CONVERSION OF ONE-WAY STREET PAIRS TO TWO-WAY OPERATIONS IN DOWNTOWN BIRMINGHAM

By

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The higher-than-ever gas prices and soaring living expenses are driving people back to city centers in search of reduced travel costs and greater proximity to services. This calls for an immediate need to revive our downtowns to make them attractive and increase their efficiency toward accommodating a variety of transportation modes, motorized and non-motorized. As a principal measure to this revival, studies are conducted country wide to understand the upshots and relevance of conversion of one-way streets to two way operations. This paper reports the findings of a study that investigated the feasibility and potential impacts of street conversion options on traffic operations in the downtown Birmingham, Alabama area. Of particular interest were issues related to conversion of grid systems from one-way to two-way operations.

First an extensive review and synthesis of the technical literature was conducted to identify issues and challenges associated with implementation of street conversions as well as best practices. Then a traffic impacts analysis was performed to assess the implications of two- way street conversion at and around the test sites. In doing so, computer simulation models were developed using SYNCHRO and CORSIM to represent current and future operations. Detailed realistic two-way operations scenarios were developed considering geometric and right-of-way restrictions, the location of land uses that generate and/or attract vehicular and pedestrian traffic, connectivity with the street grid and accessibility to nearby freeway facilities, as well as practical considerations. The simulation models were run for:

- The existing scenario (one-way operations using existing traffic volume, roadway geometry, and control), and
- Alternative scenarios (two-way altered geometry, lane designation, control, land uses etc.)

The evaluation was based on review and comparison of relevant Measures of Effectiveness (MOEs) produced by the simulation models including carrying capacity, travel speed, vehicle and pedestrian delays, queues, environmental impacts etc. The paper summarizes the main findings and provides recommendations on the most promising design and control configurations for implementation.

1. Introduction

For any city center to function efficiently, it is imperative that it accommodates various modes of travel and host diverse activities. At one point of time, downtowns of cities were believed to be the focal point for all cultural, social and recreational activities where businesses flourished and people and vehicles coexisted. As time went by people began their flight towards the suburbs in pursuit of better quality of life, reduced congestion and lesser real estate costs that were conveniently provided by the suburbs. With the advent of freeways, downtowns began to be well-connected with suburbia, increasing their accessibility and mobility, and 1980s witnessed the pinnacle of this trend.

Since then there has been a continuous movement of vast proportion of a city's population to its outskirts in search of less expensive and better living environment. This further gave birth to numerous retailers, commercial and recreational activities and service providers locating in the suburbs to better serve the local population. This trend aided in the deterioration of many urban downtowns, leading to closure of many businesses, and rendering streets blighted and unsafe after dark. Recently, with the gas prices and living costs soaring high, suburban life is not as inexpensive as it used to be. There is a renewed interest from people to stay around city centers for ease of travel and increased accessibility to facilities. This lights a ray of hope to downtown rehabilitation and is an ideal time to think of revival of city centers.

2. Project Background

As a measure to revitalize the downtown city centers, several movements have been staged over the years to convert one-way street pairs of downtown network to two-way operations. Successful conversions have been implemented in many urban settings across the United States since the early nineteen nineties. Some of them include the cities of Austin, Berkeley, Cambridge, Chattanooga, Cincinnati, Denver, Des Moines, Lansing, Louisville, Palo Alto, Portland, Sacramento, San Jose, Seattle, St. Petersburg and Tampa. The conversion to two-way streets is believed to bring about better accessibility and mobility within the downtown grid, improved neighborhood livability, economic growth, and overall enhancement of quality of life for users and residents alike.

With the aim of updating the City Center Master Plan for Birmingham, Alabama, a study was conducted by Urban Design Associates for the City of Birmingham in 2004. This study results indicated that systematic conversions of a number of one-way streets to two-way operations in downtown Birmingham would help in exploiting the enormous capacity of the downtown grid and better serve the changing mix of downtown visitors [1]. It also suggested that these conversions would create a better pedestrian-friendly environment and make shops and restaurants more accessible. This plan was officially adopted by the Birmingham Planning Commission of Greater Birmingham on 12/7/05 and thereby set foundation for this study.

2.1 Project Objective

Prior to implementing one to two way street conversions, a need exists to investigate the street conversion options, their feasibility and potential effects on existing and future traffic operations in downtown Birmingham. Hence, this study focuses on analyzing the possibility and impacts of converting a one-way streets pair to two-way operations, as a strategy for creating a sustainable transportation system in the Birmingham City Center; thereby improving accessibility, downtown circulation and providing a range of transportation options.

Particular attention has been given to ensure that the new system would improve the accessibility to new and evolving land uses and better serve the existing and future transit and non-motorized transportation needs, while maintaining overall street network flow.

2.2 Area of Study

To assess the possibility of conversion and their effects on downtown grid, a pair of one-way street in downtown Birmingham was selected to be used as test sites. This pair of street is located in the downtown Birmingham area and extends from 1st Ave N to 8th Ave N along 17th and 18th Str N. Both study facilities currently operate as one-way streets and are approximately 0.64 miles long. The posted speed limit on study streets are 30 mph. Each street has 9 intersections - from Morris Ave on the south to 8th Ave on the north, making a total of 18 intersections for the network under study. One of these 18 intersections, where 17th Str N meets with Morris Ave, is an unsignalized intersection controlled by a STOP sign.

Traveling northwards from the University of Alabama at Birmingham (UAB), the study streets operate both ways until they reach 1st Ave North. Beyond this intersection, 17th and 18th Str transform to one-way streets and continue to do so for the entire study area. Figure 1 below shows the study sites marked by blue lines. This site is the portion of Birmingham's City Center bounded by I-65, I-20/59, US 31 and railroad. 17th Str N functions as one-way street carrying vehicles south bound whereas 18th Str carries vehicles northward.

3. Research Methodology

In order to meet the objective of study, several sequential tasks were carried out in a predetermined fashion. To start, a systematic study was conducted on one to two-way street conversions carried out nationwide, to gain understanding on the methods adopted and operational influences. Much of the documents for this literature review were from technical papers and reports, newspaper articles and public responses. The findings from literature reviews have already been furnished in a previous section. Following this, extensive data collection and processing were executed to acquire insight on the existing traffic operations and demand characteristics. The types of data collected and techniques employed have been provided in the sections followed.

Once the existing conditions were determined, traffic impact analysis was performed which involved traffic simulation modeling and signal optimizations, in order to assess the implications of two-way street conversions at and around the test sites.

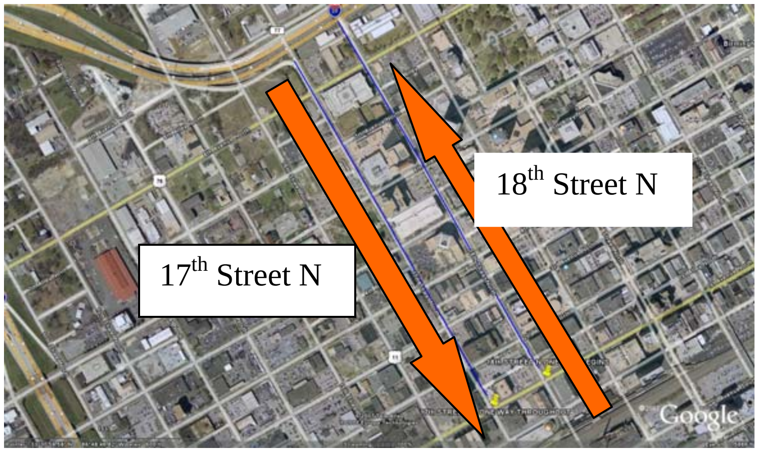

Figure 1. Study Streets with Their Direction of Operation (Source: Google Earth).

3.1 Data Collection

The data collection phase was aimed at assembling all data that would be required to model existing and future conditions at the study sites. After careful consideration, the types of data to be collected were decided to include:

a) Geometric and other fixed characteristics (e.g., number of lanes per approach, lane designation, width of traffic lanes, width of sidewalks and crosswalks, approach grades).
b) Traffic flow data including volume of vehicles using the traffic lane in one hour, vehicle classifications, turning movements, volume of pedestrians and bicycles using the crosswalk, information on vehicle-pedestrian conflicts.
c) Traffic control information like signal cycle length, phasing information, existing signs and markings, type of signal control, pedestrian signal timings, if any.
d) Land use information and projected changes in land uses.
e) Other pertinent information (e.g. parking details, transit routes and stops, location and frequency of parking maneuvers, number of buses per hour, construction works etc.)

The geometric/fixed characteristics and all other pertaining information concerning the study streets were observed during several site visits. Tapes were used to measure widths of sidewalks, crosswalks and storage bay lengths, wherever necessary.

3.1.1 Traffic Signal Data

Traffic signal information for existing downtown network was provided by the City of Birmingham. All existing downtown streets (except for 7th Ave N) operate on pre-timed signals. 7th Ave North has semi-actuated signal systems coordinated with the remaining traffic control devices. AM and PM peak timings as well as mid-day signal information were obtained from the City of Birmingham database. On compiling this information, it was found that all signals on the study streets operate at a cycle length of 76 seconds during off-peak periods and cycle length of 80 seconds during AM and PM peak hours; splits and offsets varying for each intersection. For the entire downtown streets, offsets were designed for beginning of green.

3.1.2 Vehicle Data Collection

Our next step was to check the availability of existing information on vehicle demand from the City of Birmingham and thereafter identify the needs for further field data collection. Following this, an enquiry was made with officials at City of Birmingham which established a need for an extensive field data collection as there were no recent traffic data available for downtown Birmingham streets. A data collection plan was then developed to gather all the necessary information pertaining to the study streets that would facilitate the modeling process.

