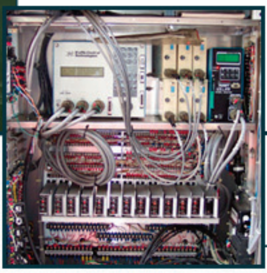
Summary Report

NASHVILLE



TRAFFIC SIGNAL TIMING OPTIMIZATION STUDY *for* *the Metro Nashville Signal System*

SUPPLEMENT II

Prepared for:

Metropolitan Government of Nashville and Davidson County Department of Public Works

May 2007

Prepared by:

Kimley-Horn and Associates, Inc.

Table of Contents

Executive Summary

The Metropolitan Government of Nashville and Davidson County's Department of Public Works (MPW) identified 14 corridors in the county that experience heavy traffic congestion and needed traffic signal timing improvements to improve traffic flow as well as fuel consumption. These corridors included a total of 161 signalized intersections:

- Corridor 10 – Charlotte Pike (35 intersections)
- Corridor 11 – White Bridge Road (6 intersections)
- Corridor 12 – Church Street (9 intersections)
- Corridor 13 – Old Hickory Boulevard (Brentwood area) (3 intersections)
- Corridor 14 – Jefferson Street and Spring Street (17 intersections)
- Corridor 15 – Thompson Lane and Briley Parkway (9 intersections)
- Corridor 16 – US 70 S (Bellevue) (11 intersections)
- Corridor 17 – Woodmont Boulevard (5 intersections)
- Corridor 18 – Haywood Lane (5 intersections)
- Corridor 19 – Metrocenter Boulevard and Clarksville Pike (20 intersections)
- Corridor 20 – Harding Place (I-65 interchange area) (5 intersections)
- Corridor 21 – SR 45 (9 intersections)
- Corridor 22 – Dickerson Pike (17 intersections)
- Corridor 23 – SR 100 (10 intersections)

This study of the above corridors was considered Supplement II to the traffic signal optimization study for the Metro Nashville signal system project initiated in June 2004. This portion of the study was wholly funded by MPW funds at a cost of $530,000. The consultant team MPW selected to conduct this study was Kimley-Horn and Associates, Inc., with Stammer Transportation Engineering, Inc. as part of the team. The project scope included significant data collection efforts, an assessment of existing conditions, identification of potential improvements, development of timing plans for each period of the day including weekdays and weekend, and field implementation of the proposed timing plans, travel time and delay studies, and complete project documentation.

For Supplement II, results from the signal timing effort included a 36 percent reduction in delay for the 14 corridors, with the greatest delay reduction of approximately 73 percent being the SR 100 corridor in southeastern Davidson County. Benefits in reduced fuel consumption also were realized with this project. A reduction of 11 percent in fuel consumption along the 14 corridors was achieved. The total project achieved a one-year benefit-to-cost ratio of 37:1. However, newly implemented signal timing plans prove to be beneficial for a time period longer than one year. Typically, the useful life for signal timing plans is three years. Therefore, the three-year benefit-to-cost ratio increases to 111:1.

For the traffic signal optimization study for the Metro Nashville signal system project, from project inception through the completion of Supplement II, nearly a 27 percent reduction in delay for the 21 corridors has been realized. Fuel consumption was reduced by nearly 9 percent. From inception to date, the total project has achieved a one-year benefit-to-cost ratio of 27:1, with a three-year benefit-to-cost ratio of 81:1.

