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Decision Support Systems Research: Reference Disciplines and a Cumulative Tradition*

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This study applies factor analysis of an author cocitation frequency matrix derived from a database file consisting of a total of 15,030 *cited* reference records taken from 692 *citing* articles. Seven informal clusters of decision support systems (DSS) research subspecialties and reference disciplines were uncovered. Four of them represent DSS research subspecialties—foundations, group DSS, model/data management, and individual differences. Three other conceptual groupings define the reference disciplines of DSS—organizational science, multiple criteria decision making, and artificial intelligence. DSS is a very young academic field and is still growing. DSS has just entered the era of growth after 20 years of research. During the 1990s, DSS research will be further grounded in a diverse set of reference disciplines. Furthermore, DSS is in the active process of solidifying its domain and demarcating its reference disciplines. A DSS theory is imminent in the very near future in some area of DSS research such as model management.

Key words—decision support systems, reference disciplines, bibliometrics, bibliography, cocitation analysis

INTRODUCTION

SINCE THE TERM "decision support systems" (DSS) was coined in the early 1970s, there has been a growing amount of research in the area of DSS [9, 10, 14, 25]. As Keen [16] indicated in the early 1980s, it is necessary for information systems research to clarify reference disciplines and to build a cumulative tradition to become a coherent and substantive field. This is necessary for DSS research as well. In the DSS area, Eom *et al.* [11] conducted an initial study to identify two areas of contributing disciplines (management science and multiple criteria decision making) and five subspecialties of DSS research (foundations, group DSS, database management systems, multiple-criteria DSS, marketing DSS, and routing DSS). Due to the restrictive nature of their data set (specific DSS applications only), their study failed to provide a comprehensive picture of DSS research subspecialties.

This study attempts to overcome the weakness of the study of Eom *et al.* [11] by expanding the number of citing articles from 259 application articles to 692 articles, thereby fostering a better understanding of how DSS has evolved to its present state. Using factor analysis of author cocitation matrix, the study attempts to identify the intellectual structure, reference disciplines, and major themes in current DSS research and provide important groundwork for future theoretical development and scientific inquiry in the DSS area.

*Note: to handle a large number of reference articles, we avoided any duplication of the articles cited in Appendix B and the References. Thus, Appendix B and References do not share the same articles. However, when necessary, articles in Appendix B are referenced as if they had appeared in the reference section.

DESCRIPTION OF THE STUDY

This study is based on the assumptions that "cocitation is a measure of the perceived similarity, conceptual linkage, or cognitive relationship between two cocited items (documents or authors)" and "cocitation studies of specialties and fields yield valid representations of intellectual structure" [19, p. 111]. For an indepth overview and the discussion of the continuing relevance of this topic, see [26].

Data

The primary data for this study were gathered from a total of 692 articles in the DSS area over the 20 year period 1971–1990. Of these 692 articles, 472 were collected from the following sources: 210 articles from [9]; 157 articles from [23]; 203 articles from [10]. Some articles appeared in more than one source. A database file was created consisting of a total of 15,030 *cited* reference records taken from the 692 *citing* articles appearing in the following 15 journals which represent 83% of the source articles: *Communications of the ACM*, *Data Base*, *Decision Sciences*, *Decision Support Systems*, *European Journal of Operational Research*, *IEEE Transactions on Systems, Man, and Cybernetics*, *Information & Management*, *Interfaces*, *Journal of MIS*, *Journal of Systems Management*, *Management Science*, *MIS Quarterly*, *Omega*, *Operations Research*, and *Sloan Management Review*. The remaining 17% of source articles were from 66 other journals.

Research methodology

The raw cocitation matrix of 67 authors was analyzed by the factor analysis program of SAS (statistical analysis systems) [22]. The cocitation rate of over 25 with himself/herself were applied to select the final author set. This step was necessary because instability of small cocitation counts tends to make interpretation of factors more difficult (see [20, p. 435]). Each cell value in the cocitation matrix in Appendix A refers to the cocitation counts of paired authors. The principle component analysis with the latent root criterion (eigenvalue 1 criterion) and Scree test was applied to obtain seven meaningful factors as a terminal solution. The seven extracted factors accounted for 82.16% of the total variance of the data set.

[1]According to McCain [20, p. 440], "Only authors with loadings greater than ± 0.7 are likely to be useful in interpreting the factor, and only loadings above ± 0.4 or ± 0.5 are likely to be reported". Therefore, care must be exercised when interpreting statistical output of citation analysis.

RESULTS

Factor analysis extracted seven factors consisting of four major areas of DSS research and three reference disciplines. Table 1 presents each factor and all authors in each factor with factor loading at 0.40 or higher.[1]

Reference disciplines

This study identified only weak influence of organizational sciences, artificial intelligence, and multiple criteria decision making on the development of DSS research subspecialties.

Factor 5 appears to represent *Organizational Sciences*. DSS are designed and implemented to support organizational as well as individual decision making. Without a detailed understanding of decision making behavior in organizations, "decision support is close to meaningless as a concept" [43, p. 61]. Organizational scientists have classified organizational decision making in terms of several schools of thought: (1) the rational model focusing on the selection of the most efficient alternatives, with the assumption of a rational, completely informed, single decision maker; (2) the organizational process model of Cyert and March [116] stressing the compartmentalization of the various units in any organization; (3) the satisfying model of Simon and his colleagues [60, 120] to find an acceptable, good enough solution, reflecting 'bounded rationality'; (4) and other models.

