DECISION SUPPORT SYSTEMS AND WEB TECHNOLOGIES: A STATUS REPORT

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Abstract

World-Wide Web technologies have rapidly transformed the entire design, development and implementation process for all types of Decision Support Systems. In particular, Web technologies have provided a new media for sharing information about decision support and a new means of delivering decision support capabilities. For DSS developers, the big leap forward is to use the "Web as computer".

Keywords: Decision Support Systems, World-Wide Web, Data Driven DSS, Model-Driven DSS, Implementation

Introduction

Modern decision support systems (DSS) provide managers a wide range of capabilities. Computerized systems support decision tasks like information gathering, model building, sensitivity analysis, collaboration, alternative evaluation and decision implementation. Also, decision support is increasingly integrated in business processes and DSS are used for ad hoc analyses. These positive developments are facilitated by Web technologies. The global Internet and the World-Wide Web are now the primary enabling technologies for delivering decision support.

In general, we see a broad resurgence of interest in using technology to support decision-makers in completing their tasks. The World-Wide Web has facilitated, nurtured and promoted this renewal. This paper reviews the current status of Decision Support Systems in the context of developments in Web technologies. The next section is a brief historical overview of the past 35 years of DSS practice and research. Following that discussion, we discuss major tasks associated with building and using DSS that can and are being supported with Web technologies. The last major section examines the "State of Practice in 2001." While we have taken a broad view of DSS developments, the paper does present a somewhat biased perspective – drawing on our own interests and efforts – and should not be viewed as an exhaustive survey, but rather as our status report.

Historical Perspective

Decision support research began in the late 1960s. A study by Michael S. Scott Morton (1971) demonstrated that managers benefited from using a computer-based management decision system. According to Klein and Methlie (1995) "… the first DSS papers were published by Ph.D. students or professors in business schools, who had access to the first time-sharing computer system: Project MAC at the Sloan School, the Dartmouth Time Sharing Systems at the Tuck School" and in France at HEC.

The 1970s was a period of conceptual and technology development for DSS. In the early 1980s, some people thought we had answered all of the questions about how to support decision-makers and that all we needed to do was implement our technologies and managers would have effective Decision Support Systems. The introduction of the personal computer reinforced this conclusion. This technology imperative view was however much too optimistic. In the mid-1980s, group decision support stormed the academic world and reinvigorated research related to supporting decision-makers. By the late

1980s, executive information systems became fashionable in companies and further broadened the scope of decision support (cf., Power, 1999).

In the early 1990s, a shift occurred from mainframe-based DSS to client/server DSS. Also, some desktop online analytical processing (OLAP) tools were introduced. In 1992-93, the first enterprise data warehouses were completed. In 1994, many companies started to upgrade their network infrastructures. According to Powell (2001), DBMS vendors "recognized that decision support was different from OLTP and started implementing real OLAP capabilities into their databases". In about 1994, the World-Wide Web was recognized by a number of software developers and academics as a serious platform for implementing Decision Support Systems (cf., Power, 1998a).

In 1995 a series of papers were presented on using the Web and Internet for decision support at the 3rd International Conference of the International Society for Decision Support Systems (c.f., Ba, Kalakota and Whinston 1995; Bhargava, King, and McQuay, 1995; Bhargava, Krishnan, and Kaplan, 1995; Goul et al., 1995; Jeusfield and Bui, 1995). In addition to Web-Based, Model-Driven DSS, researchers were also reporting in 1995 the development of Web-Based GDSS and Web access to data warehouses.

In November 1995, Power, Bhargava and Quek submitted the Decision Support Systems Research page to ISWorld. Its goal was to provide a useful starting point for accessing Web-based material related to the design, development, evaluation, and implementation of Decision Support Systems. Nine months later, a DSS/WWW Workshop was held as part of the IFIP Working Group 8.3 Conference on “Implementing Systems for Supporting Management Decisions: Concepts, Methods and Experiences”, July 21-24, 1996 in London, UK.

In 1996-97, corporate intranets were developed to support information exchange and knowledge management. The primary decision support tools in use included ad hoc query and reporting tools, optimization and simulation models, online analytical processing (OLAP), data mining and data visualization (cf., Powell, 2001). Enterprise-wide DSS using database technologies were especially popular in Fortune 2000 companies (Power, 1997). Bhargava, Krishnan and Müller (1997) continued to discuss and experiment with electronic markets for decision technologies. In 1998, innovative enterprise performance management and the balanced scorecard systems were introduced. Vendors promoted these tools as updated executive information systems.

