A Brief History of Decision Support Systems

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Summary

Information Systems researchers and technologists have built and investigated Decision Support Systems (DSS) for approximately 40 years. This paper chronicles and explores the developments in DSS beginning with building model-driven DSS in the late 1960s, theory developments in the 1970s, and the implementation of financial planning systems, spreadsheet DSS and Group DSS in the early and mid 80s. Data warehouses, Executive Information Systems, OLAP and Business Intelligence evolved in the late 1980s and early 1990s. Finally, the chronicle ends with knowledge-driven DSS and the implementation of Web-based DSS in the mid-1990s.

I. Introduction

Computerized decision support systems became practical with the development of minicomputers, timeshare operating systems and distributed computing. The history of the implementation of such systems begins in the mid-1960s. In a technology field as diverse as DSS, chronicling history is neither neat nor linear. Different people perceive the field of Decision Support Systems from various vantage points and report different accounts of what happened and what was important (cf., Arnott & Pervan, 2005; Eom & Lee, 1990b; McCosh & Correa-Perez, 2006; Power, 2003; Power, 2004a; Silver, 1991). As technology evolved new computerized decision support applications were developed and studied. Researchers used multiple frameworks to help build and understand these systems. Today one can organize the history of DSS into the five broad DSS categories explained in Power (2001; 2002; 2004b), including: communications-driven, data-driven, document driven, knowledgedriven and model-driven decision support systems.

This document is a starting point in explaining the origins of the various technology threads that are converging to provide integrated support for managers working alone, in teams and in organization hierarchies to manage organizations and make more rational decisions. History is both a guide to future activity in this field and a record of the ideas and actions of those who have helped advance our thinking and practice. Historical facts can be sorted out and better understood, but more information gathering is necessary. This web page is a starting point in collecting more first hand accounts and in building a more complete mosaic of what was occurring in universities, software companies and in organizations to build and use DSS.

This document traces decision support applications and research studies related to model and data-oriented systems, management expert systems, multidimensional data analysis, query and reporting tools, online analytical processing (OLAP), Business Intelligence, group DSS, conferencing and groupware, document management, spatial DSS and Executive Information Systems as the technologies emerge, converge and diverge. All of these technologies have been used to support decision making. A timeline of major historical milestones relevant to DSS is included in Appendix I.

The study of decision support systems is an applied discipline that uses knowledge and especially theory from other disciplines. For this reason, many DSS research questions have been examined because they were of concern to people who were building and using specific DSS. Hence much of the broad DSS knowledge base provides generalizations and directions for building more effective DSS (cf., Baskerville & Myers, 2002; Keen, 1980).

The next section describes the origins of the field of decision support systems. Section 3 discusses the decision support systems theory development that occurred in the late 1970s and early 1980s. Section 4 discusses important developments to communications-driven , datadriven, document driven, knowledge-driven and model-driven DSS (cf., Power, 2002). The final section briefly discusses how DSS practice, research and technology is continuing to evolve.

II. Decision Support Systems Origins

In the 1960s, researchers began systematically studying the use of computerized quantitative models to assist in decision making and planning (Raymond, 1966; Turban, 1967; Urban, 1967, Holt and Huber, 1969). Ferguson and Jones (1969) reported the first experimental study using a computer aided decision system. They investigated a production scheduling application running on an IBM 7094. In retrospect, a major historical turning point was Michael S. Scott Morton's (1967) dissertation field research at Harvard University.

Scott Morton's study involved building, implementing and then testing an interactive, model-driven management decision system. Fellow Harvard Ph.D. student Andrew McCosh asserts that the "concept of decision support systems was first articulated by Scott Morton in February 1964 in a basement office in Sherman Hall, Harvard Business School" (McCosh email, 2002) in a discussion they had about Scott Morton's dissertation. During 1966, Scott Morton (1971) studied how computers and analytical models could help managers make a recurring key business planning decision. He conducted an experiment in which managers actually used a Management Decision System (MDS). Marketing and production managers used an MDS to coordinate production planning for laundry equipment. The MDS ran on an IDI 21 inch CRT with a light pen connected using a 2400 bps modem to a pair of Univac 494 systems.

