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The Intellectual Development and Structure of Decision Support Systems (1991–1995)[1]

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This study extends an earlier benchmark study which examined the intellectual structure, major themes and reference disciplines of decision support systems (DSS) over the last two decades (1970–1990). Factor analysis of an author cocitation matrix over the period 1991 through 1995 extracted five major areas of DSS research (group DSS, model management, implementation, design and an unnamed factor) and three contributing disciplines (cognitive science, organizational science and multiple criteria decision making). The DSS area has undergone profound structural changes over the past five years (1991–1995) and made meaningful progress over the past two and a half decades. It is in the process of solidifying its domain and demarcating its reference disciplines. We have highlighted several notable trends and developments in the DSS research areas. © 1998 Elsevier Science Ltd. All rights reserved

Key words—decision support systems, intellectual structure, bibliometrics, cocitation analysis, factor analysis

1. INTRODUCTION

AN EARLIER STUDY of Eom [22] documented the intellectual development of the decision support systems (DSS) area over the last two decades (1970–1990) in terms of two of the three main needs defined by Keen [30], reference disciplines and a cumulative tradition. Eom [22, p. 517] concluded that "After 20 years of research, the DSS literature does not exhibit an overall DSS research paradigm as defined by Kuhn [31]. Nonetheless, this study convinces the author that DSS is in the active process of solidifying its domain and demarcating its reference disciplines". To extend the earlier benchmark study of Eom, we conducted a follow-up study to assess the ongoing changes in the intellectual development and structure of DSS research, using factor analysis of an author cocitation matrix over the period of 1991 through 1995. This study aims at identifying the intellectual structure, reference disciplines and major themes in DSS research over the past five years (1991–1995) with a particular emphasis on assessing the structural changes in the intellectual structures in the DSS area over the period of 1970 through 1990 and the period of 1991 through 1995.

2. DESCRIPTION OF STUDY

2.1. Data

The primary data for this study were gathered from a total of 498 articles in the DSS

[1]To handle a large number of reference articles, we avoided any duplication of the articles cited in Appendix B and the reference list. Thus, Appendix B and the reference list do not share the same articles. However, when necessary, articles in Appendix B are referenced as if they had appeared in the reference section.

area over the past five years (1991–1995), based on the criteria used by Eom and Lee [100, 101] and Elam *et al*. [21]. A citing article is selected if: (1) it discussed the development, implementation, operation, use, impact of DSS, or DSS components or (2) for DSS articles related to contributing disciplines, they were explicitly related to the development, implementation, operation, use, impact of DSS or DSS components. A total of 16,413 cited references taken from the 498 citing articles were added to the bibliographic database file created earlier [22].

The following 15 journals represent 93% of the source articles. They are *Communications of the ACM, Decision Sciences, Decision Support Systems, European Journal of Operational Research, INFOR, Information and Management, Information Systems Research, Interfaces, International Journal of Man-Machine Studies, Journal of Management Information Systems, Management Science, MIS Quarterly, Omega, Operations Research,* and *The Data Base for Advances in Information Systems*. The other 7% of source articles come from 25 other journals.

2.2. Research methodology

This research is based on author cocitation analysis (ACA). ACA is "a set of data gathering, analytical and graphical display techniques that can be used to produce empirical maps of prominent authors in various areas of scholarship" [36, p. 433]. The analytical and graphical display tools include factor analysis, multidimensional scaling and cluster analysis.

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 that "bibliographic citations are an acceptable surrogate for the actual influence of various information sources" [35] and that the cocitation analysis of a field yields a valid representation of the intellectual structure of the field [9, 35, 36, 52]. (For an in-depth overview and discussion of the continuing relevance of this topic, see [37, 57]). The term "author" in author cocitation analysis refers to a body of writings by a person.

Researchers in any academic discipline tend to cluster into informal networks, or "invisible colleges," which focus on common problems in common ways [44]. Within these networks, one researcher's concepts and findings are soon picked up by another to be extended, tested and refined and, in this way, each person's work builds on that of another.

Due to the possible instability of small cocitation counts, author cocitation analysis researchers introduced several *ad hoc* criteria for further screening a large pool of candidate authors to finalize a list of authors. The criteria include a *mean cocitation rate* above a certain lower limit per author in each time period (e.g. nine for 10 years of Social Scisearch data), cocitation with at least one-third of the entire author set, or restricting the final author set to the 20% receiving the highest number of citations and cocitations in initial retrieval trials. For further details on several different approaches to compiling a predetermined list of authors, see [37]. However, all these criteria were suggested to be applied to the commercial on-line databases such as SCISEARCH and SOCIAL SCISEARCH.

Our databases are significantly different from those commercial databases in terms of size of records. Besides, the cocitation matrix generation system we developed gives access to cited coauthors as well as first authors. To overcome a standard problem with the Institute for Scientific Information (ISI) databases which code only the first author of a cited work, a Fox-Base based matrix generation system was developed to compute a cocitation frequency between any pair of authors. Due to these differences, we could not follow the suggested criteria (e.g. [37]) such as "a mean cocitation rate of '*x*' or more cocitations in each time period". Rather, we had to invent a new criterion through the method of trial and error. We experimented with the sensitivity of changing the cocitation threshold on the final outcomes (number of meaningful factors to accurately represent DSS research subspecialties). With our databases, we conclude that the number of cocitations of an author with himself/herself can be a better criterion to determine the final author set due to its simplicity. Using the cocitation rate of 25 with himself/herself in the period (1991–

1995), the final set of 106 authors was selected for further analysis. For further detailed description of the research methodology, see [23, 37].

The raw cocitation matrix of 106 authors, Appendix A[2], was analyzed by the factor analysis program of SAS (statistical analysis systems) to ascertain the underlying structure of DSS research subspecialties. Principal component analysis (varimax rotation) with the latent root criterion (eigenvalue 1 criterion) was applied to obtain the initial solution of 11 factors. The scree tail test indicates that only the first ten factors should be qualified. The scree test involves the plotting of the latent roots (eigenvalues) against the number of factors in their order of extraction. There is no exact quantitative basis for deciding the number of factors to extract as the final solution [24]. Based on careful examinations and interpretation of these outputs, eight factors resulted. The eight extracted factors account for 84.18 percent of the total variances of the data set.

3. RESULTS

Factor analysis extracted eight factors consisting of five major areas of DSS research (group DSS, implementation, model management, design and an unnamed factor) and three contributing disciplines (cognitive science, organizational science and multiple criteria decision making). Table 1 below presents the rotated factor pattern of the eight-factor solution and all authors in each factor with factor loading at 0.40 or higher. According to McCain [37, 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 the statistical output of citation analysis.

To facilitate comparison, we include a summary of the findings of the earlier study [22]. Using factor analysis of an author cocitation matrix gathered from a total of 692 articles in the DSS area over the past 20 years (1971–1990), the earlier study of Eom [22] extracted seven factors consisting of three reference disciplines (organizational sciences, artificial intelligence and multiple criteria decision making) and the following four major areas of DSS research.

3.1. Foundations

Authors in this factor include founding fathers of the DSS areas who have provided definitions, concepts, methodologies, frameworks and the directions in which DSS can move. Keen and Scott Morton [104] 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 judgment; and improve the effectiveness of decision making rather than its efficiency". They also suggested three important DSS subfields from an organizational perspective: design, implementation and evaluation of DSS. The three major technology components (dialogue, data, and model) of Sprague and Carlson [108], the DDM paradigm, had been the most influential DSS architecture during the 1970s and 1980s.

3.2. GDSS

Since the mid-1980s we have witnessed an emerging DSS research theme: group decision support systems. Several descriptive research papers have been cornerstones for subsequent GDSS empirical research. They provided a comprehensive definition and an overview of GDSS. They also proposed an architecture of GDSS, a multidimensional taxonomy of GDSS and a future direction for GDSS development and research [62, 63, 66, 70].

3.3. Model/data management

Model/data management systems 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. In the model structure and representation area, the structured modelling approach [86] has advanced the model representation area of

[2]Some authors in Appendix B do not appear in the cocitation matrix (Appendix A), due to different selection criteria. The cocitation rate of over 25 with himself/herself were applied to select the final author set in Appendix A, while Appendix B lists publications receiving 15 or more citations by co-citing factor.

