Database-Driven Implementation for Future Editions of the *Manual on Uniform Traffic Control Devices*

AUTHORS
Ryan P. Avery, Ph.D., P.E., AICP
Scott O. Kuznicki, P.E.

SUBMITTAL DATE
Thursday, August 1st, 2013

TRB 14-0448

SUBMITTED TO THE
Transportation Research Board
Traffic Control Devices Committee (AHB50)

93rd Annual Meeting *of the* Transportation Research Board
January 2014
Washington, District of Columbia, USA

AUTHOR INFORMATION
Scott O. Kuznicki, P.E. **CORRESPONDING AUTHOR**
Modern Traffic Consultants
7650 SE 27th Street, Suite 622
Mercer Island, Washington 98040 USA

Ryan P. Avery, Ph.D., P.E., AICP
Parsons Brinckerhoff
999 Third Avenue, Suite 3200
Seattle, Washington 98104 USA

WORD COUNT

WORDS	6,738	6,738
TABLES	1	250
FIGURES	2	500
TOTAL		7,488

ABSTRACT

The "streamlining" of the *Manual on Uniform Traffic Control Devices* (*MUTCD*) will require solutions that move beyond managing the size and content of the *MUTCD*. Future solutions that manage the *MUTCD* must also manage the relationships of internal and external references, and the documentation, presentation, and alteration of that content. They must further interface with the vast resources available on the Internet, permitting immediate access to research, documentation, and user-generated information regarding the deployment of and implementation experience related to traffic control devices. This paper explores how a database-driven implementation of the *MUTCD* can create powerful reference and catalog tools that enable efficient and expansive use of the document, thorough and frequent updates in an increasingly complex regulatory environment, and presentation of content in formats that suit the needs of a wide variety of users. Further discussion concerning the balance between preservation of information security and leveraging of the power of community-based content management reveals a compatibility with the regulatory process that facilitates community-based development of regulatory language. The use of powerful database query and reporting tools in such a future implementation of the *MUTCD* will provide for delivery of content in ways familiar to current users while establishing the platform for future growth.

BACKGROUND

In 1935, the United States government, through its Bureau of Public Roads, published the first edition of the *Manual on Uniform Traffic Control Devices*. The *MUTCD* has grown from a booklet covering the appearance and use of basic traffic control devices into a document of nearly 1,000 pages. This document is subject to the regulatory process of the federal government. Its content addresses the appearance, use, design, and installation of nearly every traffic control device, providing direction related to size, limitations on use, and typical installation of traffic control device systems. As the *MUTCD*'s size has grown, the size and variety of the audience addressed has likewise grown. Its use is no longer limited to practitioners of traffic engineering or even transportation engineering; the weight of the document as a matter of regulation has elevated its importance in administrative and judicial proceedings for civil, criminal, and tort liability cases.

During the first decade of the 21st century, experts in the field of traffic engineering and transportation policy development made several attempts to develop a strategic plan for the *MUTCD*. Such a plan would provide a framework for the development of the document in a 25-year horizon. Policy development organizations, transportation agencies, regulators, and advocacy organizations all stand to benefit from the development of such a plan, as it would address issues related to audience, content, appearance, and user preference and needs. Defining these aspects of the *MUTCD* relationship to stakeholders will facilitate the inclusion of appropriate material and help the community determine the ideal way to store and present information.

INTRODUCTION

This paper is an attempt to address issues related to the appearance, format, and use of the *MUTCD*, as they relate in particular to the possibility of a database-driven *MUTCD*. In particular, the authors have researched a variety of library science materials in an effort to understand current trends in information presentation and management. The scope of this research is intended to avoid a discussion of content and audience, rather being focused on issues of access, management, and ease of use.

In this paper, the basic concepts of information storage and retrieval with regard to relational databases is presented and briefly discussed. Then a structure for a potential user interface is presented. This potential interface is further discussed in light of database development concepts, illustrating how objects linked by metadata can become powerful resources in an efficient quest for useful and relevant information, by multiple means and with the ability to create output in various formats. The possible benefits to policy development organizations and regulatory officials are discussed in light of the proposed structure and interfaces, with end benefits for the user described. Finally, needs for further research are identified in conjunction with the brief discussion of the subsequent steps required to begin the implementation of such a structure for the *MUTCD*.

INFORMATION STORAGE AND RETRIEVAL

The principal goal of information storage and retrieval systems is to facilitate the organization of large amounts of information by making it easier for users of a system to obtain the information they need. Prior to the computer age, most information science related to libraries, and an emblematic example of an information storage and retrieval system can be found in the Dewey Decimal System. This system was devised to make it easier for libraries to meaningfully categorize books and other media so that patrons

could reasonably locate their desired subject area. However, in cases where certain subjects intersected several classifications in the system, it was necessary for patrons to visit multiple sections of the library to complete their research.

