 AM	Avg	18.0	10.8
7:30 AM	Avg	16.7	11.3
7:45 AM	Avg	5.7	10.7

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	23.0	7.6
7:00 AM	2	22.0	7.9
7:00 AM	3	23.0	7.8
7:15 AM	1	46.0	10.8
7:15 AM	2	46.0	11.2
7:15 AM	3	45.0	11.2
7:30 AM	1	42.0	12.9
7:30 AM	2	42.0	12.4
7:30 AM	3	42.0	12.7
7:45 AM	1	8.0	12.0
7:45 AM	2	7.0	12.3
7:45 AM	3	8.0	12.1
7:00 AM	Avg	22.7	7.8
7:15 AM	Avg	45.7	11.1
7:30 AM	Avg	42.0	12.7
7:45 AM	Avg	7.7	12.1

Vistro Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	20	Sum
1	--	1.86	0.85	3.60	0.00	3.67	4.12	--	47.50
2	2.67	--	3.17	0.00	3.03	0.50	0.89	--	19.38
3	0.89	1.00	--	2.33	0.91	2.75	2.33	--	25.86
6	1.70	2.33	1.33	--	1.89	2.26	0.96	--	24.05
7	0.82	1.00	0.00	3.38	--	2.60	3.00	--	32.40
8	3.17	2.00	3.78	0.67	3.69	--	1.17	--	30.76
9	0.97	2.00	1.30	0.65	1.34	1.08	--	--	16.57
20	1.12	1.00	1.61	3.57	1.55	2.55	3.81	--	35.19
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	1.67	--	2.00	2.00	2.67	3.00	3.33	--	22.88
41	0.73	1.00	1.19	2.00	0.95	1.67	2.00	--	20.27
65	0.91	2.00	1.73	4.33	0.93	3.20	4.56	--	35.16
99	1.43	2.00	2.50	1.17	1.74	1.10	1.12	--	24.94
100	3.44	2.11	4.00	2.33	3.32	1.17	1.56	--	38.70
101	0.67	0.91	1.50	1.00	1.36	1.22	1.56	--	20.72
Sum	25.25	27.80	32.68	29.53	32.53	31.80	36.38	0.00	472.07

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	20	Sum
1	--	2.54	0.86	4.18	0.00	4.44	4.24	--	53.65
2	3.22	--	3.38	2.00	3.30	1.33	1.89	--	32.17
3	0.86	2.75	--	4.00	0.87	4.11	4.33	--	47.20
6	4.07	3.05	4.40	--	4.04	2.09	0.72	--	42.60
7	0.87	2.56	0.00	4.31	--	4.67	4.52	--	53.70
8	3.08	3.67	2.94	1.22	2.63	--	1.89	--	32.83
9	3.75	3.21	3.41	0.81	3.30	1.32	--	--	35.34
20	1.13	1.33	1.78	3.17	1.70	3.36	3.54	--	41.30
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	3.33	1.00	3.25	4.00	3.39	3.00	3.00	--	39.47
41	2.00	1.00	1.81	2.00	2.04	2.57	2.31	--	31.25
65	1.26	2.43	1.95	4.83	1.35	4.91	4.61	--	50.20
99	3.54	2.00	3.17	1.44	3.20	1.17	1.88	--	37.24
100	4.39	2.39	4.60	1.80	4.04	1.22	2.28	--	40.41
101	2.94	0.92	3.08	1.38	2.78	1.26	1.69	--	30.95
Sum	45.10	42.57	47.24	39.09	46.99	43.36	43.79	0.00	706.78

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	20	Sum
1	--	2.00	0.85	4.00	0.00	4.29	4.15	--	51.35
2	3.45	--	3.42	2.67	3.45	1.50	2.29	--	28.44
3	0.86	2.20	--	3.33	0.84	4.62	4.71	--	47.14
6	5.18	3.50	5.75	--	5.09	1.86	0.71	--	53.00
7	0.86	2.75	0.00	5.08	--	5.12	5.22	--	59.08
8	3.62	3.25	3.89	0.67	4.15	--	1.56	--	34.69
9	4.56	3.59	4.71	0.76	4.63	1.55	--	--	41.89
20	1.45	1.53	1.80	3.83	1.79	3.19	3.39	--	42.61
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	3.18	1.00	3.00	3.50	3.33	3.33	2.20	--	32.42
41	2.05	1.00	2.52	2.33	2.31	2.17	2.43	--	30.25
65	1.81	2.67	2.05	4.75	1.87	4.50	4.94	--	50.46
99	3.85	2.11	4.00	1.56	3.79	1.06	1.98	--	30.63
100	3.88	2.47	4.67	2.33	3.98	1.89	1.94	--	37.99
101	3.24	0.93	3.75	2.22	3.11	1.47	1.79	--	34.83
Sum	55.06	43.46	55.35	41.16	57.03	45.48	43.91	0.00	743.06