Table 1. Author factor loading at 0.40 or higher representing DSS research subspecialties and reference disciplines (rotation method: varimax; number of factors = 8)

Factor 1 GDSS			Factor 2 Model Management			Factor 3 Implementation		
NUNAMAKER	×73	0.949	DOLK	×21	0.958	LUCAS	×62	0.889
VOGEL	×100	0.943	GEOFFRION	×28	0.947	IVES	×40	0.889
JESSUP	×45	0.941	KRISHNAN	×58	0.916	ZMUD	×106	0.856
GALLUPE	×27	0.939	STOHR	×91	0.915	KING, W.	×54	0.840
DENNIS	×17	0.932	LIANG	×61	0.910	SANDERS	×82	0.838
WATSON, R.	×103	0.932	MURPHY	×71	0.903	ALAVI	×1	0.819
GEORGE	×29	0.930	BINBASIOGLU	×7	0.885	COURTNEY	×14	0.814
KRAEMER	×57	0.926	JONES, C. V.	×48	0.877	DEXTER	×19	0.789
DESANCTIS	×18	0.919	BLANNING	×8	0.855	REMUS	×80	0.737
POOLE	×76	0.917	BASU	×4	0.809	GINZBERG	×30	0.713
HILTZ	×36	0.915	DUTTA	×22	0.802	BENBASAT	×6	0.700
PINSONNEAULT	×75	0.914	JARKE	×42	0.727	ROCKART	×81	0.651
RAO, V. S.	×79	0.905	HOLSAPPLE	×38	0.682	WATSON, H.	×102	0.650
TUROFF	×96	0.905	ELAM	×24	0.668	KEEN	×50	0.610
MCGRATH	×67	0.900	WHINSTON	×104	0.663	SHARDA	×84	0.603
ZIGURS	×105	0.899	BONCZEK	×10	0.655	KOTTEMANN	×56	0.524
VALACICH	×98	0.896	HENDERSON	×35	0.599	ALTER	×2	0.511
CONNOLLY	×13	0.883	KOTTEMANN	×56	0.448	SIMON	×86	0.498
STEEB	×89	0.883	KONSYNSKI	×55	0.406	SCOTT MORTON	×83	0.445
MARTZ	×64	0.877				SPRAGUE	×88	0.430
APPLEGATE	×3	0.876				HENDERSON	×35	0.422
JOHNSTON	×47	0.874				NEWELL	×72	0.417
KIESLER	×52	0.872				TODD	×94	0.406
HEMINGER	×34	0.870				HUBER	×39	0.404
MCGOFF	×66	0.869						
DICKSON	×20	0.864						
GROHOWSKI	×33	0.857						
DELBECQ	×16	0.851						
KING, J.	×53	0.851						
MCGUIRE	×68	0.849						
GRAY	×32	0.844						
SHAW, M. E.	×85	0.842						
BEAUCLAIR	×5	0.839						
VAN DE VEN	×99	0.834						
JOHANSEN	×46	0.831						
DAFT	×15	0.801						
HUBER	×39	0.799						
KONSYNSKI	×55	0.795						
JANIS	×41	0.792						
JARVENPAA	×43	0.788						
MASON	×65	0.643						
MITROFF	×70	0.639						
SUCHMAN	×92	0.597						
MALONE	×63	0.595						

KAHN	×49	0.594						
FOSTER	×26	0.588						
LANNING	×59	0.586						
BOBROW	×9	0.581						
STEFIK	×90	0.576						
BUI	×11	0.574						
JELASSI	×44	0.514						
Eigenvalue		37.99			21.84			12.43
% Variance		35.8%			20.6%			11.7%
	Factor 4 Design			Factor 5 Cognitive Science			Factor 6 Unnamed	
TURBAN	×95	0.788	PAYNE	×74	0.912	STEFIK	×90	0.781
SPRAGUE	×88	0.775	EINHORN	×23	0.894	BOBROW	×9	0.777
SCOTT MORTON	×83	0.744	HOGARTH	×37	0.879	LANNING	×59	0.774
WATKINS	×101	0.731	TVERSKY	×97	0.872	FOSTER	×26	0.773
GORRY	×31	0.730	TODD	×94	0.790	SUCHMAN	×92	0.768
CARLSON	×12	0.724	SLOVIC	×87	0.788	KAHN	×49	0.762
KEEN	×50	0.683	NEWELL	×72	0.582	MALONE	×63	0.549
BONCZEK	×10	0.663	BENBASAT	×6	0.526			
WHINSTON	×104	0.656	SIMON	×86	0.523			
LEE, S. M.	×60	0.641	REMUS	×80	0.490			
EOM	×25	0.631	DEXTER	×19	0.488			
ALTER	×2	0.625	RAIFFA	×77	0.402			
WATSON, H.	×102	0.610						
HOLSAPPLE	×38	0.607						
GINZBERG	×30	0.512						
HENDERSON	×35	0.510						
ELAM	×24	0.461						
Eigenvalue		5.48			3.65			3.21
% Variance		5.2%			3.4%			3.0%
	Factor 7 Organization Science			Factor 8 MCDM/MCDSS				
RAISINGHANI	×78	0.868	RAIFFA	×77	0.765			
THEORET	×93	0.864	KEENEY	×51	0.741			
MINTZBERG	×69	0.840	BUI	×11	0.630			
MITROFF	×70	0.571	JELASSI	×44	0.617			
MASON	×65	0.508	JARKE	×42	0.473			
Eigenvalue		2.92			1.66			
% Variance		2.8%			1.6%			

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). The model abstraction structure was also developed for representing models as a feasible basis for developing model management systems [84]. In the area of AI application to model management, several authors [83] suggested the use of artificial intelligence techniques to model integration, construction and interpretation.

3.4. Individual differences

During the 1970s and 1980s, researchers in this factor have focused on the user's cognitive style as an important consideration in the design of management information systems (MIS)/DSS and comparison of various information presentation formats such as graphical and color enhanced information vs mono colored tabular, detailed reports vs summarized reports, and tabular with graphics vs tabular without graphics. Despite the numerous previous research reports, results were confusing and inconclusive. Numerous researchers made failed attempts to find interrelationships between cognitive styles and successful MIS/DSS design.

The DSS area has undergone profound structural changes in its intellectual structure over the past five years (1991–1995). This result indicates that several DSS research fields/contributing disciplines are emerging. In the DSS subfields, design and implementation have emerged as the important fields of research. In the contributing disciplines, cognitive science is a new field appearing in this study. Two subareas of DSS research are disappearing, individual differences and foundations. Group decision support systems (GDSS) research has been strengthened and model management research has been a continuously central research theme. Organization science and multiple criteria decision making are steady fields of DSS contributing disciplines.

3.5. Reference disciplines

Factor 5 seems to represent *cognitive science*, which is an interdisciplinary field which studies diverse human cognitive activities such as language understanding, thinking, visual cognition and action, etc. The focus of cognitive science research is on how cognition typically works in normal adults, how it varies across individuals/different populations/cultures, how it develops, etc.

To discuss specific findings in the literature of a psychological decision theory, Einhorn and Hogarth [20] decomposed the processes of judgement and choice into the subprocesses of information acquisition (information search and storage), evaluation, action and feedback/learning and discussed several issues related to each subprocess. In regard to evaluating a set of alternatives, Einhorn and Hogarth discussed the need for finding principles underlying choice processes including a possibility of an over-riding cost/benefit analysis, which may induce suboptimal behavior in some circumstances. Behavioral decision theorists proposed a variety of mechanisms that influence strategy selection. Of these, the cost-benefit framework of Payne [41] and his colleagues provided a basis for DSS researchers for understanding the behavior of decision makers using DSS as to the selection of their strategy and the relationship between the use of DSS and decision quality. The cost–benefit framework of cognition aims at maximizing accuracy and/or decision quality as well as minimizing cognitive effort. A study of Todd and Benbasat [54, p. 390], for example, concluded that the amount of information processed does not necessarily increase with the use of a decision aid. Instead, it appears in the study that decision makers use decision aids to reduce the amount of efforts required to complete a task. Decision makers use different processes in different types of tasks. Decision processes are sensitive to seemingly minor changes in the task-related factors. Tversky and Kahneman [112] described three heuristics in making judgement under uncertainty (representativeness, availability and adjustment and anchoring), which lead to systematic and predictable errors. The findings of Tversky and Kahneman [112] have contributed to controlling bias in user assertions in DSS and provide a guiding principle for overcoming the user's poor capabilities to calculate probabilities when designing DSS. Their findings provided a theoretical basis for reaching an important conclusion that the cognitive styles of users should not be the basis of information systems design in that "predispositions are often dysfunctional" [26].

Factor 7 appears to represent *organizational science* [114, 115]. 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" [104, p. 61]. A recent study [23] found a strong linkage between organization science and the three dominant DSS research subspecialties (foundations, model management and user-interface) indicating that organizational science is a major contributing discipline. 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 [12] stressing the compartmentalization of the various units in any organization; (3) the satisfying model of Simon and his colleagues [109] which finds an acceptable, good enough solution, reflecting "bounded rationality" and (4) and other models.