Information systems are commonly built around *metadata*. Metadata are bits of information about an object rather than information within the object itself. For example, metadata about a book includes items such as the name of the author, subject area, typical audience, publisher, and year of printing. Querying fields containing such metadata is a common way to try to find a particular piece of information related to the data in question. Continuing the example above, the Dewey Decimal System uses the discipline or field of study as the grouping classification. One of the disadvantages of the Dewey Decimal System is that a user of that system's catalog identifiers can search only for information by discipline and not, for example, by author or other metadata.

The advent of the computer age enabled more efficient means of searching and retrieving information as well as searching on various metadata. These technologies include relational databases and version control systems, both of which are discussed in further detail below. While early examples of these systems developed during the 1970s, the rapid increase in public and commercial accessibility to the internet greatly increased the use of such systems.

Relational Databases

Relational databases are data storage systems wherein information is organized in a number of tables, with relationships defined between various tables. These relationships are defined in what is referred to as a *schema*. Strict rules exist concerning what types of data may be stored in each table column and the relationships between columns and fields within the records that make up the database. A database user may *query* a table or group of tables for certain information, which is the basis of most search capabilities. Most database systems use Structured Query Language (SQL) to perform these queries. Relational databases were designed to efficiently store and retrieve this information and careful consideration must be given to the design of a relational database schema to ensure that it is efficient while also providing flexibility for future growth.

World Wide Web search engines such as Google and Bing are examples of Internet search engines which became indispensable with the rapid expansion of the Internet during the 1990s. In order for these searches to work, Google and Microsoft use computers to search (or *crawl*) the web and index as much information as possible. When a user searches for something, these indexes are queried and the results are returned.

Revision Control

Revision control describes the concept of maintaining a record of changes to an object such as a document or software programming project. Examples of systems which perform this task are referred to as Version Control Systems (VCSs). Revision control originated with software projects in the 1970s as a means of maintaining records that facilitated tracking of changes to the software, in particular, its code. The VCS permitted software developers the ability to return to a previous version of the codebase.

Revision control is necessary for projects in which a large number of people work concurrently. In a software environment, the basic workflow is as follows:

1. A user *checks out* the latest version of the code base from a centralized location referred to as a *repository*.
2. The user edits files as necessary to achieve some task such as updating a feature.
3. The user *commits* their copy of code back to the central repository.
4. If another user made changes to the same file, the user will be prompted to handle any *conflicts* between the two versions.
5. Once committed, the version number is increased and the system makes a note of metadata including which files were changed, what changes were made, and when the changes were committed.

Version control systems vary greatly in design and function, with *distributed* VCS removing the concept of a centralized server. Version control systems may track their changes in files in a database, and are organized in the manner depicted in Figure 1.

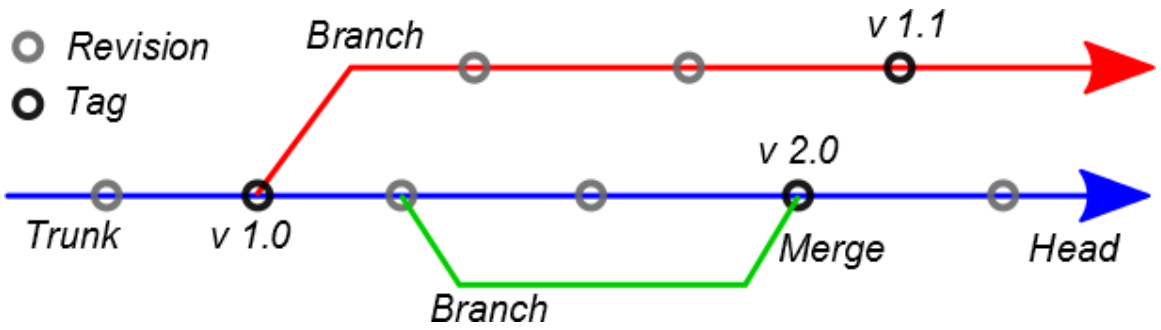


FIGURE 1 Version Control System Nomenclature

The main line of development is referred to as the *trunk*, with the latest version always referred to as the *head* revision. At points in time, a *branch* may be made from the main trunk to add new features or test a feature. Some branches of development may be *merged* back into the main trunk. Finally, certain revisions can be *tagged* so that they can be referred to by name rather than some obscure revision number.

Wikis

A *wiki* is a web-based content management system which allows numerous users to collaborate on the editing and maintenance of a group of web pages. The quintessential example is Wikipedia, in which over 100,000 unpaid collaborators work to create, edit, and improve the millions of webpages on the site, which functions as an online encyclopedia. A wiki combines aspects of both databases and revision control systems. Wikis store historical versions of pages along with metadata about the editor and when the edits were made, functioning as a revision control system[1]. Many wikis store this information in a relational database. While wikis maintain history and metadata about individual page edits, they do not

typically incorporate the concept of branches or tagging whereby a certain state of the entire project may be retrieved.

STRUCTURE FOR USER INTERFACE

When considering how the user interface is to be structured for a document, especially a regulatory document, care must be given in ascertaining how users will access the document, how the document will be edited, and what type of security must be provided for the content documents to avoid inadvertent and unauthorized intentional changes to the document.

