Accident Data For The Semantic Web

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ABSTRACT

This paper reports research exploring current impediments to dissemination of "lessons learned" from mishap investigations and hazard analyses, and how they might be overcome. Investigation data are presently documented and stored primarily in narratives and relational databases, and disseminated in many forms and media, including the internet. The impediments pose significant challenges to be overcome before improved dissemination can occur. New data concepts behind the Semantic Web being exploited elsewhere offer potential opportunities to improve investigation data acquisition, documentation and utilization approaches To exploit these opportunities,, formation of a working group to develop goals for mishap investigation lessons learned dissemination, documentation principles, machine interoperability approaches, and data structure definitions is proposed; W3C groups could serve as a model. To illustrate what an initiative might achieve, one example of this approach and how it is used to create various outputs from our research is presented.

1. Introduction: The Need For Change

The need to improve adaptive dynamic behavior of socio-technical systems through investigations of accidents, before and after they happen, has long been of interest.[1] There is even a Society for Effective Lessons Learned Sharing (SELLS).[2] Improving dissemination and utilization of "lessons learned" is a continuing quest in many circles.[2][3] One US report describes the need this way:

> "NASA stated that it must do a better job of communicating the various lessons learned sources to employees, improving mechanisms to link these sources, and ensuring appropriate training for employees in order to maximize lessons learning."[4]

Some organizations have established lessons learned "centers" to make use of mishap data and inputs from other sources to generate databases with lessons learned for use in those organizations [5] or by affiliated organizations and personnel [6] but are focused on a relatively narrow range of activities.

Current investigation practices produce many kinds of outputs, ranging from narrative reports, graphic representations, completed forms, statistical trends, summaries and tables to bulletins, recommendation letters, check lists, training materials, or e-mail alerts. These are derived by investigators or analysts who interpret investigation or incident report data. Personal use of public lessons learned databases is unknown, quantitatively, but interest in and use by individuals seems very limited. For example, one widely respected and emulated public incident lessons learned database with over 700,000 records had 88 search requests by individuals during a recent 6 year period. [7] The reasons merit examination.

New opportunities, offered by personal computers and the "Semantic Web"[8], for enabling universal personal access to many kinds of information resources, using machine accessibility, interoperability and web-friendly data structures of many kinds, are being exploited in and revolutionizing many fields.[9] To date, however, providers of lessons learned information from accident information have yet to exploit these opportunities..

These circumstances suggest that options to prevailing practices for the gathering, documentation, communication and use of lessons learned from mishap investigations merit exploration, to determine if universal personal access to such data is feasible, and if so, how it might be done.

2. Current dissemination impediments

What is the present system, and why is it of concern?

2.1 Present dissemination practices.

At present, investigators acquire, document and report "facts" or data in many forms and formats, in many diverse and often isolated systems. These data are used by investigators and analysts to piece together a description and explanation of what happened, usually in narratives or on forms, using natural language. Such accident data also forms the basis for conclusions about causes, cause factors, root causes, and other cause-oriented findings, from which recommendations for actions are derived. The findings and recommendations constitute the "lessons learned" from an investigation. The data are then abstracted, coded, characterized or otherwise condensed. The lessons learned are "published" or made public in various kinds of media as reports, articles, papers, books, graphics, training materials, check lists, etc. The "published" data are then preserved by being stored in organizational files or computerized databases for retrieval and subsequent uses at a later date.

Dissemination practices vary, but generally can be categorized as a) electronic or computer-based and b) non-electronic or written, verbal and graphic dissemination. [4] Electronic dissemination is achieved through computerized databases, as with the ASRS or on-line investigation reports, checklists accompanying investigation software, and e-mailed alerts, for example. Non-electronic dissemination is achieved through published or internal investigation reports, tables or check lists,on-the-job training, safety meetings, standards, training sessions, codes or regulations, and books.