Factor 8 seems to represent *multiple criteria decision making (MCDM)* [116]. MCDM deals with semistructured and unstructured decisions involving multiple attributes, multiple objectives, or both. Among the numerous individuals contributing to the development of the field of MCDM, Keeney and Raiffa [116] have provided us with an excellent and complete overview of multiple attribute utility theory, along with numerous examples of practical applications. By the nature of multiple criteria decision making, usually there are numerous nondominated solutions in MCDM problems. Integration of MCDM into DSS has long been advocated by the researchers in the DSS and MCDM areas. Keen and Scott Morton [104, p. 48] believe that the multiple criteria decision problem is at the core of decision support and "a marriage between MCDM and DSS promises to be practically and intellectually fruitful." An important reason for the emergence of MCDM model-embedded DSS (MCDSS) is that MCDM complements DSS and vice versa due to the differences in underlying philosophies, objectives, support mechanisms, and relative support roles. Some features of MCDM include (1) the multiple-objective goal structure designed to handle quantitative and qualitative information crucial for ill-structured problems, (2) the interactive solution search procedure designed to analyze continuous trade-offs among various alternatives until the best available solution is attained and (3) the emphasis on the decision maker's judgment or bounded rationality which better reflects his/her actual cognitive behaviors.

3.6. DSS research subspecialties

Factor 1 appears to define *group DSS*. Group DSS (GDSS) have now become a mainstream research field. The early stage of GDSS development focused on the development of a comprehensive definition, an architecture and a multidimensional taxonomy of GDSS. A brief review of previous GDSS literature up to 1990 can be found in [14, 16, 58, 77]. This study reveals that a growing number and proportion of DSS researchers are continuing GDSS research.

Factor 2 appears to represent *model management* [83–91]. Since 1975, model 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 [10]. Comprehensive literature reviews on model management can be found in [10, 11].

Factor 3, *implementation*, is a new factor that emerged in this study. DSS implementation research aims at systematically identifying factors which will influence the implementation success of DSS so that those critical factors can be managed effectively to increase the successful implementation of DSS in organizations. Several studies reported the identification of DSS implementation success factors and the linkage between those factors and DSS effectiveness [4, 27, 45]. Like so many empirical studies in other fields, no direct comparison of these studies is possible due to different methodologies, samples, etc. For example, Ramurthy *et al.* [45, p. 469] concluded that "user's domain-related expertise, systems experience, gender, intelligence and cognitive style have important influence on one or more dimensions of DSS effectiveness. However, their relative importances vary with the outcome measure of choice''. An empirical study of Igbaria and Guimaraes [27] strongly confirmed that user involvement and DSS friendliness are critical DSS success factors. Despite conflicting and confusing findings in the area of implementation research, a systematic integration and assessment of a large set of DSS implementation research [4] seems to suggest that DSS implementation research has been accumulating its research findings. A meta-analysis of 144 findings concluded that user-situational variables (involvement, training and experience) are more important than cognitive styles, personality and demographics [4]. Further the study [4, p. 111] concluded that ''future research should be directed toward developing causal models of DSS implementation that weave these key factors together in a form that makes their interrelationship explicit''.

Factor 4 seems to represent *design* of DSS [95–108]. Over the recent five-year period, design of DSS has emerged as a DSS research subfield. Traditional assumptions in the DSS area are being challenged. One of them includes the role of cognitive styles in the DSS design. A significant development in the 1990s is the demise of *individual differences* (cognitive style) research as a basis of DSS design in the DSS literature. After over a decade of cognitive styles and individual difference research, Huber [26, p. 567] concluded that ''the currently available literature on cognitive styles is an unsatisfactory basis for deriving operational guidelines for MIS and DSS designs'' and ''Further cognitive style research is unlikely to lead to operational guidelines for MIS and DSS designs''. A number of empirical studies conducted to test the existing DSS design frameworks/theory. Igbaria and Guimaraes [27] empirically tested the outcomes of user involvement in the DSS development to establish the positive relationship between user involvement and several measures of system success such as DSS usages, user overall satisfaction with the DSS, and user perceived DSS benefits. A contingency model of DSS design methodology is developed by Arinze [7] to help DSS developers select an appropriate methodology out of several methodologies of data-driven, process driven [104, 108], decision-driven [53] and systemic paradigms [97].

Others began to investigate new lines of research questions such as stimulus-based DSS. In his DSS prize winning paper, Angehrn [6] presented a new idea of stimulus-based DSS which can criticize the user. He termed this idea as the conversational framework of DSS as opposed to the traditional passive DSS framework in which DSS provide a set of operations research (OR)/management science (MS) tools. In addition to a set of tools, the conversational DSS can guide and criticize the user through providing active support of suggestions and criticism.

Factor 6 is an *unnamed* factor that appeared in this study. We did not name this factor because it consists of only six coauthors of an article in Appendix B. All these authors are a subset of the GDSS factor. A group of artificial intelligence researchers at Xerox Palo Alto Research Center explored the idea of putting computers as a collaborative problem solving tool in face-to-face meetings to replace, extend and augment the chalkboard [113]. Using an experimental meeting room equipped with personal computers which are linked together over a local area network that supports a distributed database, they created several tools for collaboration such as Boardnoter (imitating the functionality of a chalkboard), Cognoter (a cognition noter for brainstorming, organizing and evaluating ideas) and Argnoter (argument noter for organizing and evaluating arguments).

3.7. What has happened in DSS research since 1991?

Through the comparison of the study of Eom [22] and this study, we identified that the DSS area has undergone profound structural changes in its intellectual structure over the past five years (1991–1995). DSS research areas and reference disciplines can be categorized into four different groups, steady, strengthening, emerging, dying and slowly growing areas. The steady areas include model management which appeared in the previous study [22] and this study. In the reference discipline areas, organizational science and multiple criteria decision making have been consistently influential in the development of DSS research subspecialties over the past 25 years (1970–1995). The group DSS area has been strengthened significantly in the 1990s. *The emerging area* is represented by design and implementation in the DSS research area and cognitive science in the contributing disciplines. *The dying area* includes two DSS research subfields (foundations and individual differences) that appear to be no longer active. Influence of artificial intelligence is not clearly visible over the past five-year period.

3.7.1. Group DSS. The result of this study clearly shows that GDSS has become a central part of DSS research area over the past five years. Some of the important recent developments in this area can be summarized as follows:

(1) There have been continuing developments and enhancements of GDSS tools to support and augment the existing group DSS and electronic meeting systems such as the following:

— An idea consolidator to combine comments from an idea generation session by examining, cross-comparing and synthesizing them efficiently as well as precisely [2].

— An optimization-based group decision tool for combining subjective estimates and extracting the underlying knowledge of group members [51].

— A hypertext and computer-mediated communication systems to support distributed group decision making for developing a long-term plan for emergency management [55].

— A prototype GDSS for multicultural and multilingual communication to translate among several foreign languages such as English, German, Korean and Spanish [3].

— A group software for modeling and analyzing business process re-engineering [15].

— An interactive videodisc-based GDSS for directing the pattern, timing, and contents in group decision making [46].

(2) A wide range of GDSS/electronic meeting systems/decision conferencing system applications has been reported to support/facilitate the following areas:

— The conduct of strategic management meetings, comprising large heterogeneous groups of managers, in an effective and efficient manner [56].

— Quality improvement by providing support for brainstorming, issue prioritization, root-cause analysis, strategy selection, etc. [17].

— Knowledge acquisition for multiple experts via facilitating expert interaction that creates synergy and resolve conflicting views [33].

— Distributed decision making involving fairly large numbers of participants (tens to hundreds) [55].

— Developing a cognitive map of users of object-oriented techniques for understanding individual and group perceptions [49].

— Developing national economic policy [50].

— Expediting the requirements specification in the system development process by facilitating human interactions among developers, users and managers [34].

— Facilitating the United States Army = s group decision making in geographically distributed environments [25].

— Increasing managerial involvement in, and to improve the efficiency and effectiveness of, systems planning [47].

(3) A number of empirical/laboratory experimental studies have been conducted to investigate the effects of a variable on the quality of group decisions, level of agreement, subjective satisfaction, etc. Pool *et al.* [43, p. 926] reported a laboratory experiment to examine the impacts of GDSS on conflict management in small groups making a budget allocation decision and concluded that "the model predicts that the particular combination of GDSS impacts that materializes differs across groups and that the balance of these impacts, positive or negative, determines positive or negative conflict outcomes." Nunamaker and others [40] presented an integrated series of laboratory and field studies to investigate the impacts of electronic meeting systems on generating options for mutual gain for groups that meet at the same place and time and found that the use of anonymity seemed to improve option generation in some cases where there exists power differences among the participants. Jessup and Tansik [28] investigated the effects of anonymity and proximity on group process in automated group problem solving. The essence of their findings [28, p. 276] includes that "group members working under anonymous and dispersed conditions generated more comments" and "groups working

under anonymous conditions and under dispersed conditions generated a high number of critical comments".