The pioneering work of George Dantzig, Douglas Engelbart and Jay Forrester likely influenced the feasibility of building computerized decision support systems. In 1952, Dantzig became a research mathematician at the Rand Corporation, where he began implementing linear programming on its experimental computers. In the mid-1960s, Engelbart and colleagues developed the first hypermedia—groupware system called NLS (oNLine System). NLS facilitated the creation of digital libraries and the storage and retrieval of electronic documents using hypertext. NLS also provided for on-screen video teleconferencing and was a forerunner to group decision support systems. Forrester was involved in building the SAGE (Semi-Automatic Ground Environment) air defense system for North America completed in 1962. SAGE is probably the first computerized data-driven DSS. Also, Professor Forrester started the System Dynamics Group at the Massachusetts Institute of Technology Sloan School. His work on corporate modeling led to programming DYNAMO, a general simulation compiler.

In 1960, J.C.R. Licklider published his ideas about the future role of multiaccess interactive computing in a paper titled "Man-Computer Symbiosis." He saw man-computer interaction as enhancing both the quality and efficiency of human problem solving and his paper provided a guide for decades of computer research to follow. Licklider was the architect of Project MAC at MIT that furthered the study of interactive computing.

By April 1964, the development of the IBM System 360 and other more powerful mainframe systems made it practical and cost-effective to develop Management Information Systems (MIS) for large companies (cf., Davis, 1974). These early MIS focused on providing managers with structured, periodic reports and the information was primarily from accounting and transaction processing systems, but the systems did not provide interactive support to assist managers in decision making.

Around 1970 business journals started to publish articles on management decision systems, strategic planning systems and decision support systems (cf., Sprague and Watson 1979).. For example, Scott Morton and colleagues McCosh and Stephens published decision support related articles in 1968. The first use of the term decision support system was in Gorry and Scott-Morton's (1971) Sloan Management Review article. They argued that Management Information Systems primarily focused on structured decisions and suggested that the supporting information systems for semi-structured and unstructured decisions should be termed "Decision Support Systems".

T.P. Gerrity, Jr. focused on Decision Support Systems design issues in his 1971 Sloan Management Review article titled "The Design of Man-Machine Decision Systems: An Application to Portfolio Management". The article was based on his MIT Ph.D. dissertation. His system was designed to support investment managers in their daily administration of a clients' stock portfolio.

John D.C. Little, also at Massachusetts Institute of Technology, was studying DSS for marketing. Little and Lodish (1969) reported research on MEDIAC, a media planning support system. Also, Little (1970) identified criteria for designing models and systems to support management decision-making. His four criteria included: robustness, ease of control, simplicity, and completeness of relevant detail. All four criteria remain relevant in evaluating modern Decision

Support Systems. By 1975, Little was expanding the frontiers of computer-supported modeling. His DSS called Brandaid was designed to support product, promotion, pricing and advertising decisions. Little also helped develop the financial and marketing modeling language known as EXPRESS.

In 1974, Gordon Davis, a Professor at the University of Minnesota, published his influential text on Management Information Systems. He defined a Management Information System as "an integrated, man/machine system for providing information to support the operations, management, and decision-making functions in an organization. (p. 5)." Davis's Chapter 12 was titled "Information System Support for Decision Making" and Chapter 13 was titled "Information System Support for Planning and Control". Davis's framework incorporated computerized decision support systems into the emerging field of management information systems.

Peter Keen and Charles Stabell claim the concept of decision support systems evolved from "the theoretical studies of organizational decisionmaking done at the Carnegie Institute of Technology during the late 1950s and early '60s and the technical work on interactive computer systems, mainly carried out at the Massachusetts Institute of Technology in the 1960s. (Keen and Scott Morton, 1978)". Herbert Simon's books (1947, 1960) and articles provide a context for understanding and supporting decision making.

In 1995, Hans Klein and Leif Methlie noted "A study of the origin of DSS has still to be written. It seems that the first DSS papers were published by PhD 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. In France, HEC was the first French business school to have a timesharing system (installed in 1967), and the first DSS papers were published by professors of the School in 1970. (p. 112)."

III. Theory Development

In the mid- to late 1970s, both practice and theory issues related to DSS were discussed at academic conferences including the American Institute for Decision Sciences meetings and the ACM SIGBDP Conference on Decision Support Systems in San Jose, CA in January 1977 (the proceeding were included in the journal Database). The first International Conference on Decision Support Systems was held in Atlanta, Georgia in 1981. Academic conferences provided forums for idea sharing, theory discussions and information exchange.

At about this same time, Keen and Scott Morton's DSS textbook (1978) provided the first broad behavioral orientation to decision support system analysis, design, implementation, evaluation and development. This influential text provided a framework for teaching DSS in business schools. McCosh and Scott-Morton's (1978) DSS book was more influential in Europe.