The data are also used for research to find lessons learned in the form of historical trends or statistical relationships with statistical analyses techniques. The data are also frequently abstracted or characterized to generate lists of causes and causal factors used in investigation report databases, safety digests and investigation software, [7] in addition to many other uses. [8]

2.2 Lessons Learned Dissemination Impediments.

Werner and Perry (4) cite several observed barriers to effective capture and use of investigation lessons learned. These barriers, or impediments to dissemination could be summarized as:

- Reuse is rather ad hoc and unplanned
- It is often hard to know what to search for or how to find useful documents
- Taking time to search for, identify, access and then learn from them within an organization is a problem
- Lessons are not routinely identified, collected and shared across organizations and industries
- Unorganized lessons are too difficult to use, because there is too much material to search, it may be formatted differently for different reports, it's not quickly available or work pressures don't allow time or resources to find it

Numerous observations by this author over 35 years suggest that significant additional impediments impede universal dissemination of lessons learned from investigations. These additional impediments could be characterized as:

- Current perceptions of investigation data needs constrain data presently available for sharing.
- Natural language barriers lead to diverse data structures
- Data loss as software becomes obsolete.
- Liability concerns motivating a desire to withhold accident data from publicly accessible sources.

The first three impediments are observable in public as well as private investigations.

Other observed substantive investigation-related impediments include data gaps, logic errors, misinterpretation or misrepresentation of observations, biased data selection, flawed hypotheses, premature conclusions, and, rarely, deliberate falsehoods have also been observed by the author. If the principal impediments could be overcome, it is likely that these latter impediments could also be managed.

2.2.1 Perceptions of data needs

Perceptions of what investigation data should be acquired and disseminated may be the greatest impediment. Investigation purposes or mandates shape those perceptions. Investigation purposes and mandates for safety purposes are shifting, from the narrow goal of preventing similar accidents to broader goals like finding root causes or achieving process improvement. Perceptions of the nature of accidents are also shifting, from an "unforeseen event" toward a process view of these phenomena. Investigation methodologies are proliferating, with each needing either different data or differing data formats. The focus of outputs also continues to shift, from determining the cause to increasingly diverse factors, multiple causes, problems, and "root" causes, for example.

Each shift brings with it different ideas about what data are needed to support the investigation tasks, how the data are used, and findings or "lessons learned," impeding their dissemination. To achieve the needed machine interoperability, accessibility and utilization for the Semantic Web, this situation must change.

2.2.2 Natural language barriers

The preponderance of current accident data is documented using natural language, rather than a "professional language" like exists in mathematics or music or medicine or other professional fields. This usage tolerates wide variations in the syntax, morphology, meaning, context and level of abstraction of documented data, impeding machine comparisons and tabulations or rule-based manipulation like rational concatenation of elements, or interoperability, machine access and machine utilization of the data.

In these circumstances, many investigation data schemes provide accident data definition, to indicate intent and improve consistency. Data definition efforts have typically been directed at enhancing data uniformity with dictionaries or glossaries or check lists, defining words and terms.[9] However most lack a defined data *structure* for data that are reported.[10] Those that do ignore the syntax and other variants, or treat them in isolation from the other impediments. without attacking the more fundamental data structure definition need. The result is that today, almost any kind of data format and structure are represented in accident investigation findings and lessons learned, despite the increase in software applications available.[11]To be usable for the Semantic Web, this situation must change.

2.2.3 Software obsolescence.

Some of my earliest digitized investigation data and records were recorded on an IBM 360 with proprietary software, and later with Wordstar and Dbase II. None of them are available for my use today. The software used to prepare those records has been made obsolete by changed hardware, operating systems and software, little of which is fully backward compatible. Records that were prepared on proprietary software have no doubt fared as badly or worse as computers, operating systems, applications or vendors changed. My point is that software obsolescence is a threat to the future machine accessibility and dissemination of current investigation lessons learned that must be recognized when considering exploitation of the Semantic Web.

2.2.4 Liability concerns

Use or misuse of mishap data in litigation is a concern of many private organizations. A common reaction is to retain the data within the organization. Incident data are aggregated in voluntary reporting systems, but only when sufficiently abstracted for cause or synopsize to mask concrete identities of individual behaviors involved, as in the US Aviation Safety Reporting System (ASRS.)[12] The impeding effect of this decision on dissemination of investigation lessons learned is obvious: users are faced with Balkanized systems. Forced disclosure, through regulation or litigation, does not resolve the data needs and language issues. If a way to overcome this concern could be found by innovation in those areas, that would remove a key impediment to wider dissemination of useful mishap investigation findings. For useful data to be available for the Semantic Web, this impediment too must be overcome.