Two methods of data collection were employed, namely tube counters (presence type traffic counters) and manual counters.

3.1.2.1 Tube Counters

Tube counter method was employed to collect field traffic data for the study streets, with a recording interval of 15 minutes, for a total duration of 48 hours. The tube counter method utilizes a set of two tubes and a counter, TRAX I, for obtaining field data. TRAX I counter/classifier is an automatic traffic data recorder which can collect data in four modes: basic (raw) data, volume only data, per vehicle data and speed and/or gap data. The road tube and TRAX I's air switches comprise the sensing device for the unit. As vehicles run over the tubes, the sensing devices detect the passing vehicles and transmit information on vehicle classification based on their axle lengths, individual vehicle speeds and volumes to the counter [2].

Tube Installation at Site and Data Retrieval

Tubes were placed exactly perpendicular to the flow of traffic to prevent double counting (Figures 2 and 3). The far end of tubes were sealed with a plug inserted into the tube and near ends were connected to the TRAX counter. To secure far ends of tubes onto the road, a looped metal and nails were used and sticky tapes were employed at fixed intervals to hold the tubes against road during the duration of data collection. Two new counters and five old counters were used for traffic data collection purposes. Tubes, of equal length, were set at an offset distance of 2 feet for new counters and 8 feet for old counters, with counters placed at its center on one end of the road. All counters were set to 'binned' option to obtain vehicle classification, speed and gap information. Before each installation, the date and time of study were set to facilitate easy identification and retrieval of data. The road tube layout 'L5' was selected to match our requirement of one-directional traffic with no lane separation. Once all tubes were installed at site, counters were checked for proper functioning and accuracy by observing traffic as it was being recorded.

After gathering field traffic data for desired time period, the stored data was downloaded from TRAX counter to a computer using its communication port. The data was then converted to an excel format to permit easy processing and organization.

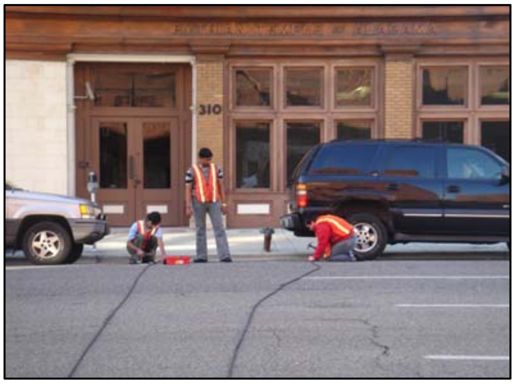

Figure 2. Tube Installation at Study Site.

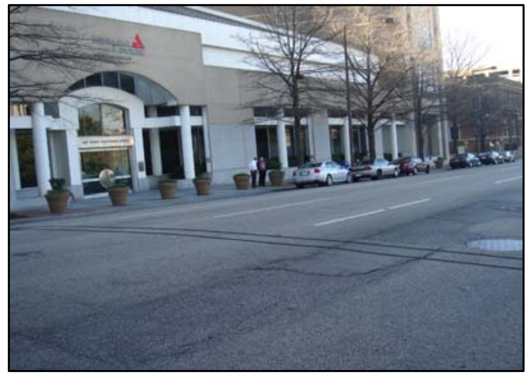

Figure 3: Tube Counter Installed at Site.

3.1.2.2 Manual Counters [3]

Manual counters (hand held), similar to the one shown in Figure 4 below, were employed to calculate vehicle turning movements, vehicle classification and pedestrian/bicycle volumes. All intersections within the study area were included in manual data collection and two people were stationed per intersection, one personnel for each direction. Considering that the study area is a Central Business District area, the data collection procedure was executed during morning and evening peak periods, between 7-9 am and 4-6 pm, assigning one hour (i.e., four 15 minute intervals) for an intersection each. Through vehicle volumes were recorded as well to compare its value with tube counter data and validate the collected information. All traffic counts were done during weekdays. Besides recording traffic on vehicular lanes, mid-block traffic, from driveways and parking garages, were also documented. Frequency and number of parking maneuvers were also observed and noted down during manual counting.

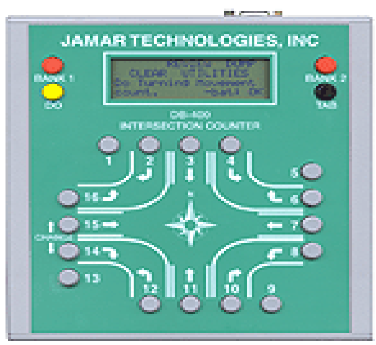

Figure 4: Manual Counter Used for Data Collection (Source: Jamar Technologies Inc).

3.2 Traffic Impact Analysis

After determining the existing conditions, a comprehensive traffic impact analysis was performed to assess the implications of two way street conversions in the Birmingham downtown area and compare their operative performances on the basis of levels of service for existing and all future scenarios.

In order to realistically represent the current and future traffic conditions within the study area, two computer models namely SYNCHRO and CORSIM were utilized to simulate the operations of the study corridors under existing and two way alternatives under peak traffic conditions. SYNCHRO [4] software was mainly used to perform capacity analysis and signal time optimizations for both scenarios (existing and future) using the procedures described in the 2001 Highway Capacity Manual (HCM) [5]. Due to its signal optimization ability, SYNCHRO was also engaged to determine the signal phasing and timing plans for each two way operation alternatives. CORSIM [6] software is capable of analyzing traffic flows on arterials and freeways and hence was utilized to assess the effects of on-street parking, transit and pedestrian movements for current and future traffic conditions. The software capabilities required for this study and reasons for selecting SYNCHRO and CORSIM are explained in the section below.

4. Software Requirements

For a successful completion of this study it was imperative that the selected simulation software represent the existing conditions as close to reality as possible, incorporating intimate details concerning traffic conditions / limitations, geometric elements and land use information. Equally important was the software capability to create/develop proposed future alternative geometries and traffic conditions accurately. After the creation of existing and future scenarios, it is expected that the software provides significant outputs in terms of vehicle delay, v/c ratio, travel time, fuel consumptions and emissions etc that would help us in evaluating the feasibility and effectiveness of potential conversions.

4.1 Why SYNCHRO and CORSIM?

SYNCHRO

SYNCHRO, developed by Trafficware Inc, is a complete software package capable of modeling and optimizing traffic signal timings [4]. SYNCHRO Version 5.0, which has been used for this study, implements the methods of the 2000 HCM, Chapter 16 for capacity analysis. Besides calculating capacity, SYNCHRO can also optimize cycle lengths, splits and offsets, thus eliminating the need to try multiple timings plans in search of the optimum. This simulation software optimizes to reduce delays and stops. Additionally, for coordinated intersections, as is our case, SYNCHRO explicitly generates progression factors which assist in determining the sufficiency of the provided signal timings. Unlike other coordination software, SYNCHRO is fully interactive and any change made to input values will automatically update the results. This feature considerably reduces the network development and simulation time.

Furthermore, a key feature for selection of SYNCHRO was that it is the only interactive software package to model actuated signals and 7th Ave N in our study area operates as a coordinated semi-actuated signal. It also supports the analysis of unsignalized intersections based on the 2000 HCM. Version 5.0 of SYNCHRO used for this project does not limit the number of intersections that can be modeled unlike SYNCHRO Light that has a limitation of 10 intersections per network.

As an output, SYNCHRO provides colorful and informative Time-Space Diagrams (TSD) where splits and offsets can be changed directly on the diagram. SYNCHRO features two styles of TSDs. The bandwidth style of TSD indicates how traffic might be able to travel down an entire arterial without stopping, and the vehicle flow styles shows individual vehicles that stop queue up and then go. This traffic flow style gives a better picture of what the traffic actually looks like.

SYNCHRO can also build input files for TRANSYT 7F, CORSIM and Highway Capacity Software (HCS). The optimized timing plans developed by SYNCHRO can again be simulated with SimTraffic or CORSIM for a more detailed analysis. The network build in SYNCHRO can be transferred to CORSIM by creating a TSIS file and hence greatly reducing the effort required to create one from scratch in CORSIM.

CORSIM

TSIS-CORSIM, developed by Federal Highway Administration (FHWA), is a microscopic simulation software package that forms a part of the Traffic Software Integrated System (TSIS) [7]. It can be employed for signal systems, freeway systems or combined signal and freeway systems. TSIS provides an integrated environment where users can define and manage traffic analysis projects, define traffic networks and create inputs for traffic simulation analysis, execute traffic simulation models and interpret the results of these models. Apart from performing microscopic simulation, CORSIM is capable of network animation as well.

TRAFVU, which is also a part of TSIS package, is used to provide graphical representation of the CORSIM network which can give the user an idea of how the given phase plans would work in real world conditions. To make result interpretation easy, CORSIM provides users with Measures of Effectiveness (MOEs) to evaluate the efficiency of the network. It is also capable of modeling actuated signals and offsets though it cannot optimize phase plans. Additionally, unlike other simulation programs, CORSIM can model varied driver behaviors and Figures different driver characteristics for each separate run. For this study, the existing and alternative future scenarios were initially modeled in SYNCHRO and then exported to CORSIM.

5. Simulation Model Development

5.1 Network Configuration Considered

SYNCHRO (Version 5.0) was used as the principal analysis tool to evaluate the study site traffic conditions from MOEs produced as a result of SYNCHRO simulations. In order to characterize the networks, inputs for traffic data were collected from a series of field visits and observations, and the existing signal timing information and traffic change patterns over years were obtained from the City of Birmingham office. Any other significant information that was thought to assist in network development was gathered from site concurrently.