In 1980, Steven Alter published his MIT doctoral dissertation results in an influential book. Alter's research and papers (1975; 1977) expanded the framework for thinking about business and management DSS. Also, his case studies provided a firm descriptive foundation of decision support system examples. A number of other MIT dissertations completed in the late 1970s also dealt with issues related to using models for decision support.

Alter concluded from his research (1980) that decision support systems could be categorized in terms of the generic operations that can be performed by such systems. These generic operations extend along a single dimension, ranging from extremely data-oriented to extremely model-oriented. Alter conducted a field study of 56 DSS that he categorized into seven distinct types of DSS. His seven types include:

- File drawer systems that provide access to data items.
- Data analysis systems that support the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operators.

- Analysis information systems that provide access to a series of decision-oriented databases and small models.
- Accounting and financial models that calculate the consequences of possible actions.
- Representational models that estimate the consequences of actions on the basis of simulation models.
- Optimization models that provide guidelines for action by generating an optimal solution consistent with a series of constraints.
- Suggestion models that perform the logical processing leading to a specific suggested decision for a fairly structured or wellunderstood task.

Donovan and Madnick (1977) classified DSS as institutional or ad hoc. Institutional DSS support decisions that are recurring. An ad hoc DSS supports querying data for one time requests. Hackathorn and Keen (1981) identified DSS in three distinct yet interrelated categories: Personal DSS, Group DSS and Organizational DSS.

In 1979, John Rockart of the Harvard Business School published a ground breaking article that led to the development of executive information systems (EISs) or executive support systems (ESS). Rockart developed the concept of using information systems to display critical success metrics for managers.

Robert Bonczek, Clyde Holsapple, and Andrew Whinston (1981) explained a theoretical framework for understanding the issues associated with designing knowledge-oriented Decision Support Systems. They identified four essential "aspects" or general components that were common to all DSS: 1. A language system (LS) that specifies all messages a specific DSS can accept; 2. A presentation system (PS) for all messages a DSS can emit; 3. A knowledge system (KS) for all knowledge a DSS has; and 4. A problem-processing system (PPS) that is the "software engine" that tries to recognize and solve problems during the use of a specific DSS. Their book explained how Artificial Intelligence and Expert Systems technologies were relevant to developing DSS.

Finally, Ralph Sprague and Eric Carlson's (1982) book Building Effective Decision Support Systems was an important milestone. Much of the book further explained the Sprague (1980) DSS framework of data base, model base and dialog generation and management software. Also, it provided a practical, and understandable overview of how organizations could and should build DSS. Sprague and Carlson (1982) defined DSS as "a class of information system that draws on transaction processing systems and interacts with the other parts of the overall information system to support the decision-making activities of managers and other knowledge workers in organizations (p. 9)."

IV. DSS Applications Development

Beginning in about 1980 many activities associated with building and studying DSS occurred in universities and organizations that resulted in expanding the scope of DSS applications. These actions also expanded the field of decision support systems beyond the initial business and management application domain. These diverse systems were all called Decision Support Systems. From those early days, it was recognized that DSS could be designed to support decision-makers at any level in an organization. Also, DSS could support operations decision making, financial management and strategic decision-making.

A literature survey and citation studies (Alavi & Joachimsthaler, 1990, Eom & Lee, 1990a, Eom, 2002, Arnott & Pervan, 2005) suggest the major applications for DSS emphasized manipulating quantitative models, accessing and analyzing large data bases, and supporting group decision making. Much of the model-driven DSS research emphasized use of the systems by individuals, i.e., personal DSS, while data-driven DSS were usually institutional, ad hoc or organizational DSS. Group DSS research emphasized impacts on decision process structuring and especially brainstorming.

The discussion in this section follows the broad historical progression of DSS research. The first subsection examines model-driven DSS, then the focus turns to data-driven DSS and executive information systems and notes the growing prominence of such systems beginning in the late 1980s. The origins of communications-driven DSS are then briefly explored and the bifurcation into two types of group DSS, model-driven and communications-driven. Developments in document storage technologies and search engines then made document-driven DSS more widely available as web-

based systems. The last subsection summarizes major developments in Artificial Intelligence (AI) and expert systems that made suggestion or knowledge-driven DSS practical.

IV.1 Model-driven DSS

Scott-Morton's (1971) production planning management decision system was the first widely discussed model-driven DSS, but Ferguson and Jones' (1969) production scheduling application was also a model-driven DSS. Many of the early decision systems mentioned in section 2, e.g., Sprinter, MEDIAC and Brandaid, are probably model-driven DSS.