Factor 6 seems to represent *multiple criteria decision making (MCDM)*. MCDM deals with semistructured and unstructured decisions involving multiple attributes, multiple objectives, or both. A critical contribution of MCDM to the development of DSS lies in the definitions of semistructured/unstructured definitions. According to Bennett [35], a task is unstructured when its objectives are ambiguous and nonoperational, or its objectives are relatively operational but numerous and conflicting. Effective decision making necessitates consideration of the multiple criteria influencing the decision [35]. As reported by Dyer *et al.* [8], numerous individuals have contributed to give rise to the field of MCDM. Among them, Keeney and

Table 1. Author factor loading at 0.40 or higher (rotation method: varimax; number of factor = 7)

Factor 1 Foundations		Factor 2 Group DSS		Factor 3 Model/data management		Factor 4 Individual differences		Factor 5 Organizational sciences		Factor 6 MCDM/MCDSS		Factor 7 Artificial intelligence	
Alter	(0.87)	Gallupe	(0.94)	Elam	(0.91)	Dexter	(0.93)	March	(0.81)	Keeney	(0.90)	Shortliffe	(0.53)
Scott-Morton	(0.87)	Hiltz	(0.93)	Dolk	(0.91)	Lusk	(0.92)	Ackoff	(0.64)	Raiffa	(0.86)	Davis R	(0.46)
Keen	(0.87)	Turoff	(0.93)	Blanning	(0.90)	Benbasat	(0.90)	Tversky	(0.63)	Jelassi	(0.56)		
Carlson	(0.81)	Gray	(0.93)	Bonczek	(0.84)	Ives	(0.84)	Newell	(0.62)	Geoffrion	(0.44)		
Sprague	(0.80)	Kraemer	(0.92)	Holsapple	(0.83)	Dickson	(0.83)	Mintzberg	(0.62)	Jarke	(0.43)		
Ginzberg	(0.79)	King JL	(0.91)	Whinston	(0.83)	Lucas	(0.82)	Mitroff	(0.54)				
Wagner	(0.78)	Bui	(0.91)	Henderson	(0.80)	Chervany	(0.78)	Simon	(0.52)				
Little	(0.77)	Applegate	(0.85)	Geoffrion	(0.77)	Zmud	(0.77)	Mason	(0.50)				
Gorry	(0.77)	DeSanctis	(0.83)	Konsynski	(0.75)	Jarvenpaa	(0.70)						
Anthony	(0.75)	Nunamaker	(0.80)	Stohr	(0.71)	Robey	(0.62)						
King W	(0.74)	Huber	(0.77)	Davis R	(0.59)	Mason	(0.51)						
Bennett	(0.73)	George	(0.77)	Shortliffe	(0.51)	Mitroff	(0.51)						
Rockart	(0.72)	Delbecq	(0.74)	Naylor	(0.48)	DeSanctis	(0.48)						
Watson H	(0.72)	Van De Ven	(0.74)	Sprague	(0.44)	King W	(0.40)						
Meador	(0.70)	Jarke	(0.70)	Watson H	(0.43)	Courtney	(0.40)						
Davis G	(0.70)	Konsynski	(0.59)	Courtney	(0.42)								
Simon	(0.65)	Jarvenpaa	(0.54)	Carlson	(0.41)								
Naylor	(0.65)	Jelassi	(0.50)	Jarke	(0.41)								
Robey	(0.55)	Dickson	(0.44)										
Courtney	(0.54)												
Sanders	(0.52)												
Ackoff	(0.47)												
Zmud	(0.46)												
Stohr	(0.44)												
Mintzberg	(0.43)												
Chervany	(0.41)												
Lucas	(0.40)												
Eigenvalue	23.57		12.74		8.98		3.55		2.55		2.18		1.48
% Variance	35.18		19.01		13.40		5.30		3.80		3.25		2.22

Raiffa [124] have provided us with an excellent and complete overview of multiple attribute utility theory, along with numerous examples of practical applications.

Factor 7 represents *Artificial Intelligence* (AI). The impact of artificial intelligence on DSS is primarily in the formation of a new hybrid system of knowledge-based DSS, the development of expert systems, and the development of model and data management systems. In the area of AI application to model management, Elam *et al.* [91] introduced the concept of knowledge-based model management systems (MMS) to support a variety of complex decision problems with the use of semantic nets. They contended that the knowledge-based MMS could facilitate the use of analytical tools in structuring as well as analyzing a decision problem. Over the past few years, AI techniques have been increasingly integrated into DSS research to form a new hybrid system of knowledge-based DSS [13].

DSS research subspecialties

Four of the informal clusters of DSS related authors uncovered represent DSS research subspecialties—foundations, group DSS, model/data management, and individual differences.

Foundations. Most authors in this factor conducted descriptive research to provide justification for a need to develop decision support systems, their definitions, and their concepts in the very early stage of DSS development. Ackoff [30] clearly pinpointed a need for another type of information systems to relieve managers suffering from an "over abundance of irrelevant information". Gorry and Scott-Morton [41] further supported Ackoff's viewpoint and claimed that "Information systems should exist only to support decisions". Anthony [34] classified all managerial activities into three categories: strategic planning, management control, and operational control. This taxonomy combined with that of Simon [59], which classified all decisions into structured, semistructured, and unstructured, provided a simple schema for classifying organizational decisions to be best supported by TPS, MIS, and DSS.

Little [50] suggested a concept of *decision calculus* as "a model-based set of procedures for processing data and judgements to assist a manager in his decision making". Although he did not use the term DSS, he proposed the concept of a decision calculus which has several desirable characteristics of DSS (*simple*, *robust*, *easy to control*, *adaptive*, *complete on important issues*, *easy to communicate with*). Keen and Scott-Morton [43] extended these previous works and suggested a widely accepted definition of DSS which implies "the use of computers to: assist managers in their decision processes in semistructured tasks; support, rather than replace managerial judgement; and improve the effectiveness of decision making rather than its efficiency". Sprague and Calson [61] added several important further research area data, model, dialogue, and decision makers, which can be termed a DSS architecture. In addition, Sprague [62] suggested an important and widely accepted definition and concept termed specific decision support systems.

Keen and Scott-Morton [43] suggested three important areas of DSS research from an organizational perspective: design, implementation, and evaluation of DSS. Several of these authors began to conduct empirical studies to build DSS theories in the process of designing, implementing, and evaluating DSS. Among them, Ginzberg's earlier work [15], based on an empirical test of the level-of-adoption hypothesis, suggested that if full benefit is to be realized, DSS must be used as a catalyst for changes in the definition of the manager's role and should be viewed in the broader context of organizational change. Ginzberg also maintained that the design of DSS is likely to be more successful if it incorporates (1) user participation, (2) normative system modeling, and (3) evolutionary or iterative design. Through the analysis of 56 implemented specific DSS, Alter [31–33] classified all DSS into seven distinct types and added several folders into the implementation drawers: patterns, risk factors, and strategies of DSS implementations. King [49] suggested an evaluation process model for evaluating MIS and DSS, which measures attitude, value perception, information usage, and decision performance in every stage of system development life cycle in a simulated environment. Sanders and Courtney [57] reported the results of a field study of organizational factors to ascertain the influence of success factors (the decision context, task interdependence, and task constraints) of DSS implementations.

