FHWA's Traffic Signal Timing Manual

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Improved mobility and safety can be achieved for any local jurisdiction that invests the time and resources necessary to update their traffic signal timing. While traffic signal timing improvements rank as one of the most cost-effective energy conservation strategies for our urban areas, the recent National Traffic Signal Report Card concludes that the attention paid to signal timing is severely lacking. To this end, the Federal Highway Administration (FHWA) has taken important steps to address this lack of attention with the development of the Traffic Signal Timing Program. The program has included initiatives on awareness and outreach, education and training, tool development and guidance, technical research, and stakeholder involvement. The efforts have developed a series of documents and other materials that not only help to identify the problem, but also give general guidance on the potential solutions.

While there is a vast array of documentation on the subject of traffic signal timing and operations, it is largely dispersed in various journals and texts. Much of the literature is outdated or vendor specific and is not applicable for practitioners. The industry lacks a comprehensive guide that identifies issues associated with traffic signal timing and presents information in an easy to use format that will improve our traffic signal timing. To address this problem, the Federal Highway Administration has embarked on the development of a Traffic Signal Timing Manual (TSTM) to support the development and advancement of the state of the practice for traffic signal timing. The 18-month effort to develop the manual kicked off in 2006 and is scheduled for completion in late 2007. This paper describes the contents of the TSTM and highlights key remaining research issues that remain in traffic signal operations.

This project has been lead by Kittelson & Associates, Inc. (KAI), and completed in association with the Texas Transportation Institute (TTI), the University of Maryland (UM), Purdue University, Siemens ITS, and the Institute of Transportation Engineers (ITE).

INTRODUCTION

This *Traffic Signal Timing Manual* (TSTM) is intended to be a comprehensive guide to the traffic signal timing engineer and technician on traffic signal control logic principles, practices, and procedures. The manual presents a comprehensive synthesis of North American traffic signal timing concepts, analytical procedures, and applications into a single publication. The manual also presents a framework for evaluating traffic signal timing applications related to maintenance and operations.

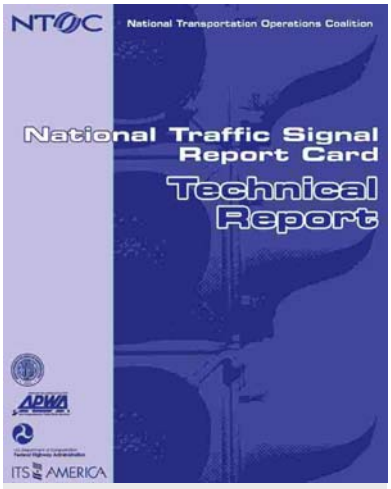
This manual is not intended to replicate or replace local engineering documents on signal timing, nor is it intended to serve as a standard or policy document. Rather, it is intended to provide a useful reference for all aspects of traffic signal timing to assist practitioners, decision makers, and students.

Kittelson & Associates, Inc. (KAI), in association with the Texas Transportation Institute (TTI), the University of Maryland (UM), Purdue University, Siemens ITS, and the Institute of Transportation Engineers (ITE), have worked on this effort for the past twelve months are looking forward to publishing this document in late 2007.

BACKGROUND

Media coverage surrounding Dick Armey's report to Congress' Subcommittee on Highways and Transit, *The Red Light Running Crisis*, offered an excellent opportunity for the industry to bring to light issues related to signal clearance interval, automated enforcement and other signal timing operational and safety issues. In March 2002, a group of practitioners from ITE met to discuss traffic signal timing in a roundtable workshop. The purpose of this workshop was to explore the nature of issues related to the area of traffic signal timing. The group concluded that there was a need for additional dialogue related to existing practices in signal timing. Shortly thereafter, the Transportation Research Board (TRB) Committee on Traffic Signal Systems discussed the possibility of holding a workshop on signal timing during their summer meeting in Portland, Oregon. As over 100 participants engaged in the dialogue related to signal timing practices, it was apparent that there was significant interest in the topic and the need to revisit elements of theory and practice in a way that presented "better" practice throughout the industry.