Compliance with Regulatory Process

In the case of the *MUTCD*, one of the primary considerations for document structure is compliance with and consideration of the regulatory process. Currently, the *MUTCD* is adopted through what is commonly known as rulemaking, the process by which a cabinet-level agency of the United States federal government implements regulations for an industry or sector. The rulemaking process ensures that an agency properly publishes proposed changes, facilitates and responds to public comment, and incorporates primarily those changes which are found to be acceptable by the broader community of those affected by the regulations.

Currently, the *MUTCD* Team of the Federal Highway Administration's (FHWA) Office of Transportation Operations is responsible for promulgating and compiling changes to the *MUTCD*. This office cooperates closely with an independent, volunteer group of professionals known as the National Committee on Uniform Traffic Control Devices (NCUTCD). The NCUTCD is given the same access to every Notice of Proposed Amendments (NPA) as the public and its comments are given equal weight. Even so, the importance of an organized group with procedures in place for evaluating proposed language (and providing proposed language outside of the regulatory process, for incorporation in subsequent NPAs) cannot be understated. In fact, it is this very organized user community that facilitates a comprehensive and robust document.

In the current *MUTCD*, there are five general categories of information presentation. All of them are subject to rulemaking prior to adoption and incorporation into the Code of Federal Regulations (CFR). The *MUTCD* contains text statements, each of which is classified as Standard, Option, Guidance, or Support. Tables provide information best presented in a tabular format. Figures illustrate the implementation of language from these statements and depict the general appearance of signing, pavement markings, traffic signals, and work zone traffic control applications. Occasional descriptive text (such as the Preamble), section headings, figure captions, and other information are not material to the regulations but are necessary to support the use of the document.

One possible way of categorizing language in the *MUTCD* is to separate its contents into binding and non-binding language. The binding language, for the purposes of this illustration, will be language which is processed through the rulemaking process and therefore becomes subject to the provisions of the CFR and is particularly enforceable by the agency. In some future edition, binding language might be considered to be all Standards, Options, Guidance, and Tables, for example, with non-binding language being Support statements and Figures (given that all signs would be included in the Standard Highway Signs book).

In such a publication, non-binding language, that is, language not subject to the rulemaking process, would have to be clearly identified. The process of developing and incorporating non-binding language would still require considerable public support, meaning that the NCTUCD would be of critical importance in the continued development of the *MUTCD*, particularly with regard to background information.

One criterion for choosing a regulatory framework for a future *MUTCD* would concern the facilitation of a user community that could be proactive, as opposed to reactionary. In a collaborative, community-based environment for content development, user control and management of information permits rapid development of material for consideration and change. Driving changes to practice through regulatory process can often be a cumbersome process. Earlier implementation of useful and proven traffic control devices and strategies, if facilitated by a robust, flexible, and well-managed process for change, could prove highly beneficial to the public.

For the purposes of this paper, five possible options for managing the regulatory process of a future *MUTCD* are considered viable. These options, summarized in Table 1, differ based on the possible alternatives with regard to treatment of binding language, treatment of non-binding language, the ownership of non-binding language, and the organization or entity responsible for release of the document.

Scenario	Binding language	Non-binding language	Owner of non-binding language	Responsible for release of document
TODAY	RULEMAKING	NONE	N/A	FHWA
1	RULEMAKING	RULEMAKING	FHWA	FHWA
2	RULEMAKING	NON-RULEMAKING	FHWA	FHWA
3	RULEMAKING	NON-RULEMAKING	FHWA	COMMUNITY
4	RULEMAKING	NON-RULEMAKING	COMMUNITY	COMMUNITY

TABLE 1 Options for Ownership and Release of *MUTCD* Language

It is important to note that release of the document is different from publication of the document. The release of the document is simply a release of information. In the current scenario, that information is formatted and provided as a complete document. The publication of the document can be performed by any organization or agency with the ability to publish material, either electronically or on paper, to a degree satisfactory for the needs of that entity.

Releasing an *MUTCD* that contains both binding and non-binding language may require changes to federal law. It will most certainly require an increased level of collaboration between the agency and stakeholder organizations. Ultimately, the separation of the development of non-binding and binding language raises a number of important questions. Chief among those is the question of whether FHWA would be willing to release non-binding language that was not subject to rulemaking.

Scenario 4 most closely matches the model of the "wiki", a community-based document. In this scenario, the "binding language" subject to rulemaking would be released by FHWA into the Federal Register, but not organized beyond a basic structure necessary to maintain the register. The user community would be responsible for organizing and releasing a document with the information from the CFR and all other information determined relevant by the community. This allows for maximum flexibility in creating a product that reflects the needs, experiences, and contributions of the widest variety of users, the main attraction of Wikipedia. Further, it permits the maintenance of a large document with volunteer labor. On the other hand, a non-*MUTCD*-based reading of the CFR would prove exceedingly difficult to understand and questions may arise concerning the ownership of community-created content and the community's ability to appropriately, adequately, and completely incorporate all language included in the CFR.