GDSS. Since the mid-1980s we have witnessed an emerging DSS research theme: group decision support systems. Earlier works by Delbecq *et al.* [68] experimentally compared three alternative methods for group decision making: the conventional interacting (discussion) group, the nominal group technique, and the Delphi technique. Many of these techniques (silent and independent idea generation, presenting each idea in a round-robin procedure, silent independent voting, etc.) were successfully utilized in the development of GDSS in the 1980s.

In the early stages of GDSS development, several descriptive research papers have been cornerstones for subsequent GDSS empirical research. Huber [78] provided a comprehensive definition and proposed an architecture of GDSS. Another landmark paper is the result of the work of DeSanctis and Gallupe [69]; it presents an overview of GDSS, the potential impact of GDSS on group processes and outcomes, and proposes a multidimensional taxonomy of GDSS. Kraemer and King [80] present a comprehensive assessment of GDSS development and use in the US by reviewing the current status of GDSS activities. They conceive GDSS as a sociotechnical 'package' of (1) hardware, (2) software, (3) organizationware and (4) people. They classified GDSS into the following 6 types: the electronic boardroom, teleconferencing facilities, the information center, the decision conference, the collaboration laboratory, and the group network.

During the second half of the 1980s, a group of researchers began to conduct empirical GDSS research. There are four comprehensive reviews of major GDSS research [2, 6, 21, 71]. Turoff and Hiltz [82] conducted two experiments to study the impact of computer-based conferencing systems on group decision making and concluded that GDSS helped the computer-aided groups reach quality decisions more often than groups unaided by a GDSS. Jarke, Jelassi, and Bui seem to define an important field of GDSS—multiple criteria decision making (MCDM)-model embedded group decision support systems [66].

Model/data management. Model/data management systems have emerged as the third major research area in the DSS field. Since 1975, model/data management has been researched to encompass several central topics such as model base structure and representation, model base processing, and application of artificial intelligence to model integration, construction, and interpretation [3]. In the model structure and representation area, the structured modelling approach by Geoffrion [92] has advanced the model representation area of model management, which is an extension of the entity–relationship data model and a necessary step for advancing to the next stage of model management (model manipulation). Dolk and Konsynski [90] developed the model abstraction structure for representing models as a feasible basis for developing model management systems.

In the model processing area, Blanning [84] investigated important issues in the design of relational model bases and presented a framework for the development of a relational algebra for the specification of join implementation in model bases. In the area of AI application to model management, Bonczek *et al.* [85–88] suggested the use of AI techniques in determining how models and data should be integrated in response to a user query. Elam *et al.* [91] introduced the concept of knowledge-based model management systems (MMS) to support a variety of complex decision problems with the use of semantic nets. They contended that the knowledge-based MMS could facilitate the use of the analytical tools in structuring, as well as analyzing, a decision problem.

Individual differences. The initial investigation of this topic was begun by the earlier works of Mason and Mitroff [112, p. 478], who hypothesized that "What is the information for one type will definitely not be information for another. Thus, as designers of MIS, our job is not to get (or force) all types to conform to one, but to give each type the kind of information he is psychologically attuned to and will use most effectively". Bariff and Lusk [96] presented a model for useful classification of behavioral variables for attaining successful MIS design. The Bariff and Lusk model proposed that the successful design and implementation of an MIS should explicitly involve consideration of the system's user cognitive styles. Benbasat and Dexter [99, 100] conducted a series of similar experiments to conclude that "an appropriate information system design can help overcome a mismatch between task environment and psychological type" [100, p. 8]. Despite those positive claims emphasizing the user's cognitive style as an important consideration in the design of management information systems and DSS, Huber [106, p. 567] concluded that (1) "the currently available literature on cognitive styles is an unsatisfactory basis for deriving operational guidelines for MIS and DSS designs", and (2) "further cognitive style research is unlikely to lead to operational guidelines for MIS and DSS designs".

Other subgroups of researchers in this factor have focused on the evaluation of graphical and color enhanced information presentation and other presentation formats (e.g. tabular). Chervany and Dickson [102] and Dickson *et al.* [104] compared the decision impacts of detailed reports with summarized reports; Lusk and Kersnick [109], Lucas and Nielson [110], and Lucas [111] compared tabular with graphics; and DeSanctis [103] comprehensively investigated previous research in this area up to 1984. Despite the numerous previous research reports, results are confusing and inconclusive [101, 103, 107]. Jarvenpaa *et al.* [108] argued that numerous equivocal findings could be attributable to the various tasks used in these experiment and the match between the task and presentation method as well as the lack of a sound taxonomy for classifying data extraction tasks. They recommend the development of some type of taxonomy of tasks as a basis of interpreting the impact of the graphical presentation format.

CONCLUSION AND IMPLICATIONS FOR FUTURE DSS RESEARCH

In 1980, a founding father of DSS stated that "At present, MIS research is a theme rather than a substantive field" [16, p. 9]. He further suggested the following three main needs of information systems research to be a coherent and substantive field.

(1) Clarification of reference disciplines.
(2) Defining the dependent variables.
(3) Building a cumulative tradition.

This study documented the intellectual development of the DSS area over the last two decades (1970–1990) and identified a group of influential and responsible DSS researchers, representing the major forces that have shaped the intellectual structure of DSS research. This research provides a piece of evidence to assess the current state of DSS development as an academic discipline in terms of two of the three main needs defined by Keen [16]—reference disciplines and a cumulative disciplines. These two are discussed following brief remarks on the third.

Dependent variables

The definition of the dependent variables has been recently examined by DeLone and McLean [5], based on the review of 180 empirical studies that have attempted to measure some aspects of 'MIS success'. Their study presents a more integrated view of the concept of information systems (I/S) success. A more comprehensive model of information systems success is formulated. The main thrust of their conclusion is as follows [5, p. 88].

