

Enhancing Electronic Highway Design Standards and Specifications

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ABSTRACT

Within the last decade, highway design standards in electronic format have been developed by many organizations to help engineers and contractors work without piles of design standard books. Since the Iowa Electronic Reference Library (ERL) was developed for the Iowa DOT, designers, inspectors, contractors, and owners have studied the project requirements, specifications, and standard road plans more easily than before. Users can search or query information they need by using the internet-based ERL instead of reading through piles of books, as in the traditional research process. However, to make the ERL more usable, two areas of development are provided in this paper: (1) a framework for future development, and (2) recommendations for enhancing the existing system.

(1) The existing ERL can be more powerful and useful if it is always available from desktop computers and cell phones, or if it is used between web browsers and CADD software (e.g., Microstation or AutoCAD). Users would always have data when they need it. A designer could embed a road specification and a standard road plan into a drawing simply by clicking an icon in Microstation, and contractors can then read the drawing and retrieve the specification and standard by clicking another icon. However, ERL is currently a standalone application that is difficult to integrate with other software. An approach to this problem is to develop a new system on top of the existing ERL. The ERL2 model framework will be introduced in this paper under the concepts of reusability, availability, and extensibility with new web standards and technologies based on Extensible Markup Language (XML) and Resource Description Framework (RDF). The ERL2 architecture is composed of a programming model, a metadata model, and a data model, which are available to be developed separately. The new system will be used for major CADD software and software that implements specifications and standards, such as the Object-Oriented Design and Specification (OODAS) being developed at Iowa State University. The expected benefits of this research include saved work-hours and money.

(2) Currently, the ERL only supports the Microsoft Windows operating system with Microsoft Internet Explorer. Widely used mobile computers, such as PDAs or internet-based cellular phones, and Macintosh computers cannot interpret ERL data properly. To support other users and improve usability in the field, the ERL should be standardized. Other enhancements, including improving the search module and user interface, are also discussed.

Key words: data management—design standards and specifications—information and intelligent systems—knowledge management

INTRODUCTION

Within the last decade, highway design standards in electronic format have been developed by many organizations to help engineers and contractors work without piles of design standard books. Some organizations provide their standards on CD or make them available over the internet. Some incorporate illustration design standards, animations, and even a search function into their standards. The Washington Asphalt Pavement Association (WAPA) provides interactive animations instructing users about the asphalt design standards. The Iowa DOT provides design standards and drawing plans with a search function on its website. Organizations are migrating to electronic formats because electronic documents are easy to use, share, and maintain.

This paper provides an electronic highway specification development framework based on the Iowa Electronic Reference Library (ERL). Since there have been no major changes from its initial development in the past five years, the ERL uses the same technology. Many new technologies have come out in recent years. New technologies are explained that can adopt web services to enhance and improve the capabilities of electronic standards and specifications, including ERL. This paper describes and evaluates the existing Iowa ERL framework and provides (1) a framework for future development, and (2) recommendations for enhancing the existing system.

Background of the Iowa ERL

The Iowa ERL was developed to provide access to Iowa design standards and specifications, in electronic format since 2000. It is available both online, on the Iowa DOT's website, and in CD format; however, a traditional hardcopy is still published. The ERL has been modified and published twice a year. The main contents in the latest version (April 2005) include standard specifications, supplemental specifications, material instructional memoranda, standard road plans, standard culvert plans, standard bridge plans, the construction manual, the flagger's handbook, and statewide urban standard specifications. They are all stored in HTML and PDF formats. Besides these contents, there are other features. The navigation feature provides navigational link menus on the left-hand panel for selecting different sections. The search feature provides a box that can find a word or phrase in all design standards. Phonebook listings also provide up-to-date contact lists of Iowa DOT officers and engineers. The ERL system has been created and maintained based on HTML, PDF, and Javascript by Microsoft FrontPage, version 5.0. However, it only supports the Microsoft Internet Explorer browser, version 4.0 or later, with the Microsoft Windows platform.

