Summary Report

NASHVILLE

TRAFFIC SIGNAL TIMING OPTIMIZATION STUDY
for the Metro Nashville Signal System

Supplement III

Prepared for:

Metropolitan Government of
Nashville and Davidson County
Department of Public Works

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EXECUTIVE SUMMARY

The Metropolitan Government of Nashville and Davidson County’s Department of Public Works (MPW) identified the central business district (CBD) and eight corridors in the County that experience heavy traffic congestion and needed traffic signal timing improvements to improve traffic flow as well as fuel consumption. The CBD and these corridors included a total of 158 signalized intersections:

- **Central Business District** – Downtown Nashville (107 intersections)
- **Corridor 24** – Donelson Pike (7 intersections)
- **Corridor 25** – Lebanon Pike (8 intersections)
- **Corridor 26** – Stewarts Ferry Pike/Bell Road (6 intersections)
- **Corridor 27** – 8th Avenue South/Franklin Pike/Wedgewood Avenue (8 intersections)
- **Corridor 28** – Elm Hill Pike (11 intersections)
- **Corridor 29** – McGavock Pike (5 intersections)
- **Corridor 30** – Broadway (3 intersections)
- **Corridor 31** – 12th Avenue South (3 intersections)

This study of the above corridors was considered Supplement III 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 $795,300. The consultant team 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, field implementation of the proposed timing plans, travel time and delay studies, and complete project documentation. Additionally, Supplement III included a maintenance task that utilized the consultant team to provide on-call traffic engineering services for MPW throughout the country.

For Supplement III, results from the signal timing effort included a 38 percent reduction in delay for the CBD and the eight corridors, with the greatest delay reduction of approximately 87 percent being the McGavock Pike corridor near the Opryland complex.

Benefits in reduced fuel consumption also were realized with this project. A reduction of 11 percent in fuel consumption along the CBD and the eight corridors was achieved. For Supplement III, a one-year benefit-to-cost ratio of 27:1 was achieved. However, newly implemented signal timing plans prove to be beneficial for a time period longer than one year. In other words, the useful life for signal timing plans is three years. Therefore, the three-year benefit-to-cost ratio increases to 81:1.

For the Traffic Signal Optimization Study for the Metro Nashville signal system project, from project inception through the completion of Supplement III, 542 intersections were included with a 30 percent reduction in delay for the CBD and the 29 corridors has been realized. Fuel consumption was reduced by nearly 8.4 percent. From inception to date, a one-year benefit-to-cost ratio of 27:1 was achieved for the total project, 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:

1. Reduction in traffic congestion for Davidson County motorists
2. Environmental improvements (i.e., reduction in fuel consumption)
3. Fiscally beneficial (i.e., the benefits greatly outweigh the costs)
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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 then selected Kimley-Horn and Stammer Transportation Engineering, Inc., to complete additional work to this project. This portion of the project, known as Supplement II, 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.

After Supplement II was completed, MPW selected Kimley-Horn and Stammer Transportation Engineering, Inc., to complete additional work to this project. Supplement III consisted of performing a Traffic Signal Optimization Study for the downtown Nashville central business district (CBD) plus eight corridors within Nashville and Davidson County, which included 158 signalized intersections. Supplement III also included a maintenance task that utilized the consultant team to provide on-call services for MPW. The notice to proceed was issued in January 2007 and the project was substantially completed in May 2008, with maintenance tasks ongoing. This portion of the project was wholly funded by MPW funds.

Supplement III involved studying the CBD signal system and eight corridors throughout the county (see Figure 1):

- **Central Business District** – Downtown Nashville (107 intersections)
- **Corridor 24** – Donelson Pike (7 intersections)
- **Corridor 25** – Lebanon Pike (8 intersections)
- **Corridor 26** – Stewarts Ferry Pike/Bell Road (6 intersections)
- **Corridor 27** – 8th Avenue South/Franklin Pike/Wedgewood Avenue (8 intersections)
- **Corridor 28** – Elm Hill Pike (11 intersections)
- **Corridor 29** – McGavock Pike/US 70 S (Bellevue) (11 intersections)
- **Corridor 17** – Woodmont Boulevard (5 intersections)
- **Corridor 30** – Broadway (3 intersections)
- **Corridor 31** – 12th Avenue South (3 intersections)

The major components of this supplement included:

1. Data collection
2. Existing conditions evaluation
3. Timing plan development
4. Field implementation and fine tuning
5. Travel time and delay study
6. Project documentation
Data Collection

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

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

MPW staff provided the existing timing data for all intersections, the as-built traffic signal plans or file drawings, the signal controller manuals, coding sheets, and software. Stammer Transportation Engineering was responsible for collecting the turning movement counts, intersection approach photos, intersection geometry, and preparation of the intersection sketches (see Figure 2). Kimley-Horn documented and compiled this data and collected the remaining data.

However, for the CBD signal system full turning movement count data was not gathered since recent data was available and provided by MPW for use on this project. Also, intersection sketches were not prepared for the CBD signal system. Rather, a confirmation of geometric data was performed by Kimley-Horn staff based upon existing information provided by MPW.

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.

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
these 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.

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 determined the optimal timing plan for each hour of a typical weekday and weekend day and was 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 3). 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. These observations were made during all time periods of the day, during each timing plan, and at transition times between timing plans. Using time-space diagrams, each timing plan was verified for its effectiveness (see Figure 4). 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 by MPW staff from the central office, 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 submitted 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. For the CBD signal system, five corridors were identified by MPW staff for travel time data collection.

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 Supplement III was approximately 38 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 87 percent to 27 percent by corridor (see Figure 5). For all corridors, the improved signal timing plans yielded dramatic improvements in reduced delay as well as fuel consumption. The result of the fuel consumption analysis for Supplement III was a reduction of 11.4 percent. Figure 6 illustrates the fuel consumption reductions for each corridor.
Figure 5, Percent Change in Delay for Each Corridor

Figure 6, 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 were achieved from implementing 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 Supplement III. For a one-year period, this benefit was calculated to be $12,019,800. 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 $2,498,100 for a one year time frame. By using the engineering fee for this project, a benefit-to-cost ratio was calculated. The benefits were the

**Figure 7, One-Year Benefit-to-Cost Ratios Per Corridor**
sum of the delay and fuel benefits over a one-year time frame totaling $14,517,900. The cost was the contract value for the project—$543,800 (this does not include the maintenance portion of Supplement III or the portion of the CBD signal system that was not part of the travel time analysis). This yielded a one-year benefit-to-cost ratio of 27:1. Figure 7 shows the individual one year benefit-to-cost ratios for the CBD and each of the corridors as a part of Supplement III. 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. A recent ITE Journal article1 states, “At a minimum, an operating agency should budget to retime traffic signals at least every three years.” Therefore, the three-year benefit is $43,553,700, while the cost remains only $543,800. This yields a three-year benefit-to-cost ratio of 81:1. Figure 7 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 III, 542 intersections were optimized. The entire project has realized a 30 percent reduction in delay. Fuel consumption was reduced by 8.4 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.

Each portion of the study delivered positive results in terms of delay reductions, fuel consumption, and economic results. Figure 8 shows the delay reductions for each portion of the study (the initial study, which includes Supplement I, Supplement II, and Supplement III). Also shown on Figure 8 is the aggregate delay reduction from the study inception through the completion of Supplement III. Figures 9 and 10 show similar data for fuel consumption reductions and the one-year benefit-to-cost ratios for each portion of the project.

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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 27:1).

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

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