1999 was the year of the Web! The rush was on by laggards to introduce new Web-based analytical applications. Many DBMS vendors shifted their focus to Web-based analytical applications and business intelligence solutions. Last year, 2000, application service providers (ASPs) began hosting the application software and technical infrastructure for decision support capabilities. DSS technology had gone full-circle and we again have time-sharing DSS. 2000 was also the year of the portal. More sophisticated "enterprise knowledge portals" were introduced by vendors that combined information portals, knowledge management, business intelligence, and communications-driven DSS in an integrated Web environment. We have concluded the Web is now the platform of choice for building DSS.

Web-Based Decision Support Systems

Power (1998b) defined a Web-Based Decision Support System as a computerized system that delivers decision support information or decision support tools to a manager or business analyst using a "thin-client" Web browser like Netscape Navigator or Internet Explorer. The computer server that is hosting the DSS application is linked to the user's computer by a network with the TCP/IP protocol. The idea of Web-enabled or Web-Based Decision Support Systems as services has been explored by various researchers (see e.g., Bhargava et al. 1997a, 1997b) and involves the concept of offering decision computation technologies as services on the Web. These services could, in principle, be accessible to anyone with a problem and an Internet connection. At a higher level of organization, the concept of Web DSS involves the creation of an electronic market of decision technologies, where the market would bring together, and provide services for matching consumers, providers, and Web-enabled decision computation services. Web-enabled decision computation would allow the development of Decision Support Systems that combine components from multiple sources, perhaps “on the fly” to deliver application-specific solution packages.

A number of frameworks or typologies have been proposed for organizing our knowledge about Decision Support Systems (cf., Power, 2000a; 2000b). The two most widely implemented approaches for delivering decision support are Data-Driven

and Model-Driven DSS. Data-Driven DSS help managers organize, retrieve, and synthesize large volumes of relevant data using database queries, OLAP techniques, and data mining tools; Model-Driven DSS use formal representations of decision models and provide analytical support using the tools of decision analysis, optimization, stochastic modeling, simulation, statistics, and logic modeling. Three other approaches have become more wide spread and sophisticated because of Web technologies. Communication-Driven DSS rely on electronic communication technologies to link multiple decision makers who might be separated in space or time, or to link decision makers with relevant information and tools. The Web has expanded this technology. Knowledge-Driven DSS can suggest or recommend actions to managers. The Web helps deliver this type of DSS to a much broader audience of decision-makers. Finally, Document-Driven DSS integrate a variety of storage and processing technologies to provide managers document retrieval and analysis. Our primary focus in this status report and discussion is on the first two categories of Decision Support Systems: Data-Driven DSS and Model-Driven DSS.

Web-based DSS is a "hot" topic. Recently, Cohen, Kelly and Medaglia. (2000) discussed the use of Web-technologies for the development of DSS tools at SAS, Inc., a leading developer of decision support technologies. Czyzyk, Owen, and Wright (1997) described the development of NEOS, a "free" Internet-based optimization service. The concept of decision computation as a service has also been adopted by the commercial software industry, as witnessed in the concept of ASPs, "application service providers," application hosting (a term used by IBM and Oracle) and e-services (a term used by Hewlett-Packard). Today some firms offer application-specific DSS services to specific industries or companies. For example, OptAmaze.com provides paper trim optimization and transportation optimization services to paper mills from its Web site.

The recent popularity and widespread use of the World Wide Web and the Internet has been accompanied by the development of a variety of computing technologies that enable the realization of the "decision technologies as services" vision. Bhargava and Krishnan (1998) discussed the role of a series of enabling technologies in the context of Model-Driven DSS, covering technologies that enable the use of the Web for communication of decision information and computation, technologies that enable the remote and platform-independent access of DSS, and technologies that allow DSS components to be distributed over the Web. Fraternalli (1999) discussed technologies for developing Web-enabled data-intensive applications. Coddington, Hawick, and James (1998) discussed Web technologies in the context of DSS based on geographic information systems tools. Fourer and Goux (2001) discussed the concept of optimization as an Internet service and review various alternative ways of delivering such computation.

As discussed in Bhargava and Krishnan (1998), Web enabling technologies can be classified as those enabling server-side computation that facilitate platform-independent and universal access to decision support applications (common technologies include CGI, Java applications, server-side scripting languages, Active Server pages and Java server pages) and those enabling client-side computation that allow more capabilities to be embedded in the user interface (common technologies include client-side scripting languages, Java applets, ActiveX controls, and browser plugins), and those enabling a distributed implementation and deployment of DSS components (CORBA, DCOM, Java RMI and Java Beans are relevant technologies in this area). Together, these computing technologies create vast possibilities for changing the way decision support systems are developed, deployed and used.