Success of the ERL

The first online ERL survey (Cetin 2001) showed ERL's success with its users, including highway contractors, designers, and Iowa DOT officers, after they had migrated from paper to electronic format. Many field engineers prefer to use the ERL because of the ease of field use for people carrying only a computer laptop with a CD drive, rather than huge specification books. Users also preferred the search and navigation features. The bottom line for users was the up-to-date information provided every six months, displayed in red or strike-through text. This feature warned users of changes, preventing misunderstandings due to conflicts between different specifications.

IMPLEMENTATION OF THE ERL2 MODEL FRAMEWORK

Although the ERL is updated every six months, the ERL updates still use the same technology used in the initial development of the ERL in 2000. This paper introduces new technologies, called the ERL2 model framework, to enhance the capabilities of the existing system.

The major benefits of adopting the new technology are as follows:

- The new system will follow the standards of the World Wide Web Consortium (W3C), which makes data available in any device, from existing desktop computers to internet cellular phones or even new devices that come out after the system is developed.
- The existing data will be ready to use in any software, including CADD software (e.g., Microstation or AutoCAD) or newly developed software.
- The only maintenance issue will involve updating the design standards and specifications, rather than HTML technical issues.
- A glossary will be used and easily created from the existing files.
- The new system will reduce redundant information between design standards and specifications from different years.
- Information about general usage will be gathered automatically for analysis during further developments. Statistical data, including keyword searches, frequency of use, and types of user operating systems or browsers, will be collected.
- The system will follow W3C accessibility standards.

The use of some of the technologies listed here on the existing system without making major changes is discussed at the end of this paper.

ERL2 SYSTEM ARCHITECTURE

The ERL2 system development is based on three main concepts: reusability, availability, and extensibility. Reusability means that data created one time will be available in any format. Availability means that data will be available under any circumstances, such as cell phone access. Extensibility means that data will ideally be infinitely expandable. Ultimately, all data management will be organized by an automated system to reduce costs and human error. However, human reviews will still be needed for the contents.

In 2001, Li demonstrated that an automated system can generate hyperlinks using the Perl and Gwak programming languages and thus decrease labor/maintenance costs. At that time, automated functions did not work well because data was still unstable, and the system could not generate 100% of the data. Cetin (2001) introduced the internet database approach to managing ERL data. In July 2002, Wikipedia, an open-content encyclopedia on the internet, provided an infinitely extensible encyclopedia using software named MediaWiki. MediaWiki (2002) is data management software that works by programming model reading contents, which are kept separately. The results are then generated in plain HTML. This approach has also been used in various types of software, due to the advantages of smaller data size and data reusability. MediaWiki also introduced [[]] (double square brackets) to replace the full HTML tags, saving editing time and reducing typos.

Design Approach for the ERL2 Model Framework

The ERL2 will include three models: a programming model, a metadata model, and a data model (Figure 1). The programming model includes the programming coding and user interface. The metadata model

will be used as a bridge between the programming model and the data model. The data model will include the main contents (design standards and specifications).