In conclusion, this signal timing optimization program proved to be beneficial in three distinct areas:

- Reduction in traffic congestion for Davidson County motorists
- Environmental improvements (i.e., reduction in fuel consumption)
- Fiscally beneficial (i.e., the benefits greatly outweigh the costs)

TRAFFIC SIGNAL TIMING OPTIMIZATION STUDY for the Metro Nashville Signal System

SUPPLEMENT II

Project Background and Scope

Project Background

The Metropolitan Government of Nashville and Davidson County, Department of Public Works, Engineering Division (MPW) selected the Kimley-Horn and Associates, Inc. team to perform a traffic signal optimization study for seven arterial corridors within the Metro Nashville signal system that included 223 signalized intersections. The consultant team included staff from Kimley-Horn, Stammer Transportation Engineering, Inc., and Bowlby & Associates, Inc. MPW selected the Kimley-Horn team for this project and issued a notice to proceed in June 2004. The seven corridors studied were generally completed individually beginning with corridor 4 (Nolensville Pike/Harding Place). The project was completed in April 2006, wholly funded by the Nashville Area Metropolitan Planning Organization's (MPO's) transportation improvement program (TIP) at a cost of $750,000.

MPW selected Kimley-Horn, teamed with Stammer Transportation Engineering, Inc., to complete additional services on this project, known as Supplement II. This portion of the project consisted of performing a traffic signal optimization study for 14 corridors within Nashville and Davidson County, which included 161 signalized intersections. The notice to proceed was issued in October 2005 and the project was completed in April 2007. This portion of the project was wholly funded by MPW funds.

Project Scope

Supplement II involved studying the following 14 corridors throughout the county (see Figure 1):

- Corridor 10 – Charlotte Pike (35 intersections)
- Corridor 11 – White Bridge Road (6 intersections)
- Corridor 12 – Church Street (9 intersections)
- Corridor 13 – Old Hickory Boulevard (Brentwood area) (3 intersections)
- Corridor 14 – Jefferson Street and Spring Street (17 intersections)
- Corridor 15 – Thompson Lane and Briley Parkway (9 intersections)
- Corridor 16 – US 70 S (Bellevue) (11 intersections)
- Corridor 17 – Woodmont Boulevard (5 intersections)
- Corridor 18 – Haywood Lane (5 intersections)
- Corridor 19 – Metrocenter Boulevard and Clarksville Pike (20 intersections)
- Corridor 20 – Harding Place (I-65 interchange area) (5 intersections)
- Corridor 21 – SR 45 (9 intersections)
- Corridor 22 – Dickerson Pike (17 intersections)
- Corridor 23 – SR 100 (10 intersections)

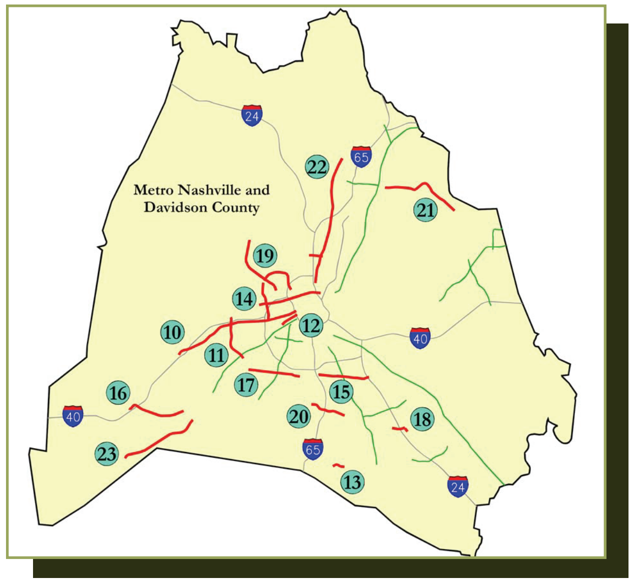


Figure 1, Project Location Map

The major components of this project included:

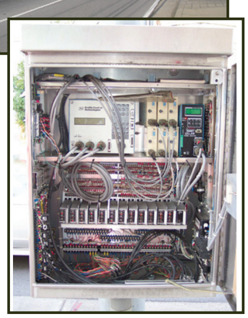
- Data collection
- Existing conditions evaluation
- Timing plan development
- Field implementation and fine tuning
- Travel time and delay study
- Project documentation