For the purposes of subsequent discussion, solely Scenario 1 will be considered. This scenario is most like the current arrangement excepting that it differs in that there would be "non-binding" language in the *MUTCD*. Categorically, "non-binding" language is that which is not subject to the rulemaking process but still included in the *MUTCD*. In this discussion, "non-binding" language will include such items as background information, relationships (links) to other items, links to other research, and other such information that would be clearly identified as not subject to rulemaking.

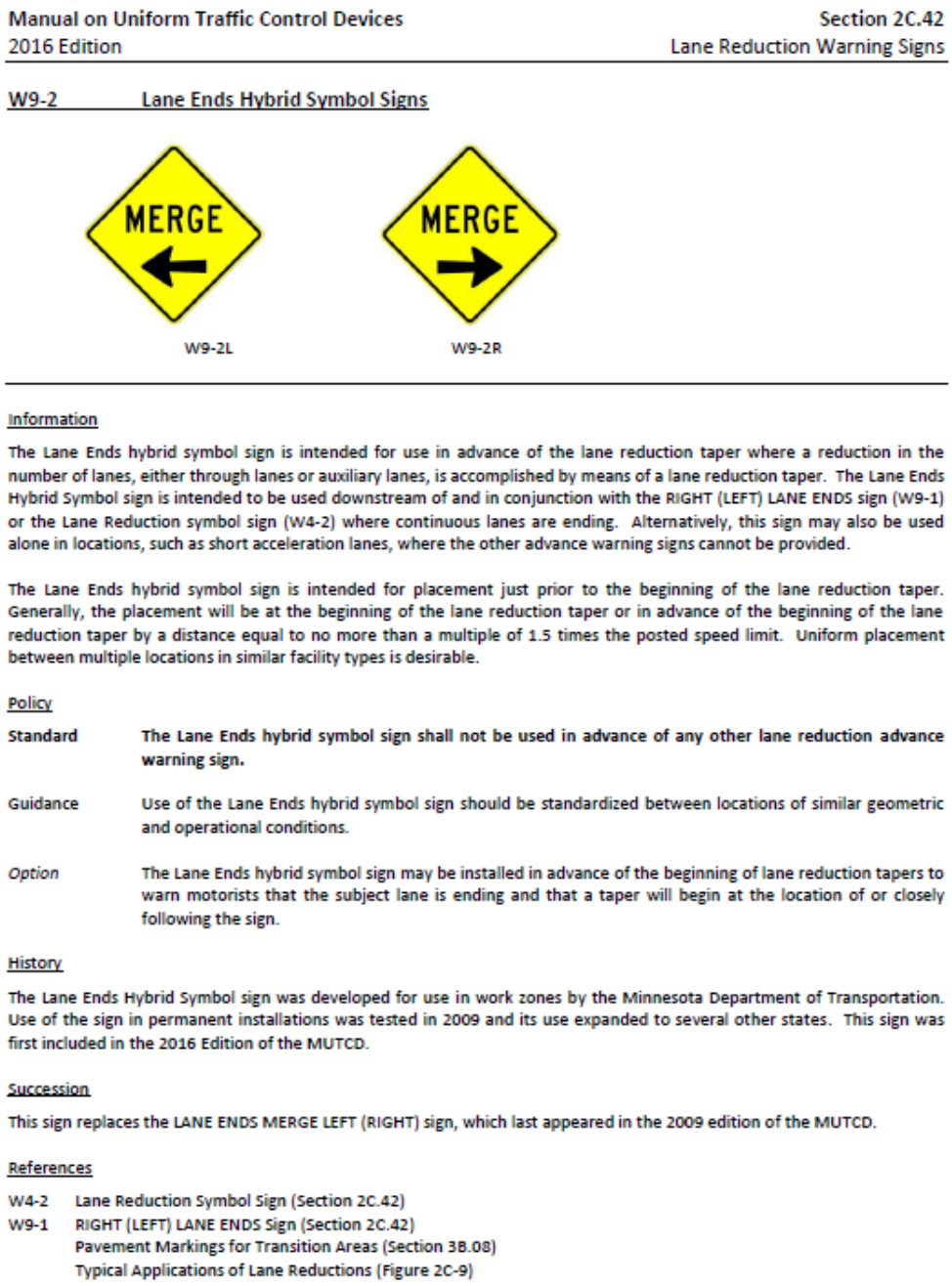
Physical Structure of the Document

The user community of the *MUTCD* is currently using a book-style product. The document is divided into Parts, subdivided into Chapters and Sections, and accessible by means of a Table of Contents, including an Index of Figures and Index of Tables, but lacking a General Index. The physical structure of the document is essentially according to the category of traffic control device (by appearance, function, or use), groups of similar traffic control devices or operational concepts, and individual traffic control devices, with regulatory language contained in sections pertaining to an individual traffic control device or group of devices.

If one were to simply press the "Print" button on the raw contents of the database, it would lack a discernible structure. Rather, the structure of the document is determined by how relationships are defined, ordered, and processed by a user interface. A user interface provides structure to the document, and that can be adapted to suit the development of user preferences while at the same time permitting the use of all the powerful tools realized by the employment of a relational database.