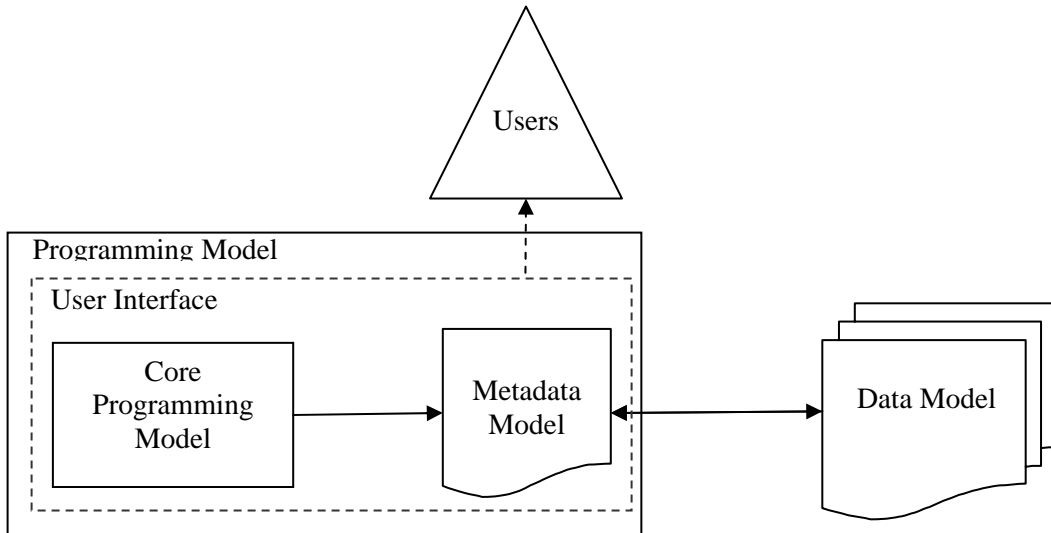


Figure 1. ERL2 model framework

The ERL2 system works by using the programming model as a core. It requests data from data model via the metadata model and then renders the requested data into plain HTML, depending on each user's interface.

Programming Model

The programming model develops the major contents of the ERL2 system, including publishing and maintaining data. The core system works as software that reads and edits the data model.

The user interface will be flexible, changing due to data usage (Thinkmap Inc. 2004). Figure 2 illustrates three different uses of the same data source in ERL2. The spider chart (top left) displays the relationship between each data node. The closed-relationship data nodes are displayed for every data node, so users can navigate quickly. In this example, the data node relates to ERL displays. The clustering chart (top right) shows a data relationship similar to that depicted in the spider chart, but emphasizes the types of relationships by displaying the data in different colors and sizes. In this example, the dark color represents the deeply detailed data. The chronology chart (bottom) shows the data in different timelines, which, in this example, shows standards with different update times. Different user interfaces can be added later without creating a new core system.

Although the programming model is designed for a web-based platform, CADD applications, such as Microstation or AutoCAD, can also access the data model with different user interfaces. Moreover, the Object-Oriented Design and Specifications project currently being developed at Iowa State University is able to access this data model.

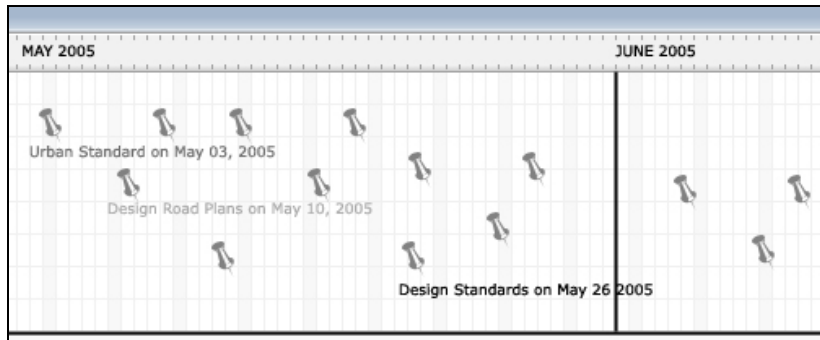
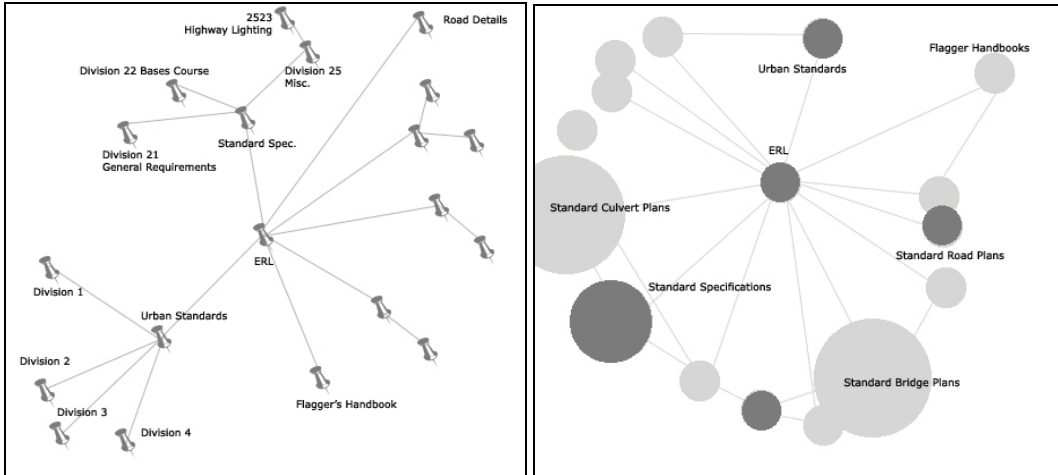