As a result of these meetings and strong interest from FHWA, the Office of Operations convened a traffic signal timing peer group in January 2004 to discuss a recommended program for furthering the efforts. The initial program, developed by ITE and the Center for Advanced Transportation Technology at the University of Maryland, described specific focus areas that could be used to raise the bar related to traffic signal timing and operations. The peer group concluded that a manual of signal timing practices should be developed for practitioners that focuses on topics that cover planning (signal placement), design (detector placement), operations (controller timing), and maintenance.



The National Traffic Signal Report Card was a significant effort to raise awareness related to the problems associated with poorly timed traffic signals.

To support FHWA's efforts, the TRB Committee on Traffic Signal Systems (TSS) has initiated a Subcommittee to ensure active participation with the manual development. The Subcommittee has worked on many issues associated with the development of the manual and developed a research program that identifies areas for further study once this initial manual is complete. The Subcommittee conducted its first meeting this past July at the Committee's Summer meeting in Las Vegas and has plans to engage the Highway Capacity and Quality of Service Committee's Signalized Intersections Subcommittee in a Joint

Session at the 2006 TRB meeting.

The publication of the National Traffic Signal Report Card highlighted the ongoing challenge for our profession in its transition from one of construction of new facilities to one of maintaining and managing the facilities we have. Traffic signal timing is a significant management function for the traffic engineering community, but is often neglected due to inadequate operations and maintenance budgets; the Proactive Management grade on the Report Card was an F. The conclusions of this report are further supported by the assessment of the current state-of-the-practice in traffic signal operations performed by the University of Maryland for the Federal Highway Administration and ITE. This report also provided conclusive information regarding the current challenges to be addressed by the profession in the area of traffic signal timing.

Improved mobility and safety can be achieved for any local jurisdiction that invests the time and resources necessary to update their traffic signal timing. While traffic signal timing improvements rank as one of the most cost-effective energy conservation strategies for our urban areas, the recent National Traffic Signal Report Card concludes that the attention paid to signal timing is severely lacking. To this end, the Federal Highway Administration (FHWA) has taken important steps to address this lack of attention with the development of the Traffic Signal Timing Program. The program has included initiatives on awareness and outreach, education and training, tool development and guidance, technical research, and stakeholder involvement. The efforts have developed a series of documents and other materials that not only help to identify the problem, but also give general guidance on the potential solutions.

While there is a vast array of documentation on the subject of traffic signal timing and operations, it is largely dispersed in various journals and texts. Much of the literature is outdated or vendor specific and is not applicable for practitioners. The industry lacks a comprehensive guide that identifies issues associated with traffic signal timing and presents information in an easy to use format that will improve our traffic signal timing.

Considering all of the available reference materials is a daunting task for the practicing traffic engineer or technician that is in responsible control of traffic signals and responding to complaints. Our assessment of the practice, which is supported by results of the Report Card, indicates that many practitioners do not have ready access to guidance regarding how to deal with the disparate settings and situations that are found in the field.

The purpose of this project is to consolidate the existing available information into a concise manual in a way that is readily accessible and useable. To this end, the document must be graphical and easily navigable, relate closely to practical applications (including the provision of example problems that cover a range of solutions), and include sound explanations related to areas where there is not consensus among practitioners. The manual will also identify sound timing practices and address existing and state of the art equipment in a way that is both comprehensive and forward- looking. Lastly, the first edition of the manual will be based on state-of-the-practice knowledge but its framework will be sufficiently comprehensive that findings from future research can be easily accommodated in the development of subsequent manual editions. The manual should also use a matrix-based approach that defines purposes for settings that affect the quality of service from the perspective of the user, the agency, and society.