A number of empirical/laboratory experimental studies have produced inconsistent and/or conflicting results (see [14] for a review of previous electronic meeting systems (EMS) laboratory experiments and field studies up to the summer of 1990). Dennis *et al.* [14] insisted that these differences in findings reflect different situations in organizational contexts, group characteristics, tasks, and EMS environments and therefore EMS researchers need to make explicit design decisions for each of these aspects. The inconsistent results of empirical study are an important bottleneck in generalizing research findings to articulate DSS theories.

(4) GDSS is being integrated with other technologies such as expert systems and case-based reasoning, etc. A prototype system that embedded expert systems into GDSS has been developed to make a GDSS a more user-friendly and powerful tool for group support by capturing the scarce expertise of human facilitators GDSS session management knowledge [1]. The distributed artificial intelligence approach for designing and developing group problem solving systems is being investigated to coordinate organizational activities in a distributed environment through the development of prototype systems comprising a network of expert systems [48].

3.7.2. Model management. In the area of model management, there has been a variety of new approaches to manage models as organizational resources. Some notable approaches include the following:

(1) Development of graph-based modeling: *graph-based* modeling is an emerging research area. Jones [29] presented a prototype system of graph-based modeling, NETWORKS, which allows the user to represent a wide variety of decision problems in a graphical form such as bar chart, decision tree, decision network, etc. Further, the users manipulate the models (e.g. deleting/adding subtrees for decision trees) using a graph-grammar by applying a set of operations (or productions).

(2) Object-oriented approach: an object-oriented framework for effective model administration is proposed to provide a unifying context for model management research and for integrating model management and data management. Using the object-oriented framework, Muhanna [38] designed and implemented a prototype model management system to build, store, retrieve composite models and to maintain the integrity of model bases through providing the functional capability of model sharing and re-useablity. A critical issue in model management systems is the lack of an integrated modeling environment that provides supports for entire sets of modeling related activities within an organization–model administration for sharing and reusing models and knowledge, problem–model linkage, model–model linkage and model–data linkage [39].

(3) Modeling by analogy (analogical modeling) and case-based learning are suggested as potentially fruitful avenues for increasing the productivity of model formulation. Analogical modeling is a process by which model X is constructed based on a known model for problem X and the similarity between problems X and Y [32]. In addition to a knowledge base which stores facts and rules, cased based reasoning systems maintain a case base which is a repository of all previous cases solved. To find a solution for a new problem, the system identifies the most similar case from its case base to be applied.

(4) Modeling by example is a methodology suggested by Angehrn [5] that permits decision makers to access the knowledge stored in DSS via dynamic exchange of *examples* as an effective means of facilitating human-computer interaction along a decision-making process. Consequently, this approach resulted in the development of a knowledge-based DSS which intelligently assists modelers and users to access and use complex problem solving techniques with more flexibility and which permits modelers and end-users to formulate models in flexible ways.

(5) Active modeling systems are expert systems embedded modeling systems which provide intelligent support to the modelers [18].

(6) Model construction: a knowledge-based linear programming (LP) model construction system has been developed to help non-expert users construct linear programming models of production, distribution and inventory planning [90].

(7) Integrating simulation modeling and inductive learning in an adaptive decision support system. A prototype DSS has been devel-

oped to incorporate machine learning capabilities for model management as a means by which the system adapts itself to the environment through continuously updating and refining the knowledge-base [42].

(8) Object-oriented model integration: a DSS formulates and integrates optimization and simulation modeling and heuristic reasoning for non-expert users through an object-oriented domain-specific knowledge base [13].

(9) Model integration using metagraphs: Basu and Blanning presented a new approach to model integration, a graphical approach. This approach is based on a metagraph which is defined as "a graph-theoretic construct that captures relationships between pairs of sets of elements" [8, p. 195]. They show that the process of model integration can be significantly expedited by utilizing certain connectivity properties in metagraph.

Although model management research has not progressed enough to develop a theory of models, Dolk and Kottemann [19, p. 51] believe that the emergence of a theory of models 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".

4. CONCLUSION AND IMPLICATIONS FOR FUTURE DSS RESEARCH

To extend the benchmark study [22], this study has attempted to investigate an ongoing change in the intellectual structure of DSS research fields through a comparison of the bibliometrical study between the first two decades of DSS research (1970–1990) and the recent five years (1991–1995). We are now in a better position to understand the dynamic dimension of the intellectual structure of DSS research. This study identified a dynamic dimension of DSS research areas to account for the ongoing changes in its "disciplinary matrix", the four emerging areas (implementation, design, cognitive science and the unnamed factor); continuously growing areas (GDSS, model management, MCDM and organization science); dying areas (individual differences and foundations) and growing at a slow pace (artificial intelligence).

In a nutshell, the factors in this study appear to reflect the maturing stages of DSS research, aiming at providing a macro view of DSS research literature with a goal of providing a basis for developing coherent DSS theories to sort out a confusing body of a variety of DSS literature. Indeed, the changes in the intellectual structures in decision support systems have been profound over the recent five years (1991–1995). The focus of DSS research appears to be shifting from the study of DSS components (data, model, individual differences of decision makers) during the period 1970 through 1990 to the design, implementation, and user-interface management (which have not been shown to be substantive DSS research subspecialties in the previous research), to provide useful guiding principles for practitioners in the integrated processes of design, implementation and evaluation of decision support systems. The model management and group decision support systems areas have been continuously researched over the two periods of investigation. In the area of model management, much progress has been made in the sub-areas of model representation, model base processing, model integration and the application of artificial intelligence to model management.

A host of new tools are becoming an integral part of a set of recent developments in the MIS/DSS industries. These emerging tools include the data warehouse/multidimensional databases (MDDB), data mining, on-line analytical processing (OLAP), intelligent agents, the Internet and corporate intranets developing World Wide Web technology-based DSSs. These new tools are a set of inseparable tools that add new capabilities to decision support systems and executive support systems. Unfortunately, these practical tools and technologies have not been the subjects of intense academic DSS research over the past five years (1991–1995). Bridging the gap between practitioners and researchers is another challenge.