Figure 2. Illustration of different user interfaces for the same data source

Metadata Model

The metadata model explains the data model to the programming model. Instead of using the programming model with the data model, the metadata model organizes the data and decreases the complexity of both the programming model and the data model. Unlike other standards, such as Industry Foundation Class, TransXML, or LandXML, the metadata model does not itself define data. It defines data and the data model location as a resource description framework (RDF), which is a schema in XML.

Figure 3 shows a simple example of metadata in HTML, the code in the left column, and the rendered result in right column. HTML tags, <h1>, <h2>, <h3>, and so forth, are used to define heading formats, shown in the right column. At the same time in the back-end engine, content formatted in <h1> and referring to heading 1 is classified as more important than the content under <h2> and <h3>. The contents are then classified themselves by the metadata categories <h1>, <h2>, and <h3>.

<pre> <h1>Iowa ERL</h1> <h2>Design Standards</h2> <h3>Concrete Pavement</h3> <h2>Standard Specifications</h2> <h3>General Requirement<h3> <h3>Equipment Requirement</h3> </pre>	<pre> Iowa ERL Design Standards Concrete Pavement Standard Specifications General Requirement Equipment Requirement </pre>
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Figure 3. Example of metadata heading categories in HTML

XML, instead of using heading tags as metadata, defines its tag names more meaningfully than HTML tag names. That is, the same data can be used in several more ways than data in HTML format. Figure 4 shows the same metadata as Figure 3, but in XML format.

```
<Title name="Iowa ERL">
  <Book name="Design Standards">
    <Subject>Concrete Pavement</Subject>
  </Book>
  <Book name="Standard Specifications">
    <Topic>General Requirement</Topic>
    <Topic>Equipment Requirement</Topic>
  </Book>
</Title>
```

Figure 4. Example of using XML as metadata

RDF, an XML technology, is used in the ERL2 model framework. It allows the sharing and reusing of data between different applications or enterprises. It integrates a variety of data using the XML syntax for pointing to specific data locations, instead of explaining data (see Figure 5). With this framework, the data model is kept separate using the RDF metadata model, which is well-organized and reusable.

```
<RDF>
  <Description about="Iowa ERL Standards
    and Specifications">
    <Title>Highway Lighting</Title>
    <Location> GS/content/2523.htm</Location>
  </Description>
</RDF>
```

Figure 5. Example of RDF as metadata

Other XML schemas that can be used in the ERL2 model framework are Extensible Style-sheet Language (XSL) and Document Type Definition (DTD).

Data Model

The data model consists of two different parts: contents and a data tag. Contents are plain text or graphic representations of highway design standards and specifications, while a data tag is plain text that defines a feature of the contents. The contents, modified by specification engineers and updated twice a year, as mentioned, include text, images, drawing plans, graphs, tables, media files, and animations. This paper shows examples of the glossary and hyperlink features.

Glossary Feature

The data tag “[Glossary:]” (double square brackets containing the attribute “Glossary”) is added to the contents to define words or phrases in the contents. The glossary tag defines different words or phrases, creating the glossary links that appear in the results. When users select the tagged contents, the glossary is displayed instead of a hyperlink to other pages, as with the traditional method. Figure 6 displays examples of glossary tags used for contents. The code is in the left column and the rendered result is in the right column.