Data Collection

This project required a tremendous amount of data to be collected. This was accomplished by staff from Stammer Transportation Engineering, Inc., Kimley-Horn, and MPW. The data collected included the following elements:

- Existing signal timings and operational settings
- As-built traffic signal plans or file drawings (where available)
- Signal controller user's manuals, coding sheets, and software
- Aerial photography
- Turning movement counts for each intersection (AM, mid-day, and PM counts, two hours each)
- Average daily traffic (ADT) tube counts (from TDOT count stations)
- Field inventories (including intersection geometrics)
- Intersection approach photographs
- Signal controller cabinet photographs
- Field observations of existing conditions

MPW staff members provided the existing timing data for all intersections, the as-built traffic signal plans or file drawings, and the signal controller manuals, coding sheets, and software. Stammer Transportation Engineering, Inc., was responsible for collecting the turning movement counts, intersection approach photos, intersection geometry, and preparation of the intersection sketches. Kimley-Horn documented and compiled this data and collected the remaining data.

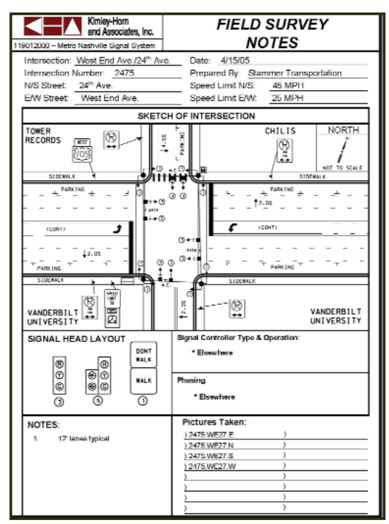


The data collected for each corridor was then summarized in a technical memorandum and submitted to MPW staff along with the electronic data collected, where applicable. The accuracy of the data collection was crucial to the success of this project since it was used to develop the model and the new signal timing plans.

Existing Conditions Evaluation

Prior to developing the new signal timing plans, it was important to understand and validate the existing conditions in each corridor. By using the data collected in the field and knowledge of the existing conditions observed in the field, a network was built for each peak period using Synchro®. All assumptions used in developing the models were documented and discussed with MPW staff, and all electronic files were provided to MPW staff. The existing conditions of the signals along each corridor were analyzed in a manner consistent with the *Highway Capacity Manual 2000* methodologies.

Kimley-Horn then performed an operational analysis for each intersection in each corridor. The capacity analyses were consistent with the *Highway Capacity Manual 2000* methodology when comparing improvement options. Existing and proposed signal phasing and sequencing were analyzed as well as identifying other possible operational improvements, such as pavement marking changes, geometric improvements, signal control equipment additions and/or upgrades, etc. Consideration was given to compliance issues with the FHWA *Manual on Uniform Traffic Control Devices, 2003 Edition* (MUTCD). This information was compiled in a technical memorandum that was submitted to MPW on a per corridor basis.


Kimley-Horn and Associates, Inc.
119012000 – Metro Nashville Signal System

FIELD SURVEY NOTES

Intersection: West End Ave./24th Ave.
Intersection Number: 2475
N/S Street: 24th Ave.
E/W Street: West End Ave.
Date: 4/15/05
Prepared By: Stammer Transportation
Speed Limit N/S: 45 MPH
Speed Limit E/W: 25 MPH