> As an examination of the literature on I/S success makes clear, there is not one success measure but many. However, on more careful examination, these many measures fall into six major categories—SYSTEM QUALITY, INFORMATION QUALITY, USE, USER SATISFACTION, INDIVIDUAL IMPACT, and ORGANIZATIONAL IMPACT. Moreover, these categories or components are interrelated and interdependent, forming an I/S success model, as well as the components themselves, a clear picture emerges as to what constitutes information systems success.

Reference disciplines

There have been a number of assumed reference disciplines in the DSS/information systems areas such as cognitive science/psychology, computer science, macro economics, management accounting, management science, information economics, organizational science, political science, etc. Nevertheless, this study identified only the weak influence of multiple criteria decision making, organizational sciences, and artificial intelligence on the development of DSS research subspecialties.

What are the implications of this finding concerning the progress of DSS as a substantive academic field? Recently, the editor of a prestigious information systems journal stated [17, p. 293]:

> . . . information systems probably is not a field, but rather an intellectual convocation that arose from the confluences of interests among individuals from many fields who continue to pledge allegiance to those fields through use ties of various kinds. The strongest support for this conjecture is the consistent appearance of the term 'reference disciplines' in IS discourse.

This study presents an archival view of DSS development over the last two decades

(1970–1990). In other words, the snapshot of the DSS picture does not reveal the dynamic dimensions of the intellectual evolution of the DSS fields—stagnant, growing, or dying. The interpretation of the result of this research largely depends on the specific point in time in the whole life cycle of the DSS research at which the research has been conducted. DSS is a very young academic field and is still growing. The author's own conjecture is that DSS has just entered the era of growth after 20 years of research. During the 1990s, DSS research will be further grounded in a diverse set of reference disciplines. Nonetheless, this result can also be interpreted as an important signal to all DSS researchers to search for more thoroughly grounded DSS theories. Benbasat *et al.* [2] have pointed out the need for underlying theories to provide a better and fuller understanding of relationships among many variables, based on the qualitative reviews of the empirical research in management support systems.

Cumulative DSS research tradition

In 1980, Keen [16] stated that MIS research lacked a cumulative tradition.[2] In this view, there was virtually no cumulative research tradition in the MIS area without "continued follow-up on interesting lines of inquiry". In addition to a number of studies that have been conducted to assess the extent of progress towards building a cumulative research tradition in the DSS area such as identification of leading institutions, faculty, and journals for DSS research [12], this study provided further convincing evidence to show that DSS researchers have built on each other's and their own previous work, and definitions and topics have been shared in the areas of foundations, group DSS, and model management, and individual differences.

During the 1990s, we will see the emergence of a rich set of DSS subspecialties including design, implementation, and evaluation of DSS. Over the last two decades (1970–1990), DSS research has mainly concentrated on each component (data/model/dialogue/decision maker) of specific DSS. They are basic building blocks of DSS research. As the DSS area enters the era of growth during the 1990s, the author conjectures that DSS research will redirect its attention to these underdeveloped areas of DSS research to provide useful guiding principles for practitioners in the integrated process of design, implementation, and evaluation.

After 20 years of research, the DSS literature does not exhibit an overall DSS research paradigms as defined by Kuhn [18]. Nonetheless, this study convinces the author that DSS is in the active process of solidifying its domain and demarcating its reference disciplines. A DSS theory is imminent in the very near future in some area of DSS research such as model management [1, 7]. Dolk and Kottemann [7, p. 51] believe that the emergence of a theory of model is imminent and the current model integration research is projected as "the springboard for building a theory of models equivalent in power to relational theory in the database community". Comprehensive literature reviews on model management can be found in [3, 4].

This research has provided hard evidence that most empirical DSS research areas (e.g. GDSS and individual differences) have produced an accumulation of conflicting results due to methodological problems [108], lack of a commonly accepted causal model, different measures of dependent variables, hardware and software designed under different philosophies, and different tasks [71]. Future empirical DSS research needs to integrate the seemingly conflicting results of numerous empirical experiments in the area of group DSS, individual differences [24], DSS implementation, etc.

As Farhoomand [14, p. 55] notes, "It is only through well-grounded theories that the discipline will be able to shape the goals and boundaries of its domain structurally, not cosmetically".

This paper establishes a benchmark to be used in future research, which is necessary to account for the ongoing changes in the intellectual development and structure of DSS research before solid conclusions can be reached about the maturity of the field.

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[2]Keen [16, p. 13] defined a cumulative research tradition as one where:

(1) Researchers build on each other's and their own previous work;
(2) Definitions, topics and concepts are shared;
(3) Senior researchers view their main role as shaping the field;
(4) Each journal in the field has a clear focus;
(5) There is some definition of orthodoxy, while unorthodoxy is not discouraged.