The traffic input information like transit volume, pedestrian and bicycle volumes / conflicts and heavy volume percentage were altered / estimated to meet with the proposed increasing demand. Wherever these values could not be estimated at site, default values offered by the program were used. Care was also taken to optimize all signals as one coordinated unit to complement with entire downtown street network and to accommodate the increasing congestion.

Traffic network was created in SYNCHRO with the help of links and nodes, links defining streets and nodes representing intersections. Lane data, traffic volumes and signal timings were then entered by clicking on these links. Care has been taken to recreate actual distances at site with the assistance of digital photos, Google maps/earth and field observations, with an aim to attain a near accurate distance measures.

The lane input window makes it possible to specify lane groups, lane width, grade, area type, storage length, detector locations and other information. Storage length data is useful when it comes to detecting blockage problems. Traffic volumes for each lane group, peak hour factor, percentage of heavy vehicles and other related details were entered using the traffic volume input sheet. Signal timing information, like left turn type, phase number, lead/lag assignment minimum and maximum splits, lost times etc can be entered in the timing and phasing windows.

Three scenarios were considered for network creation and simulation, namely Existing Conditions, Lane Configuration 1 (LC 1) and Lane Configuration 2 (LC 2). LC 1 and LC 2 are the two proposed designs for future two way operations. Both these designs have been conceived envisaging future vehicle demands and needs. Accordingly, LC 1 and LC 2 eliminate any need for additional ROW requirements and retain existing parking facilities wherever possible. Also, care has been taken to eliminate serpentine motion of vehicles that could be created by varying lane widths in consecutive intersections.

5.1.1 Existing Conditions

This scenario was utilized to accurately represent the currently existing site conditions and lane configurations. Here the street pair operates as one-way, with wider and more number of lanes per direction compared to future proposed designs. 17^{th} Str N consists of 3 and 4 lanes that carry vehicles south bound and 18^{th} Str N comprises of 4 and 5 numbers of lanes carrying vehicles northward.

Major arterials (17^{th} and 18^{th} Str) are modeled as horizontal links extending E-W and intersecting streets are shown as N-S links (Figures 7 and 8). The intersection between Morris Ave and 17^{th} Str N is the only existing unsignalized intersection at site controlled by a STOP sign. However, during model creation a huge volume sink was experienced on 18^{th} Str N between 7^{th} and 8^{th} Ave due to substantial vehicle turnings into the Alabama Power parking garage located in between 7^{th} and 8^{th} Ave, and thereby losing sizeable quantities before reaching the 8^{th} Ave intersection. The well thought-out way to portray this situation was to introduce an unsignalized intersection at the location of parking garage and reroute site-calculated vehicle volumes to the minor street thus depicting site conditions.

It should be noted that the avenues intersecting the major streets behave as one-way streets alternatively. This asks for greater caution while planning future operations. Unless otherwise specified, all turns are shared with through traffic. 17^{th} Str N has a consistent ROW of 50 feet whereas 18^{th} Str N has a ROW of 70 feet that decreases to 60 feet beyond 4^{th} Ave.

5.1.2 Future Conditions - LC 1

The existing ROW, parking facilities and, wherever possible, lane widths have been maintained to concur with site conditions.

17th Street North:
Exclusive turn lanes have been provided wherever possible/required. Care has been taken to maintain all on-street parking, except on section of road between 7th and 8th Ave N. On-street parking on 8th Ave has been removed because of need to provide exclusive left turn lanes. It seemed, from the study of this area from Google earth, that there is adequate off-street parking facility in this area. The building adjacent to this location is Alabama Power Company which provides a private parking garage for its employees. Moreover, during site visits it was observed that this on-street parking facility was under-utilized. Not many parking maneuvers were recorded for this facility.

18th Street North:
They are designed to provide no less than two lanes for each direction of flow with Two Way Left Turn Lane (TWLTL) wherever possible. Care was taken to retain on-street parking throughout the study area on 18th Str N. No additional ROW needs.

5.1.3 Future Conditions – LC 2

The main feature of this lane configuration is that all turns have been designed to share movements with through lanes. Number and width of lanes have been retained as existing in places made possible and parking has been eliminated at some sections of road for greater flexibility in design. This decision was taken due to site visit observations that adequate off street and public parking facilities are available at site.

17th Street North:
On street parking has been retained only on alternate sections of roadway.

18th Street N:
Based on the ROW availability and design features, parking facilities have been retained wherever possible. Two lanes carry vehicles towards west and EB traffic has three lanes at their disposal.

5.2 Traffic Design Options

Three methods of assigning vehicle volumes to the networks created were devised.

5.2.1 Retain the Current Vehicle Demand

In order to better evaluate the two-way traffic behavior immediately after conversion, it was considered best to estimate vehicle volumes currently experienced at site and apply them wholly to the network streets. An important aspect considered during this assignment was of driver behavior/expectancy.

It is assumed that since the existing 17th and 18th Str carry vehicles WB and EB respectively, drivers automatically tend to adopt 17th Str for traveling westwards and 18th Str for going eastwards. Keeping this in mind, it was decided to retain greater volumes of traffic on streets respective to their current flow direction and distribute volumes in 3:2 proportions. Meaning, two-way operating 17th Str will carry 60% of the currently existing demand of WB vehicles and distribute the remaining 40% to 18th Str and vice versa.

However, the above is true only for movements' currently nonexistent at site. E.g.: at the intersection of 17th Str and 1st Ave, NB through vehicles is 595 veh/hr and on 18th Str this volume is 368 veh/hr. These volumes will be retained as such. Conversely, at this intersection, there is no NB right turn movement on 17th Strdue to its one-way operation. Whereas, on 18th Str, this volume is 60 veh/hr. This 60 veh/hr was distributed into 36 veh/hr and 24 veh/hr and allocated to 18th and 17th Str respectively. Figures 5 through 7 show volume distribution for current and future network scenarios.