SKETCH OF INTERSECTION

SIGNAL HEAD LAYOUT

Signal Controller Type & Operation:
* Elsewhere

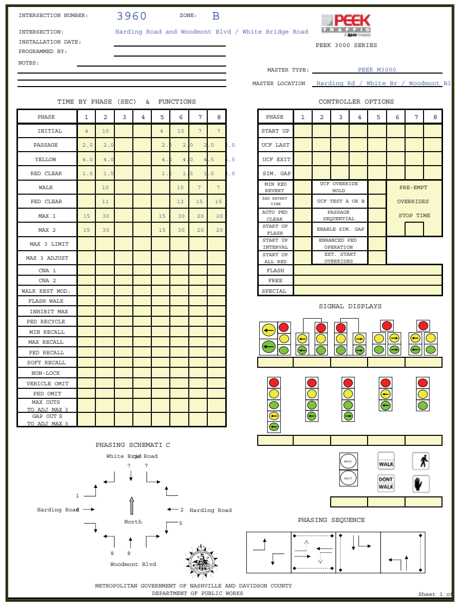
Phasing:
* Elsewhere

NOTES:
1. 12' lanes typical

Pictures Taken:
) 2475.WE27.E)
) 2475.WE27.N)
) 2475.WE27.S)
) 2475.WE27.W)

Timing Plan Development

New timing plans were developed for each corridor using the data previously collected. Typically, four timing plans were developed for each system—an AM, mid-day, PM, and off-peak plan. The development of the timing plans began with an evaluation of each corridor and its system boundaries. Each corridor was broken into multiple systems or zones to ensure the signals within each zone would operate in the same coordination pattern. The zone boundaries were established by Kimley-Horn with input from MPW staff. A number of criteria were used including ADT and turning movement count data, intersection spacing, cycle length requirements, driver expectancy, Synchro® coordination factors, coupling indices, and existing features.



INTERSECTION NUMBER: 3960 ZONE: B
INTERSECTION: Harding Road and Woodmont Blvd / White Bridge Road
INSTALLATION DATE:
PROGRAMMED BY:
NOTES:

PEEK TRAFFIC
PEEK 3000 SERIES

MASTER TYPE: PEEK M3000
MASTER LOCATION Harding Rd / White Br / Woodmont Bl

TIME BY PHASE (SEC) & FUNCTIONS

PHASE	1	2	3	4	5	6	7	8
INITIAL	4	10			4	10	7	7
PASSAGE	2.0	2.0			2.0	2.0	2.0	2.0
YELLOW	4.0	4.0			4.0	4.0	4.5	4.5
RED CLEAR	1.5	1.5			1.5	1.5	1.5	2.0
WALK		10				10	7	7
PED CLEAR		11				13	15	15
MAX 1	15	30			15	30	20	20
MAX 2	15	30			15	30	20	20
MAX 3 LIMIT								
MAX 3 ADJUST								
CNA 1								
CNA 2								
WALK REST MOD.								
FLASH WALK								
INHIBIT MAX								
PED RECYCLE								
MIN RECALL								
MAX RECALL								
PED RECALL								
SOFT RECALL								
NON-LOCK								
VEHICLE OMIT								
PED OMIT								
MAX OUTS TO ADJ MAX 3								
GAP OUT S TO ADJ MAX 3								

CONTROLLER OPTIONS

PHASE	1	2	3	4	5	6	7	8
START UP								
UCF LAST								
UCF EXIT								
SIM. GAP								

MIN RED REVERT		UCF OVERRIDE HOLD		PRE-EMPT
RED REVERT TIME		UCF TEST A OR B		OVERRIDES
AUTO PED CLEAR		PASSAGE SEQUENTIAL		STOP TIME
START UP FLASH		ENABLE SIM. GAP		
START UP INTERVAL		ENHANCED PED OPERATION		
START UP ALL RED		EXT. START OVERRIDES		
FLASH				
FREE				
SPECIAL				

SIGNAL DISPLAYS

WALK
WAIT
WALK
DONT WALK

PHASING SCHEMATI C
White Brige Road
7 7
1
Harding Road 6
2 Harding Road
5
North
8 8
Woodmont Blvd

PHASING SEQUENCE

METROPOLITAN GOVERNMENT OF NASHVILLE AND DAVIDSON COUNTY
DEPARTMENT OF PUBLIC WORKS
Sheet 1 of

Figure 2, Coding Sheet

Once the zones were established, cycle lengths were determined for each zone and for each proposed timing plan. This was accomplished by the use of Synchro® cycle length evaluations, knowledge gained from field observations, and professional judgment. Proposed cycle lengths were discussed with MPW staff and documented in a memorandum submitted to MPW.