ESTABLISHING THE NEED FOR RETIMING

Traffic professionals have long recognized the value of designing effective signal timing to meet changing travel patterns and characteristics. In 1995, the U.S. General Accounting Office (GAO) reported, “Properly designed, operated and maintained traffic control signal systems yield significant benefits along the corridors and road networks on which they are installed. They mitigate congestion and reduce accidents, fuel consumption, air pollutants and travel times. Resource constraints have prevented the use of traffic signals to their full potential.” The Traffic Signal Report Card Technical Report goes on to state:

> "It became clear that for safety and liability reasons, agencies must ensure a basic level of operation of the traffic signal system so that signals continue to turn green, yellow and red. The signals may not function efficiently for traffic or pedestrians, but, technically, the signals are working and that is what people see. However, the uniformly low scores (on the National Report Card) indicate that, for the most part, people consistently experience poor traffic signal performance and, as a consequence, their expectations are low. The pattern, once again, is one where agencies are forced to use their resources to deal with critical maintenance issues when they arise rather than proactively. Signal systems are managed to simply ensure base levels of performance."

The National Transportation Operations Coalition (NTOC) and FHWA continue to work to make the case that additional resources are needed to develop signal timing plans and to modernize equipment. There's an old saying that transportation engineers leave a little of their intelligence on the street when they design an intersection, but these designs are limited by the technology they have to work with. The use of 20-year-old technology and infrastructure may satisfy the requirement for the signal to display green, yellow, and red, but it may not offer the opportunity to efficiently operate the system or provide preferential treatment for a certain type of user to meet the policies and desires of the community. In most cases, upgraded equipment improves the efficiency for staff to manage the system, assuming the staff is properly trained to operate the upgraded equipment.

These efficiencies are observed with updating traffic signal timing plans, developing new strategies to improve transportation, and improving customer service. There have been some great technological advances in the past five years, such as the development of transit signal priority, which seeks to provide preferential treatment to buses as they approach the traffic signal. This new technology allows the engineer to allocate green time that more closely reflects the community's transportation policies.

Benefits of Up-to-Date Timing

Studies around the country have shown that the benefits of area-wide signal timing outweigh the costs 40:1 (or more). The benefits of up-to-date signal timing include shorter commute times, improved air quality, and reduced driver frustration.(*1*)

The NTOC recently surveyed the quality of traffic signal operations in the United States. The NTOC concluded that the nation scored a D– in terms of the overall quality of traffic signal operation. "If the nation supported its signals at an 'A' level, we would see:

- Reductions in traffic delay ranging from 15-40% (*2*); reductions in travel time up to 25%; and reductions in stops ranging from 10-40% (*3*). For example, if you spent two hours in your car commuting to and from work and running errands, you'd save 50 hours per year (or more than a work week) because of improved signal timing.
- Reductions in fuel consumption of up to 10%. Nationwide this would amount to a savings of almost 17,000 million gallons of motor fuels per year.(*4*)
- Reduction in harmful emissions (carbon monoxide, nitrogen oxides, volatile organic compounds) up to 22% (*5*). According to the Surface Transportation Policy Project, motor vehicles are the largest source of urban air pollution. (*6*) In addition, the EPA estimates that vehicles generate 3 billion pounds of air pollutants yearly.(*7*,*8*)

Beyond the benefits to vehicular traffic, there are opportunities to improve performance for transit, pedestrians, and freight movement. Chapter 9 summarizes some of the advanced concepts that address some of the broad policies that have gained in popularity since the inception of the Intermodal Surface Transportation Efficiency Act of 1991 (*9*.)

ORGANIZATION OF THE MANUAL

The manual is organized into nine chapters that can be broadly described by four basic parts:

Part 1 — Policy, Planning, and Funding Considerations. This part, comprising Chapter 1, Introduction, and Chapter 2, Signal Timing Policy, describes the need for and benefits of signal timing. It presents a discussion of relevant federal, state, regional, and local issues, as well as typical funding needs and options.

Part 2 — Fundamental Concepts of Traffic Signal Operations, Safety and Design. This part, comprising Chapter 3, Operational and Safety Analysis, and Chapter 4, Traffic Signal Design, provides key background information needed to understand signal timing. This chapter provides a basic foundation from which to describe more complicated concepts in later chapters.