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	20	Sum
1	--	2.22	0.84	4.00	0.00	3.57	4.20	--	37.14
2	3.05	--	3.29	3.00	3.42	1.50	2.50	--	31.52
3	0.84	1.33	--	5.00	0.83	3.60	4.40	--	31.03
6	4.45	2.56	5.00	--	4.55	2.21	0.73	--	42.26
7	0.86	1.33	0.00	4.25	--	4.12	4.47	--	38.78
8	3.25	2.00	3.50	1.00	3.12	--	1.59	--	25.55
9	4.00	2.94	4.17	0.76	4.43	1.10	--	--	34.76
20	1.58	1.25	1.96	2.75	1.80	3.17	3.72	--	43.21
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	3.13	2.00	3.33	4.00	3.30	--	2.00	--	29.97
41	2.13	1.00	2.25	2.00	2.32	2.00	2.33	--	26.05
65	2.05	2.33	2.42	5.00	1.99	5.00	4.80	--	44.41
99	3.67	2.00	5.00	1.50	3.95	1.21	2.00	--	31.48
100	4.22	2.25	3.00	2.00	4.05	1.43	2.33	--	38.58
101	2.82	0.87	3.67	2.00	3.30	1.31	2.00	--	33.76
Sum	48.86	33.01	46.16	40.33	54.16	37.37	42.19	0.00	613.91

Simulation 4: TransModeler Optimization

Project: Master simulation model
Scenario: TransModeler Optimization
Run(s): Batch (3 runs)
Simulated: Various
Time: 07:00:00 - 08:00:00
Interval: 15 min
Selection: --

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	9.0	10.4
7:00 AM	2	9.0	10.5
7:00 AM	3	9.0	10.1
7:15 AM	1	18.0	10.6
7:15 AM	2	18.0	10.7
7:15 AM	3	18.0	11.1
7:30 AM	1	17.0	10.8
7:30 AM	2	17.0	10.9
7:30 AM	3	16.0	10.7
7:45 AM	1	3.0	11.1
7:45 AM	2	3.0	10.2
7:45 AM	3	5.0	11.0
7:00 AM	Avg	9.0	10.3
7:15 AM	Avg	18.0	10.8
7:30 AM	Avg	16.7	10.8
7:45 AM	Avg	3.7	10.8

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	22.0	8.2
7:00 AM	2	23.0	8.3
7:00 AM	3	22.0	8.1
7:15 AM	1	46.0	12.0
7:15 AM	2	45.0	12.2
7:15 AM	3	46.0	11.8
7:30 AM	1	43.0	12.8
7:30 AM	2	42.0	12.9
7:30 AM	3	42.0	12.8
7:45 AM	1	8.0	12.1
7:45 AM	2	9.0	12.1
7:45 AM	3	7.0	12.6
7:00 AM	Avg	22.3	8.2
7:15 AM	Avg	45.7	12.0
7:30 AM	Avg	42.3	12.8
7:45 AM	Avg	8.0	12.3

TransModeler Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	20	Sum
1	--	2.67	0.88	4.50	0.00	4.33	5.33	--	57.93
2	1.67	--	2.14	2.00	1.71	1.00	1.50	--	20.18
3	0.87	1.67	--	4.00	0.95	3.00	3.56	--	37.15
6	3.56	3.56	3.50	--	3.86	1.52	0.89	--	44.85
7	0.96	1.80	0.00	3.67	--	4.00	4.41	--	41.36
8	2.64	3.00	2.89	0.50	2.79	--	1.10	--	29.90
9	1.87	1.88	2.95	0.86	2.01	0.76	--	--	20.21
20	0.97	2.44	1.74	4.00	1.22	3.45	4.46	--	45.72
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	1.90	1.00	3.00	1.00	1.56	2.00	2.67	--	21.98
41	0.67	1.00	1.06	2.50	0.74	2.33	2.75	--	24.86
65	0.84	1.00	2.00	2.00	0.88	2.00	2.89	--	23.36
99	1.75	1.50	2.00	1.33	1.95	0.89	1.58	--	22.53
100	1.33	2.22	2.50	2.00	1.83	1.00	1.78	--	21.06
101	1.00	0.94	1.00	2.20	1.17	1.80	2.61	--	23.37
Sum	28.11	33.68	36.08	32.03	31.44	32.84	40.87	0.00	528.39