APPENDIX A

Raw Cocitation Matrix

Author	No.																														
Akoff	1	56																													
Alter	2	10	109																												
Anthony	3	9	15	40																											
Applegate	4	8	3	1	39																										
Benbasat	5	12	16	5	8	71																									
Bennett	6	3	21	9	2	7	45																								
Blanning	7	6	16	2	6	8	6	47																							
Bonczek	8	10	25	9	11	13	19	36	93																						
Bui	9	5	2	2	19	8	3	4	8	35																					
Carlson	10	16	66	18	6	23	31	30	53	9	163																				
Chervany	11	10	13	2	0	26	3	5	7	1	15	41																			
Courtney	12	8	17	5	6	12	2	12	14	8	22	10	42																		
Davis GB	13	8	15	10	2	9	7	3	8	6	18	13	9	45																	
Davis R	14	2	6	4	3	4	4	5	15	4	13	0	5	3	27																
Delbecq	15	8	4	1	8	4	1	1	4	9	7	3	4	6	2	25															
DeSanctis	16	9	8	3	28	33	7	8	18	29	18	9	18	9	8	13	82														
Dexter A	17	1	9	1	1	37	5	5	6	1	12	16	7	3	1	1	23	37													
Dickson	18	16	15	3	16	43	5	6	13	17	17	34	15	15	2	10	43	26	84												
Dolk	19	6	7	1	9	4	3	21	23	4	13	2	8	0	4	1	8	1	3	30											
Elam	20	7	17	1	13	11	6	27	35	6	23	5	12	3	6	2	15	6	10	23	54										
Gallupe	21	6	3	2	28	12	4	4	10	29	10	2	9	3	6	13	50	4	23	5	9	51									
Geoffrion	22	2	3	2	4	3	0	11	13	2	13	0	1	1	1	0	4	0	2	10	12	1	40								
George	23	6	7	1	14	8	0	3	3	10	3	2	9	3	3	4	22	3	12	4	8	17	0	27							
Ginzberg	24	7	34	7	2	13	9	6	15	4	32	10	14	12	4	3	8	8	13	4	9	3	2	3	58						
Gorry	25	13	30	17	2	13	11	5	11	2	34	9	8	13	4	3	7	5	9	3	3	3	1	2	15	67					
Gray	26	4	2	0	17	4	2	2	6	19	6	0	2	1	1	11	24	1	14	3	5	24	2	6	1	2	30				
Henderson	27	10	22	3	13	16	8	26	34	6	33	8	16	8	6	7	16	9	13	22	42	8	11	6	14	8	6	67			
Hiltz	28	6	3	0	20	8	2	3	7	21	6	1	6	4	3	14	28	2	20	4	5	28	0	12	2	1	19	7	37		
Holsapple	29	11	25	9	11	13	17	35	84	8	49	7	14	8	15	4	16	6	13	22	33	9	12	3	14	12	6	33	6	87	
Huber	30	13	23	7	26	22	8	9	23	28	34	11	19	11	8	18	49	12	35	9	18	42	3	17	21	12	26	22	30	23	93
Ives	31	4	4	3	4	15	1	1	3	2	5	9	6	8	2	4	17	12	18	1	1	4	1	3	6	5	2	2	3	3	8
Jarke	32	3	3	3	13	5	4	11	18	26	17	1	6	4	5	8	23	1	12	9	12	23	7	2	4	2	15	11	16	16	232
Jarvenpaa	33	2	3	0	8	17	1	2	2	9	4	6	7	3	1	3	26	14	26	0	5	12	1	10	3	2	6	3	10	2	16
Jelassi	34	1	0	3	6	2	2	4	9	15	11	1	4	2	3	3	12	1	4	3	4	12	3	2	4	0	5	6	7	10	121
Keen	35	33	92	26	10	44	34	23	46	15	112	30	30	32	13	11	33	23	45	9	31	14	10	11	53	46	10	45	11	46	47
Keeney	36	1	1	1	1	2	1	3	5	3	9	1	1	0	3	3	4	1	3	3	3	3	10	0	2	1	2	4	3	5	6
King JL	37	6	3	0	16	5	0	2	3	16	4	0	3	2		10	19	1	11	2	3	19	1	8	2	2	16	2	16	3	173
King W	38	8	25	6	2	13	6	5	8	1	20	13	8	11	0	5	9	8	14	3	7	7	2	2	17	13	2	10	2	8	14
Konsynski	39	13	16	0	36	12	7	27	34	19	24	4	15	5	9	9	33	3	19	29	37	28	12	19	8	4	16	37	21	32	35
Kraemer	40	5	4	0	17	6	0	2	4	17	6	1	3	2	2	10	20	1	13	3	3	20	1	8	3	1	18	5	16	4	19
Little	41	7	22	7	2	4	10	6	8	1	25	2	2	4	5	0	3	1	1	4	5	3	2	1	10	17	2	3	1	9	6
Lucas	42	7	14	5	0	28	2	4	11	0	18	19	9	12	2	3	18	19	29	1	5	1	1	1	14	11	2	7	2	11	16
Lusk	43	2	6	2	2	25	1	5	6	1	8	13	4	5	3	2	15	19	21	2	5	2	0	1	6	6	1	6	1	6	7
March	44	8	2	6	3	4	3	2	3	3	7	3	2	5	3	3	5	1	3	1	1	4	2	1	1	3	3	3	3	3	11
Mason R	45	19	15	7	9	24	1	6	8	5	22	16	9	13	4	5	16	11	23	9	7	7	0	7	13	16	5	16	5	8	20
Meador	46	6	22	6	4	4	11	6	12	2	26	4	11	5	5	2	7	2	4	4	15	3	3	4	11	8	0	18	2	12	10
Mintzberg	47	14	11	8	6	14	2	7	11	5	14	7	9	5	5	8	14	7	14	5	7	8	3	8	6	8	7	11	6	11	19
Mitroff	48	18	12	7	8	22	1	7	8	5	18	16	11	12	3	6	17	11	23	8	7	7	0	6	10	15	5	17	15	8	17
Naylor	49	3	12	2	1	4	1	9	13	1	14	2	3	4	3	0	1	2	3	3	6	1	1	0	5	6	1	5	1	13	6
Newell	50	11	10	4	3	12	4	7	12	2	11	8	8	8	3	2	8	9	9	4	9	2	1	4	2	7	1	11	2	10	9
Nunamaker	51	9	5	2	36	8	2	8	16	18	7	1	6	3	4	8	28	1	16	12	17	28	5	19	2	3	16	16	19	12	54
Raiffa	52	7	3	2	2	3	1	5	8	4	10	2	4	1	4	3	11	2	4	5	5	5	10	3	2	1	2	6	2	8	9
Robey	53	2	9	4	0	14	2	2	5	0	15	11	8	7	2	2	7	11	11	0	1	2	0	0	10	8	1	6	2	5	12
Rockart	54	4	9	2	1	3	3	0	1	0	13	4	2	5	1	2	0	1	2	1	0	0	0	0	3	4	1	6	1	1	3
Sanders GL.	55	4	7	3	4	6	0	5	6	5	13	6	18	5	3	5	9	5	9	3	4	4	0	3	9	5	3	8	5	6	15
Scott-Morton	56	27	83	28	9	38	29	21	42	15	101	26	21	31	12	11	27	18	39	8	25	14	9	9	42	62	8	34	9	41	39
Shortliffe	57	3	4	2	2	3	4	3	13	1	8	2	3	3	15	0	4	1	4	3	5	2	0	2	5	6	1	5	1	13	4
Simon	58	26	38	24	11	31	18	18	33	8	54	20	21	24	11	9	28	16	34	12	22	12	7	7	17	39	6	26	5	33	37
Sprague	59	13	67	19	10	31	28	29	59	13	133	20	26	20	16	11	27	17	26	17	29	15	14	8	38	32	11	44	11	56	49
Stohr	60	4	13	4	4	6	10	16	29	10	27	4	9	7	7	3	13	3	7	12	18	9	8	2	16	3	3	20	3	27	15
Turoff	61	7	3	0	20	8	2	2	6	21	5	2	6	5	4	14	28	2	21	3	4	28	0	12	2	1	19	6	36	6	32
Tversky	62	5	3	0	3	6	1	4	5	2	9	2	2	2	2	1	10	4	4	6	4	4	3	3	2	2	2	4	3	4	8
Van de ven	63	8	4	1	8	5	1	1	4	9	7	3	4	6	2	25	14	2	11	1	2	13	0	4	4	4	11	7	14	4	19
Wagner	64	3	19	7	3	7	7	5	5	3	18	8	7	6	0	2	4	6	9	2	2	4	1	2	9	7	3	4	3	5	14
Watson H	65	6	28	8	3	11	10	11	21	3	37	8	10	8	7	2	7	6	9	7	13	2	6	4	15	6	3	19	3	20	18
Whinston	66	11	27	9	11	13	19	36	93	8	54	7	15	8	16	4	19	6	14	23	35	11	13	3	15	13	7	34	7	87	24
Zmud	67	10	17	4	3	26	3	4	8	4	20	16	13	8	2	6	17	19	25	3	6	4	0	2	15	12	2	15	5	8	20
Author number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