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APPENDIX A

Raw cocitation matrix

Author	No.																																				
ALAVI	1	22																																			
ALTER	2	3	34																																		
APPLEGATE	3	3	2	87																																	
BASU	4	0	1	4	21																																
BEAUCLAIR	5	1	3	15	0	39																															
BENBASAT	6	13	14	9	2	4	53																														
BINBASIOGLU	7	0	1	2	8	0	0	27																													
BLANNING	8	0	5	10	11	0	5	8	40																												
BOBROW	9	1	2	18	0	9	7	2	5	47																											
BONCZEK	10	4	11	13	10	4	8	11	26	8	82																										
BUI	11	2	4	12	1	9	6	1	4	5	7	28																									
CARLSON	12	9	15	10	7	5	17	4	13	8	31	7	75																								
CONNOLLY	13	2	3	19	0	9	8	0	0	8	0	4	2	45																							
COURTNEY	14	7	5	6	4	1	15	1	2	3	6	3	12	4	31																						
DAFT	15	1	0	9	0	3	7	0	2	8	2	0	1	11	2	29																					
DELBECQ	16	0	1	15	0	8	5	0	0	4	0	3	3	10	2	8	38																				
DENNIS	17	4	5	37	2	17	24	1	5	21	5	8	7	27	5	18	21	110																			
DESANCTIS	18	11	9	50	5	26	40	2	3	25	14	20	17	29	18	16	21	68	127																		
DEXTER	19	10	6	3	0	0	29	0	0	1	2	0	9	1	11	0	1	7	18	33																	
DICKSON	20	8	5	27	1	12	31	0	2	12	6	8	10	13	10	9	10	37	55	19	66																
DOLK	21	0	4	10	12	1	3	13	22	2	21	1	11	0	1	1	0	4	3	0	0	38															
DUTTA	22	0	2	4	18	1	2	9	10	2	15	2	12	0	5	0	0	2	6	1	2	12	25														
EINHORN	23	1	3	0	1	0	14	1	2	1	4	2	6	0	3	1	0	3	7	7	5	2	1	28													
ELAM	24	3	5	11	12	2	12	7	18	4	24	5	16	2	8	1	0	8	13	6	7	17	13	6	51												
EOM	25	2	3	2	1	2	5	0	4	3	7	5	10	1	3	0	1	4	8	4	5	1	3	1	10	26											
FOSTER	26	1	2	17	0	9	7	0	2	30	5	5	5	7	2	7	4	20	23	1	12	0	1	1	1	2	45										
GALLUPE	27	8	5	47	5	27	24	2	3	21	12	18	14	28	10	16	23	64	99	6	40	3	5	2	10	5	20	125									
GEOFFRION	28	1	4	8	10	0	3	17	23	4	23	3	11	0	2	0	0	4	2	1	1	30	13	1	18	4	0	2	45								
GEORGE	29	3	4	37	1	16	16	1	4	19	5	8	8	26	9	18	20	69	61	1	32	2	2	0	5	2	18	59	1	107							
GINZBERG	30	7	11	2	1	2	12	0	4	3	11	4	15	1	9	0	1	4	11	8	10	1	2	2	6	5	3	6	1	1	31						
GORRY	31	4	6	4	1	2	6	1	6	3	12	3	12	0	3	1	0	1	8	1	3	2	4	1	6	4	3	7	1	1	6	29					
GRAY	32	3	4	17	0	15	7	0	2	10	3	9	4	6	3	3	8	22	23	1	12	1	0	0	2	3	10	24	1	20	2	0	38				
GROHOWSKI	33	1	1	18	0	13	6	0	0	9	2	6	1	12	2	8	7	25	26	0	16	1	2	0	2	1	9	26	1	24	1	2	8	47			
HEMINGER	34	0	0	19	0	13	4	0	0	9	3	4	2	11	2	8	7	28	26	0	17	1	2	0	2	1	9	27	1	25	2	2	7	26	47		
HENDERSON	35	10	8	13	8	4	11	5	15	5	19	7	17	3	12	5	1	6	14	6	12	14	9	3	22	5	4	12	13	8	8	8	4	2	3	36	
HILTZ	36	5	0	30	0	13	8	0	1	11	1	6	2	14	3	10	15	35	35	4	24	1	1	0	2	2	10	38	1	34	2	1	15	18	19	6	60
HOGARTH	37	1	3	2	1	1	13	1	3	3	6	4	9	1	5	1	1	4	10	6	6	3	3	22	8	3	2	4	4	0	4	2	1	2	2	4	0
HOLSAPPLE	38	3	9	16	12	6	9	11	26	10	52	8	24	1	7	2	1	8	20	2	8	19	12	2	20	7	7	18	21	7	7	11	5	2	2	19	3
HUBER	39	13	13	41	6	23	33	3	9	18	24	16	24	19	23	14	20	48	73	16	36	7	9	11	28	11	16	68	6	46	15	15	21	20	23	23	31
IVES	40	7	3	1	1	2	12	0	1	1	2	1	7	2	11	3	2	4	12	10	8	0	3	0	4	4	1	5	1	3	8	4	0	2	2	7	2
JANIS	41	1	3	11	1	6	3	0	1	5	1	3	3	8	3	8	10	16	18	1	8	2	2	2	1	1	4	17	2	11	1	0	5	3	4	4	8
JARKE	42	2	6	14	9	10	5	20	11	9	19	18	12	3	5	2	3	10	22	0	4	14	13	2	12	5	7	21	21	10	3	3	10	8	6	12	8
JARVENPAA	43	4	7	22	1	12	29	0	1	10	4	6	10	15	8	7	10	28	41	16	31	0	2	10	8	2	10	29	0	24	6	2	10	11	10	8	15
JELASSI	44	1	5	11	1	14	5	1	1	9	9	14	14	3	4	1	5	10	23	1	6	2	4	1	2	4	8	22	4	8	4	3	8	6	8	5	6
JESSUP	45	3	5	37	0	20	16	0	2	18	3	7	5	31	4	17	20	63	55	1	31	1	1	0	3	1	17	55	0	59	1	1	20	24	26	6	33
JOHANSEN	46	2	2	13	0	8	3	0	0	8	0	2	1	5	2	3	4	18	19	1	11	1	0	0	1	0	8	19	0	16	0	1	13	7	6	3	11
JOHNSTON	47	0	0	15	0	13	3	0	0	4	1	7	1	7	2	1	7	15	20	0	11	1	0	0	1	1	4	21	0	13	0	0	8	9	10	3	13
JONES, C.V.	48	0	2	3	5	1	2	5	13	4	13	1	7	0	2	2	0	2	1	0	1	14	7	0	9	2	2	1	17	2	1	1	0	1	1	6	0
KAHN	49	1	2	17	0	9	6	0	1	30	4	5	5	7	2	6	5	21	25	1	11	0	0	1	1	2	30	21	0	19	3	3	11	9	9	3	10
KEEN	50	17	27	13	5	8	32	2	12	8	31	11	48	5	20	4	7	15	31	15	16	8	9	7	21	14	6	27	6	13	25	16	10	4	4	23	10
KEENEY	51	0	1	7	0	2	5	0	2	2	4	8	5	1	2	1	4	1	8	0	1	1	1	4	3	3	0	8	5	2	1	1	1	2	2	2	2
KIESLER	52	3	1	21	0	10	5	0	0	10	2	6	2	11	3	6	10	17	22	0	13	0	0	1	0	1	9	23	0	17	1	1	11	9	8	3	17
KINGJ	53	1	3	23	3	13	10	1	5	14	5	7	5	9	6	5	8	27	34	2	20	3	3	1	5	3	14	34	1	28	2	3	13	10	13	7	18
KINGW	54	7	8	3	0	1	16	0	1	1	5	1	9	0	10	2	2	7	11	11	10	1	0	1	5	3	1	7	3	3	9	4	2	0	1	6	4
KONSYNSKI	55	5	6	61	3	15	13	10	19	21	25	14	19	19	12	10	14	36	51	5	30	23	15	4	30	4	18	48	21	37	7	6	17	19	20	25	31
KOTTEMANN	56	4	3	5	3	1	14	3	8	1	6	0	11	1	4	2	2	6	9	7	5	11	2	5	6	2	1	6	6	4	5	3	2	2	2	6	2
KRAEMER	57	2	3	29	3	17	14	1	4	15	3	10	3	15	4	10	13	40	47	1	29	2	2	0	4	3	15	48	1	39	2	3	19	16	18	6	27
KRISHNAN	58	1	2	3	10	0	1	15	13	2	13	0	6	0	0	0	0	1	1	0	0	21	11	1	7	0	0	4	27	0	0	0	0	0	0	5	0
LANNING	59	1	2	17	0	9	7	0	2	30	5	5	5	7	2	7	4	20	23	1	12	0	1	1	1	2	30	20	0	18	3	3	10	9	9	4	10
LEE, S.M.	60	3	3	4	1	3	5	0	4	3	7	6	11	2	3	0	1	5	9	4	5	1	3	1	10	24	2	6	4	3	5	4	5	2	1	5	3
LIANG	61	4	7	11	10	5	7	11	17	4	19	4	14	2	8	1	2	4	11	5	7	22	10	1	15	3	4	10	20	5	5	2	4	0	0	15	3
LUCAS	62	7	5	2	1	1	13	0	2	1	2	1	7	2	11	0	3	4	13	13	11	2	1	4	3	4	1	4	3	2	11	3	1	1	1	5	3
MALONE	63	3	3	9	3	6	5	0	3	10	5	3	4	3	5	1	1	12	14	2	6	1	4	1	6	2	10	13	0	11	3	3	9	4	4	9	8
MARTZ	64	1	1	19	1	15	6	0	1	10	2	7	3	13	3	8	8	27	29	0	18	1	3	0	3	2	10	29	1	25	1	3	9	31	27	4	19
MASON	65	3	1	14	1	4	7	0	4	7	3	5	6	10	8	8	9	14	20	4	8	0	1	2	4	3	5	19	2	14	5	5	5	5	6	8	8
MCGOFF	66	1	1	20	0	14	7	0	0	11	2	6	1	13	2	8	8	27	31	0	17	1	2	0	2	1	11	31	1	27	1	3	9	31	26	2	19
MCGRATH	67	2	2	18	0	9	9	0	1	8	3	4	1	15	2	12	14	24	30	1	14	0	1	1	2	1	7	27	0	24	2	2	6	15	11	3	12
MCGUIRE	68	0	1	17	0	9	4	0	0	9	2	5	2	8	3	3	9	13	18	0	11	0	0	0	0	1	8	18	0	13	1	0	9	7	6	1	14
MINTZBERG	69	5	3	11	3	2	8	2	2	4	5	4	7	9	7	9	4	10	15	4	7	2	5	6	9	2	3	12	1	9	3	6	3	4	4	9	7
MITROFF	70	1	1	12	1	4	5	1	3	6	3	5	4	10	5	9	9	14	19	2	7	1	1	5	2	3	5	17	2	13	3	5	5	5	6	5	7
MURPHY	71	0	2	6	7	0	1	15	14	2	13	1	6	0	0	0	0	0	0	0	0	22	8	1	10	0	0	0	28	0	0	1	0	0	0	8	0
NEWELL	72	2	6	8	1	0	14	1	3	2	2	2	8	4	8	2	1	10	15	8	9	2	2	9	7	1	1	10	3	7	3	3	2	0	1	7	5
NUNAMAKER	73	3	5	62	7	25	18	4	12	26	17	15	15	29	8	21	25	76	79	2	40	11	9	0	13	3	25	77	11	74	3	5	26	31	33	18	40
PAYNE	74	1	1	1	0	1	16	0	0	2	1	2	6	0	2	1	1	3	7	9	8	0	1	16	6	1	2	3	0	0	3	1	1	1	1	3	1
PINSONNEAULT	75	1	0	15	2	8	8	1	1	4	1	5	2	9	3	7	11	21	26	0	17	1	1	0	1	2	4	26	0	21	1	0	8	10	9	2	16
POOLE	76	4	4	28	0	4	16	0	1	17	4	8	3	19	4	13	13	39	50	3	32	1	0	1	3	2	16	43	1	36	2	0	14	17	14	5	22
RAIFFA	77	0	2	6	1	3	7	0	4	1	4	11	5	0	3	1	4	2	11	0	2	1	2	7	4	4	0	9	6	3	2	1	3	2	2	4	2
RAISINGHANI	78	1	2	6	2	0	5	2	1	3	3	2	2	6	6	7	3	7	10	3	4	2	3	6	6	0	2	6	1	5	1	2	1	1	2	2	3
RAOVS	79	2	3	21	0	12	8	0	0	8	2	6	3	14	3	6	10	19	27	2	18	0	0	0	1	1	8	26	0	21	1	0	10	11	10	3	13
REMUS	80	5	4	2	0	0	18	0	1	1	3	1	10	2	8	0	1	6	11	13	12	1	0	7	4	3	1	4	0	2	7	3	1	1	1	4	3
ROCKART	81	6	5	8	0	2	8	0	2	2	3	3	8	1	6	2	0	5	9	3	7	0	1	1	4	2	2	9	1	7	7	6	3	1	2	8	2
SANDERS	82	7	5	2	0	0	9	1	2	1	3	1	8	1	15	1	1	2	5	6	4	1	0	2	3	2	1	3	2	3	9	3	1	0	0	7	2
SCOTT MORTON	83	10	18	9	4	6	17	1	10	3	20	6	32	2	11	2	4	8	16	6	7	3	10	7	14	7	2	15	4	7	9	24	6	3	3	16	5
SHARDA	84	3	7	3	1	1	15	0	1	1	4	3	10	2	7	0	3	4	10	9	11	1	3	5	7	3	1	7	2	3	5	2	1	2	2	4	2
SHAWME	85	0	0	14	0	1	4	0	2	5	2	2	2	11	1	7	8	16	15	0	7	1	0	0	1	1	5	17	1	15	0	1	3	10	10	1	10
SIMON	86	8	13	17	5	4	30	8	10	8	23	8	25	8	17	7	6	23	36	17	24	11	12	17	22	5	5	27	12	17	15	14	4	6	7	18	14
SLOVIC	87	4	2	2	1	2	11	0	1	2	4	2	6	1	4	2	2	5	11	8	7	0	2	13	5	2	2	6	1	2	5	3	0	1	1	5	1