2.2.5 Other impediments

Other impediments I have observed that impair findings and the dissemination of lessons learned by machine include

- data gaps in incomplete descriptions or explanations of what happened;
- logic errors in sequencing or coupling elements of descriptions and explanations, or in the conclusions drawn from the data;
- misinterpretation or misrepresentation of observations due to unsuspected biases, unwarranted assumptions, ambiguities, ambivalence or unknowns;
- biased data selection to fit predetermined hypotheses, prior experiences or obstinate mind sets
- generalizations or abstractions masking actionable details about lessons learned;
- premature conclusions which lead to inadequately supported or misdirected findings; and
- rarely, deliberate falsehoods

Present data schemes posed other impediments, including the inability to apply statistical analysis methods to derive findings from an episodic occurrence, and risks inherent in waiting for sufficient occurrences to discover statistical relationships.

2.3 The Challenges

Ideally, lessons learned from investigations should be disseminated universally to everyone whose behavior should change to achieve safer and better task performance so each one has the opportunity to access, learn and act on the lesson.

Each impediment poses significant research challenges to achieving this goal; any alternative approaches need to address these challenges. To bring about better future performance, information that might adversely impact their future performance needs to be made accessible to all individuals who can act on the information.

As I see it, the first challenge is to enumerate who the users should be and then what investigation data would best would help those users to do better. Only people can produce new behaviors, in themselves, in objects they design or operate or energies they manage, for example. Mishaps can involve numerous people and tasks, ranging from individuals operating equipment to managerial, design, financial, training and many other kinds of personnel. What data would enable users to relate their own behaviors, tasks or processes to prior experiences? The information should be actionable for the user, which suggests that behavioral data to which users could related their own behaviors about people, objects or energies is needed. It's not clear how cause determinations could provide such data. This will require a change in the present causal lens through which present practices formulate mishap investigations and lessons learned data..

A second challenge is how to overcome the natural language barriers that produce such diverse data investigation inputs and outputs, so the identified data needs can be produced and delivered to personal users in a form they can use directly. This will require a consistent data structure and format for investigation building blocks from which mishap processes descriptions and explanations are developed, and from which the lessons learned are be developed, The structure and format must support data sequencing, coupling and logic testing, and the storage, access and presentation in unambiguous behavioral terms.

A third major challenge is to define the structure and content of the lessons learned data system satisfying users while also enabling machine documentation, processing, remote access, interoperability, and utilization for timely, efficient presentation of readily internalized lessons learned behavioral information.

A fourth major challenge is the development of the system that would facilitate the transition from present practices to a newly devised lessons learned dissemination system and practices.

Finally, the challenges inherent in devising a new system such as resources, management, staffing, control , access, and ownership need to be recognized.

3. Potential Opportunities

To address these challenges, any potential opportunities to improve lessons learned dissemination should be explored. The exploding use of the world wide web to improve productivity in many fields is clearly such an opportunity waiting to be explored. Other opportunities such as previous research or developments to improve *investigation processes* or new investigation software also merit consideration.

3.1 Data dissemination innovations

The semantic web is an evolving extension of the World Wide Web in which web content can be expressed not only in natural language, but also in a format that can be read and used by software agents, thus permitting them to find, share and integrate information more easily. Based on progress in other fields, innovations related to the developments supporting the Semantic Web are creating a new opportunities in many fields.[6]] Developments such as Extensible Markup Language (XML) for use on the internet at the World Wide Web Consortium (W3C) are designed to describe data and focus on what data is.[13[

XML documents use self describing and simple syntax, and are extensible: they can be extended to carry more information. XML elements can have attributes in the start tag, just like html, to provide additional information about an element. Language such as XML makes possible the introduction of self-contained, stand alone, "free-floating" data that can be utilized for analyses or displays in whatever ways are necessary to meet the user's needs. Experience in the definition and utilization of such data is already widely available, due to work in other fields by W3C working groups.

Another aspect of this opportunity offered by the Semantic Web is the ability to present text data in forms in which the text data can be readily visualized [14] which we found during our project. More about that below.

3.2 Prior research

Some research has been aimed at improving investigations and the presentation of data during investigations. Little lessons learned dissemination research, aside from Johnson's, ASRS's and Weaver and Perry's paper has been found, and theirs is constrained by the framework of existing investigation practices. Research outside that framework is indicated for order of magnitude improvement in dissemination.