A model-driven DSS emphasizes access to and manipulation of financial, optimization and/or simulation models. Simple quantitative models provide the most elementary level of functionality. Model-driven DSS use limited data and parameters provided by decision makers to aid decision makers in analyzing a situation, but in general large data bases are not needed for model-driven DSS (Power, 2002). Early versions of model-driven DSS were called model-oriented DSS by Alter (1980), computationally oriented DSS by Bonczek, Holsapple and Whinston (1981) and later spreadsheet-oriented and solver-oriented DSS by Holsapple and Whinston (1996).

The first commercial tool for building model-driven DSS using financial and quantitative models was called IFPS, an acronym for interactive financial planning system. It was developed in the late 1970's by Gerald R. Wagner and his students at the University of Texas. Wagner's company, EXECUCOM Systems, marketed IFPS until the mid 1990s. Gray's Guide to IFPS (1983) promoted the use of the system in business schools. Another DSS generator for building specific systems based upon the Analytic Hierarchy Process (Saaty, 1982), called Expert Choice, was released in 1983. Expert Choice supports personal or group decision making. Ernest Forman worked closely with Thomas Saaty to design Expert Choice.

In 1978, Dan Bricklin and Bob Frankston co-invented the software program VisiCalc (Visible Calculator). VisiCalc provided managers the opportunity for hands-on computer-based analysis and decision support at a reasonably low cost. VisiCalc was the first "killer" application for personal computers and made possible development of many model-oriented, personal DSS for use by managers. The history of microcomputer spreadsheets is described in Power

(2000). In 1987, Frontline Systems founded by Dan Fylstra marketed the first optimization solver add-in for Microsoft Excel.

In a 1988 paper, Sharda, Barr, and McDonnell reviewed the first 15 years of model-driven DSS research. They concluded that research related to using models and financial planning systems for decision support was encouraging but certainly not uniformly positive. As computerized models became more numerous, research focused on model management and on enhancing more diverse types of models for use in DSS such as multicriteria, optimization and simulation models. The idea of model-driven spatial decision support system (SDSS) evolved in the late 1980's (Armstrong, Densham, and Rushton, 1986) and by 1995 the SDSS concept had become firmly established in the literature (Crossland, Wynne, and Perkins, 1995). Data-driven spatial DSS are also common.

IV.2 Data-driven DSS

In general, a data-driven DSS emphasizes access to and manipulation of a time-series of internal company data and sometimes external and realtime data. Simple file systems accessed by query and retrieval tools provide the most elementary level of functionality. Data warehouse systems that allow the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operators provide additional functionality. Data-Driven DSS with On-line Analytical Processing (cf., Codd et al., 1993) provide the highest level of functionality and decision support that is linked to analysis of large collections of historical data. Executive Information Systems are examples of data-drivenDSS (Power, 2002). Initial examples of these systems were called data-oriented DSS, Analysis Information Systems (Alter, 1980) and retrievalonly DSS by Bonczek, Holsapple and Whinston (1981).

One of the first data-driven DSS was built using an APL-based software package called AAIMS, An Analytical Information Management System. It was developed from 1970-1974 by Richard Klaas and Charles Weiss at American Airlines (cf. Alter, 1980).

As noted previously, in 1979 John Rockart's research stimulated the development of executive information systems (EIS) and executive support systems (ESS). These systems evolved from single user model-driven decision support systems and from the development of relational database products. The first EIS used pre-defined information screens maintained by analysts for senior executives. For example, in the Fall of 1978, development of an EIS called Management Information and Decision Support (MIDS) system began at Lockheed-Georgia (cf., Houdeshel and Watson, 1987).

The first EIS were developed in the late 1970s by Northwest Industries and Lockheed "who risked being on the 'bleeding edge' of technology …. Few even knew about the existence of EIS until John Rockart and Michael Treacy's article, 'The CEO Goes On-line,' appeared in the January-February 1982 issue of the Harvard Business Review. (Watson, Houdeshel and Rainer, 1997, p. 6)" Watson and colleagues. further note "A major contributor to the growth of EIS was the appearance of vendor-supplied EIS software in the mid-1980s. Pilot Software's Command Center and Comshare's Commander EIS made it much easier for firms to develop an EIS by providing capabilities for (relatively) easy screen design, data importation, user-friendly front ends, and access to news services. (p. 6)" In a related development in 1984, Teradata's parallel processing relational database management system shipped to customers Wells Fargo and AT&T.