After the cycle lengths were determined, the optimal phase split times were established. This data was entered into the Synchro® model and then the phase sequences and offsets were evaluated to maximize the arterial greenband widths, thus reducing vehicle stops and delay. Greenbands were adjusted to accommodate the directional split of traffic on the arterial roadway for the AM and PM timing plans, while the mid-day and off-peak timing plans were generally optimized for two-way progression on the arterial roadway. MPW staff reviewed the proposed timing plans and approved them prior to field implementation.

The final component to the timing plans was the time-of-day clock settings for the new timing plans. This determines the optimal timing plan for each hour of a typical weekday and weekend day and were made by evaluating the 24-hour ADT tube count data and from field observations. These recommendations were submitted to MPW staff and approved prior to implementation. The final step prior to field implementation of the new timing plans was to prepare coding sheets for each intersection. Kimley-Horn transferred the proposed timing plans from the Synchro® model into a format compatible with MPW's traffic signal controller software database programs. This data was recorded on coding sheets that were developed by Kimley-Horn in Excel® to replicate the traffic signal controller software input screens. This resulted in coding sheets for MPW's Peek 3000 series of signal controllers and the TCT LMD 8000 series of signal controllers (see Figure 2). Coding sheets were submitted to MPW prior to field implementation in an electronic format. MPW then entered the new timing plans into the traffic signal controller database.

Field Implementation

Field implementation began with downloading the newly developed timing plans to each traffic signal controller. Kimley-Horn and MPW made field observations to determine the effectiveness of these timing plans over a course of several days for each corridor. Observations were made during all time periods of the day, during each timing plan, and at transition times between timing plans.

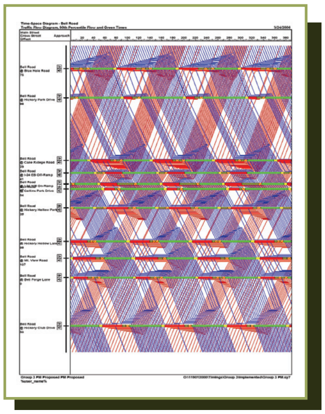


Figure 3, Time-Space Diagram

Using time-space diagrams, each timing plan was verified for its effectiveness (see Figure 3). These field observations served as a quality control measure for the new timing plans, and as a way to fine tune the timing plans. Potential changes were evaluated on site by Kimley-Horn and discussed with MPW. Changes were then typically made either by MPW staff or Kimley-Horn staff in the controller cabinet, which included offset adjustments and split allocation changes. Less common changes were time-of-day clock settings and cycle lengths. The field implementation observations and edits made while in the field were documented in a memorandum submitted to MPW. The Synchro® model also was updated to reflect the implemented timing plans.

Project Results

To quantify the results and to evaluate the effectiveness of the newly implemented timing plans, a before and after travel time study was conducted. This study provided actual travel times along the arterial roadways—not the theoretical output from the model. Prior to implementing the timing plans, multiple sets of travel time data were collected during the AM, mid-day, and PM peak periods for each of the arterial roadways in each corridor. This process was repeated several weeks after the timing plans were implemented and the results from these sets of data were analyzed.

Travel Time Study

The travel time study provided the data necessary for a delay study and a fuel consumption analysis. For each corridor, delay reductions were calculated for each arterial roadway for each of the three peak periods in each direction. For the project as a whole, the individual amounts of delay were summed for before and after conditions. The percent change in delay for the project was approximately 36 percent. A similar study was made on fuel consumption changes due to the improved traffic signal timings.

The delay reductions for the project ranged from approximately 73 percent to 22 percent by corridor (see Figure 4). For all corridors, the improved signal timing plans yielded dramatic improvements in reduced delays as well as fuel consumption. The result of the fuel consumption analysis for the whole project was a reduction of 11 percent. Figure 5 illustrates the fuel consumption reductions for each corridor.