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	20	Sum
1	--	2.85	0.85	4.90	0.00	4.22	5.51	--	61.26
2	1.69	--	2.64	4.00	2.39	2.00	2.27	--	28.54
3	0.88	2.00	--	4.67	0.86	3.33	4.39	--	38.86
6	5.31	4.94	5.83	--	5.35	2.72	0.70	--	60.46
7	0.91	2.56	0.00	4.47	--	4.17	5.28	--	54.89
8	3.17	2.67	3.78	1.22	3.48	--	2.15	--	33.33
9	4.19	4.09	4.88	0.91	4.44	1.81	--	--	43.99
20	1.47	2.50	1.89	4.38	1.55	3.70	4.24	--	51.33
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.13	--	2.60	3.00	2.72	2.00	3.33	--	34.41
41	1.00	1.00	1.50	2.67	1.32	2.29	3.15	--	31.29
65	1.86	1.17	2.10	2.67	2.03	2.60	3.78	--	35.75
99	2.15	3.00	3.20	1.22	2.76	1.11	1.43	--	30.79
100	2.67	3.17	4.00	2.00	2.98	1.67	2.72	--	36.01
101	1.44	0.93	2.43	2.78	1.90	2.74	3.27	--	31.88
Sum	45.67	46.37	54.50	40.98	48.94	41.17	47.02	0.00	737.26

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	20	Sum
1	--	2.77	0.84	5.10	0.00	4.72	5.52	--	62.12
2	2.06	--	3.08	1.50	2.78	1.33	2.09	--	22.98
3	0.86	3.00	--	4.50	0.86	4.00	4.56	--	48.09
6	5.45	5.06	6.00	--	5.61	3.14	0.85	--	64.47
7	0.96	3.12	0.00	3.69	--	4.33	5.14	--	54.61
8	3.67	3.33	4.00	1.56	4.00	--	1.90	--	39.70
9	4.94	4.62	5.43	0.92	4.96	2.01	--	--	51.06
20	1.59	2.47	2.71	3.67	1.60	3.62	3.96	--	45.04
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.33	1.00	3.25	3.00	3.12	2.00	3.60	--	31.97
41	1.05	1.00	1.90	3.00	1.66	2.50	3.62	--	30.27
65	1.95	1.33	2.78	3.20	2.28	2.89	2.83	--	37.12
99	2.79	3.00	3.75	1.22	2.79	0.88	1.30	--	32.20
100	3.00	2.56	4.67	2.17	2.86	1.67	2.65	--	43.63
101	2.12	0.93	2.92	2.56	2.69	2.11	2.68	--	37.12
Sum	51.51	52.31	57.48	38.44	54.43	42.86	45.93	0.00	783.59

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	20	Sum
1	--	2.75	0.84	4.00	0.00	4.67	5.50	--	50.12
2	1.90	--	3.40	2.00	2.47	1.67	2.11	--	25.57
3	0.85	2.67	--	1.00	0.87	4.20	3.60	--	40.46
6	5.22	4.80	--	--	5.43	2.76	0.76	--	50.30
7	0.89	2.67	0.00	3.00	--	3.75	5.27	--	47.24
8	3.75	3.50	4.33	1.17	3.80	--	2.00	--	34.15
9	4.75	3.90	6.00	0.89	4.96	1.91	--	--	47.26
20	1.63	1.91	2.57	4.33	1.53	4.00	4.29	--	45.95
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.15	2.00	3.00	2.00	3.00	3.00	2.50	--	27.06
41	1.19	1.00	2.00	--	1.57	2.25	4.00	--	33.46
65	1.75	1.00	2.38	2.33	2.21	2.33	3.50	--	32.90
99	2.67	2.75	4.00	1.00	2.61	1.00	1.14	--	30.88
100	3.50	2.33	4.00	2.67	2.58	1.71	2.89	--	34.80
101	2.00	0.90	3.00	2.00	2.62	2.44	2.46	--	31.98
Sum	42.00	44.18	35.52	28.82	52.47	42.94	43.08	0.00	657.42

Simulation 4: Tru-Traffic Optimization

Project: Master simulation model
Scenario: Tru-Traffic Optimization
Run(s):   Batch (3 runs)
Simulated: Various
Time: 07:00:00 - 08:00:00
Interval: 15 min
Selection: --