In about 1990, data warehousing and On-Line Analytical Processing (OLAP) began broadening the realm of EIS and defined a broader category of data-driven DSS (cf., Dhar and Stein, 1997). Nigel Pendse (1997), author of the OLAP Report, claims both multidimensional analysis and OLAP had origins in the APL programming language and in systems like Express and Comshare's System W. Nylund (1999) traces the developments associated with Business Intelligence (BI) to Procter & Gamble's efforts in 1985 to build a DSS that linked sales information and retail scanner data. Metaphor Computer Systems, founded by researchers like Ralph Kimball from Xerox's Palo Alto Research Center (PARC), built the early P&G data-driven DSS. Staff from Metaphor later founded many of the Business Intelligence vendors: The term BI is a popularized, umbrella term coined and promoted by Howard Dresner of the Gartner Group in 1989. It describes a set of concepts and methods to improve business decision making by using fact-based support

systems. BI is sometimes used interchangeably with briefing books, report and query tools and executive information systems. In general, business intelligence systems are data-driven DSS.

Bill Inmon and Ralph Kimball actively promoted decision support systems built using relational database technologies. For many Information Systems practitioners, DSS built using Oracle or DB2 were the first decision support systems they read about in the popular computing literature. Ralph Kimball was "The Doctor of DSS" and Bill Inmon was the "father of the data warehouse". By 1995, Wal-Mart's data-driven DSS had more than 5 terabytes of on-line storage from Teradata that expanded to more than 24 terabytes in 1997. In more recent years, vendors added tools to create web-based dashboards and scorecards.

IV.3 Communications-driven DSS

Communications-driven DSS use network and communications technologies to facilitate decision-relevant collaboration and communication. In these systems, communication technologies are the dominant architectural component. Tools used include groupware, video conferencing and computer-based bulletin boards (Power, 2002).

Engelbart's 1962 paper "Augmenting Human Intellect: A Conceptual Framework" is the anchor for much of the later work related to communications-driven DSS. In 1969, he demonstrated the first hypermedia/groupware system NLS (oNLine System) at the Fall Joint Computer Conference in San Francisco. Engelbart invented the both the computer mouse and groupware.

Joyner and Tunstall's article (1970) reporting testing of their Conference Coordinator computer software is the first empirical study in this research area. Murray Turoff's (1970) article introduced the concept of Computerized Conferencing. He developed and implemented the first Computer Mediated Communications System (EMISARI) tailored to facilitate group communications.

In the early 1980s, academic researchers developed a new category of software to support group decision-making called Group Decision Support Systems abbreviated GDSS (cf., Gray, 1981; Huber, 1982; Turoff and Hiltz, 1982).

Mindsight from Execucom Systems, GroupSystems developed at the University of Arizona and the SAMM system developed by University of Minnesota researchers were early Group DSS.

Eventually GroupSystems matured into a commercial product. Jay Nunamaker, Jr. and his colleagues wrote in 1992 that the underlying concept for GroupSystems had its beginning in 1965 with the development of Problem Statement Language/Problem Statement Analyzer at Case Institute of Technology. In 1984, the forerunner to GroupSystems called PLEXSYS was completed and a computer-assisted group meeting facility was constructed at the University of Arizona. The first Arizona facility, called the PlexCenter, housed a large U-shaped conference table with 16 computer workstations.

On the origins of SAMM, Dickson, Poole and DeSanctis (1992) report that Brent Gallupe, a Ph.D. student at the University of Minnesota, decided in 1984 "to program his own small GDSS system in BASIC and run it on his university's VAX computer".

DeSanctis and Gallup (1987) defined two types of GDSS. Basic or level 1 GDSS are systems with tools to reduce communication barriers, such as large screens for display of ideas, voting mechanisms, and anonymous input of ideas and preferences. These are communications-driven DSS. Advanced or level 2 GDSS provide problem-structuring techniques, such as planning and modeling tools. These are model-driven group DSS. Since the mid-1980s, many research studies have examined the impacts and consequences of both types of group DSS. Also, companies have commercialized model-driven group DSS and groupware.

Kersten (1985) developed NEGO, a computerized group tool to support negotiations. Bui and Jarke (1986) reported developing Co-op, a system for cooperative multiple criteria group decision support. Kraemer and King (1988) introduced the concept of Collaborative Decision Support Systems (CDSSs). They defined them as interactive computer-based systems to facilitate the solution of ill-structured problems by a set of decision makers working together as a team.

In 1989, Lotus introduced a groupware product called Notes and broadened the focus of GDSS to include enhancing communication, collaboration and coordination among groups of people. Notes had its roots in a product called PLATO Notes, written at the Computer-based Education Research Laboratory (CERL) at the University of Illinois in 1973 by David R. Woolley.