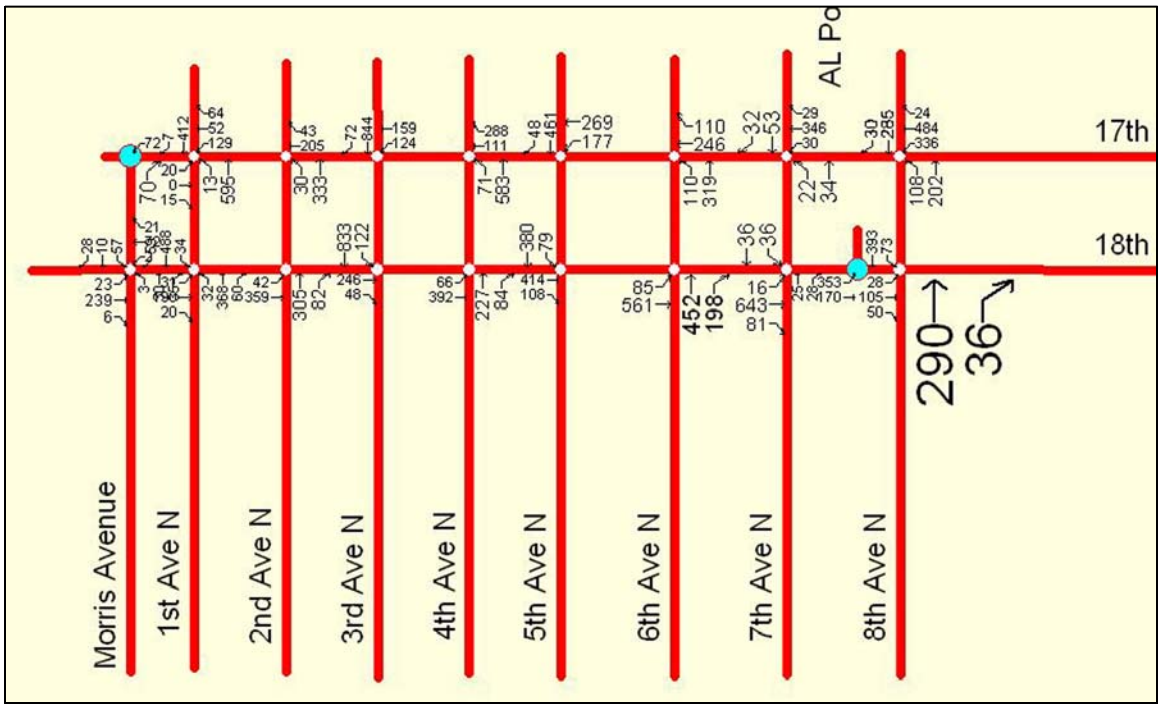

Figure 5: Traffic Volumes Currently Present at Study Site

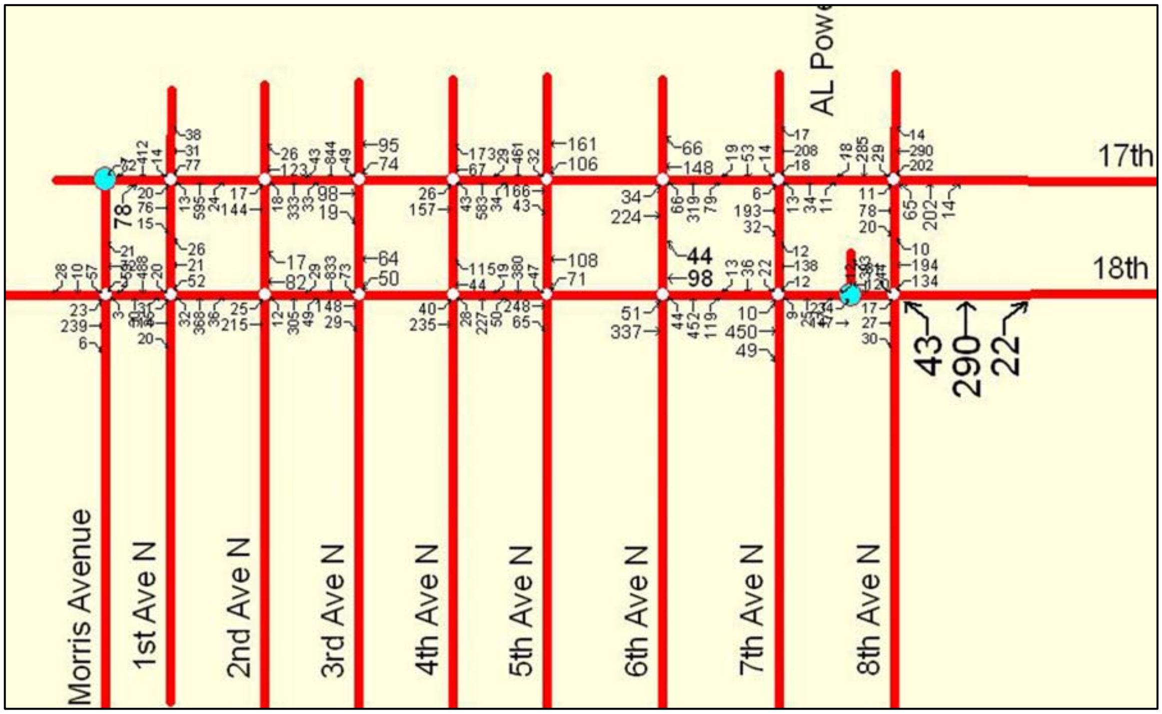

Figure 6: Vehicles in 3:2 Ratio for Future Designs

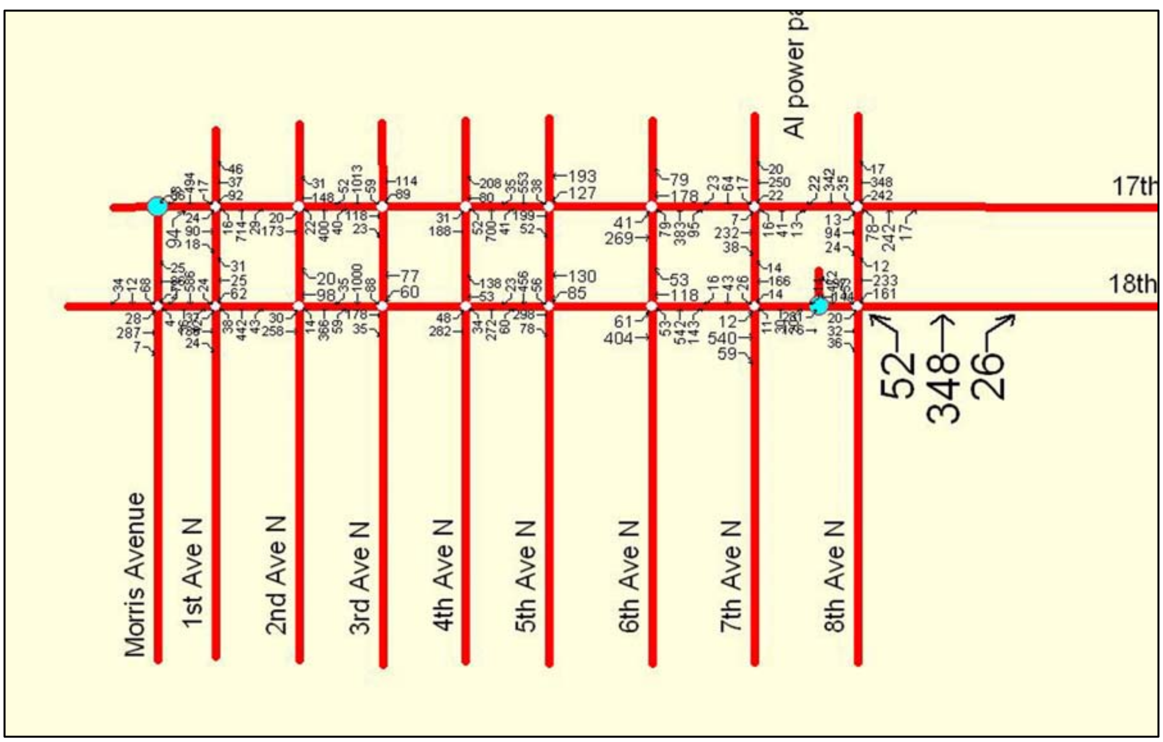

Figure 7: LC 1 and LC 2 Volumes with 20% Increased Demand

5.2.2 Increment Demand by 20%

In order to accommodate future traffic growths the existing demand was increased by 20% on all streets and analyzed (Figure 11). Subsequent to vehicle volume increase, pedestrian/bike volumes, heavy vehicle percentages, turning movements etc were also increased.

5.2.3 Increment Demand by 40%

As a measure to assess the maximum retaining capacity of the network and to provide further allowance to future growth, the second technique thought about was increasing current demand by 40% (Figure 12). Subsequent increments were made to pedestrian/bike volumes, heavy vehicle percentages, turning movements as well. Detailed results of analysis and simulation are furnished in Results section.

6. Results

6.1 SYNCHRO Optimization Results

The existing and proposed alternate networks were modeled using SYNCHRO and were further ran to analyze for possible glitches in operation and efficiency. Simulation using SYNCHRO was carried out in two basic steps:

a) Intersection split optimizations and
b) Network cycle length optimizations.

Since the study streets are a part of the greater downtown grid, changing cycle lengths (CL) and offsets would throw off the entire downtown system. For this reason, it was considered appropriate to retain the cycle lengths and offsets for every intersection to match with the present values and hence all proposed scenarios, including base condition, have been optimized for splits alone. This provides a more realistic timing scenario and greater coherence with the downtown network. Hereinafter, 'optimized' will attribute to cases that have been optimized for splits throughout the following document.

6.1.1 Intersection Split Optimizations

The intersection split optimizations were performed for every individual intersection, for all scenarios considered, within the study streets. This automatically sets the splits for all phases where time is assigned based on each lane group's traffic volume divided by its adjusted saturation flow rate. All phases are assigned a split greater than or equal to their minimum split. When optimizing splits, SYNCHRO first attempts to provide enough green time to serve the 90th percentile lane group flow and if there is not enough cycle time to meet this objective, SYNCHRO attempts to serve the 70^{th} percentile traffic and then the 50^{th} percentile traffic [4].

Sample results for intersection split optimization are shown in Figure 8. The timing diagram at the bottom of the page in the sheet highlights splits for each intersection and enables easy comparison.

Timings
16: 18th Street North & 3rd Ave N

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5/13/2008

Lane Group	EBT	SBT
Lane Configurations		
Volume (vph)	246	833
Turn Type		
Protected Phases	2	4
Permitted Phases		
Detector Phases	2	4
Minimum Initial (s)	4.0	4.0
Minimum Split (s)	36.0	36.0
Total Split (s)	37.0	43.0
Total Split (%)	46%	54%
Yellow Time (s)	3.0	3.0
All-Red Time (s)	2.0	2.0
Lead/Lag		
Lead-Lag Optimize?		
Recall Mode	Max	Max
Act Effct Green (s)	33.0	39.0
Actuated g/C Ratio	0.41	0.49
v/c Ratio	0.13	0.46
Uniform Delay, d1	12.1	13.6
Delay	10.8	6.8
LOS	B	A
Approach Delay	10.8	6.8
Approach LOS	B	A

Intersection Summary	
Cycle Length: 80	
Actuated Cycle Length: 80	
Offset: 11 (14%), Referenced to phase 2:EBT, Start of Green	
Natural Cycle: 75	
Control Type: Pretimed	
Maximum v/c Ratio: 0.46	
Intersection Signal Delay: 7.8	Intersection LOS: A
Intersection Capacity Utilization 54.9%	ICU Level of Service A

Splits and Phases: 16: 18th Street North & 3rd Ave N

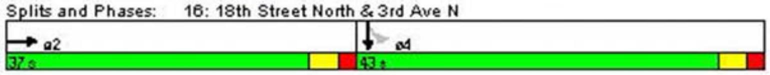
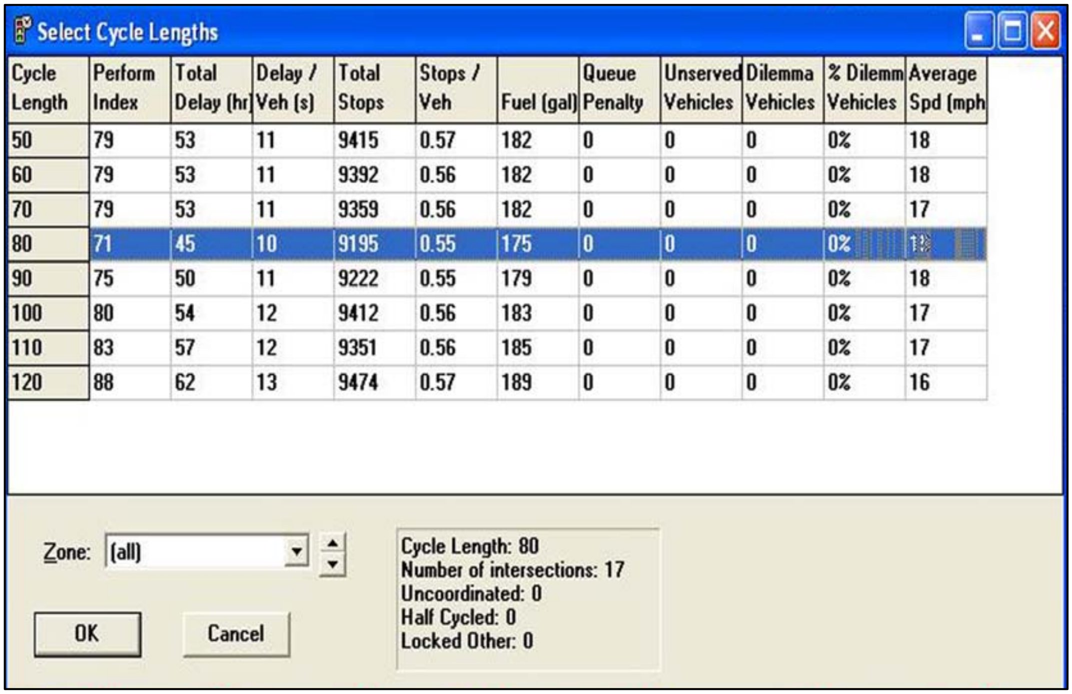


Figure 8: SYNCHRO Sheet Exhibiting Value of Split for an Intersection Before Intersection Split Optimization

6.1.2 Network CL Optimizations

Similar to split optimizations, network cycle length optimizations too were carried out for all situations, including the existing conditions, with minimum and maximum CL values of 50 seconds and 120 seconds respectively, incremented by 10 seconds. The optimizer in SYNCHRO evaluates every cycle length between the minimum and maximum at increment intervals. This cycle length optimization attempts to determine the shortest cycle length that performs best based on MOEs. The entire network was considered as a single zone with no half cycles and uncoordinated intersections.