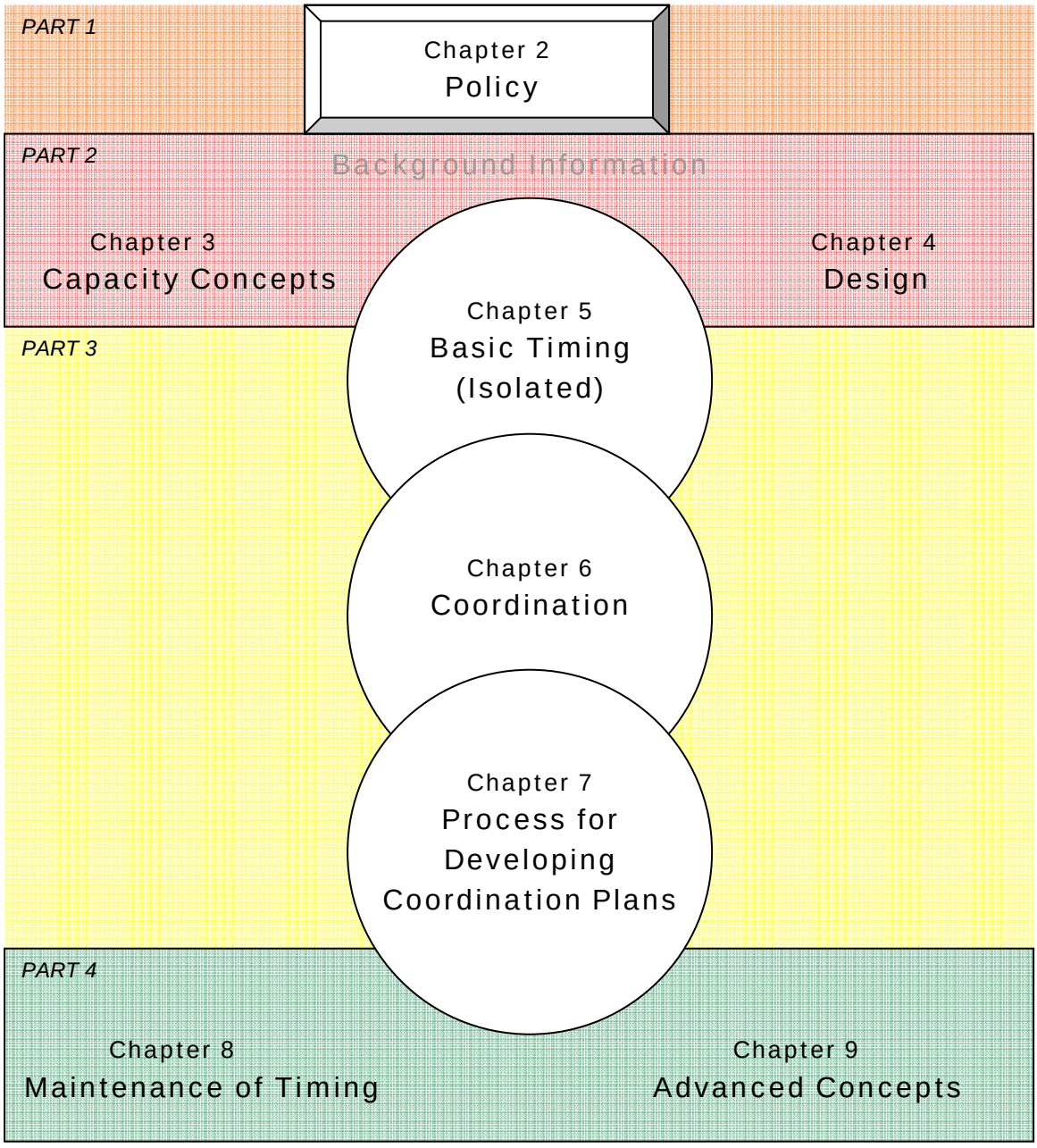
Part 3 — Signal Timing Details. This part, comprising Chapter 5, Basic Signal Timing; Chapter 6, Coordination; and Chapter 7, Developing Signal Timing Plans, describes traffic signal timing details from concepts to application, with guidelines where appropriate based on industry practice. The chapters include several examples from agencies that represent good practice.