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4	0	1	0	20	0	2	10	3	2	2	11	8	4	11	4	9	12	0	5	0	1	29														
3	0	0	0	17	0	0	5	5	1	4	5	0	3	6	3	5	5	1	3	3	0	2	27													
3	4	2	3	21	2	3	4	7	3	0	7	4	3	9	9	4	9	2	6	4	3	7	2	25												
14	17	11	12	174	9	10	34	23	9	33	27	15	10	37	29	22	33	15	17	11	9	15	16	14	206											
2	2	1	1	13	2	1	4	4	1	5	2	1	2	5	3	4	2	4	4	2	3	0	0	1	12	27										
13	13	11	8	82	5	5	17	28	5	18	22	13	22	24	21	29	27	4	39	14	12	12	10	13	82	9	143									
8	20	7	12	126	7	7	26	35	10	20	20	10	10	25	28	25	22	14	11	13	9	21	14	15	105	10	58	182								
1	22	0	15	31	5	1	4	17	2	5	3	2	2	5	7	7	5	3	6	5	6	0	1	3	27	5	20	32	49							
3	15	10	7	13	4	16	2	20	16	1	2	1	4	6	3	7	6	1	1	19	4	2	1	5	10	2	6	11	2	40						
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31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67

APPENDIX B

Publications receiving 10 or more citations by co-citing factor (76 articles and 21 Books)

Factor 1: *Foundations* (24 *articles and* 9 *books*)

30. Ackoff Rl (1967) Management misinformation systems. *Mgmt Sci.* **14,** No. 12, B147–B156 (25 citations).
31. Alter SL (1980) *Decision Support Systems: Current Practice and Continuing Challenges.* Addison-Wesley, Reading, Mass. (62 citations).
32. Alter SL (1977) A taxonomy of decision support systems. *Sloan Mgmt Rev.* **19,** No. 1, 39–56 (27 citations).
33. Alter SL (1975) A study of computer aided decision making in organizations. Unpublished Ph.D. thesis, MIT (19 citations).
34. Anthony RN (1965) Planning and control systems—a framework for analysis. Division of Research, Graduate School of Business, Harvard University, Cambridge, Mass., pp. 13–43 (37 citations).
35. Bennett JL (1983) (Ed.) *Building Decision Support Systems.* Addison-Wesley, Reading, Mass. (24 citations).
36. Carlson ED and Sutton JA (1974) A case study of non-programmer interactive problem-solving. *IBM Research Report,* IBM Research Laboratory, San Jose, Calif. Res. Rep. RJ 1382 (11 citations).
37. Carlson ED (1979) An approach for designing decision support systems. *Data Base* **10,** No. 3, 3–15 (10 citations).
38. Davis GB and Olson MH (1985) *Management Information Systems: Conceptual Foundations, Structure, and Development,* 2nd edition. McGraw-Hill, New York (25 citations).
39. Ginzberg MJ (1978) Redesign of managerial tasks: a requisite for successful decision support systems. *MIS Q.* **1,** No. 2, 39–52 (11 citations).
40. Ginzberg MJ and Stohr EA (1982) Decision support system: issues and perspectives. In *Decision Support Systems: Proceedings of the NYU Symposium on Decision Support Systems* (Edited by Ginzberg MJ, Reitman W and Stohr EA), pp. 9–31. North-Holland, Amsterdam (12 citations).
41. Gorry GA and Scott-Morton MS (1971) A framework for management information systems. *Sloan Mgmt Rev.* **13,** No. 1, 55–70 (59 citations).
42. Hackathorn RD and Keen PGW (1981) Organizational strategies for personal computing in decision support systems. *MIS Q.* **5,** No. 3, 21–27 (13 citations).
43. Keen PGW and Scott-Morton MS (1978) *Decision Support Systems: An Organizational Perspective.* Addison-Wesley, Reading, Mass. (158 citations).
44. Keen PGW (1976) Interactive computer systems for manager: a modest proposal. *Sloan Mgmt Rev.* **18,** No. 1, 1–17 (15 citations).
45. Keen PGW and Wagner GR (1979) DSS: an executive mind support system. *Datamation* **25,** No. 11, 117–122 (15 citations).
46. Keen PGW (1980) Adaptive design for decisions support systems. *Data Base* **12,** No. 1–2, 15–25 (26 citations).
47. Keen PGW (1980) Decision support systems: translating analytic techniques into useful tools. *Sloan Mgmt Rev.* **21,** No. 3, 33–44 (15 citations).
48. Keen PGW (1981) Value analysis: justifying decision support systems. *MIS Q.* **5,** No. 1, 1–16 (34 citations).
49. King WR and Rodriguez JI (1978) Evaluating management information systems. *MIS Q.* **2,** No. 3, 43–51 (10 citations).
50. Little JDC (1970) Models and managers: the concepts of a decision calculus. *Mgmt Sci.* **16,** B466–B485 (28 citations).
51. Little JDC (1979) Decision support systems for marketing managers. *J. Mktg* **43,** No. 2, 9–26 (12 citations).
52. McKenney JL and Keen PGW (1974) How managers' minds work. *Harvard Business Rev.* **52,** No. 3, 79–90 (10 citations).
53. Meador CL and Ness DN (1974) Decision support system: an application to corporate planning. *Sloan Mgmt Rev.* **15,** No. 2, 51–68 (14 citations).
54. Meador CL, Guyote MJ and Keen PGW (1984) Setting priority for DSS development. *MIS Q.* **8,** 117–129 (12 citations).
56. Rockart JF (1979) Chief executives define their own data needs. *Harvard Business Rev.* **25,** 81–93 (12 citations).
57. Sanders GL and Courtney JF (1985) A field study of organizational factors influencing DSS success. *MIS Q.* **9,** No. 1, 77–93 (13 citations).
58. Scott-Morton MS (1971) *Management Decision Systems: Computer Based Support for Decision Making Division of Research.* Graduate School of Business Adminstration, Harvard University, Cambridge, Mass. (43 citations).
59. Simon HA (1960) *The New Science of Management Decision.* Harper & Row, New York (75 citations).
60. Simon HA (1969) *The Sciences of the Artificial.* MIT Press, Cambridge, Mass. (15 citations).
61. Sprague RH Jr and Carlson ED (1982) *Building Effective Decision Support Systems.* Prentice-Hall, Englewood Cliffs, N.J. (121 citations).
62. Sprague RH Jr (1980) A framework for the development of decision support systems. *MIS Q.* **4,** No. 4, 1–26 (67 citations).
63. Sprague RH Jr and Watson HJ (1975) MIS concepts: Part II. *J. Syst. Mgmt* **26,** No. 2, 35–40 (10 citations).
64. Wagner GR (1981) Decision support systems: the real substance. *Interfaces* **11,** No. 2, 77–86 (14 citations).