Optimization of network cycle lengths was mainly executed to validate and ascertain the provision of 80 second cycle length for future and existing operations respectively. Sample sheets showing results of network cycle length optimizations for various scenarios are given in Figure 9. Detailed results of network cycle length optimizations can be found in the report [8].



Select Cycle Lengths

Cycle Length	Perform Index	Total Delay (hr)	Delay / Veh (s)	Total Stops	Stops / Veh	Fuel (gal)	Queue Penalty	Unserved Vehicles	Dilemma Vehicles	% Dilemm Vehicles	Average Spd (mph
50	79	53	11	9415	0.57	182	0	0	0	0%	18
60	79	53	11	9392	0.56	182	0	0	0	0%	18
70	79	53	11	9359	0.56	182	0	0	0	0%	17
80	71	45	10	9195	0.55	175	0	0	0	0%	[illegible]
90	75	50	11	9222	0.55	179	0	0	0	0%	18
100	80	54	12	9412	0.56	183	0	0	0	0%	17
110	83	57	12	9351	0.56	185	0	0	0	0%	17
120	88	62	13	9474	0.57	189	0	0	0	0%	16

Zone: (all)

OK Cancel

Cycle Length: 80
Number of intersections: 17
Uncoordinated: 0
Half Cycled: 0
Locked Other: 0

Figure 9: Network CL Optimization Result for LC-1 with Existing Demand

SYNCHRO provided an optimum CL value of 80 seconds for all scenarios and hence our usage of 80 sec signal cycle length for future operations to match with the remaining downtown street networks is validated.

6.1.3 Measures of Effectiveness (MOEs)

Apart from optimal CL and split values, SYNCHRO also generates several additional MOEs as simulation outputs. The MOE reports display quantitative information about the performance of intersections and network as a whole. Network reports display information about each approach, intersection, arterial and entire zone or network selected. Values shown in Table 1 are network totals, for all study scenarios. The values given for 'Existing Condition' scenario do not incorporate any type of optimization.

All above shown values are for SYNCHRO analysis for signalized intersections as SYNCHRO does not provide analysis for unsignalized intersections. The delays shown are percentile signal delay and delays/vehicle is delays divided by unadjusted volumes. The performance index is a function of delays, stops and queuing penalty. The MOEs given above have been represented in graphical format in Figures 10 (a), (b) and (c) to facilitate pictorial comparisons.

From the graphs and tables, it can be comprehended that the signal timings currently present at site, with modified splits, can efficiently move vehicles under all the proposed two-way operational conditions. No major impacts on traffic circulation are expected from a potential conversion.

MOE provided for the entire network	Existing Condition	LC 1			LC 2		
		Existing demand (V_{exs1})	V_{exs1} + 20%	V_{exs1} + 40%	Existing demand (V_{exs2})	V_{exs2} + 20%	V_{exs2} + 20%
Signal delay / veh (sec)	12	12	13	13	12	12	13
Total signal delay (hrs)	56	58	73	89	56	70	85
Stops / veh	0.63	0.76	0.78	0.77	0.76	0.78	0.79
Stops	10943	13265	16257	18857	13292	16371	19343
Average speed (mph)	17.00	17.00	17.00	16.00	17.00	17.00	17.00
Total travel time (hrs)	132	134	164	195	132	161	191
Distance Traveled (mi)	2277	2265	2716	3170	2265	2717	3170
Fuel Consumed (gal)	195	209	255	300	208	254	300
Fuel Economy (mpg)	11.7	10.8	10.6	10.6	10.9	10.7	10.6
CO Emissions (kg)	13.65	14.63	17.85	20.96	14.53	17.74	20.95
NOx Emissions (kg)	2.66	2.85	3.47	4.08	2.83	3.45	4.08
VOC Emissions (kg)	3.16	3.39	4.14	4.86	3.37	4.11	4.85
Unserved vehicles (#)	0	0	0	0	0	0	0
Vehicles in Dilemma Zone (#)	0	0	0	0	0	0	0
Queuing Penalty (veh)	0	0	0	0	0	0	0
Performance Index	86.50	95.20	118.40	141.20	93.00	115.80	138.60

Table 1: Comparison of Various MOEs for Entire Network Provided by SYNCHRO Simulations.