In general, groupware, bulletin boards, audio and videoconferencing are the primary technologies for communications-driven decision support. In the past few years, voice and video delivered using the Internet protocol have greatly expanded the possibilities for synchronous communications-driven DSS.

IV.4 Document-driven DSS

A document-driven DSS uses computer storage and processing technologies to provide document retrieval and analysis. Large document databases may include scanned documents, hypertext documents, images, sounds and video. Examples of documents that might be accessed by a document-driven DSS are policies and procedures, product specifications, catalogs, and corporate historical documents, including minutes of meetings and correspondence.
A search engine is a primary decision-aiding tool associated with a document-driven DSS (Power, 2002).
These systems have also been called text-oriented DSS (Holsapple and Whinston,1996).

The precursor for this type of DSS is Vannevar Bush's (1945) article titled "As We May Think". Bush wrote "Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, 'memex' will do". Bush's memex is a much broader vision than that of today's document-driven DSS. Text and document management emerged in the 1970s and 1980s as an important, widely used computerized means for representing and processing pieces of text (Holsapple and Whinston, 1996). The first scholarly article for this category of DSS was written by Swanson and Culnan (1978). They reviewed document-based systems for management planning and control. Until the mid-1990s little progress was made in helping managers find documents to support their decision making. Fedorowicz (1993, 1996) helped define the need for such systems. She estimated in her 1996 article that only 5 to 10 percent of stored business documents are available to managers for use in decision making.

The World-wide web technologies significantly increased the availability of documents and facilitated the development of document-driven DSS.

IV.5 Knowledge-driven DSS

Knowledge-driven DSS can suggest or recommend actions to managers. These DSS are person-computer systems with specialized problemsolving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems (Power, 2002). These systems have been called suggestion DSS (Alter, 1980) and knowledge-based DSS (Klein & Methlie, 1995). Goul, Henderson, and Tonge (1992) examined Artificial Intelligence (AI) contributions to DSS.

In 1965, a Stanford University research team led by Edward Feigenbaum created the DENDRAL expert system. DENDRAL led to the development of other rule-based reasoning programs including MYCIN, which helped physicians diagnose blood diseases based on sets of clinical symptoms. The MYCIN project resulted in development of the first expert-system shell (Buchanan and Shortliffe, 1984).

Bonczek, Holsapple and Whinston's (1981) book created interest in using these technologies for DSS. In 1983, Dustin Huntington established EXSYS. That company and product made it practical to use PC based tools to develop expert systems. By 1992, some 11 shell programs were available for the MacIntosh platform, 29 for IBM-DOS platforms, 4 for Unix platforms, and 12 for dedicated mainframe applications (National Research Council, 1999). Artificial Intelligence systems have been developed to detect fraud and expedite financial transactions, many additional medical diagnostic systems have been based on AI, expert systems have been used for scheduling in manufacturing operation and web-based advisory systems. In recent years, connecting expert systems technologies to relational databases with web-based front ends has broadened the deployment and use of knowledge-driven DSS.

V. Web-based DSS

Beginning in approximately 1995, the World-wide Web and global Internet provided a technology platform for further extending the capabilities and deployment of computerized decision support. The release of the HTML 2.0 specifications with form tags and tables was a turning point in the development of web-based DSS. In 1995, a number 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 (ISDSS). In addition to Web-based, model-driven DSS, researchers were reporting Web access to data warehouses. DSS Research Resources was started as a web-based collection of bookmarks. By 1995, the World-Wide Web (Berners-Lee, 1996) was recognized by a number of software developers and academics as a serious platform for implementing all types of Decision Support Systems (cf., Bhargava & Power, 2001).

In November 1995, Power, Bhargava and Quek submitted the Decision Support Systems Research page for inclusion in ISWorld. The 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 organized by Power and Quek 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 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 1999, vendors introduced new Web-based analytical applications. Many DBMS vendors shifted their focus to Web-based analytical applications and business intelligence solutions. In 2000, application service providers (ASPs) began hosting the application software and technical infrastructure for decision support capabilities. 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 (cf., Bhargava and Power, 2001).

Power (1998) 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.

VI. Conclusions

DSS practice, research and technology continue to evolve. By 1996, Holsapple and Whinton had identified five specialized types of DSS, including text-oriented DSS, database-oriented DSS, spreadsheet-oriented DSS, solver-oriented DSS, and rule-oriented DSS. These last four types of DSS match up with some of Alter's (1980) categories. Arnott and Pervan (2005) traced the evolution of DSS using seven sub-groupings of research and practice: personal DSS, group support systems, negotiation support systems, intelligent DSS, knowledge management-based DSS, executive information systems/business intelligence, and data warehousing. These sub-grouping overlap, but reflect the diverse evolution of prior research.