Experience in the definition and utilization of Web-friendly data is already widely available, due to developmental work in other fields by W3C working groups. While the content remains a challenge, the structural research results seem to offer a viable opportunity for progress to help develop content.

3.3 Organizing to address the challenges

This suggests that the challenges cited above could probably be addressed successfully by an Investigation Data Disseminatino Working Group to develop investigation lessons learned dissemination system, including data structure definitions that facilitate dissemination of investigation findings utilizing semantic web concepts and experience.

The achievements of the World Wide Web Consortium (W3C) working groups suggest a model for the organization of a such a group. The mission of the W3C is to lead the World Wide Web to its full potential by developing common protocols that promote its evolution and ensure its interoperability. The W3C is organized for and oversees the development of web standards. Web standards exist for programming languages, operational systems, data formats, communications protocols and electrical interfaces. The W3C follows processes that promote the development of high-quality standards based on the consensus of the Membership, Team, and public. W3C processes promote fairness, responsiveness, and progress: all facets of the W3C mission.

The W3C processes are described in a W3C Process Document, posted on the internet. [15] If there is sufficient interest, the process is initiated. An initial step could be the convening of an international or intercontinental workshop of conference, to gauge the degree of interest in the topic. After a successful workshop, and discussion on an advisory mailing list, the W3C Director announces an activity or a working group charter.

The impediments to dissemination cited are offered as a possible general framework for an initiating conference. Further analyses of dissemination impediments should of course be entertained as they are identified and defined. The aim of such a conference or workshop should be at least a preliminary identification of potential data and data structure options that a formal working group or activity might pursue. A working group should draft a list of “shall be” or “should be” mandates for investigation lessons learned data and its structures.

4. A Research Example

This section describes an example of an investigation data structure definition developed for the Semantic Web, during research to improve lessons learned creation, documentation, and dissemination. It provides a combination of both text and visual machine implementation of web-accessible lessons learned data.

4.1 Data needs.

Prior noteworthy inquiries by Johnson [16], Ladkin [17] and others, attempting to apply rigorous logical reasoning to investigation reports, have demonstrated problems with large narrative reports and suggested remedial options. However, their focus has been primarily on the logic and presentation problems with the information in the reports, rather than lessons learned data needs, grammar or structure of data employed in the reports. Past and current improvement efforts, with some exceptions [18], are aimed primarily at achieving data *consistency* to enhance relational database machine analyses or data and text mining to identify trends, identify safety improvements and prevent accidents. We tried to rethink what data should be gathered, documented and made available to lessons learned users. Since behavioral change is the goal, we postulated that behaviors and their relationships during the process that produced the unintended outcomes should be our focus.

We had to distinguish between data definitions and data structure definitions. Data *definitions,* in the form of glossaries, dictionaries or instructions, tell data suppliers what data are desired, and are provided for use in specific forms, relational databases or narrative outputs. Data *structure definitions* specify the format, content, grammar and attributes of a stand alone data element, with no relation to a specific database structure. The distinction is critically important for Semantic Web use. Data designed and defined for a specific database has limited utility because of the ambiguity and abstractness of the natural language data reported. 4.2. Data selection.

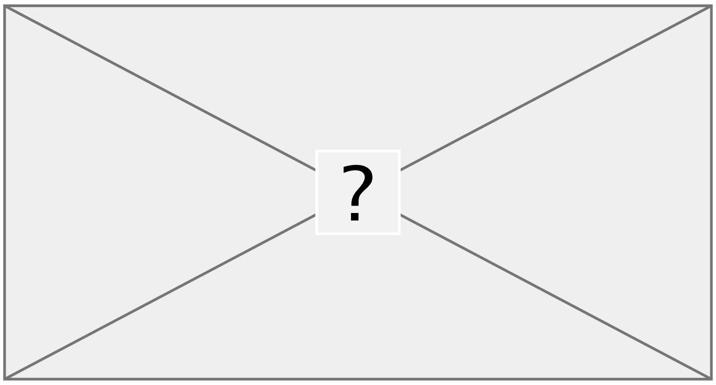
We noted that investigators create "building blocks" they use to construct a description and explanation of what happened and why it happened during an investigation. Many kinds of building blocks exist for this purpose, including building blocks created for investigation software.[11] We elected to use the most fully formalized behavioral investigation building blocks available, originally developed for manual implementation as a product of prior research in 1976 [18][20] They met the behavior data needs, and had the further advantage of having well defined data elements and structure .