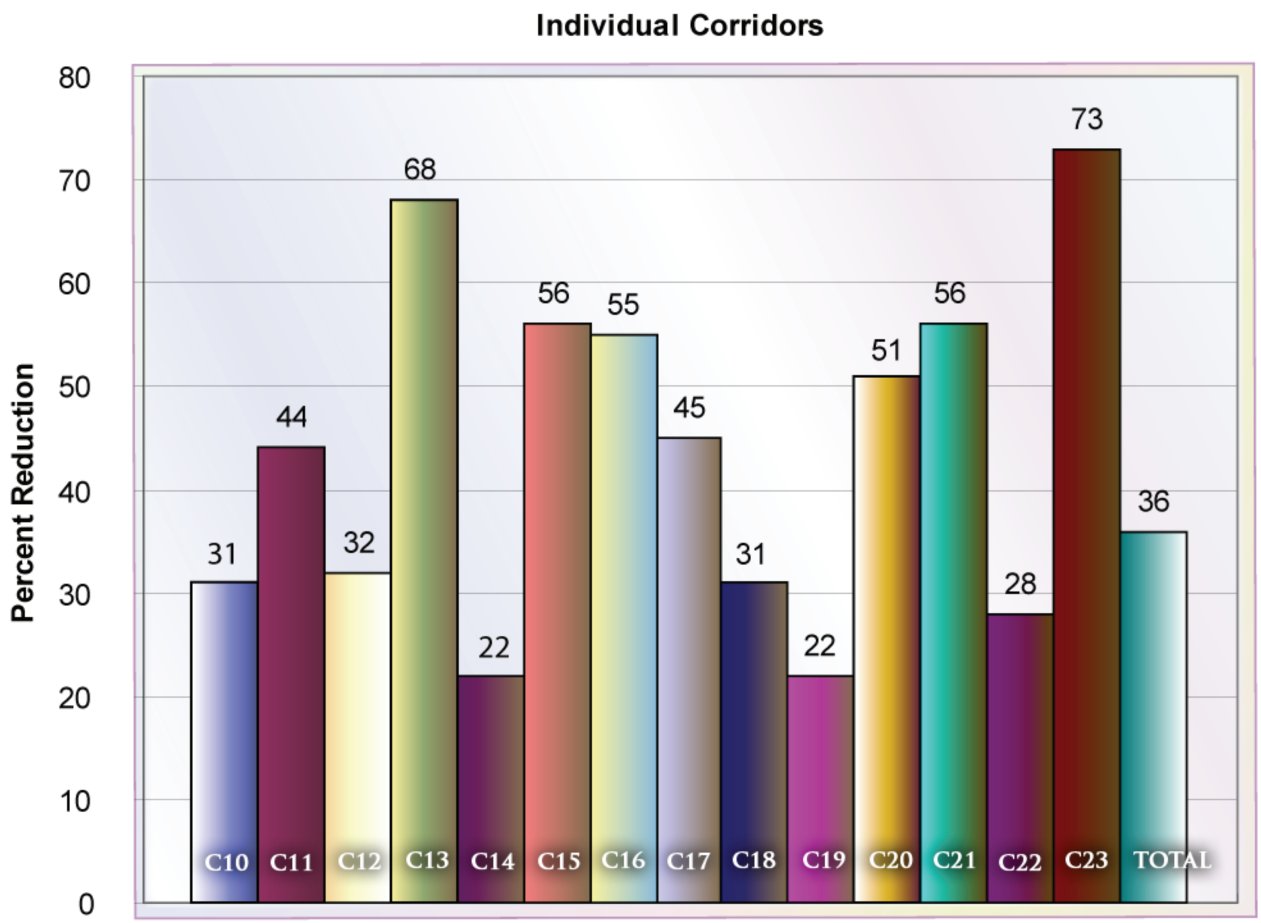
Economic Analysis

Based on the results from the delay study and fuel consumption analysis, an economic evaluation was conducted to determine what benefits arose from the implementation of the new signal timing plans. The benefits studied included a reduced road user cost from reduced delay experienced by the motoring public and fuel consumption. To determine these economic benefits, Kimley-Horn studied the AM, mid-day, and PM peak periods of the weekdays because of the available travel time study. Therefore, economic benefits were not quantified for the nonpeak hours of the day and are not reflected in this analysis.