This chapter used an expanded DSS framework (Power, 2001, 2002) to retrospectively discuss the historical evolution of decision support systems. The Web has had a significant impact on the variety, distribution and sophistication of DSS, but handheld PCs, wireless networks, expanding parallel processing coupled with very large data bases and visualization tools are continuing to encourage the development of innovative decision support applications.

Historians use two approached to apply the past to the future: reasoning by analogy and projection of trends.
In many ways computerized decision support systems are like airplanes, coming in various shapes, sizes and forms, technologically sophisticated and a very necessary tool in many organizations. Decision support systems research and development will continue to exploit any new technology developments and will benefit from progress in very large

data bases, artificial intelligence, human-computer interaction, simulation and optimization, software engineering, telecommunications and from more basic research on behavioral topics like organizational decision making, planning, behavioral decision theory and organizational behavior.

Trends suggest that data-driven DSS will use faster, real-time access to larger, better integrated databases. Model-driven DSS will be more complex, yet understandable, and systems built using simulations and their accompanying visual displays will be increasingly realistic. Communications-driven DSS will provide more real-time video communications support. Document-driven DSS will access larger repositories of unstructured data and the systems will present appropriate documents in more useable formats. Finally, knowledge-driven DSS will likely be more sophisticated and more comprehensive. The advice from knowledge-driven DSS will be better and the applications will cover broader domains.

Decision Support Systems pioneers came from a wide variety of backgrounds and faced many challenges that they successfully overcame to demonstrate the value of using computers, information technologies and specific decision support software to enhance and in some situations improve decision making. The DSS pioneers created particular and distinct streams of technology development and research that serve as the foundation for much of today's interest in building and studying computerized decision support systems. The legacy of the pioneers must be preserved. Check the Decision Support Systems Pioneers list at DSSResources.com/history/pioneers/pioneerslist.html.

The future of decision support systems will certainly be different than the opportunistic and incremental innovations seen in the recent past. Decision support systems as an academic discipline is likely to follow a path similar to computer architecture and software engineering and become more rigorous and more clearly delineated.
DSS consulting, teaching and research can be mutually supportive and each task can help establish a niche for those interested in building and studying DSS whether in Colleges of Information, Business or Engineering.

The history of Decision Support Systems covers a relatively brief span of years, and the concepts and technologies are still evolving. Today it is still possible to reconstruct the history of Decision Support Systems (DSS) from retrospective

accounts from key participants as well as from published and unpublished materials. Many of the early innovators and early developers are retiring but their insights and actions can be captured to guide future innovation in this field. It is hoped this paper leads to email and retrospective accounts that can help us understand the "real" history of DSS. The Internet and Web have speeded-up developments in decision support and have provided a new means of capturing and documenting the development of knowledge in this research area. Decision support pioneers include many academic researchers from programs at MIT, University of Arizona, University of Hawaii, University of Minnesota and Purdue University. The DSS pioneers created particular and distinct streams of technology development and research that serve as the foundation for much of today's work in DSS.