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	9.0	7.6
7:00 AM	2	9.0	7.8
7:00 AM	3	9.0	7.7
7:15 AM	1	18.0	10.3
7:15 AM	2	18.0	10.4
7:15 AM	3	18.0	10.3
7:30 AM	1	17.0	10.0
7:30 AM	2	17.0	10.5
7:30 AM	3	17.0	10.0
7:45 AM	1	5.0	9.9
7:45 AM	2	4.0	9.5
7:45 AM	3	6.0	9.1
7:00 AM	Avg	9.0	7.7
7:15 AM	Avg	18.0	10.3
7:30 AM	Avg	17.0	10.2
7:45 AM	Avg	5.0	9.5

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	22.0	7.3
7:00 AM	2	23.0	7.3
7:00 AM	3	23.0	7.7
7:15 AM	1	45.0	10.6
7:15 AM	2	46.0	11.3
7:15 AM	3	45.0	11.2
7:30 AM	1	42.0	12.0
7:30 AM	2	42.0	11.9
7:30 AM	3	43.0	11.5
7:45 AM	1	13.0	10.7
7:45 AM	2	11.0	11.1
7:45 AM	3	11.0	11.1
7:00 AM	Avg	22.7	7.4
7:15 AM	Avg	45.3	11.0
7:30 AM	Avg	42.3	11.8
7:45 AM	Avg	11.7	11.0

Tru-Traffic Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	20	Sum
1	--	1.75	0.92	3.17	0.00	2.36	2.72	--	40.56
2	1.72	--	2.67	--	2.13	1.00	1.33	--	17.40
3	0.85	1.00	--	1.50	0.90	2.00	2.00	--	20.92
6	2.07	2.89	2.00	--	2.33	2.32	0.81	--	34.71
7	0.93	1.20	0.00	2.00	--	1.11	1.96	--	28.33
8	2.55	1.50	4.00	0.33	3.15	--	1.17	--	29.14
9	0.60	1.56	1.00	0.70	0.71	1.15	--	--	10.51
20	1.01	2.00	1.89	4.88	1.44	3.83	4.44	--	48.27
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	1.30	--	2.00	2.00	2.00	--	3.00	--	24.13
41	0.50	1.00	1.31	2.00	0.58	2.00	2.17	--	28.37
65	1.16	1.25	2.10	4.33	1.19	3.40	3.56	--	36.48
99	1.00	1.50	3.00	2.25	1.52	1.00	2.27	--	29.92
100	2.56	2.11	2.50	1.33	2.68	1.00	2.00	--	24.31
101	0.78	0.92	1.17	1.20	0.92	1.09	1.28	--	19.20
Sum	23.54	27.04	30.61	29.26	25.51	28.03	34.46	0.00	484.81

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	20	Sum
1	--	1.80	0.84	3.45	0.00	2.22	4.48	--	42.77
2	2.14	--	2.93	2.00	2.14	1.67	2.70	--	24.18
3	0.87	1.00	--	2.67	0.86	2.67	3.44	--	31.47
6	3.78	3.83	4.00	--	3.96	2.63	0.63	--	49.58
7	0.90	1.11	0.00	2.79	--	2.33	3.48	--	30.77
8	2.30	3.00	2.72	1.00	2.74	--	1.04	--	28.40
9	2.58	2.71	3.17	0.80	2.88	1.19	--	--	28.11
20	1.63	2.78	1.81	4.14	1.76	3.26	4.77	--	53.55
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	1.57	--	2.50	3.50	2.11	3.00	4.33	--	32.68
41	0.55	1.00	1.50	2.67	1.13	2.67	3.00	--	30.61
65	2.05	1.67	2.86	4.17	2.06	3.64	4.06	--	42.67
99	2.23	1.88	2.40	1.70	2.33	1.39	1.96	--	28.89
100	2.28	3.06	3.20	2.33	3.16	1.67	2.50	--	39.86
101	1.78	0.93	1.85	2.00	1.88	0.95	2.75	--	27.99
Sum	33.76	36.87	40.40	37.05	41.30	35.92	45.97	0.00	623.78