To calculate the cost savings resulting in the reduction of delay by the motoring public, a dollar value was assigned to the delay. The United States Department of Transportation provides data for this purpose. Using this data, analyses were made for each corridor in the project, and these results were tallied to yield a benefit in terms of reduced delay for the entire project. For a one-year period this benefit was calculated to be $15,037,180. Similarly, the economic benefit was determined for the reduced fuel consumption. A conservative value of $2.50 per gallon of fuel was used for this analysis. For the whole project, this was found to be $4,317,860 for a one-year timeframe.

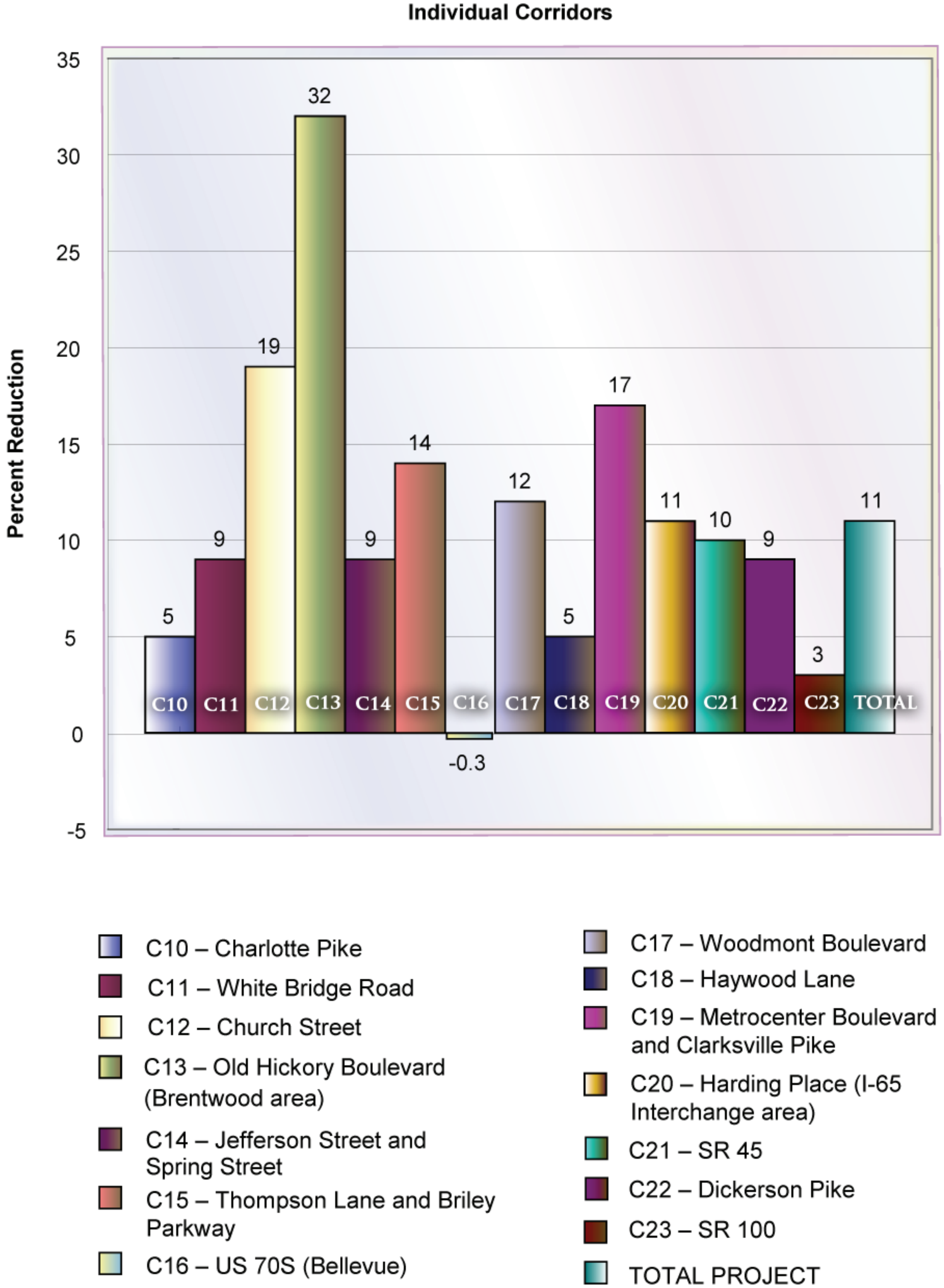
By using the engineering fee for this project, a benefit-to-cost ratio was calculated. The benefits were the sum of the delay and fuel benefits over a one-year timeframe totaling $19,355,040. The cost was the contract value for the project—$530,000. This yielded a one-year benefit-to-cost ratio of 37:1. However, the newly implemented signal timing plans will be used and prove to be beneficial for a time period longer than one year. Typically the useful life for signal timing plans is believed to be three years.