SPRAGUE	88	12	23	20	8	8	23	5	16	10	43	9	68	5	15	1	6	16	30	13	16	15	14	7	25	14	7	24	13	14	21	18	9	6	7	22	7
STEEB	89	0	0	17	0	13	4	0	1	5	2	8	2	7	2	1	7	16	21	0	11	1	0	0	2	1	5	22	0	14	0	0	9	9	10	3	13
STEFIK	90	1	2	18	1	10	7	2	4	34	9	5	8	7	3	7	4	21	24	1	12	4	3	1	6	3	30	21	4	19	3	3	11	10	10	7	11
STOHR	91	1	6	9	8	1	5	16	18	3	20	6	15	0	1	0	1	2	5	1	2	23	10	2	13	3	1	5	30	1	8	5	2	1	1	12	1
SUCHMAN	92	1	2	18	0	9	6	0	1	29	4	5	5	8	2	6	4	19	23	1	12	0	1	1	1	2	29	20	0	17	3	3	10	9	9	4	11
THEORET	93	1	2	6	2	0	5	2	1	3	3	2	2	6	6	7	3	7	10	3	4	2	3	6	6	0	2	6	1	5	1	2	1	1	2	2	3
TODD	94	1	2	1	0	0	20	0	0	0	0	0	4	0	2	0	0	7	9	12	9	1	1	10	5	0	0	2	1	1	1	0	0	0	0	0	3
TURBAN	95	6	15	10	5	4	13	3	9	5	26	5	26	0	6	1	1	5	12	6	4	5	8	4	12	7	3	11	7	5	10	9	4	2	3	15	2
TUROFF	96	4	0	29	0	12	8	0	2	13	1	6	2	12	3	10	15	34	35	3	22	1	1	0	2	2	12	38	1	33	2	2	15	17	19	6	41
TVERSKY	97	1	3	3	2	2	11	2	3	3	6	2	8	1	4	2	3	5	10	5	7	3	4	14	9	2	1	5	6	2	4	1	1	2	2	4	1
VALACICH	98	2	1	21	0	12	11	0	0	11	1	5	3	29	4	16	13	50	43	0	23	0	1	0	2	1	10	42	0	48	0	0	13	20	18	1	23
VAN DE VEN	99	0	1	15	0	7	8	0	0	4	0	3	4	10	5	8	27	22	24	4	13	0	0	3	0	1	4	24	0	20	2	0	8	6	6	2	15
VOGEL	100	7	5	42	2	26	21	0	3	24	8	13	11	27	8	18	23	75	76	4	40	1	4	2	8	5	23	73	2	70	5	5	26	31	33	11	39
WATKINS	101	2	6	4	3	2	5	2	6	2	19	5	10	0	5	0	0	3	9	2	3	3	3	2	8	3	2	7	2	3	8	4	3	1	2	10	2
WATSONH	102	14	12	12	4	1	17	2	10	2	16	2	19	2	11	3	1	8	14	8	10	5	4	0	11	6	2	11	4	8	13	12	4	1	0	16	3
WATSONR	103	1	2	27	1	14	10	0	2	10	4	6	4	15	5	9	12	27	36	1	24	2	2	0	4	3	9	34	1	29	1	0	12	12	10	6	17
WHINSTON	104	5	12	19	11	6	11	13	28	12	69	10	34	1	8	2	1	10	22	3	10	21	16	4	25	8	8	18	26	8	11	13	5	3	3	21	3
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ZMUD	106	7	5	5	1	2	17	0	1	2	3	2	9	3	11	4	3	7	13	11	10	0	1	4	4	2	2	8	1	6	10	5	1	2	2	8	4
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HUBER	39	12	24	99																																	
IVES	40	1	2	14	22																																
JANIS	41	6	3	16	1	26																															
JARKE	42	4	21	19	2	3	36																														
JARVENPAA	43	8	7	35	9	9	5	54																													
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JESSUP	45	1	4	40	2	14	9	23	10	97																											
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JOHNSTON	47	0	2	19	0	6	6	13	5	16	6	31																									
JONES, C.V.	48	3	13	5	2	0	7	1	2	1	0	0	23																								
KAHN	49	2	6	17	1	5	8	10	8	17	9	5	1	45																							
KEEN	50	10	23	49	17	5	18	17	16	10	6	4	8	6	84																						
KEENEY	51	7	3	9	0	2	11	5	10	1	0	2	2	0	9	25																					
KIESLER	52	1	3	20	1	6	6	12	6	17	8	9	0	9	7	2	33																				
KINGJ	53	1	10	29	1	6	9	6	8	25	11	12	1	13	12	4	9	54																			
KINGW	54	1	4	19	9	3	1	6	2	3	0	0	0	1	21	0	0	2	28																		
KONSYNSKI	55	8	25	47	4	11	26	25	14	35	13	14	9	18	25	9	21	24	6	90																	
KOTTEMANN	56	5	6	12	3	1	4	4	0	3	2	1	7	1	13	1	0	4	6	5	21																
KRAEMER	57	0	7	37	0	8	10	22	8	38	17	16	0	15	12	6	14	39	2	29	3	72															
KRISHNAN	58	1	14	2	0	0	15	0	2	0	0	0	15	0	4	0	0	0	0	11	6	0	36														
LANNING	59	2	7	16	1	4	7	10	8	17	8	4	2	30	6	0	9	14	1	18	1	15	0	45													
LEE, S.M.	60	3	8	11	4	1	7	2	5	2	0	1	2	2	14	3	2	3	3	5	2	3	0	2	27												
LIANG	61	2	22	12	3	1	17	7	6	3	1	2	14	4	14	3	4	4	4	22	7	3	17	4	3	33											
LUCAS	62	4	1	14	12	0	2	9	2	2	1	1	3	1	14	1	1	3	10	5	4	3	1	1	4	4	21										
MALONE	63	2	5	14	2	0	6	5	4	8	11	3	2	11	9	1	4	9	0	14	2	10	0	10	2	2	5	24									
MARTZ	64	2	3	23	2	5	9	12	7	26	8	11	1	10	5	2	10	13	0	21	2	19	0	10	3	1	1	4	50								
MASON	65	3	4	20	5	9	3	10	4	13	3	3	1	5	13	4	7	7	4	15	3	10	0	5	3	4	7	4	7	33							
MCGOFF	66	2	2	23	2	3	8	12	7	26	9	9	1	11	5	3	10	11	0	20	2	19	0	11	2	0	1	6	31	7	52						
MCGRATH	67	2	3	19	2	9	4	12	2	23	5	7	1	9	6	1	11	9	0	18	2	15	0	7	2	1	1	4	15	9	16	43					
MCGUIRE	68	0	3	15	0	5	5	10	6	13	5	9	0	8	5	2	20	8	0	17	0	12	0	8	1	4	1	3	8	6	8	9	28				
MINTZBERG	69	8	4	20	5	8	4	8	2	11	3	0	2	4	14	2	9	2	4	13	1	3	1	3	4	4	2	3	5	10	4	7	3	35			
MITROFF	70	6	4	18	2	9	3	8	4	12	3	3	0	5	8	4	8	7	2	12	2	10	1	5	3	3	4	3	7	25	7	9	6	12	31		
MURPHY	71	1	13	2	0	0	15	0	0	0	0	0	13	3	0	0	0	0	0	14	5	0	22	0	0	16	2	0	0	0	0	0	0	1	1	41	
NEWELL	72	7	2	17	1	3	4	9	3	7	1	0	1	1	14	3	4	3	4	10	2	5	1	1	1	4	4	2	0	6	1	3	3	9	7	1	33
NUNAMAKER	73	5	17	55	3	18	21	29	19	66	23	18	5	25	19	11	23	34	4	68	6	48	4	25	4	12	3	18	35	19	36	29	18	15	18	6	9
PAYNE	74	17	1	9	1	2	1	12	1	0	0	0	1	2	9	5	1	1	0	3	4	0	0	2	1	0	3	2	1	2	1	2	0	4	3	0	10
PINSONNEAULT	75	0	3	21	0	6	4	14	2	21	9	11	0	4	6	2	11	12	0	15	1	28	0	4	2	1	1	1	12	5	11	11	10	2	5	0	1
POOLE	76	2	8	31	1	12	7	24	6	36	11	12	0	17	9	3	16	19	3	27	3	30	0	16	2	6	2	7	18	10	19	21	13	9	10	0	4
RAIFFA	77	9	3	11	0	2	13	5	12	1	0	2	3	0	10	29	2	5	1	8	2	7	1	0	4	3	1	1	2	4	3	0	1	4	6	1	8
RAISINGHANI	78	7	1	12	2	7	2	5	1	7	1	0	1	2	6	2	4	2	3	8	1	2	1	2	0	3	2	0	1	9	1	3	3	23	11	1	8
RAOVS	79	0	4	24	1	8	5	27	6	21	7	13	0	9	6	2	12	14	1	21	1	21	0	8	1	6	2	3	12	6	12	12	10	3	6	0	1
REMUS	80	7	2	11	5	0	0	11	0	2	1	1	0	1	13	0	1	2	8	5	13	2	0	1	3	2	8	2	1	4	1	1	1	1	2	1	5
ROCKART	81	1	3	18	10	1	3	4	4	6	4	0	1	2	15	0	2	3	6	7	0	3	0	2	2	2	5	3	2	6	1	2	0	13	3	0	7
SANDERS	82	2	1	15	9	0	3	3	3	1	1	0	1	2	17	1	1	2	8	4	6	1	1	1	2	5	9	2	0	5	0	0	1	1	3	1	3
SCOTT MORTON	83	9	19	29	8	3	12	13	7	6	4	4	5	2	54	7	3	6	10	17	6	7	1	2	7	6	6	9	4	7	3	4	2	12	5	1	7
SHARDA	84	3	4	16	3	2	2	10	3	3	0	4	1	1	14	2	3	4	7	6	5	4	0	1	3	3	3	1	3	2	2	3	3	4	2	2	2
SHAWME	85	0	3	8	1	2	3	5	2	16	2	3	0	7	2	1	7	5	0	15	1	8	0	5	1	3	1	1	10	7	10	11	5	4	6	0	2
SIMON	86	21	15	44	11	8	15	16	8	18	5	3	7	6	46	6	9	6	14	28	9	11	8	5	5	11	12	7	6	12	7	9	5	23	13	7	34
SLOVIC	87	14	4	12	4	5	3	7	3	3	0	0	2	2	9	3	1	1	4	4	4	0	0	2	2	3	7	2	1	4	1	4	0	7	5	0	9
SPRAGUE	88	11	35	41	10	3	17	16	16	12	3	4	7	7	64	6	5	14	15	29	15	10	6	7	15	18	10	7	7	6	6	7	4	9	4	6	9
STEEB	89	0	3	19	0	6	7	13	5	18	6	21	0	5	5	2	9	13	0	16	2	17	0	5	1	2	1	4	11	4	9	7	9	0	3	0	1
STEFIK	90	3	10	18	1	5	10	10	9	18	9	5	5	30	9	1	9	15	1	22	2	16	2	30	3	5	1	11	11	5	12	7	8	4	5	2	2
STOHR	91	2	18	10	1	0	22	1	6	0	1	1	13	1	12	3	2	1	3	19	10	1	23	1	4	18	4	1	1	3	1	1	1	1	4	31	3
SUCHMAN	92	2	6	17	1	4	7	9	8	16	8	4	1	30	6	0	9	15	1	19	1	16	0	29	2	4	2	11	10	5	11	7	8	4	5	0	1
THEORET	93	7	1	12	2	7	2	5	1	7	1	0	1	2	6	2	5	2	3	8	1	2	1	2	0	3	2	0	1	9	7	3	3	23	11	1	8
TODD	94	9	1	8	4	2	0	15	1	1	0	0	0	1	8	3	0	1	4	2	4	1	0	0	0	0	4	1	0	0	0	0	0	3	0	0	8
TURBAN	95	6	22	20	7	2	11	4	7	4	1	1	6	3	32	4	1	4	10	13	7	4	5	3	8	7	6	8	2	5	2	2	1	7	2	3	4
TUROFF	96	0	4	31	2	8	8	13	6	32	11	12	0	12	10	2	16	19	4	30	2	28	0	12	2	3	3	9	18	9	19	11	14	6	8	0	4
TVERSKY	97	20	6	13	2	6	5	10	4	3	0	0	5	1	9	7	2	0	2	6	4	0	2	1	2	5	4	1	2	4	2	3	1	8	4	2	10
VALACICH	98	1	2	25	1	9	6	14	5	44	12	9	0	11	7	1	15	13	4	22	0	24	0	10	2	1	0	6	21	10	21	20	11	9	10	0	1
VAN DE VEN	99	4	1	21	3	10	3	13	4	20	4	7	0	5	9	2	10	8	3	14	2	13	0	4	1	3	6	1	7	10	7	14	9	4	10	0	1
VOGEL	100	5	7	57	7	14	15	29	18	64	21	20	2	24	21	6	21	30	6	45	6	45	0	23	6	5	4	16	34	18	36	29	17	12	17	0	8
WATKINS	101	2	14	11	2	0	7	3	4	2	1	1	1	2	14	2	1	4	3	6	3	4	1	2	3	5	3	6	1	3	1	2	1	3	2	1	2
WATSONH	102	0	16	25	11	2	4	5	1	5	3	0	3	2	32	0	3	5	11	10	9	5	2	2	7	10	5	2	2	7	1	2	1	11	3	2	5
WATSONR	103	0	7	29	0	10	7	20	6	29	9	13	1	9	7	2	13	20	1	26	4	26	0	9	3	5	1	5	13	9	14	17	11	4	9	0	4
WHINSTON	104	6	62	27	2	3	24	7	12	7	1	2	14	7	34	5	3	9	7	31	7	7	15	8	8	22	2	7	4	7	3	3	3	6	6	15	3
ZIGURS	105	1	5	24	2	12	7	20	6	25	8	14	0	9	8	1	9	18	3	19	2	24	0	9	1	5	2	3	13	7	11	15	8	4	7	0	1
ZMUD	106	3	4	20	12	3	3	11	3	4	0	2	0	2	20	1	4	3	12	8	3	2	0	2	2	3	12	2	2	7	2	2	3	9	4	0	6
Author number		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	68	69	70	71	72