This paper proposes that a future *MUTCD* be optionally accessible as printable copy, generated using a *report generating system.* Typically, these systems respond to a user query of the database to release content, in a readable and/or printable format, that matches the user's query. In the case of the *MUTCD*, such systems would deliver content in a structure discernible to the user. Presentation of reports would be in a format such that the structure of multiple reports, when assembled, would follow some type of organizational pattern. Some examples of potential organizational hierarchies include

device group, device type, facility implementation, and level of mandate. One example of a generated report from a query is displayed in Figure 2.



Manual on Uniform Traffic Control Devices
2016 Edition

Section 2C.42
Lane Reduction Warning Signs

W9-2 Lane Ends Hybrid Symbol Signs

W9-2L W9-2R

Information

The Lane Ends hybrid symbol sign is intended for use in advance of the lane reduction taper where a reduction in the number of lanes, either through lanes or auxiliary lanes, is accomplished by means of a lane reduction taper. The Lane Ends Hybrid Symbol sign is intended to be used downstream of and in conjunction with the RIGHT (LEFT) LANE ENDS sign (W9-1) or the Lane Reduction symbol sign (W4-2) where continuous lanes are ending. Alternatively, this sign may also be used alone in locations, such as short acceleration lanes, where the other advance warning signs cannot be provided.

The Lane Ends hybrid symbol sign is intended for placement just prior to the beginning of the lane reduction taper. Generally, the placement will be at the beginning of the lane reduction taper or in advance of the beginning of the lane reduction taper by a distance equal to no more than a multiple of 1.5 times the posted speed limit. Uniform placement between multiple locations in similar facility types is desirable.

Policy

Standard **The Lane Ends hybrid symbol sign shall not be used in advance of any other lane reduction advance warning sign.**

Guidance Use of the Lane Ends hybrid symbol sign should be standardized between locations of similar geometric and operational conditions.

Option The Lane Ends hybrid symbol sign may be installed in advance of the beginning of lane reduction tapers to warn motorists that the subject lane is ending and that a taper will begin at the location of or closely following the sign.

History

The Lane Ends Hybrid Symbol sign was developed for use in work zones by the Minnesota Department of Transportation. Use of the sign in permanent installations was tested in 2009 and its use expanded to several other states. This sign was first included in the 2016 Edition of the MUTCD.

Succession

This sign replaces the LANE ENDS MERGE LEFT (RIGHT) sign, which last appeared in the 2009 edition of the MUTCD.

References

W4-2 Lane Reduction Symbol Sign (Section 2C.42)
W9-1 RIGHT (LEFT) LANE ENDS Sign (Section 2C.42)
Pavement Markings for Transition Areas (Section 3B.08)
Typical Applications of Lane Reductions (Figure 2C-9)

FIGURE 2 "Fact Sheet" Sample (Typical Publication of Material from Database)

One point often repeated in user community discussions concerning the MUTCD is that the document has not become too large; rather, it has become too unwieldy. A database-driven document, accessed primarily by means of an interactive environment, would allow users to view information pertaining to their particular query, as well as other relevant information. The printed version of the document would rely on the generation of material that presented information in a concise format with mention of all relevant content available to the user. Such presentation of material, in the printed form, is essential to maintaining usability of the document in a fashion similar to the current format while playing to the strengths of the database-driven implementation.

To that end, it is proposed that the document, if published from a query for "all information", would contain two types of presentation styles. The first, Typical Applications, would provide an overview of information pertaining to a related set of concepts. The second, colloquially referred to here as "Fact Sheets", would provide information specific to a traffic control device, traffic control strategy, traffic control device system, or other discrete element. For the purposes of this discussion, it is assumed that a Typical Application diagram has been prepared for a lane reduction transition and that a user is querying the database for information on a particular sign shown on that Typical Application.

Typical Applications

The purpose of the Typical Applications sheets is to permit users to view a general arrangement of traffic control devices, depicted in conjunction with some geometric feature, device system, or other scenario that relates similar or complementary devices. Users would use the Typical Applications sheet as a guide for the layout of devices, in conjunction with all applicable regulatory language. That regulatory language is related to each device shown on the Typical Application and therefore necessitates that each device be assigned a particular section and made report-compatible.

Fact Sheets

The means by which individual devices can be presented from a query is a simple sheet that contains all of the information and related references necessary for a practitioner to adequately use a traffic control device or traffic control device system. This type of presentation of information is very similar to what one might find when presented with a "cut sheet" or product specifications guide. In fact, when mechanical engineers select bolts, bar, and chain for use in projects, they often refer to large catalogs containing basic information for an individual device or product.

Title and Header

In the initial deployment(s) of a database-driven *MUTCD*, the use of Section references will be of considerable importance, as they are in the current *MUTCD*. Preservation of these Section references, by means of metadata attached to individual components in the database, will be the primary means of ensuring that report generation

Depiction

The depiction displays the general appearance of the traffic control device. Its function is similar to any figure in the current *MUTCD*. In this particular case, having only the subject sign depicted helps provide clarity; current warning sign figures in Chapter 2C of the *MUTCD* show related signs, often not in proximity to any related text.