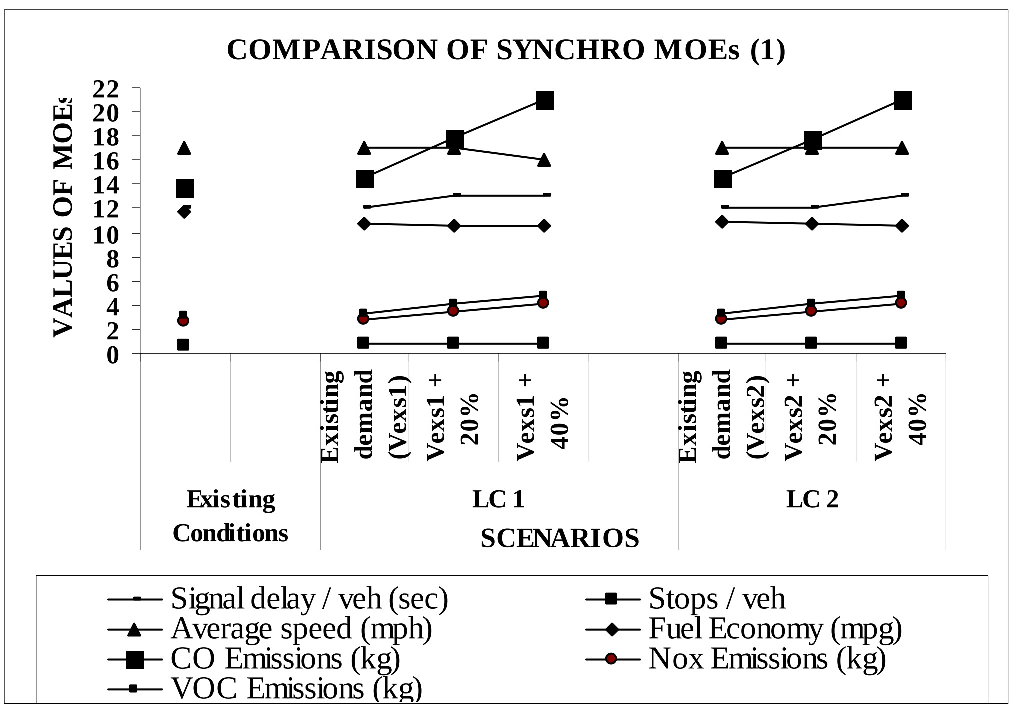


Figure 10 (a): SYNCHRO MOE Values for Entire Network

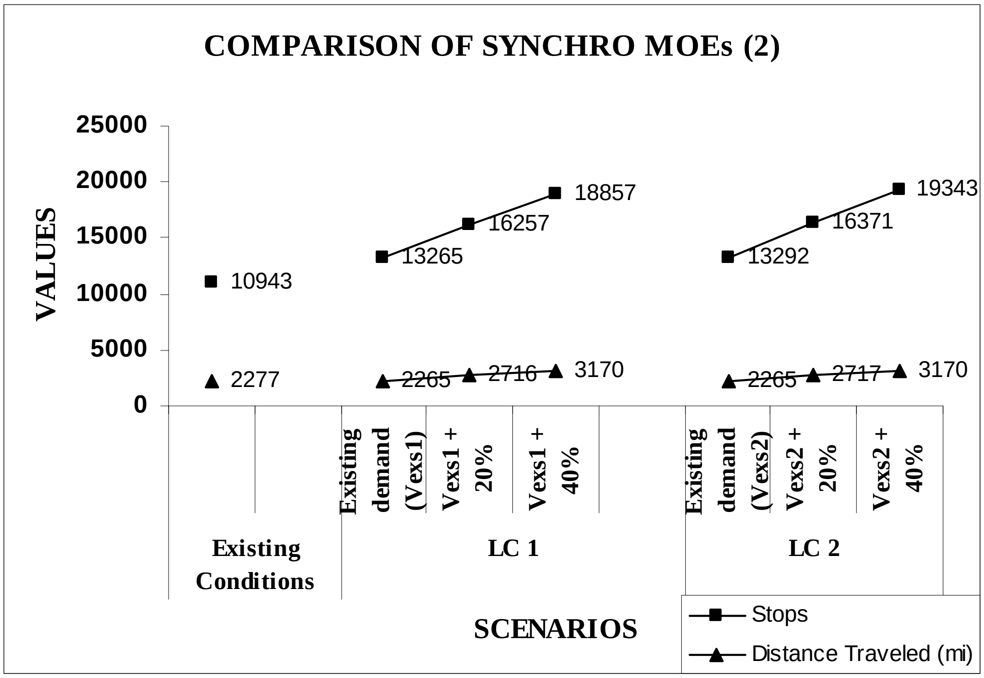


Figure 10 (b): SYNCHRO MOE Comparisons for Entire Network

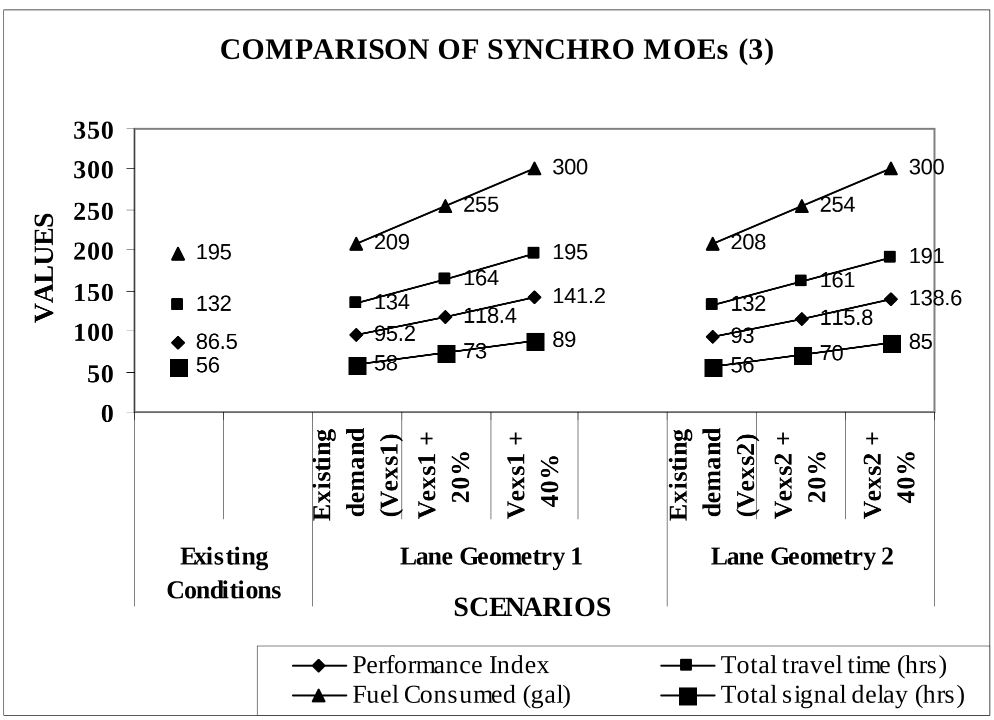
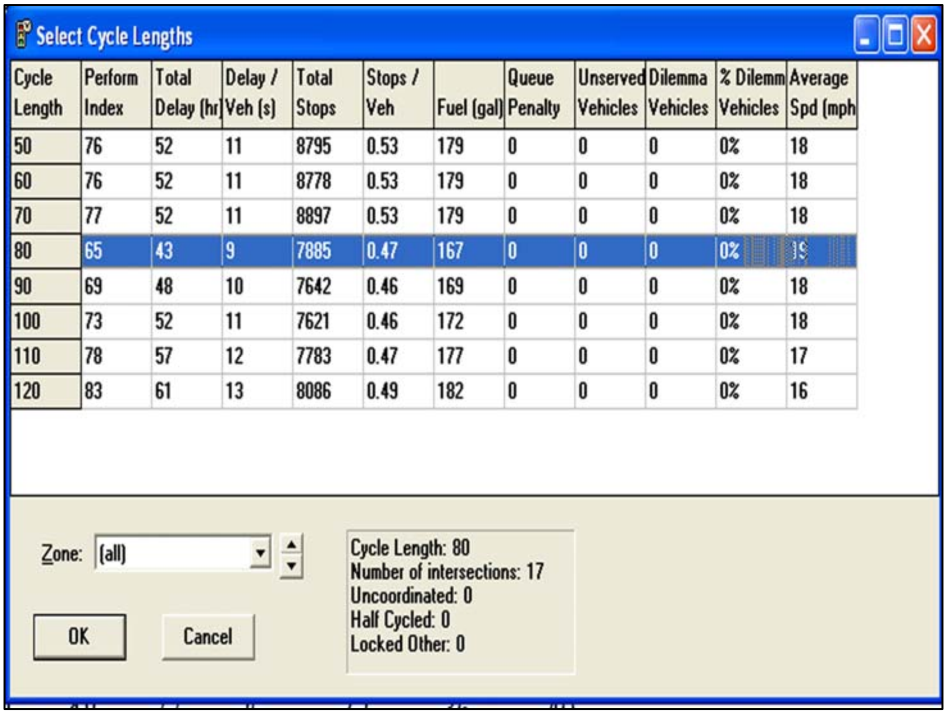


Figure 10 (c): SYNCHRO MOE Comparisons for Entire Network

6.1.4 Auxiliary Results from SYNCHRO

6.1.4.1 Base Case

As mentioned in the above section the 'Existing Condition' values shown in the MOE table is not inclusive of any optimization results since it was desired to represent this scenario as close to reality as possible. However, in order to inspect the soundness of present signal timing values the 'Existing Condition' scenario was further optimized for split and network CL and results obtained are presented below (Figure 11).



Cycle Length	Perform Index	Total Delay (hr	Delay / Veh (s)	Total Stops	Stops / Veh	Fuel (gal)	Queue Penalty	Unserved Vehicles	Dilemma Vehicles	% Dilemm Vehicles	Average Spd (mph
50	76	52	11	8795	0.53	179	0	0	0	0%	18
60	76	52	11	8778	0.53	179	0	0	0	0%	18
70	77	52	11	8897	0.53	179	0	0	0	0%	18
80	65	43	9	7885	0.47	167	0	0	0	0%	19
90	69	48	10	7642	0.46	169	0	0	0	0%	18
100	73	52	11	7621	0.46	172	0	0	0	0%	18
110	78	57	12	7783	0.47	177	0	0	0	0%	17
120	83	61	13	8086	0.49	182	0	0	0	0%	16

Figure 11: Network CL Optimization Result for Existing Condition.

The above result of optimization of CL for the Existing condition network, also referred to as base scenario, establish that the streets within Birmingham downtown network has been updated/maintained to efficiently carry varying vehicle demands, plus authenticates our decision to retain a CL of 80 seconds. Table 2 highlights the difference in MOE values for base case - unoptimized and optimized conditions.

6.1.4.2 Analysis of Signalized Intersections

In addition to the basic percentile delay method, SYNCHRO offers two other independent methods to analyze signalized intersections, namely HCM signalized method and Intersection Capacity Utilization (ICU). The chief MOE produced by SYNCHRO delay method is delay whereas for HCM it is delay and v/c ratio, and v/c ratio for ICU.

MOE for the Entire Network	Existing Conditions Un-optimized	Existing Conditions Optimized
Signal delay / veh (sec)	12	13
Total signal delay (hrs)	56	60
Stops / veh	0.63	0.69
Stops	10943	11895
Average speed (mph)	17	17
Total travel time (hrs)	132	136
Distance Traveled (mi)	2277	2277
Fuel Consumed (gal)	195	204
Fuel Economy (mpg)	11.7	11.2
CO Emissions (kg)	13.65	14.23
NOx Emissions (kg)	2.66	2.77
VOC Emissions (kg)	3.16	3.3
Unserved vehicles (#)	0	0
Vehicles in Dilemma Zone (#)	0	0
Queuing Penalty (veh)	0	0
Performance Index	86.5	93.2

Table 2: Existing Operational Condition MOEs for Un-optimized and Optimized Scenarios.

The ICU method is designed to be used for planning applications and its primary benefits are higher accuracy, ease of use and reproductability. Volume capacity ratios are inherently more accurate than delay calculations. ICU assumptions of protected left turns and disregard of coordination, eliminates any inaccuracies and uncertainty. Conflicting movements are not allowed to use the intersection at the same time and hence capacity is not double counted.

The HCM Signalized method is based on the Highway Capacity Manual and the delay produced by HCM method is less accurate. Besides, the analyst has to estimate the affects of coordination and actuated signals which lead to further loss of accuracy. SYNCHRO delay methods are designed for operations and signal timing optimizations. SYNCHRO's method is called the percentile method. Though this method is capable of modeling coordination and actuated signals in detail, delays calculated are less accurate than capacity based methods[4].

Tables 3(a) through (c) are provided to assist in comparison of delays and LOS values generated by the above three analysis methods. Careful observation of these values would reveal that the SYNCHRO v/c ratios are consistently higher than those produced by the HCM method. On the other hand, delays resulting from the HCM method are greater than SYNCHRO analysis, as was expected due to the effects of coordination and actuated signals. In case of LOS values, it is noticed that SYNCHRO and HCM methods yield relatively similar result. However ICU LOS values are found to differ, overestimating in some cases and underestimating in others. To view MOE values for all other scenarios refer to the report[8].