Figure 4, Percent Change in Delay for Each Corridor



- C10 – Charlotte Pike
- C11 – White Brdige Road
- C12 – Church Street
- C13 – Old Hickory Boulevard (Brentwood area)
- C14 – Jefferson Street and Spring Street
- C15 – Thompson Lane and Briley Parkway
- C16 – US 70S (Bellevue)
- C17 – Woodmont Boulevard
- C18 – Haywood Lane
- C19 – Metrocenter Boulevard and Clarksville Pike
- C20 – Harding Place (I-65 Interchange area)
- C21 - SR 45
- C22 - Dikerson Place
- C23 - SR 100
- TOTAL PROJECT

Figure 5, Fuel Consumption Reductions for Each Corridor



A recent ITE Journal article[1] states, "At a minimum, an operating agency should budget to retime traffic signals at least every three years." Therefore, the three-year benefit is $58,065,120, while the cost remains only $530,000. This yields a three-year benefit-to-cost ratio of 111:1. Figure 6 shows the breakdown of the benefit-to-cost ratio for each corridor.

Total Project Results

For the traffic signal optimization study for the Metro Nashville signal system project, from project inception through the completion of Supplement II, nearly a 27 percent reduction in delay for the 21 corridors has been realized. Fuel consumption was reduced by nearly 9 percent. From inception to date, the total project has achieved a one-year benefit-to-cost ratio of 27:1, with a three-year benefit-to-cost ratio of 81:1.

Conclusions

The implementation of the traffic signal timing optimization study for the Metro Nashville signal system has proven to be beneficial to Davidson County motorists based upon the project results discussed. Hence, the traffic signal retiming effort has been a cost-effective way to improve traffic flow along the project corridors such that it has reduced travel times, delays, and vehicle stops. Furthermore, this project has achieved fuel consumption reductions, which helps to improve the environment. In addition, this project has proven to be financially beneficial in that the yearly benefit of the signal retiming effort greatly outweighs the cost (i.e., a yearly benefit-to-cost ratio of 37:1).

In conclusion, this signal timing optimization program proved to be beneficial in three distinct areas:

- Reduction in traffic congestion for Davidson County motorists
- Environmental improvements (i.e., reduction in fuel consumption)
- Fiscally beneficial (i.e., the benefits greatly outweigh the costs)

[1] Srinivasa Sunkari, P.E., "The Benefits of Retiming Traffic Signals," ITE Journal, April 2004, pages 26-29.

Figure 6, One-year Benefit–to–Cost Ratios Per Corridor