Web Technologies and DSS Tasks

To understand how Web technologies can influence the development, deployment and use of Decision Support Systems, we have examined the major tasks at various stages of using and building Data and Model-Driven DSS. Web technologies are making it possible to perform all of these tasks via a remote Web client. In thinking of such tasks, it is useful to recall the distinction made by Sprague (1980) about application-specific DSS that consist of software, data, and models for a specific decision problem and DSS generators that provide tools and algorithms for building a variety of specific DSS. Application-specific DSS are far easier to build, but rarely reusable; DSS generators are far more complex to build but can be adapted to build many specific systems.

Figure 1 summarizes the relationships among 10 major tasks involved in building and using Data and Model-Driven DSS. For example, using an application-specific Model-Driven DSS, a user would be given the relevant decision models and data, and would focus on tasks such as model execution, development of reports, or analysis. Using a corresponding DSS generator, on the other hand, would require the performance of additional tasks such as model definition and creation of a custom user interface. Model-driven DSS often involve all the tasks in the model rows as well as the tasks in the data-driven DSS rows. Similarly, using a DSS generator involves the tasks listed in the DSS generator column as well as those for an Application-specific DSS. The 10 distinct DSS related tasks that can be executed by users from a Web browser include: model instantiation, model execution, creation of analyses and reports, data visualization, query and retrieval, data analysis, model definition, data definition, analysis definition, and user interface definition. From a browser, one can create decision support capabilities for others or use predefined capabilities.

	Model instantiation		Model definition
Model-driven	Model execution	→	Analysis definition
	Analysis and reports		U.I. definition
↑	↑		↑
	Data visualization		Data definition
Data-driven	Query and Retrieval	→	Analysis definition
	Data analysis		U.I. definition
	Application-specific	→	DSS Generator

Figure 1. Working with Decision Support Systems: Common Tasks

State of Practice 2001

In a number of prior papers, we have examined the extent to which current DSS products have "Web-enabled" the above decision support related tasks, and we have examined the evolution of DSS and especially Web-Based DSS. In this section, we provide an informal tour of our major findings.

Web technologies provide both the communication of decision-related information and software and a means of providing remote access to distributed DSS components. We discuss the first function in terms of the Web as media and the second we call the Web as computer. How these capabilities or functions can be used to support decision-making is still evolving. There is much scope for imagination here, but we have identified a few important beneficial uses of these capabilities and we will now review recent developments in each of these areas.

Web as media

The Web has facilitated the creation of a number of industry-wide **DSS Information Portals**. For example, the OLAP Report (http://www.olapreport.com/index.htm) and DataWarehousing Online (http://www.datawarehousingonline.com/). Both are industry-wide decision support portals that offer information about software products, vendors, methodologies, and white papers in the context of OLAP and data warehousing technologies. DSSResources.COM (http://dssresources.com/) is a "knowledge repository" for a broadly defined set of Decision Support Systems. IBM's COIN initiative (http://oss.software.ibm.com/developerworks/opensource/coin/) and e-optimization.com (http://www.e-optimization.com/) offer similar portals for optimization. InfoHarvest (http://oss.software.ibm.com/developerworks/opensource/coin/) and the Decision Analysis Society (http://faculty.fuqua.duke.edu/daweb/) have created portals related to decision analysis.

Individual firms have used Web technologies to communicate information about their decision support products and methods, or allow users to conduct various tasks like ordering, payment or Internet delivery related to purchasing DSS products. In the context of using the Web for "providing company and product information" there is substantial activity across all categories of Decision Support Systems.

DSS firms may also use the "Web as media" capabilities to engage in electronic retailing, that is completing the order fulfillment and payment phases over the Web, and distributing DSS products as downloadable software. In the area of Data-Driven DSS, most vendors appear to make substantial use of Web technologies for disseminating company and product information, and in supporting the product sales functions. In the case of Model-Driven DSS, however, there is surprising lack of activity in the area of Web-enabled sales. Few companies offer order placement and payment over the Web; fewer still allow buyers to download decision support software over the Web rather than wait for a package to arrive in the mail (this limitation may be explained by the size and complexity of the software).

Web as computer

We generally discuss the use of the "Web as computer" capabilities in three categories: digital product demonstrations, preview using online interactive examples, and on-line, Web-based Decision Support Systems.

The first category, product demonstrations, represents a baseline for the use of the Web's capabilities for remote computation. Online demonstrations can be delivered as animated multimedia documents (e.g., QuickTime movies, or Shockwave animation) that require or allow little user interaction. As a next step, online interactive examples allow users to interact (e.g., by setting parameter values, or choosing which command to execute next, or designing the format of a report) with the DSS tool in the context of a specific example. Both of these methods allow DSS developers to advertise their features to potential buyers, and can be developed with relatively little expertise in Web-enabled computation.