Factor 2: *Group DSS* (15 *articles and* 4 *books*)

65. Applegate LM (1986) Idea management in organization planning. Unpublished Ph.D. dissertation, University of Arizona (12 citations).
66. Bui T and Jarke MA (1984) DSS for cooperative multiple criteria group decision making. *Proceedings of the 5th International Conference on Information Systems,* Tucson, Ariz. pp. 101–113 (12 citations).
67. Bui TX and Jarke MA (1986) Communication requirements for group decision support systems. *J. Mgmt Inform. Syst.* **2,** No. 4, 8–20 (11 citations).
68. Delbecq AL, Van de Ven AH and Gustafson DH (1975) *Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes.* Scott, Foresman, Glenview, Ill. (15 citations).
69. DeSanctis G and Gallupe B (1987) A foundation for the study of group decision support systems. *Mgmt Sci.* **33,** 589–609 (35 citations).
70. DeSanctis G and Gallupe B (1985) Group decision support systems: a new frontier. *Data Base* **16,** No. 2, 3–10 (21 citations).
71. Dennis AR, George JF, Jessup LM, Nunamaker JF Jr and Vogel DR (1988) Information technology to support electronic meetings. *MIS Q.* **12,** 591–624 (13 citations).

72. Gallupe RB (1985) The impact of task difficulty on the use of a group decision support system. Ph.D. dissertation, University of Minnesota (14 citations).
73. Gallupe RB, DeSanctis GL and Dickson GW (1988) Computer-based support for group problem finding: an experimental investigation. *MIS Q.* **12,** 277–298 (13 citations).
74. Gray P, Aronofsky JS, Berry NW, Helmer O, Kane GR and Perkins TE (1981) The SMU decision room project. *Proceedings of the Second International Conference on Information Systems*, Cambridge, Mass. pp. 122–129 (17 citations).
75. Hiltz SR and Turoff M (1978) *The Network Nation: Human Communication via Computer.* Addison-Wesley, Reading, Mass. (11 citations).
76. Huber GP (1982) Group decision support systems as aids in the use of structured group management techniques. *DSS-82 Transactions: 2nd International Conference on DSS*, San Francisco, Calif. (Edited by Dickson G), pp. 96–108 (18 citations).
77. Huber GP (1984) The nature and design of postindustrial organizations. *Mgmt Sci.* **30,** 928–951 (12 citations).
78. Huber GP (1984) Issues in the design of group decision support systems. *MIS Q.* **8,** 195–204 (40 citations).
79. Konsynski BR, Kottemann JE, Nunamaker JF Jr and Stott JW (1984) PLEX-SYS-84: an integrated development environment for information systems. *J. Mgmt Inform. Syst.* **1,** No. 3, 64–104 (10 citations).
80. Kraemer KL and King JL (1988) Computer-based systems for cooperative work and group decision making. *Comput. Surv.* **20,** 115–146 (12 citations).
81. Nunamaker JF Jr, Applegate LM and Konsynski BR (1987) Facilitating group creativity: experience with a group decision support system. *J. Mgmt Inform. Syst.* **3,** No. 4, 5–19 (17 citations).
82. Turoff M and Hiltz SR (1982) Computer support for group versus individual decisions. *IEEE Trans. Commun.* **COM30,** No. 1, 82–92 (26 citations).
83. Watson R, DeSanctis G and Poole MS (1988) Using a GDSS to facilitate group consensus: some intended and unintended consequences. *MIS Q.* **12,** 463–478 (12 citations).