Intersection between	SYNCHRO Delay Method			ICU Method		HCM Method		
	Max v/c ratio	Delay	LOS	ICU LOS	ICU	Delay	v/c ratio	LOS
18th St. N & Morris Ave.	0.21	10.00	A	D	80.00%	11.60	0.20	B
17th St N & 1st Ave N	0.45	12.30	B	B	62.40%	13.50	0.37	B
18th St N & 1st Ave N	0.33	10.90	B	A	48.30%	12.10	0.29	B
17th St N & 2nd Ave N	0.20	8.90	A	A	44.30%	9.60	0.17	A
18th St N & 2nd Ave N	0.17	10.80	B	A	34.00%	12.30	0.16	B
17th St N & 3rd Ave N	0.49	15.60	B	A	43.30%	16.50	0.33	B
18th St N & 3rd Ave N	0.46	7.80	A	A	54.90%	8.70	0.31	A
17th St N & 4th Ave N	0.35	16.00	B	A	50.30%	22.10	0.30	C
18th St N & 4th Ave N	0.18	11.90	B	A	41.90%	13.50	0.18	B
17th St N & 5th Ave N	0.30	19.00	B	A	45.20%	19.60	0.27	B
18th St N & 5th Ave N	0.25	9.40	A	A	46.60%	10.70	0.24	B
17th St N & 6th Ave N	0.25	5.90	A	A	43.50%	6.90	0.21	A
18th St N & 6th Ave N	0.30	9.60	A	A	47.20%	11.70	0.32	B
17th St N & 7th Ave N	0.17	17.90	B	A	56.70%	19.80	0.16	B
18th St N & 7th Ave N	0.33	17.40	B	B	70.00%	19.00	0.20	B
17th St N & 8th Ave N	0.46	13.80	B	A	50.40%	14.60	0.38	B
18th St N & 8th Ave N	0.22	7.70	A	A	51.60%	9.20	0.20	A

Table 3 (a): MOEs for Existing Condition (Un-optimized) by SYNCHRO, HCM and ICU methods

Intersection between	SYNCHRO Delay Method			ICU Method		HCM Method		
	Max v/c ratio	Delay	LOS	ICU LOS	ICU	Delay	v/c ratio	LOS
18th St. N & Morris Ave.	0.20	12.00	B	D	80.00%	14.00	0.20	B
17th St N & 1st Ave N	0.47	12.40	B	B	65.00%	13.40	0.32	B
18th St N & 1st Ave N	0.41	10.60	B	A	48.30%	11.80	0.28	B
17th St N & 2nd Ave N	0.24	9.70	A	B	65.00%	10.60	0.23	B
18th St N & 2nd Ave N	0.20	10.80	B	A	41.70%	12.10	0.18	B
17th St N & 3rd Ave N	0.50	15.20	B	C	71.60%	16.10	0.34	B
18th St N & 3rd Ave N	0.48	7.20	A	A	45.80%	8.00	0.33	A
17th St N & 4th Ave N	0.36	13.10	B	A	52.90%	21.10	0.38	C
18th St N & 4th Ave N	0.20	11.30	B	B	70.00%	15.90	0.19	B
17th St N & 5th Ave N	0.31	12.70	B	C	70.40%	13.70	0.29	B
18th St N & 5th Ave N	0.24	9.90	A	A	58.60%	11.20	0.22	B
17th St N & 6th Ave N	0.32	10.40	B	B	66.70%	14.2	0.28	B
18th St N & 6th Ave N	0.34	9.50	A	A	56.70%	11.30	0.31	B
17th St N & 7th Ave N	0.35	13.10	B	A	56.70%	14.70	0.24	B
18th St N & 7th Ave N	0.43	17.80	B	D	84.00%	19.20	0.25	B
17th St N & 8th Ave N	0.46	18.40	B	A	48.70%	20.00	0.37	B
18th St N & 8th Ave N	0.35	13.00	B	A	43.30%	14.00	0.33	B

Table 3 (b): MOEs for LC-1 with Current Demand by SYNCHRO, HCM and ICU methods

Intersection between	SYNCHRO Delay Method			ICU Method		HCM Method		
	Max v/c ratio	Delay	LOS	ICU LOS	ICU	Delay	v/c ratio	LOS
18th St. N & Morris Ave.	0.21	10.50	B	D	80.00%	12.30	0.20	B
17th St N & 1st Ave N	0.47	11.70	B	B	65.00%	12.70	0.32	B
18th St N & 1st Ave N	0.41	8.40	A	A	48.30%	9.50	0.27	A
17th St N & 2nd Ave N	0.21	8.10	A	B	65.00%	8.90	0.18	A
18th St N & 2nd Ave N	0.16	10.30	B	A	50.00%	11.50	0.16	B
17th St N & 3rd Ave N	0.50	14.30	B	C	72.40%	15.20	0.35	B
18th St N & 3rd Ave N	0.48	4.50	A	A	58.30%	5.20	0.30	A
17th St N & 4th Ave N	0.35	9.60	A	B	63.30%	10.60	0.29	B
18th St N & 4th Ave N	0.18	9.50	A	B	63.30%	12.70	0.18	B
17th St N & 5th Ave N	0.31	11.40	B	C	72.40%	12.20	0.29	B
18th St N & 5th Ave N	0.24	6.90	A	C	74.40%	7.60	0.22	A
17th St N & 6th Ave N	0.24	4.20	A	A	60.00%	4.9	0.24	A
18th St N & 6th Ave N	0.27	10.70	B	B	65.00%	12.40	0.26	B
17th St N & 7th Ave N	0.22	9.80	A	A	56.70%	11.10	0.17	B
18th St N & 7th Ave N	0.31	7.40	A	E	95.00%	8.40	0.20	A
17th St N & 8th Ave N	0.56	11.50	B	A	49.10%	12.70	0.42	B
18th St N & 8th Ave N	0.37	12.00	B	A	43.30%	13.00	0.34	B

Table 3 (c): MOEs by SYNCHRO, HCM and ICU Methods for LC-2 with Present Demand

Besides the 17 intersections controlled by pre-timed signals, our networks also contains two unsignalized intersections. MOEs for these unsignalized intersections were provided by the HCM method as shown in Table 4.

Scenarios	Morris Ave & 17th Street N		18th Street N & AL Power Parking	
	Delay	HCM LOS	Delay	HCM LOS
Base Case	7.5	A	-	-
LC 1 - Present Demand	7.5	A	8.8	A
LC 1 with 20% Increase in Demand	7.7	A	9.8	A
LC 1 with 40% Increase in Demand	7.9	A	11.1	B
LC 2 - Present Demand	7.5	A	-	-
LC 2 with 20% Increase in Demand	7.7	A	-	-
LC 2 with 40% Increase in Demand	7.9	A	-	-

Table 4: HCM MOE for Unsignalized Intersections.

The HCM evaluation of intersection between 18th Str N and Alabama Power Parking Garage for base case did not yield any result since this intersection has three lanes per direction with an fourth lane reserved for right turns and HCM method is inept in evaluating any unsignalized intersection with more than two lanes per leg and any channelized right turn lanes.

In LC 1, 18th Str N contains two lanes per direction, with shared left and right turns, between 7th and 8th Ave N where Alabama Power Garage is located, and hence HCM is able to evaluate the unsignalized intersection at this location. At the location of Alabama Power Parking Garage on 18th Str North, LC 2 was designed for three lanes with shared turns, which makes HCM incapable of any assessment.

In addition to the above, SYNCHRO produces several supplementary reports as well, including:

Arterial Travel Time Rreport – This contains information about the speed and travel time for an arterial and its intersecting streets and can be used to compare with field travel time studies. A report is created for each direction of the arterial. Arterial LOS is thereby created based on their speed and class.

Actuated Green Time Summary – Information regarding phases, percentile, green time and termination are provided for each phase and percentile in this report and is helpful for looking at actuated signals to see the range of green times. A detailed bar graph is also shown.

Permitted Left Turn Factors Report – The permitted left turn factors report furnishes details about lanes and saturation flow rates. It is roughly equivalent to the HCM's value as SYNCHRO calculates left turn factors based on maximum green times rather than actuated green times.

Coordinatability Analysis Report – This report gives information about coordinatability factors (CF) and elements used to calculate them. CF is a measure of desirability of coordinating intersections. Any score above 80 indicates that intersections must be coordinated to avoid blocking problems and any score below 20 shows that intersections are far apart and hence coordination is not desirable.

TSD – The TSD can be used to see graphically how traffic flows between intersections. A TSD can be invoked for a selected arterial as well as an intersection. Traffic flow lines or traffic density diagrams are represented by diagonal and horizontal lines and timing bands, indicated by red, green and yellow bands, signify the phase of signal for each part of the cycle.

The diagram also shows speeds and positions of vehicles. Each line represents one or more vehicles. The slope of each line is proportional to the vehicle's speed. Horizontal lines represent stopped cars. Best timing plans are the ones with fewest and shortest horizontal lines. The triangles of horizontal lines show stopped vehicles queued at a red light. The width of a triangle is the longest waiting time. The height of triangle represents the maximum queue. The TSD allows us to view traffic flows for 90th, 70th, 50th, 30th and 10th percentile cycles for the hour for which volume data is given. A TSD also provides information on average delays for each movement and overall intersection, as well as on lane groups operating above capacity. A sample TSD graph for 17th Str N (Base Scenario Optimized) is shown in Figure 12 below. Detailed results are available in [8].