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	20	Sum
1	--	1.92	0.85	3.64	0.00	2.83	3.89	--	44.15
2	2.06	--	3.07	2.00	2.33	2.00	2.58	--	25.70
3	0.85	0.60	--	2.67	0.87	2.11	3.29	--	28.81
6	4.45	4.11	5.75	--	5.09	2.69	0.78	--	57.45
7	0.92	1.44	0.00	3.00	--	2.35	3.20	--	32.64
8	3.19	2.75	3.44	1.00	3.36	--	1.00	--	29.15
9	3.00	3.28	3.37	0.73	3.27	1.00	--	--	32.65
20	1.81	2.53	1.85	4.25	1.85	3.73	4.61	--	49.77
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.24	1.00	3.00	3.00	2.00	3.50	3.50	--	31.67
41	1.05	1.00	1.77	3.00	1.42	2.17	2.75	--	31.48
65	2.37	1.17	3.15	3.80	2.28	3.67	3.82	--	42.06
99	2.43	2.00	3.25	2.00	2.79	1.56	2.15	--	33.40
100	2.44	2.69	2.67	2.40	3.09	1.89	2.12	--	33.92
101	3.06	0.91	3.25	2.14	3.00	1.26	2.71	--	34.18
Sum	46.82	39.55	51.72	36.59	49.14	37.86	42.90	0.00	660.99

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	20	Sum
1	--	2.00	0.83	3.00	0.00	2.86	3.60	--	35.52
2	2.14	--	3.00	2.00	2.31	1.00	2.37	--	22.37
3	0.86	1.00	--	2.00	0.84	2.25	3.00	--	26.46
6	4.00	3.14	6.00	--	3.73	2.29	0.70	--	48.09
7	0.94	0.80	0.00	2.33	--	1.88	2.60	--	30.75
8	2.80	3.00	3.20	1.00	2.90	--	1.03	--	27.88
9	2.53	2.91	3.00	0.76	3.00	0.96	--	--	28.84
20	1.68	2.42	1.82	4.40	1.73	3.91	4.24	--	47.79
21	--	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	--	0.00
29	2.08	--	2.67	4.00	1.91	3.00	3.33	--	29.65
41	1.06	1.00	2.21	--	1.45	2.00	2.33	--	23.96
65	2.16	1.67	3.46	4.00	2.17	3.50	3.60	--	37.98
99	2.38	1.67	4.50	2.00	2.46	1.42	2.04	--	28.56
100	2.70	2.69	3.00	2.33	2.41	1.33	1.78	--	28.42
101	3.09	0.89	3.88	2.00	2.73	1.08	2.50	--	34.41
Sum	39.34	37.26	48.73	34.42	43.40	33.68	39.91	0.00	580.01

Simulation 5: TranSync Optimization

Project: Master simulation model
Scenario: TranSync Optimization
Run(s): Batch (3 runs)
Simulated: Various
Time: 07:00:00 - 08:00:00
Interval: 15 min
Selection: --

Corridor Travel Time - Overview

Between Disc Dr and Greg St - Sparks Blvd NWB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	9.0	7.9
7:00 AM	2	9.0	8.2
7:00 AM	3	9.0	7.7
7:15 AM	1	18.0	9.5
7:15 AM	2	18.0	9.3
7:15 AM	3	18.0	9.1
7:30 AM	1	17.0	9.2
7:30 AM	2	17.0	8.8
7:30 AM	3	17.0	9.4
7:45 AM	1	6.0	9.0
7:45 AM	2	7.0	9.8
7:45 AM	3	6.0	9.1
7:00 AM	Avg	9.0	7.9
7:15 AM	Avg	18.0	9.3
7:30 AM	Avg	17.0	9.1
7:45 AM	Avg	6.3	9.3

Between Disc Dr and Greg St - Sparks Blvd SB

Interval	Run	Number of Vehicles	Average Travel Time (min/veh)
7:00 AM	1	23.0	7.6
7:00 AM	2	22.0	7.7
7:00 AM	3	22.0	7.6
7:15 AM	1	45.0	11.6
7:15 AM	2	45.0	11.6
7:15 AM	3	46.0	11.0
7:30 AM	1	44.0	12.5
7:30 AM	2	42.0	12.7
7:30 AM	3	42.0	12.5
7:45 AM	1	8.0	12.0
7:45 AM	2	5.0	12.4
7:45 AM	3	7.0	12.5
7:00 AM	Avg	22.3	7.6
7:15 AM	Avg	45.3	11.4
7:30 AM	Avg	42.7	12.6
7:45 AM	Avg	6.7	12.3

TranSync Average Vehicle Stops Matrices

Northbound: Row 9 (Origin Greg St); Column 7 (Destination Disc Dr)

Southbound: Row 7 (Origin Disc Dr); Column (Destination Greg St)