4.2.1 Building Block Structure example

The building blocks were originally conceived and created to define for investigators the format for documenting observations during investigations. By transforming investigator's observations into this actor + action-based building block format, the behaviors can be properly described, ordered, linked, tested and utilized to show the logical flow of the interactions needed to produce the outcomes of interest.

The elements of these building blocks are shown in Figure 1.

Figure 1 Investigation Data Building Blocks



Source: 10 MES Investigation Guides, Guide 1,Starline Software Ltd

4.2.2 XML Investigation Building Blocks

To adapt these elements to the Web, we elected to configure these manual investigation building block data elements into an XML structure. XML was also chosen over an SQL database format largely because of the need for flexibility for handling varying numbers of links among the blocks. Additionally, the XML structure offered relatively reliable consistency and flexibility for file design, investigation data entry, editing, access, search, parsing, integration and display. A concern was the large number of files that would be created for very complex investigations, and concatenated documents.

The XML document structure that resulted is shown in Figure 2. Like other files created for display on the internet, the structure uses tags for data elements and other purposes. The first line of the document is the XML declaration. The “mesblock” tag is the XML root element, which is given a unique identification attribute to distinguish the document from all others. The other tags are XML document elements or building block element tags, which have attributes consisting of the data.

Figure 2 Investigation Building Block Elements in XML Document *

```
<?xml version="1.0"?>
<mesblock unique_id=""> (9)
        <actor></actor> (1)
        <action></action> (2)
        <object></object> (3)
        <location></location> (4)
        <start_time type=""> (6)**
                <year></year>
                <month></month>
                <day></day>
                <hour></hour>
                <minute></minute>
                <second></second>
                <millisecond></millisecond>
        </start_time>
        <end_time type=""> (7)
                <year></year>
                <month></month>
                <day></day>
                <hour></hour>
                <minute></minute>
                <second></second>
                <millisecond></millisecond>
        </end_time>
        <source></source> (5)
        <remarks></remarks> (8)
        <nstest> </nstest>***
        <link></link>****
</mesblock>
```

* Numbers in parentheses refer to Figure 1 legends
** type is used for attributes of tag
*** nstest is used to indicate whether link passed n/s logic tests.
**** link tags are used to document coupling to other XML documents

4.2.3. Expanding the data

The tags with number suffixes were the manual elements added to the XML document; the remaining tags were added to meet additional needs as the document was used to create experimental graphic and tabular outputs. For example, sometimes events were separated by milliseconds, so provision had to be made for more detailed time data. Then we discovered it was necessary to add new XML elements to accommodate the links and linked events (<link></link>), and the logic test status indicator element (<nstest> </nstest>) to indicate the state of completion of the event sets.

Later, when the scope of the experiments was expanded beyond investigation to include recommendation development, we created and linked a separate recommendation XML file to event blocks to accommodate the inputs and displays of problem statements, statement analyses, options for solving the problems, their analysis, and recommendation selection.

Note that conditions are not included as elements; all the elements and attributes refer to events. The rational for excluding conditions is was that conditions remain unchanged until acted on my some action by someone or something. This the focus led to actions again.

4.5 Use of Building Blocks

We used these XML building blocks in the generation of new files that produced graphic flow charts, glossaries, event block tags, links among two or more building blocks, event sets, jump maps, sortable tabular displays, parsed text files, event block tags, problem statements, recommendation options and assessments, duration-adjustable event blocks displays, and event block input-output tabulations. Hard copies or internet files with examples of the outputs discussed can be provided upon request to the author.

We also created web pages which provided for the remote entry of XML event block data from any internet-accessible computer with project access. These data files have been stored on protected web sites for authorized persons to peruse. The displays can be printed or saved and stored as graphics files for dissemination on the internet, as they are created, to show investigators the status of an investigation in real time. At the end of an investigation, the completed data can be presented graphically, in tabular form or as text phrases for inclusion in narrative reports.