Information

Basic background on the use, function, and general safety performance of the subject traffic control device or system is provided in the Information portion of the Fact Sheet. This portion of the Fact Sheet would most likely not be subject to the rulemaking process, but is essential to aiding user understanding of the importance of the device, its function in any larger group or system of devices, and potential pitfalls associated with its use.

Policy

The policy portion of the Fact Sheet contains only that information which was subject to rulemaking (though rulemaking-subjected information may also be included in other portions of the Fact Sheet). The policy statements follow those included in the MUTCD today, but may also include other levels of mandate, such as those described in the NCUTCD's *Strategic Plan*. A user's guide to the MUTCD and perhaps a mandatory display on an interface device screen prior to accessing the database, would call attention to the necessity of compliance with all Policy statements, to the extent required by statute.

History

A general history of the subject device or system is provided, based on metadata and a fields entered related to device history.

Succession

Often, devices are introduced that replace other devices and, more rarely, a device will experience a lapse in *MUTCD* inclusion. The ability of users to see the relationship of new devices to those that have been phased out permits immediate recognition of the need for device replacement and the identification of the appropriate device.

References

As the development of content in the MUTCD becomes based less on heuristics and field experience and more on the results of peer-reviewed research conducted under controlled circumstances, the user community will demand improved references to available research. This section, however, will specifically reference only internal content and content in related publications that are named in the

COMPONENTS

A database-driven document allows the user to instantly access information that has been related by means of the proper development and management of the tables in the database. An electronically managed version of the *MUTCD* would consist of a large database containing text, figures, and tables organized into objects and/or groups of objects. The database is simply information organized into various components which represent elements of the *MUTCD*. Managing these items as objects can provide benefits in terms of easier maintenance of information and elimination of duplication of information.

Components, sometimes referred to as objects, include items such as text, tables, links, and figures. Text components represent the main text of the *MUTCD*, and include Standards, Options, Guidance, and Support. For example, a text component could represent a Standard statement for a discrete traffic control device. Links are components which aid navigation both internally and externally,

and are discussed in greater detail in the following section. Figures and tables are components which store graphical or tabular data, respectively, and are also discussed in greater detail below.

A search of all these components and their associated metadata can be performed by either entering text into a search field or by selecting metadata from a list. This database search and reporting system will search all text in the document as raw text, all metadata and tags for all objects in the document, and metadata and tags for paragraphs and sections in the document. The entire database, including all components, would be managed by a version control system.

Text would be searchable as raw text or according to metadata assigned to a group of text elements stored as a single object. An example of such a text object would be a Standard statement for a discrete traffic control device. Its metadata might be very similar to Guidance and Option statements for the same device, with variations depending on the contents of the text objects.

Hyperlinks

Web hyperlinks (or simply links) are one example of a component type. Links can be classified as internal or external. Internal links serve as a type of cross-reference to another part of the manual. These are suitable for highlighting related objects and definitions. Links facilitate consistency for editors, since they are encouraged to review sections which are related.

Alternatively, external links point to documents and content outside of the *MUTCD*, such as additional research and information concerning device implementation policies and practices. External links can be either direct or indirect. Direct links provide a connection from the published document directly to the research, typically found in some online repository. Such links are "hard" encoded into the document and, after publication, cannot be changed or updated. Indirect links provide a link between the published document and a database entry that contains the link to an external resource. This database entry can be updated as resource locations change, thus allowing all released publications access to the most recent external resource locations without the need for perpetual releases of updated publications merely to maintain external link continuity.

Tables and Figures

Tables and figures are an integral part of the *MUTCD*, especially since many *MUTCD* concepts are best presented in a tabular format and tend to be graphical in nature. Managing tables and figures as components makes sense particularly when images or tables are used in multiple parts of the *MUTCD*, allowing for an update of one object to automatically update all other objects. Figures would be discrete objects but would also contain objects and references. For example, a figure containing depictions of signing and traffic signals might contain objects referenced from those other "Sections" of the *MUTCD*.

ACCESS METHODS

The MUTCD can be accessed, for viewing or report generation, either online or offline.

Online editions

An Internet web site displaying the contents of the managed *MUTCD* is an obvious example of an online edition of the *MUTCD*. While a web-browser-based version of the *MUTCD* is an obvious example, there are other examples of online editions. For example, an *MUTCD app* (typically a mobile application)

could be developed for smartphones. Such an app would display information from the *MUTCD* in a customized interface suitable for smaller screens like those found on smartphones and tablet computers. These apps would resource data from the same database that powers the online web site, so these apps can be thought of as a means of obtaining, formatting, and displaying data for smartphone and tablet devices. The power of relational databases would eliminate the usual frustration of flipping from page to page in a 1000-page document, as instant searches would bring up all related objects and allow for immediate access to internal and external content, assuming an adequate internet connection is available.

Offline Editions

Offline editions can be developed in a variety of formats. The most familiar is the traditional print version of the *MUTCD*. A print version could be released based on the state of the online database at various times. This print version could be produced as a PDF which is also suitable for printing, as is currently done.