There is substantial exploitation of these capabilities in the category of data-driven DSS. For example, MicroStrategy offers both self-running and interactive demonstrations (http://store.microstrategy.com) of its OLAP and data warehousing software. Surprisingly, again, very few Model-driven DSS vendors exploit these capabilities. Most company Websites do not go much beyond mentioning DSS products; very few provide online demonstrations or interactive examples. Exceptions include Lumina and TreeAge, both companies offer demonstrations and interactive examples to demonstrate how their products support decision analysis.

The next step in the use of the "Web as computer" capabilities is to **offer application-specific DSS to users** that have decision problems within the supported categories. Recall our earlier example of OptAmaze.com which provides paper trim optimization and transportation optimizaton services to paper mills. Grazing Systems Limited offers decision support services in the agricultural sector. The value of such deployment of DSS may be appreciated by considering the difficulties that user firms would have in installing, maintaining and applying complex DSS tools on their own; Web-enabled DSS allow such firms to use decision support tools without encountering these difficulties.

For DSS developers, the big leap forward in the use the "Web as computer" capabilities is to develop off-the-shelf products that could generate Web-enabled application-specific DSS of the sort described above. Very few vendors have yet developed this expertise. Exceptions include Lumina and TreeAge. Lumina offers Analytica, a desktop DSS generator based on influence diagram techniques. But it also offers the Analytica Decision Engine (http://www.lumina.com/software/ADE.html) that allows developers to produce Web-enabled DSS applications. TreeAge Software sells DATA Interactive, a version of its DSS development products that enables development of Internet-based decision tree applications. Our observations about the state of practice in these categories are summarized in Table 1. The entries in the table cells are hyperlinks.

Table 1. State-of-Practice for Data and Model-Driven DSS 2001

	OLAP/Data Warehousing	Data Mining	Decision Analysis	Multi-Criteria DM	Optimi-zation	Simulation
Industry Portal	OLAP Report DW Online DSSResources.COM		DAS	InfoHarvest	eOpt. IBM OSS	
Company/ Product Information	Dimensional Insight Hyperion	IBM Information Discovery	DPL Aliah	Expert Choice Info Harvest	iLog CPlex	Decisioneering BizLand
Sales and Downloads	Cognos		Treeage Lumina			
Demo and Trial-run	Cognos Microstrategy		TreeAge HDS			BizLand
Vertical applications	Midway Airline		Cow Culling	Personalogic	Grazing Systems optAmaze	
Vertical app Generator	Dimensional Insight		Treeage Lumina			

Conclusions

The practice of building Decision Support Systems can benefit in many ways from the availability of Web technologies. These technologies provide platform-independent, remote, and distributed computation and the exchange of complex multimedia information. The state of practice has benefited considerably from these technologies but much, in our view, remains to be done. While there is significant promise in the idea of Web-Based Decision Support Systems there are also some important challenges that must be overcome. We need to resolve technological, economic and social and behavioral challenges to realize the benefits the Web can provide as a platform for building Decision Support Systems.

Tecnological challenges: The basic Web architectural model was designed for random jumps in hyperspace, hence the Web does not provide for persistent connections or persistence of state. This design is quite unlike the typical interaction found in a DSS application. Traditionally a DSS would have repeated interactions between the same site and the exchange of large amounts of data over multiple interactions. Therefore, DSS developers must continuously find ways around these limitations, or make use of recent and anticipated developments such as the new version of Internet protocols.

Economic challenges: To offer decision support as a service, providers must experiment with new payment models. Few providers have found ways to sell information goods, such as news, community information, and music for profit, and the same challenge holds true for decision support services. Bhargava, Krishnan and Müller (1997b) discuss some of the challenges in engaging in electronic commerce in decision support services. Only a few firms presently offering decision computation applications have well-defined revenue models: for example, optAmaze.com offers a subscription-based model for its trim-optimization service, charging differential prices based on the number of machines optimized.

Social and behavioral challenges: Decision support applications have historically been designed for industrial and organizational users, who are typically repeat users with a professional interest in using the application. The Web enables the development of DSS for casual users including consumers, but it is not clear that the cognitive and user interfaces that work for professional users will work as well for casual non-frequent users. It remains to be seen, also, whether business DSS users will be willing to cede control of internal corporate data and models and host DSS with application service providers.

Decision support capabilities are of great interest to a broad range of stakeholders and enormous resources have been and will be committed to building systems that promise to improve the quality, speed and effectiveness of specific decisions. We see the Web as a technology that can help realize these goals, but expectations need to be managed "downward" and we need to restrain the “hype” about creating intelligent enterprises and putting decision information at the "decision-makers finger tips". We have not answered all of the questions about how to support decision makers. We need to do much more than implement our technologies to build effective Decision Support Systems.

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