With the ability to easily concatenate XML-based event block files, we can break down the investigation tasks and assign individual file preparation duties to two or more investigators, and combine their data files into one project file as their contributions became available.. When more investigations were documented, we created aggregated data files for groups of investigations. The aggregated files provide tabular listings of all events, which could be screened to find common events across all the incidents in the file, with detailed information about each file's building blocks.

4.6 Event Set Displays

The building blocks and links were read to create a graphic display showing the relationships of all the blocks to each other, with links between logically coupled blocks. The display data were converted to graphics files that could be processed for distribution on the web.

One of the most useful products of this research was the development of event set displays of coupled events, in which all the events necessary to produce an accident outcome could be displayed in tabular form, in the sequence they occurred. This searchable display provided both every input to each event disclosed by the investigation, and also every output that each event produced. We termed this our Event Block Input/Output (EBIO) display.

4.6.1 Conducting investigations.

EBIO displays help investigators during investigations, by displaying the flow of events shown by the data already acquired; any gaps in the flow of the events indicates a need for better understanding (e.g., more data) to complete the investigation. It offers guidance for interviewers by showing what an actor did during the accident process, with gaps indicating unknown actions, perhaps By searching for any "actor" involved in an incident, a designer, operator, trainer, supervisor or any other interested individual could determine at a glance how what they are doing might be involved in an accident

4.6.2 Disseminating Lessons Learned.

This display provided a way to disseminate investigation "lessons learned" although in an unconventional format. Each input/event/output event set offers a description of part of an accident process, which if replicated can play a role in another accident. Concatenated case files can identify event set patterns within or across activities.

5. Utility of the Semantic Web.

We found one of the key attractions of our files was their compatibility with web architecture. They were relatively easy to create, edit, archive, retrieve and parse with web-oriented coding instructions like html, php, and other programming languages.

However, the biggest attraction is that the files can be used to generate new understanding and insights by reorganizing, merging, sharing, displaying, and experimenting with objective, unambiguous individual building blocks or coupled pairs, or grouping building blocks into machine readable coupled Event Sets, in ways that enable individuals to see and understand the flow of events, relationships among the behaviors, and how the effects of the reported behaviors relate to their present or future activities and behaviors.

References

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[9] For an extensive list of examples of applications in Europe, see XML Applications at Work at http://www.softwareag.com/xml/dt/default.htm

[10] See Lessons Learned Database Product Overview at http://www.secutorsolutions.com/ [

[7] See commercial Bow Tie BlackBox and Tripod Beta software, for example

[8] For an extensive list of uses for accident investigation data see Appendix A, Accident Investigations: A Case For New Perceptions And Methodologies, SAE Special Publication-80/461, 1980 at
http://www.iprr.org/research/SAE80.html

[9] For example see the European Community Road Accident Database Glossary of Definitions, http://europa.eu.int/comm/transport/care/glossary/index_en.htm

[10] For example, see U.S. DEP ARTME NT OF HOMELAND SECURITY U.S.-COASTGUARD C G-2692 (Rev. 06-05), p 4

[11] See http://www.iprr.org/tools/softw.html for a list of software reviewed.

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[16] Johnson, C.W., Improving the Presentation of Accident Reports on the World Wide Web, which argues that imagemaps, VRML models and QuicktimeVR techniques might be used to improve both the quality and structure of these electronic documents posted by investigation agencies. Emphasis was on documents, not lessons learned. (http://www.dcs.gla.ac.uk/~johnson/papers/Web_accidents/paper.html)

[17] Ladkin, Peter, A QUICK INTRODUCTION TO WHY-BECAUSE ANALYSIS. 1999 http://www.rvs.uni-bielefeld.de/research/WBA

[18]See for example Kansas Department of Transportation Electronic Accident Data Collection and Reporting (EADCR) Components/Process/Output Information, which uses XML files.

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[20] Benner, L., 10 MES Investigation Guides, Starline Software Ltd, Oakton, VA 22124

[21] Personal knowledge of efforts by Investigation Systems Inc. in 1993 to computerize the manual system using flat databases with "The Investigator's Workbench" programmed in C++ had resulted in stunted charts and major programming difficulties with links, recommendations, editing, printing and output designs, and no web interoperability.