The applications developed for mobile devices as described above can also be configured to operate as offline interfaces. The offline app would be identical to the online version, with the exception that instead of resourcing information from the online database, the app would have a local static copy of this database. This static copy could be updated as releases are available by downloading packages of files based on the results of the version control software integrated into the database and application. Such routine downloads would eliminate the need for users to update the application itself, except as necessary to facilitate functionality and provide patches for software bugs. This type of offline version may be appealing to those with mobile devices who may not have internet access at all times, particularly in environments where immediate access to information is desired, such as on construction sites.

IMPLEMETATION PROPOSALS

In the process of collecting information concerning user community input on a strategic plan for the *MUTCD*, users mentioned the imperative that the *MUTCD* remain usable to the vast majority of users, presented in a format that makes sense to those users and is accessible and usable in a variety of circumstances. This necessitates that the database-driven document be implemented in such a way that continuity of use is always provided.

Hotlinks . . . A Step into the Future

Subsequent to the release of the 2009 edition of the *MUTCD*, the FHWA prepared and released a PDF copy of the *MUTCD* that contained a variety of "hotlinks". These were simply hyperlinks to internal and external resources. Examples of the hotlinks in the released version include pop-up definitions, links to other sections within the PDF, and links to external documents, including resources, research, and FHWA-produced documentation related to Requests for Experimentation and Official Interpretations. Those latter elements, in fact, are all searchable via a comprehensive relational database that was initially developed by FHWA in 2011 and continues to be expanded. Such a database could be easily incorporated into a database-driven implementation of the *MUTCD* to provide a depth of content only possible with the powerful referencing tools provided by relational databases.

Implementation of the "Wiki" Model

The wiki model is well-suited for adoption by the *MUTCD* since it maintains a clear record of when changes were made and by whom, while also allowing for a large number of contributors. A wiki is supportable with a dedicated user community and multiple resources are available for organizing, managing, and securing the database. This scenario assumes that the FHWA secures data storage systems, database management software, and database management services for security and operations. The FHWA would then provide access to the database in such a way that only the authorized version of the *MUTCD* would be available to general users.

A standard template could be developed to provide typical sections such as standards, guidance, and information, with some flexibility based on the variety of content in the *MUTCD*. Internal links would point to other resources in the wiki, which would also highlight relevant sections reviewers should check when making a modification to one part of the *MUTCD*.

Formatting of Printable Documents

This online document would always represent the latest version of the *MUTCD*, but care could be taken to only make the latest approved version publicly viewable, while privileged editors could continue to edit the latest version. As discussed previously, print versions are also possible and can be produced using a reporting system that generates all or a portion of the requested content in a uniform format.

Version Control and Security

In subsequent sections of this paper, the concept of providing for branch revisions of the *MUTCD* will be discussed. This is a form of version control that permits multiple users to create branch revisions of the document, as a type of "test" document, for the purposes of developing versions that will eventually be merged into the trunk.

All revisions of the MUTCD, that is, any work that involves database work beyond a query, must be subjected to the highest levels of security and data management policies. Security policies and data management policies can be community-driven and community-implemented, although it is likely that the FHWA will explicitly monitor security policies and guide the development of data management policies.

The simplest security management implementation strategy for a user community-based forum or database is to establish users who function as *moderators*. These users, who might be trained by an FHWA contractor, for example, would have the ability to permit the inception of branch revisions, the ability to elevate revisions to NPA candidate status, and other rights granted them to facilitate the management of the community. The ability of moderators to manage discussions, approve content, and generally provide oversight of the forums and content of the community is essential to maintaining a community-managed product that remains compliant with the regulatory process.

Management of *MUTCD* NPAs

The process of preparing, releasing, and disposing of an NPA is extremely time intensive for all parties involved, for agency officials and for those providing comments. Improvements to the NPA process can improve the consistency, applicability, and acceptance of regulations.

The use of a database-driven NPA release permits extreme flexibility for the agency and the public alike. This flexibility is obtained due to the improved management of related content and due to

the improved ability to track, analyze, and understand the development of content. Such improved content management ensures that users of the *MUTCD* will not "miss" content when searching for information concerning a particular device, concept, or implementation.

The powerful query tools of a relational database permit the agency to ensure that all associated content is addressed in a proposed change. In the case of the *MUTCD*, the document has items with related content spread throughout. For example, a change to language for a regulatory sign associated with a traffic signal would affect content presently occurring in Part 2 and Part 4, with potential impacts to Parts 3, 6, 7, 8, and 9. Presently, these associations are identified and addressed by those in the agency with a great degree of familiarity with the *MUTCD*. Organizations such as the NCUTCD, with knowledgeable practitioners, are also effective in addressing these cross-cutting issues. The relational database would help ensure that these issues are identified early in the process. Maintenance of the database in this regard, by linking objects and improving metadata, also serves to assist the user community as a whole.