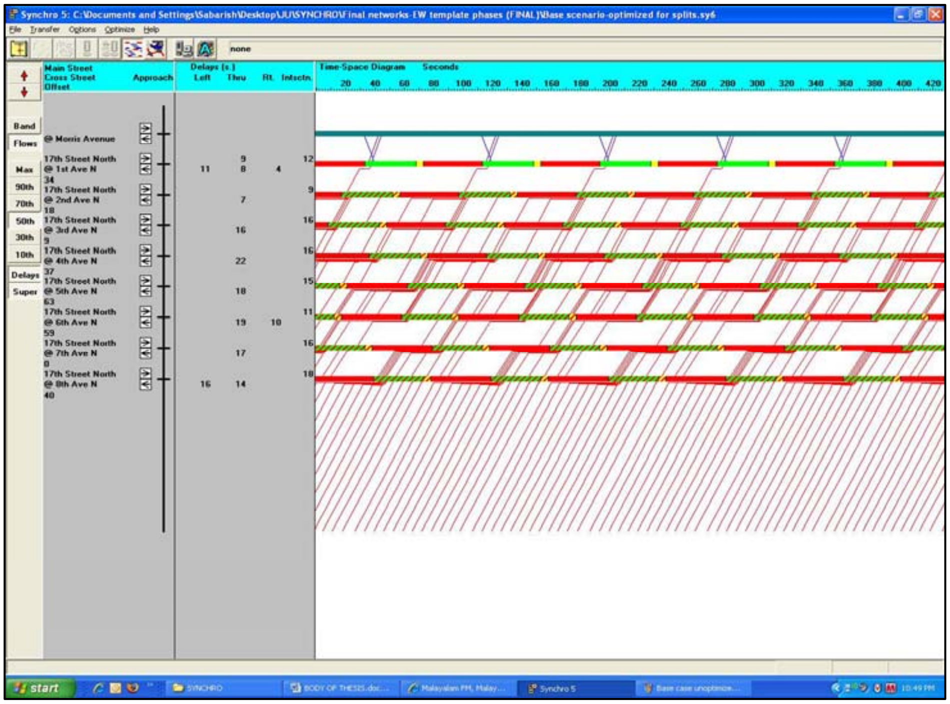


Figure 12: TSD for Base Scenario Optimized – 17th Str

6.2 CORSIM Simulation and Animation Results

Once all proposed networks were modeled and optimized in SYNCHRO, the models were transferred to CORSIM for further timing analysis and simulation. To perform CORSIM analysis, it was necessary to first create a TSIS file in SYNCHRO after split and CL optimizations. The entire network (as one single zone) to simulate was then specified with simulation time of one hour, split into four 15-minute intervals (900 seconds each). It was done so to view traffic hitches and spillbacks if any and to obtain traffic flow pattern for every 15 min.

As results of CORSIM analysis and animation, numerous MOEs were developed as network summaries for each design; like total vehicle miles traveled, vehicle hours of move time, delay and total time, average speed and minutes per miles of delay time. Samples of those MOEs are displayed in Figures 13 and 14 below.

6.2.1 Total vehicle miles traveled (VMT)

As shown in Figure 13, the total VMT for both future lane configurations (for two-way operations) where current demand is retained and distributed in 60 - 40 proportions remain equal to presently existing one-way operation VMT. Hence it can be judged that a potential conversion, with demand being more or less the same, would not affect traffic operations extensively. Similarly, VMT values remain equivalent for LC 1 and 2 with demand increased by 20%, and for LC 1 and 2 with 40% of increased demand conditions; thus causing us to believe that lane configuration designs 1 and 2 for future operations with similar demand statistics, does not significantly vary from one another in terms of traffic operations, thereby rendering both designs competent.

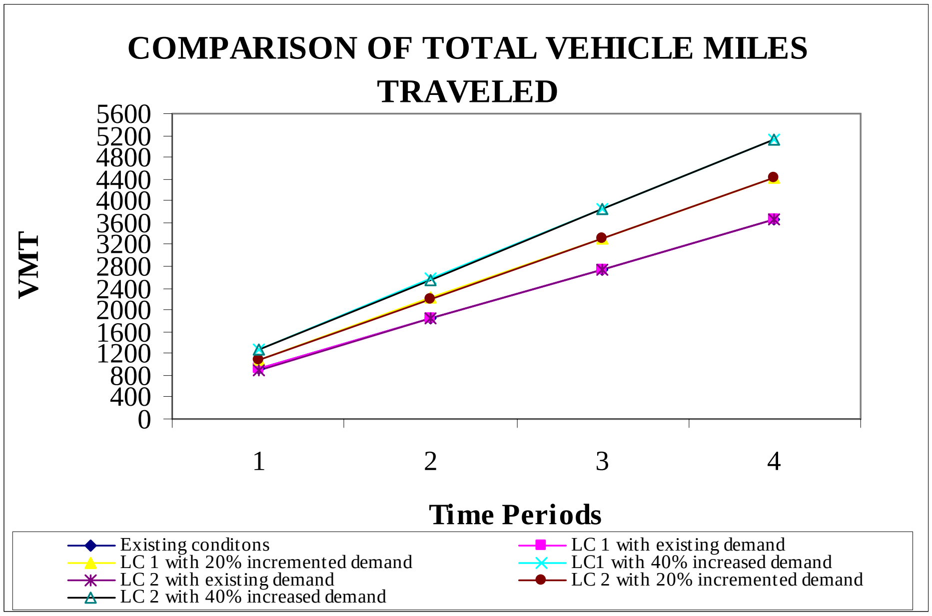


Figure 13: Comparison of Total Vehicle Miles Traveled for all Scenarios.

6.2.2 Vehicle Moving Time in Hours

Similar to the VMT, all vehicles' moving time appears independent of the lane configuration. This is evident from the CORSIM findings in Figure 14.

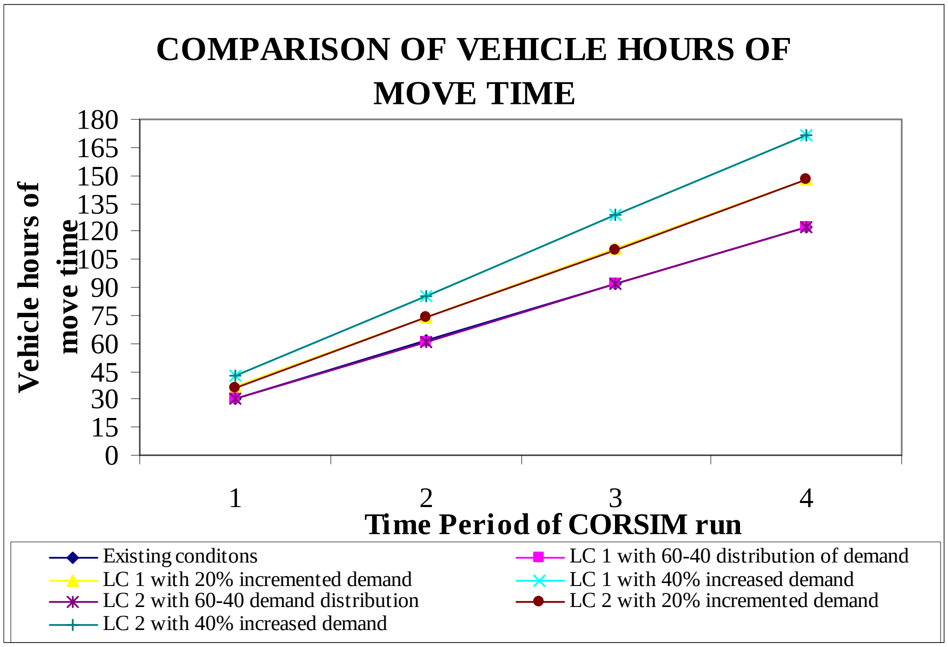


Figure 14: Comparison of Vehicle Travel Times for all Scenarios.

6.2.3 Average Speed

As shown in Table 5, the average vehicle speed existing at site currently is around 18.74 mph. However, estimates indicate that when converted to two way streets, designed as per LC 1, the vehicle average speed is likely to increase to 19.06 mph and to 19.13 mph for LC 2. For demands increased by 20% and 40%, LC 2 is found to perform slightly better compared to LC 1. To conclude, minor differences in speeds are observed among all study scenarios and LC 2 functions best among the proposed scenarios, for all demand conditions.

Average speeds (mph) for:	**Time Period of Run**				**Average Speed (mph)**
	1	**2**	**3**	**4**	
Existing conditions	18.66	18.75	18.75	18.78	18.74
LC 1 with existing demand	19.02	19.09	19.07	19.05	19.06
LC 1 with 20% incremented demand	18.76	18.71	18.66	18.66	18.70
LC 1 with 40% increased demand	18.78	18.65	18.59	18.54	18.64
LC 2 with existing demand	19.14	19.14	19.15	19.10	19.13
LC 2 with 20% incremented demand	18.90	18.83	18.78	18.78	18.82
LC 2 with 40% increased demand	18.74	18.72	18.66	18.60	18.68

Table 5: Average Vehicle Speed Comparisons for each Scenario.

7. Results and Conclusions

Results of the study conducted in Birmingham downtown area to analyze the feasibility and impacts of conversion of one-way street pairs to two way operations are presented below.

- The signal timings currently existing at the site, with splits slightly modified, are adequate to move vehicles efficiently, under all the proposed two-way operational scenarios.
- The current downtown network is maintained/ updated to accommodate varying vehicle demands.
- The use of cycle length of 80 sec for all scenarios was ascertained by network cycle length optimizations.
- All scenarios with their proposed signal timings exhibit satisfactory signal progression and smooth traffic flows. No major impacts on traffic circulation, like unfavorable delays or spillbacks are expected from a potential conversion.
- The LC 1 and LC 2 designs proposed in the study are equally competent in terms of traffic operations and have similar operational statistics.
- The vehicles' moving and travel times are found to be independent of lane configurations.
- Among all scenarios proposed, LC 2 is found to function best for all demand conditions.

However, further studies are suggested to assess the impacts of one to two-way conversions on operations of the entire downtown grid and address access and other issues.

7. References

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[8] V. P. Sisiopiku and J. Chemmannur, 2008: “Study of the Impacts from One to Two-Way Street Conversion”. Final Report to the UAB ADVANCE Program of the Office for the Advancement of Women in Science and Engineering.