Part 4 — Maintenance of Timing and Advanced Topics. This part, comprising Chapter 8, Maintenance of Signal Timing, and Chapter 9, Advanced Signal Timing Topics, presents an overview of a number of advanced topics related to improving signal timing operations that will be especially relevant to sophisticated timing engineers that are implementing innovative strategies (transit signal priority, adaptive signal timing, etc).

Glossary and Index. This part includes a listing and definition of terms related to traffic signal timing as discussed in the manual.

This organization is described in Figure 1-1.

Figure 0-1 Organization of the Manual



USE OF THE MANUAL

The *Traffic Signal Timing Manual* (TSTM) is intended to be a comprehensive document describing the procedures for generating signal timing plans for North America applications. It is intended for use by a range of practitioners, including traffic engineers, signal technicians, design engineers, management personnel, teachers, and university students. To use the manual effectively and apply its methodologies, some technical background is desirable, typically technical

training either provided as a part of continuing education, or at the university-level. The authors envision the manual being used a variety of ways, including the following examples:

- City/county traffic engineers and/or public works directors who are not involved in the day-to-day detailed management of the signal system may be more interested in overall policies and the measures of effectiveness to evaluate those policies, as well as how often further investment in signal timing may be justified. For this audience, Chapters 2, 3, and 8 are of particular value. They may also be interested in some of the advanced applications presented in Chapter 9.
- An experienced signal timing engineer may seek a better understanding of some of the details of how a controller implements a particular type of operation. For this audience, Chapters 5 and 6 are of particular value for day-to-day operation.
- A graduate student taking a course on traffic signal operations will likely find value in how the fundamentals presented in Chapters 3 and 4 tie to the details in Chapters 5 and 6 and the signal timing process in Chapter 7.

REMAINING RESEARCH

There is little in the (TSTM) that is truly new information. The primary purpose of this document isn't more information, but rather to make sense of what we already know and provide a common language. It is intended to be a document that provides entry to those that aren't familiar with the topic some insights into the complications of traffic signal timing. It is also intended to encourage a broader dialogue about the topic and to inform those making choices about consequences. This being said, there is considerable room for improvement on a number of fronts, some of which I will describe here.

The most basic concept where improvement is necessary is in detection design. There continues to be innovation in the type of detection technology used, but more effort is needed to improve how we use the information we retrieve from detectors and what control logic is used based on that information. Once detection is more reliable, accurate, and sustainable (maintenance free), then operational strategies can be built to take advantage of this improved detection. This improved detection requires a revamped operational strategy and these elements must be considered carefully in a holistic manner.

Specifically, the issue of detection at high speed intersections is an area where the research has not translated into effective practice. There are several agencies that have a practice for application of detection, but comprehensive safety evaluations have been limited by the data needs at these locations. This relates closely to the final topic of using the existing detector logic for performance measurement and identification of oversaturated conditions.

Finally, an issue that is relevant to the theme of this conference is the issue of sustainability for traffic signal timing. Sustainability is an area that has been explored by the City of Portland in a few different areas, whether it be use of Light Emitting Diodes (LEDs) for reducing power consumption or selling carbon offset credits by reducing emissions on arterials with traffic signals. The area of transit signal priority or signal timing for transit preferential treatment is briefly described and more research is needed to articulate the realm of possibilities for improving our systems to reflect the policies and desires of our communities.

REFERENCES

1 Ibid.

2 "Temporary Losses of Highway Capacity and Impacts on Performance: Phase 2, Oakridge National Laboratory, November 2004, ORNL/TM-2004/209 and "Benefits of Retiming Traffic Signals", ITE draft Informational Report, 2005.

3 "Benefits of Retiming Traffic Signals", ITE draft Informational Report, 2005.

4 http://www.bts.gov/publications/national_transportation_statistics/2004/html/table_04_05.html

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6 Surface Transportation Policy Project. http://www.transact.org/library/factsheets/environment.asp.

7 National Toxics Inventory, 1996. http://www.epa.gov/otaq/regs/toxics/d00003.pdf

8 Ibid "National Traffic Signal Report Card"

9 "ISTEA Reauthorization Policy Statement And Principles", U.S. Department of Transportation, http://www.dot.gov/ost/govtaffairs/istea/isteap&p.html, visited January 6, 2007.