In addition to the benefits of content association, content management with regard to an NPA is vastly improved on account of the VCS. The VCS provides multiple benefits. First, it permits the FHWA the ability to progress on branch revisions that allow a complete document to be rendered without the need to make changes to the existing head revision. Secondly, it allows the FHWA and users to review past versions and to view proposed changes side-by-side with the current language. Finally, the VCS could allow users to view the *MUTCD* as it will exist in the future, in the context of compliance dates, for example.

Management of Future Releases

Once the migration to a wiki format is completed, management of future releases will likely be facilitated by the improved technology. Collaborators can easily view the current state of any portion of the *MUTCD* and make edits, while those with approval authority can review and approve proposed changes. All of this work can occur behind the scenes until the new version of the document is ready for release, at which point it can be released to the publicly-available online version.

Errata

Current management of *MUTCD* errata follows the typical process of managing document errors. Identified errors that are not material to the intent of the document are addressed in errata and include errors such as mistakes in spelling, incorrect or missing punctuation, and, occasionally, a missing portion of text or a figure intended for publication but inadvertently not included.

A document listing errata by Part, Chapter, Section, and line number is released by the FHWA. The user bears the responsibility for comparing the errata to the document and ensuring incorporation of these elements. A database-driven manual can provide great assistance, as users utilizing the online version of the manual will transparently receive the latest version with errata incorporated (and noted, in the Version Control System). Users of offline versions may also be prompted to download the latest version. This could occur by notification if they are using an offline app version designed for a mobile device or tablet, or users may be notified by e-mail of updates if they provided an address when downloading their offline version. It is expected that a greater number of users would be incorporating the errata into their use of the *MUTCD* in a more-consistent and less time-consuming way than is currently possible.

Amendments

Amendments differ from errata in that they are material to the intent of the document, being typically developed in response to public comment on a major release of the *MUTCD*. Currently, the *MUTCD* is published on the web site of the FHWA with amendments incorporated and amendments are clearly identified by the FHWA.

Amendments are technically revisions that occur on the head revision or on a branch that is merged into the head revision. As such, amendments, being initiated by the FHWA, raise the question of community-generated amendments on a community-owned branch revision. Such amendments and revision acceptance through a regulatory process are worthy of further exploration.

Submission of Changes

Among the most powerful tools inherent in a database-driven document with a VCS is the ability to allow users to create branch revisions of content, keeping those branches private. The FHWA or any organization, such as the NCUTCD, could develop such branch revisions, releasing them for public comment, organizational use, and, in the case of the NCUTCD, sponsor comment and use by the task forces, joint task forces, and technical committees of the NCUTCD.

Branch revisions, when formatted appropriately according to guidelines established for the database, could seamlessly be incorporated in to the *MUTCD*'s head revision once all applicable requirements pertaining to the regulatory process were met. A user-community-based branch revision, invisible to the public and not included in the head revision, that is, the current *MUTCD*, would function just as any content in the main trunk and head revision, being subject to all query and reporting tools and essentially functioning as its own document. This powerful ability to create multiple instances of the *MUTCD* could allow users to immediately see the effects of changes to their portion of the document on all other portions of the document.

SUGGESTED FUTURE RESEARCH

The ongoing process by the NCUTCD to develop a 20-year strategic plan for the *MUTCD* will, to a great extent, provide a sense of the direction in which the industry's foremost practitioners wish to take the development of the *MUTCD*. Considerable research will be necessary to determine user preferences, technical capabilities, and preferred methods of obtaining, accessing, disseminating, and reacting to information contained in the *MUTCD*. The ability of users to provide immediate and substantial feedback to a user community, in a structured environment of professional courtesy and respect, is absolutely essential. The Institute of Transportation Engineers (ITE) operates on online forum that may be ideal for facilitating these discussions. Use of ITE, American Society of Civil Engineers (ASCE), American Traffic Safety Services Association (ATSSA), and American Association of State Highway & Transportation Officials (AASHTO) organizations as a means of collecting information cannot be understated.

Compiling and distributing a document containing federal regulations by means of a database system must be evaluated in light of international experience, similar projects at state and local levels, and the experience of other agencies within the federal government.

In particular, with regard to extra-agency experience, it is imperative that planning for such a deployment adequately investigates the use of community-based, collaborative content, web-based

information management systems in disseminating regulatory information. In particular, the question of a wiki for other regulatory documents necessitates much additional investigation.

The proposed model for information presentation and management depends greatly on the concept of user-community-updated links to external resources. This is necessary to validate information and ensure consistency throughout the *MUTCD* with regard to cited research and analysis of research, and it is important as it impacts selected regulatory language and supporting information.

Ultimately, for a database-driven document to exist and develop in a community-based environment, the community of users must be invested in its success.

REFERENCES

1. Wikipedia Statistics (https://en.wikipedia.org/wiki/Wikipedia:Statistics, ACCESSED July 26th, 2013)
2. Hawkins, H. Gene. "Draft 20-Year Vision and Strategic Plan for the *Manual on Uniform Traffic Control Devices*." July 18th, 2013.
3. Office of the Federal Register. "Guide to the Rulemaking Process" 2010.