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:00-07:15)

	1	2	3	6	7	8	9	Sum
1	--	1.29	0.90	2.75	0.00	1.56	1.88	28.62
2	2.67	--	2.62	0.00	2.73	0.00	0.94	18.99
3	0.87	0.00	--	--	0.92	1.00	2.11	14.23
6	2.59	3.44	3.33	--	2.70	2.55	0.89	42.37
7	0.89	0.75	0.00	1.12	--	0.89	1.07	19.08
8	1.82	2.50	2.22	0.80	2.07	--	1.04	23.37
9	0.70	1.27	1.19	0.94	1.01	0.80	--	16.33
20	1.03	2.00	1.67	3.33	1.54	2.83	2.93	37.50
21	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	0.00
29	2.09	1.00	3.00	1.00	2.44	1.00	1.33	20.04
41	0.33	1.00	0.50	--	0.58	1.00	1.14	13.64
65	1.89	1.67	2.10	3.00	1.92	3.17	3.11	34.01
Sum	27.50	26.96	32.04	20.56	26.93	24.53	27.84	433.13

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:15-07:30)

	1	2	3	6	7	8	9	Sum
1	--	1.79	0.87	2.80	0.00	2.39	2.54	32.76
2	2.72	--	2.71	2.00	2.84	0.75	1.42	22.94
3	0.86	1.75	--	1.75	0.87	1.78	2.00	26.88
6	5.13	3.63	5.20	--	4.97	2.72	0.72	53.84
7	0.83	1.56	0.00	2.36	--	2.17	2.15	33.03
8	2.64	3.25	3.28	1.56	3.00	--	1.93	30.98
9	3.65	3.52	4.05	0.90	3.67	1.98	--	36.74
20	1.29	2.00	1.75	2.60	1.73	2.26	2.58	38.65
21	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	0.00
29	3.05	1.00	2.25	2.00	2.83	1.00	2.33	27.27
41	1.30	1.00	1.39	1.67	1.27	1.83	2.13	26.25
65	2.73	2.14	2.50	3.33	2.77	3.33	3.17	41.75
Sum	44.97	38.98	45.50	29.28	46.45	32.92	32.83	607.82

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:30-07:45)

	1	2	3	6	7	8	9	Sum
1	--	2.00	0.84	2.36	0.00	2.35	2.64	35.67
2	3.46	--	3.69	1.00	3.78	1.25	1.53	25.49
3	0.84	1.33	--	2.00	0.83	1.67	1.56	25.61
6	5.90	4.12	7.33	--	5.90	2.75	0.63	58.53
7	0.92	1.78	0.00	2.38	--	2.17	2.16	34.47
8	3.90	3.75	4.25	1.56	4.08	--	1.79	36.77
9	4.41	4.00	4.64	0.89	4.62	2.28	--	42.50
20	1.97	2.44	2.15	2.46	1.95	2.24	2.56	44.78
21	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	0.00
29	3.30	1.00	4.00	2.00	3.38	1.67	2.60	36.27
41	2.00	1.00	2.10	1.67	2.12	2.00	2.15	27.40
65	3.12	2.17	3.42	2.83	3.11	2.80	3.00	43.54
Sum	57.28	42.11	65.99	29.00	60.49	34.09	31.93	685.00

Matrix1 - Batch Trip Statistics O-D Matrix - Average Vehicle Stops (07:45-08:00)

	1	2	3	6	7	8	9	Sum
1	--	1.25	0.83	4.00	0.00	2.00	2.43	30.80
2	3.65	--	4.50	1.50	4.03	1.50	1.30	29.89
3	0.85	1.00	--	0.50	0.83	1.50	1.83	22.79
6	5.67	3.71	--	--	4.33	2.52	0.74	40.82
7	0.80	1.17	0.00	1.80	--	1.67	2.00	24.03
8	4.00	3.00	3.67	1.33	4.00	--	1.73	32.91
9	4.75	3.25	5.20	0.90	4.80	2.11	--	39.42
20	1.93	1.67	2.09	3.00	1.88	3.09	2.30	39.44
21	--	--	--	--	--	--	--	0.00
22	--	--	--	--	--	--	--	0.00
29	3.80	--	4.00	2.00	4.00	2.67	1.00	30.31
41	2.67	1.00	2.37	2.00	2.68	1.00	1.67	25.91
65	3.17	1.75	3.60	2.50	3.26	3.17	3.67	34.78
Sum	60.60	31.75	46.34	28.63	54.04	33.85	28.24	580.15