Factor 3: *Model/Data Management* (11 *articles and* 1 *book*)

84. Blanning RW (1982) A relational framework for model management in decision support systems. *DSS-82 Trans.* June, 16–28 (13 citations).
85. Bonczek RH, Holsapple CW and Whinston AB (1979) Computer-based support of organization decision making. *Decis. Sci.* **10,** 268–291 (18 citations).
86. Bonczek RH, Holsapple CW and Whinston AB (1980) The evolving roles of models in decision support systems. *Decis. Sci.* **11,** 337–356 (21 citations).
87. Bonczek RH, Holsapple CW and Whinston AB (1980) Future directions for developing decision support systems. *Decis. Sci.* **11,** 616–631 (17 citations).
88. Bonczek RH, Holsapple CW and Whinston AB (1981) *Foundations of Decision Support Systems.* Academic Press, New York (55 citations).
89. Bonczek RH, Holsapple CW and Whinston AB (1981) A generalized decision support system using predicate calculus and network data base management. *Opns Res.* **29,** 263–281 (13 citations).
90. Dolk DR and Konsynski BR (1984) Knowledge representation for model management systems. *IEEE Trans. Software Engng* **SE-10,** 619–628 (15 citations).
91. Elam JJ, Henderson JC and Miller LW (1980) Model management systems: an approach to decision support in complex organizations. *Proceedings of the First International Conference on Information Systems*, Philadelphia, Pa, pp. 98–110 (29 citations).
92. Geoffrion AM (1987) An introduction to structured modeling. *Mgmt Sci.* **33,** 547–589 (10 citations).
93. Konsynski B and Dolk D (1982) Knowledge abstractions in model management. *DSS-82 Trans.* June, 187–202 (16 citations).
94. Naylor TH and Horst S (1976) A survey of user of corporate planning models. *Mgmt Sci.* **22,** 927–937 (13 citations).
95. Stohr EA and Tanniru MR (1980) A database for operations research models. *Int. J. Policy Anal. Inform. Syst.* **4,** 105–121 (13 citations).

Factor 4: *Individual Differences* (19 *articles*)

96. Bariff ML and Lusk EJ (1977) Cognitive and personality tests for the design of management information systems. *Mgmt Sci.* **23,** 820–829 (12 citations).
97. Benbasat I and Schroeder R (1977) An experimental investigation of some MIS design variables. *MIS Q.* **1,** 37–50 (21 citations).
98. Benbasat I and Taylor RN (1978) The impact of cognitive styles on information systems design. *MIS Q.* **2,** 43–54 (12 citations).
99. Benbasat I and Dexter AS (1979) Value and events approaches to accounting: an experimental evaluation. *Account. Rev.* **54,** 735–749 (10 citations).
100. Benbasat I and Dexter AS (1982) Individual differences in the use of decision support aids. *J. Account. Res.* **20,** 1–11 (15 citations).
101. Benbasat I and Dexter AS (1985) An experimental evaluation of graphical and color-enhanced information presentation. *Mgmt Sci.* **31,** 1348–1364 (15 citations).
102. Chervany NI and Dickson GW (1974) An experimental evaluation of information overload in a production environment. *Mgmt Sci.* **20,** 1335–1344 (15 citations).
103. DeSanctis G (1984) Computer graphics as decision aids: directions for research. *Decis. Sci.* **15,** 463–487 (21 citations).
104. Dickson GW, Senn JA and Chervany NL (1977) Research in management information systems: the Minnesota experiments. *Mgmt Sci.* **23,** 913–923 (21 citations).
105. Dickson GW, DeSanctis G and Mcbride DJ (1986) Understanding the effectiveness of computer graphics for decision support: a cumulative experimental approach. *Commun. ACM* **29,** 40–47 (13 citations).
106. Huber GP (1983) Cognitive style as a basis for MIS and DSS design: much ado about nothing? *Mgmt Sci.* **29,** 567–579 (15 citations).
107. Ives B (1982) Graphical user interfaces for business information systems. *MIS Q.* **6,** 15–46 (12 citations).
108. Jarvenpaa SL, Dickson GW and DeSanctis G (1985) Methodological issues in experimental IS research: experiences and recommendations. *MIS Q.* **9,** 141–156 (15 citations).
109. Lusk EJ and Kersnick M (1979) The effect of cognitive style and report format on task performance: the MIS design consequences. *Mgmt Sci.* **25,** 787–798 (14 citations).
110. Lucas HC and Nielson NR (1980) The impact of the mode of information presentation on learning and performance. *Mgmt Sci.* **26,** 982–993 (20 citations).
111. Lucas HC (1981) An experimental investigation of the use of computer based graphics in decision making. *Mgmt Sci.* **27,** 757–768 (13 citations).

112. Mason RO and Mitroff II (1973) A program for research on management information systems. *Mgmt Sci.* **19,** 475–487 (37 citations).
113. McKenney JL and Keen PGW (1974) How managers' minds work. *Harvard Business Rev.* **52,** 79–90 (10 citations).
114. Zmud RW (1979) Individual differences and MIS success: a review of the empirical literature. *Mgmt Sci.* **25,** 966–979 (17 citations).

Factor 5: Organizational Sciences (2 articles and 5 books)

115. Ackoff RL (1967) Management misinformation systems. *Mgmt Sci.* **14,** B147–B156 (25 citations).
116. Cyert RM and March JG (1963) *A Behavioral Theory of the Firm.* Prentice-Hall, Englewood Cliffs, N. J. (18 citations).
117. Mintzberg H (1973) *The Nature of Managerial Work.* Harper & Row, New York (23 citations).
118. Mintzberg H, Raisinghani D and Theoret A (1976) The structure of "unstructured" decision processes. *Admin. Sci. Q.* **21,** 246–275 (27 citations).
119. March JG and Simon HA (1958) *Organizations.* Wiley, New York (14 citations).
120. Newell A. and Simon HA (1972) *Human Problem Solving.* Prentice-Hall, Englewood Cliffs, N.J. (26 citations).
121. Simon HA (1969) *The Sciences of the Artificial.* MIT Press, Cambridge, Mass. (15 citations).
122. Tversky A and Kahneman D (1974) Judgement under uncertainty: heuristics and biases. *Science* **185,** 1124–1131 (10 citations).

Factor 6: MCDM (2 articles and 1 book)

123. Geoffrion AM, Dyer JS and Feinberg A (1972) An interactive approach for multi-criteria optimization with an application to the operation of an academic department. *Mgmt Sci.* **19,** 357–368 (13 citations).
124. Keeney RL and Raiffa H (1976) *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* Wiley, New York (26 citations).
125. Jelassi MT, Jarke M and Stohr EA (1985) Designing a generalized multiple criteria decision support system. *J. Mgmt Inform. Syst.* **1,** No. 4, 24–43 (12 citations).

Factor 7: Artificial Intelligence (1 article and 1 book)

126. Shortliffe EH (1976) *Computer Based Medical Consultation: MYCIN.* American Elsevier, New York (11 citations).
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