<p>...All apparatus, materials, and work shall be in accordance with the contract documents and with standards, practices, and codes of the electrical industry. Particular attention is directed to the following.</p> <ul style="list-style-type: none"> ▪ <code>[[Glossary:National Electric Code (NEC)]]</code>, latest edition, including amendments; ▪ <code>[[Glossary:IEEE Standards]]</code> and Practices; <p>The completed lighting installation shall conform to all local and special laws, codes, or ordinances of all Federal, State, and <code>[[Glossary:municipal authorities]]</code> with due jurisdiction.</p> <p>Lighting materials shall meet requirements of <code>[[Division 41]]</code>.</p>	<p>...All apparatus, materials, and work shall be in accordance with the contract documents and with standards, practices, and codes of the electrical industry. Particular attention is directed to the following.</p> <ul style="list-style-type: none"> ▪ <u>National Electric Code (NEC)</u>, latest edition, including amendments; ▪ <u>IEEE Standards</u> and Practices; <p>The completed lighting installation shall conform to all local and special laws, codes, or ordinances of all Federal, State, and <u>municipal authorities</u> with due jurisdiction.</p> <p>Lighting materials shall meet requirements of <u>Division 41</u>.</p>
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Figure 6. Glossary data tags in the data model

Hyperlink Feature

Similar to the glossary feature, the hyperlink feature creates links by using double square brackets. The current version of the ERL, using plain HTML code, defines a link in the contents as follows:

```
<a name="2523" href="../content/2523.htm">Section 2523 Highway Lighting</a>
```

In the ERL2 model framework, double square brackets are used instead, as in the following example:

```
[[Section 2523]] Highway Lighting
```

Although the outputs from the HTML code and the double square brackets of the ERL2 framework show the same result, the double square brackets help organize data and reduce data size. Furthermore, the amount of typos and maintenance time will decrease significantly. Other data tags in the ERL2 framework include, but are not limited to, the following:

- `[[__]]` – for same-specification links
- `[[Glossary:__]]` – for the glossary
- `[[GS:__]]` – for links to general specifications
- `[[US:__]]` – for links to urban standard specifications
- `[[IM:__]]` – for links to material instructional memoranda

Maintenance Issues

Because of the automated system for the ERL2 model framework, maintenance issues will only include updating the design standards and specifications from the specification engineers, and not HTML coding. When new highway design standards and specifications are released, the old programming and metadata

models will work with the new data model. Even for the next generation, when the new programming model must be changed, the same metadata model and data model can be used without changes.

POSSIBLE CHANNELS AND SOLUTIONS FOR ENHANCING THE EXISTING ERL

Adopting new technologies within the existing ERL will enhance some of its present capabilities. The possible channels and solutions for enhancing the capabilities of existing system are explained below.

Web Standards

The current ERL only supports the Microsoft Windows operating system with the Microsoft Internet Explorer browser, as mentioned in the ERL manual since its initial development. However, users who are not using the Microsoft platform cannot access and use the ERL properly. Widely used browsers such as Netscape (including AOL) and Mozilla Firefox, mobile computers such as PDAs or internet cell phones, and Macintosh computers are not able to interpret ERL data properly. Figure 7 shows the layout mismatch that happens on browsers other than Microsoft Internet Explorer. These standard browsers (Netscape, Mozilla Firefox, Safari, and Opera) do not render the first page of the ERL correctly. To support users who do not use Microsoft products and to improve usability in the field, a standardized ERL data system is a cost effective approach.

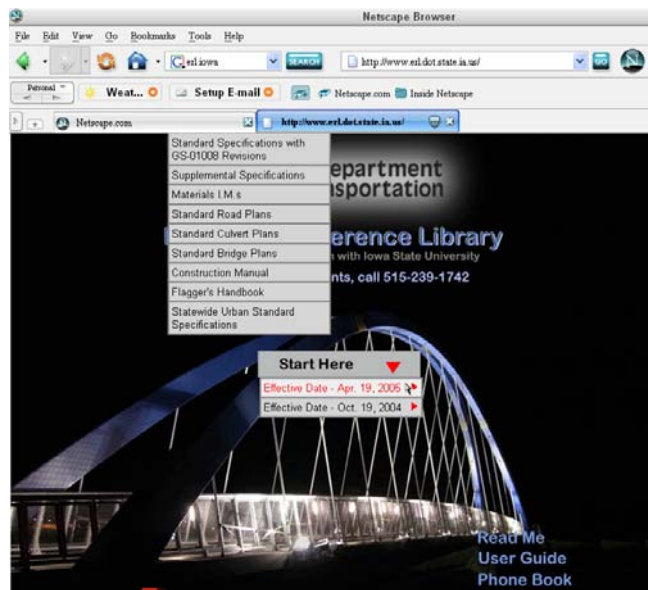


Figure 7. Netscape browser mismatch rendering

Other minor difficulties with accessibility standards include font sizes and font colors. These problems can be diminished by supporting accessibility standards and testing the ERL in standard browsers with both desktop and laptop computers. Besides the standards, the text and table positions should be in relevant size or absolute size, which is less than 240 pixels, to allow mobile users to read tables easily in one page width.