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JONES, C.V.	48																																			
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KEEN	50																																			
KEENEY	51																																			
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KINGW	54																																			
KONSYNSKI	55																																			
KOTTEMANN	56																																			
KRAEMER	57																																			
KRISHNAN	58																																			
LANNING	59																																			
LEE, S.M.	60																																			
LIANG	61																																			
LUCAS	62																																			
MALONE	63																																			
MARTZ	64																																			
MASON	65																																			
MCGOFF	66																																			
MCGRATH	67																																			
MCGUIRE	68																																			
MINTZBERG	69																																			
MITROFF	70																																			
MURPHY	71																																			
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SANDERS	82	3	2	1	0	1	1	1	1	5	7	24																								
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SHARDA	84	2	4	4	4	4	2	3	4	7	2	4	7	23																						
SHAWME	85	2	19	0	6	9	1	3	5	1	1	0	1	1	27																					
SIMON	86	34	26	15	6	12	12	16	3	13	9	9	25	10	5	64																				
SLOVIC	87	9	5	11	0	6	7	5	2	5	2	3	7	1	0	18	26																			
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STEEB	89	1	20	0	11	12	2	0	13	2	1	1	4	4	5	6	0	6	32																	
STEFIK	90	2	26	2	4	17	2	3	8	1	2	1	4	1	5	9	3	11	6	47																
STOHR	91	3	9	0	0	1	5	1	0	4	3	3	6	3	1	12	1	17	1	3	38															
SUCHMAN	92	1	25	2	4	16	0	2	8	1	2	1	2	1	5	6	3	7	5	29	1	44														
THEORET	93	8	8	3	1	6	4	23	1	1	4	1	4	3	3	16	5	3	0	3	1	2	31													
TODD	94	8	1	12	1	2	3	3	0	5	1	1	7	5	0	11	6	5	0	0	0	0	3	24												
TURBAN	95	4	11	3	1	3	5	2	1	6	10	6	25	3	1	18	5	37	3	7	8	3	2	3	49											
TUROFF	96	4	40	0	15	21	2	3	12	2	2	2	5	2	11	14	1	7	13	13	1	13	3	2	2	60										
TVERSKY	97	10	8	15	0	4	11	6	2	6	2	1	7	5	1	23	19	10	0	3	2	2	6	9	4	1	31									
VALACICH	98	1	52	0	16	27	1	6	14	1	1	0	3	3	12	12	1	5	9	10	0	10	6	1	0	21	1	77								
VAN DE VEN	99	1	24	4	11	13	2	3	10	4	0	3	4	3	8	9	5	7	7	4	1	4	3	2	1	15	6	13	38							
VOGEL	100	8	89	3	23	42	8	7	24	4	9	6	12	4	17	24	7	19	21	24	3	23	7	3	8	39	6	51	22	120						
WATKINS	101	2	3	0	1	3	3	1	1	2	2	2	8	1	0	11	2	18	2	4	6	2	1	1	21	2	1	0	0	3	30					
WATSONH	102	5	11	0	2	5	1	3	2	8	21	10	21	4	1	14	3	34	1	2	9	2	3	1	21	3	1	2	2	8	6	46				
WATSONR	103	4	36	0	16	32	2	3	20	2	2	2	4	4	7	7	1	9	13	10	1	9	3	1	2	16	1	21	12	33	2	3	53			
WHINSTON	104	3	22	1	3	9	5	3	4	4	5	4	23	5	4	29	5	48	5	12	22	7	3	1	28	4	7	3	1	11	20	20	7	90		
ZIGURS	105	1	28	1	16	30	2	2	20	1	2	1	5	4	5	6	5	5	14	10	0	9	2	2	3	13	3	15	11	27	2	4	23	6	48	
ZMUD	106	6	5	3	1	5	1	4	3	8	9	8	10	4	2	13	7	12	2	2	4	2	4	5	12	4	3	3	6	6	4	14	2	5	5	29
Author number		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106