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Appendix I. DSS Timeline

Year Major Milestones

1945 Bush proposed Memex
1947 Simon book titled Administrative Behavior
1952 Dantzig joined RAND and continued research on linear programming
1955 Semiautomatic Ground Environment (SAGE) project at M.I.T. Lincoln Lab uses first light pen; SAGE completed 1962, first data-driven DSS
1956 Forrester started System Dynamics Group at the M.I.T. Sloan School
1960 Simon book The New Science of Management Decision; Licklider article on "Man-Computer Symbiosis"
1962 Licklider architect of Project MAC program at M.I.T.; Iverson's book A Programming Language (APL); Engelbart's paper "Augmenting Human Intellect: A Conceptual Framework"
1963 Englebart established Augmentation Research Center at SRI
1965 Stanford team led by Feigenbaum created DENDRAL expert system; Problem Statement Language/Problem Statement Analyzer (PSL/PSA) developed at Case Institute of Technology
1966 UNIVAC 494 introduced; Tymshare founded and Raymond article on computer time-sharing for business planning and budgeting
1967 Scott Morton's dissertation completed on impact of computer-driven visual display devices on management decision-making process; Turban reports national survey on use of mathematical models in plant maintenance decision making
1968 Scott Morton and McCosh article; Scott Morton and Stephens article; Englebart demonstrated hypermedia—groupware system NLS (oNLine System) at Fall Joint Computer Conference in San Francisco
1969 Ferguson and Jones article on lab study of a production scheduling computer-aided decision system running on an IBM 7094; Little and Lodish MEDIAC, media planning model; Urban new product model-based system called SPRINTER
1970 Little article on decision calculus support system; Joyner and Tunstall article on Conference Coordinator computer software; IRI Express, a multidimensional analytic tool for time-sharing systems, becomes available; Turoff conferencing system
1971 Gorry and Scott Morton SMR article first published use of term Decision Support System; Scott Morton book Management Decision Systems; Gerrity article Man-Machine decision systems; Klein and Tixier article on SCARABEE
1973 PLATO Notes, written at the Computer-based Education Research Laboratory (CERL) at the University of Illinois by David R. Woolley
1974 Davis's book Management Information Systems; Meador and Ness article DSS application to corporate planning
1975 Alter completed M.I.T. Ph.D. dissertation "A Study of Computer Aided Decision Making in Organizations"; Keen SMR article on evaluating computer-based decision aids; Boulden book on computer-assisted planning systems
1976 Sprague and Watson article "A Decision Support System for Banks"; Grace paper on Geodata Analysis and Display System
1977 Alter article "A Taxonomy of Decision Support Systems", Klein article on Finsim; Carlson and Scott Morton chair ACM SIGBDP Conference DSS Conference
1978 Development began on Management Information and Decision Support (MIDS) at Lockheed-Georgia; Keen and Scott Morton book; McCosh and Scott Morton book; Holsapple dissertation completed; Wagner founded Execucom to market IFPS; Bricklin and Frankston created Visicalc (Visible Calculator) microcomputer spreadsheet; Carlson from IBM, San Jose plenary speaker at HICSS-11; Swanson and Culnan article document-based systems for management planning

1979 Rockart HBR article on CEO data needs
1980 Sprague MISQ article on a DSS Framework; Alter book; Hackathorn founded MicroDecisionware
1981 First International Conference on DSS, Atlanta, Georgia; Bonczek, Holsapple, and Whinston book; Gray paper on SMU decision rooms and GDSS
1982 Computer named the "Man" of the Year by Time Magazine; Rockart and Treacy article "The CEO Goes On-Line" HBR; Sprague and Carlson book; Metaphor Computer Systems founded by Kimball and others from Xerox PARC; ESRI launched its first commercial GIS software called ARC/INFO; IFIP Working Group 8.3 on Decision Support Systems established
1983 Inmon Computerworld article on relational DBMS; IBM DB2 Decision Support database released; Student Guide to IFPS by Gray; Huntington established Exsys; Expert Choice software released
1984 PLEXSYS, Mindsight and SAMM GDSS; first Teradata computer with relational database management system shipped to customers Wells Fargo and AT&T; MYCIN expert system shell explained
1985 Procter & Gamble use first data mart from Metaphor to analyze data from checkout-counter scanners; Whinston founded Decision Support Systems journal; Kersten developed NEGO
1987 Houdeshel and Watson article on MIDS; DeSanctis and Gallupe article on GDSS; Frontline Systems founded by Fylstra, marketed solver add-in for Excel
1988 Turban DSS textbook; Pilot Software EIS for Balanced Scorecard deployed at Analog Devices
1989 Gartner analyst Dresner coins term business intelligence; release of Lotus Notes; International Society for Decision Support Systems (ISDSS) founded by Holsapple and Whinston
1990 Inmon book Using Oracle to Build Decision Support Systems; Eom and Lee co-citation analysis of DSS research 1971–1988
1991 Inmon books Building the Data Warehouse and Database Machines and Decision Support Systems; Berners-Lee's World Wide Web server and browser, become publicly available
1993 Codd et al. paper defines online analytical processing (OLAP)
1994 HTML 2.0 with form tags and tables; Pendse's OLAP Report project began
1995 The Data Warehousing Institute (TDWI) established; DSS journal issue on Next Generation of Decision Support; Crossland, Wynne, and Perkins article on Spatial DSS; ISWorld DSS Research pages and DSS Research Resources
1996 InterNeg negotiation software renamed Inspire; OLAPReport.com established;
1997 Wal-Mart and Teradata created then world's largest production data warehouse at 24 Terabytes (TB)
1998 ACM First International Workshop on Data Warehousing and OLAP
1999 DSSResources.com domain name registered
2000 First AIS Americas Conference mini-track on Decision Support Systems
2001 Association for Information Systems (AIS) Special Interest Group on Decision Support, Knowledge and Data Management Systems (SIG DSS) founded
2003 International Society for Decision Support Systems (ISDSS) merged with AIS SIG DSS

Author Profile

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