Search Technology

The ERL provides a search function based on the Javascript programming language. This feature helps users easily search specific keywords in an entire section of the specification book. However, publishing

both online and in CD format, the Iowa DOT needs to pay the annual license fee for the number of CDs distributed, a major maintenance cost. In the past few years, many search engines have entered the market. They improve search capabilities, providing a faster search at a lower cost. Some of them support a natural language search so users can find information by asking questions in plain sentences. Many of them do not require annual fees to use and publish. Using a new search engine for the ERL will improve its capabilities and at the same time decrease costs in the long term. The following companies, though not limited to these, provide search engines:

- Macromedia RoboHelp provides an online and offline (CD format) search system
- Microsoft HTMLHelp provides a free offline search system
- Google provides a free online search system

Index Module

The index module is similar to a book index, which functions as a pointer to a specific section. The index will help users search for specific keywords, which are human-generated and thus more exact and appropriate than search engines generated by computers. Moreover, an index created by people in the same field as the users, e.g., highway engineers, will help users find the right data better than keywords in a search engine. Adding an index into the current system is a bonus to the existing ERL. Figure 8 shows an example index page in the ERL system. Furthermore, an index will be more useful when adapting data into future developments, such as object-oriented data.

Tree-View Module

The example of the tree-view module, shown in Figure 8, illustrates the expandable menu and submenu. This menu type helps users browse the system easily from section to subsection and vice versa without getting lost.

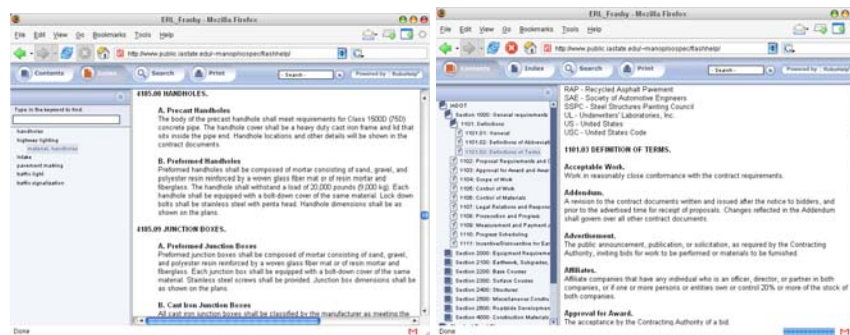


Figure 8. Examples of an index module (left) and tree-view module (right) created by RoboHelp

Test System for Enhancing the Existing ERL

The test system runs on Windows XP, Pentium III 800 MHz, RAM 640 MB, with Internet Explorer 6, Netscape 8.0, and Mozilla Firefox 1.04 browsers. An interactive example is available at the author's web site at <http://www.public.iastate.edu/~manop/oospec/flashhelp/>.

The example was created for illustrative purposes by RoboHelp X5. The search and index features are limited because of the software demo version. The Iowa DOT general specifications are excerpted only.

CONCLUSION

The ERL2 model framework continues from the success of the existing ERL system. The new system has been created with newly introduced technologies under the guiding concepts of reusability, availability, and extensibility. The three components of the ERL2 architecture, the programming model, metadata model, and data model, are able to develop separately under W3C standards. The primary purpose is to help users work faster by accessing data anywhere using state-of-the-art technologies.

An enhancement for the existing system has also been provided in this paper. Many approaches are provided, including standardizing the contents and improving the existing search engine. Minor enhancements for improving the ERL user interface and offering a tree-view feature were also introduced.

While this paper has explained a system based on the Iowa DOT ERL, other design standards or data management approaches can adopt the same technologies to follow the ERL2 model framework.

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