APPENDIX B

Publications receiving 15 or more citations by co-citing factor (82 articles and 25 books).

Factor 1: Group DSS (21 articles and 4 books)

58. Benbasat I, Nault BR (1990) An evaluation of empirical research in management support systems. *Decision Support Systems 6*, No. 1, 203–226 (21 citations).

59. Connolly T, Jessup LM and Valacich JS (1990) Effects of anonymity and evaluative tone on idea generation in computer-mediated groups. *Management Science 36*, 689–703 (28 citations).

60. Dennis AR, George JF, Jessup LM, Nunamaker JF Jr. and Vogel DR (1988) Information technology to support electronic meetings. *MIS Quarterly 12*, No. 4, 591–624 (56 citations).

61. Dennis AR, Heminger AR, Nunamaker JF Jr. and Vogel DR (1990) bringing automated support to large groups: the burr-brown experience. *Information and Management 18*, No. 3, 111–121 (21 citations).

62. DeSanctis G and Gallupe B (1987) A foundation for the study of group decision support systems. *Management Science 33*, No. 5, 589–609 (80 citations).

63. DeSanctis G and Gallupe B (1985) Group decision support systems: a new frontier. *Data Base 16*, No. 2, 3–10 (20 citations).

64. Diehl M and Stroebe W (1987) Productivity loss in brainstorming groups: toward the solution of a riddle. *Journal of Personality and Social Psychology 53*, No. 3, 497–509 (18 citations).

65. Gallupe RB, DeSanctis GL and Dickson GW (1988) computer-based support for group problem finding: an experimental investigation. *MIS Quarterly 12*, No. 2, 277–298 (32 citations).

66. Huber GP (1984) Issues in the design of group decision support systems. *MIS Quarterly 8*, No. 3, 195–204 (44 citations).

67. Jarke M, Jelassi MT and Shakun MF (1987) MEDIATOR: toward a negotiation support system. *European Journal of Operational Research 31*, No. 3, 314–334 (16 citations).

68. Jarvenpaa SL, Rao VS and Huber GP (1988) Computer support for meetings of groups working on unstructured problems: a field experiment. *MIS Quarterly 12*, No. 4, 645–665 (23 citations).

69. Johansen R (1989) *Groupware: Computer Support for Business Teams*. The Free Press, New York (18 citations).

70. Kraemer KL and King JL (1988) Computer-based systems for cooperative work and group decision making. *ACM Computing Surveys 20*, No. 2, 115–146 (25 citations).

71. McGrath JE (1984) *Groups: Interaction and Performance*. Prentice-Hall, Englewood Cliffs, NJ (32 citations).

72. Nunamaker JF Jr., Applegate LM and Konsynski BR (1988) Computer-aided deliberation: model management and group decision support. *Operations Research 36*, No. 6, 826–848 (18 citations).

73. Nunamaker JF Jr., Applegate LM and Konsynski BR (1987) Facilitating group creativity: experience with a group decision support system. *Journal of Management Information Systems 3*, No. 4, 5–19 (16 citations).

74. Nunamaker JF Jr., Dennis AR, Valacich JS, Vogel DR and George JF (1991) Electronic meeting systems to support group work. *Communications of the ACM 34*, No. 7, 40–61 (29 citations).

75. Nunamaker JF Jr., Vogel DR, Heminger A, Martz B, Grohowski R and McGoff C (1989) Experiences at IBM with group support systems: a field study. *Decision Support Systems 5*, No. 2, 183–196 (20 citations).

76. Osborn A (1954) *Applied Imagination*. Scribner's, New York (18 citations).

77. Pinsonneault A and Kraemer KL (1989) The impact of technological support on groups: an assessment of the empirical research. *Decision Support Systems 5*, No. 2, 197–216 (15 citations).

78. Steeb R and Johnston SC (1981) A computer-based interactive system for group decision making. *IEEE Transactions on Systems, Man, and Cybernetics 11*, No. 8, 544–552 (19 citations).

79. Steiner ID (1972) *Group Process and Productivity*. Academic Press, New York (16 citations).

80. Turoff M and Hiltz SR (1982) Computer support for group versus individual decisions.

IEEE Transactions on Communications 30, No. 1, 82–92 (22 citations).

81. Watson R, DeSanctis G, and Poole MS (1988) Using a GDSS to facilitate group consensus: some intended and unintended consequences. *MIS Quarterly 12*, No. 3, 463–478 (27 citations).

82. Zigurs I, Poole MS and DeSanctis G (1988) Study of influence in computer-mediated group decision making. *MIS Quarterly 12*, No. 4, 625–644 (21 citations).

Factor 2: Model management (7 articles and 2 books)

83. Bonczek RH, Holsapple CW and Whinston AB (1981) *Foundations of Decision Support Systems*. Academic Press, New York (49 citations).

84. Dolk DR and Konsynski BR (1984) Knowledge representation for model management systems. *IEEE Transactions on Software Engineering 10*, No. 6, 619–628 (19 citations).

85. Dutta A and Basu A (1984) An artificial intelligence approach to model management in decision support systems. *IEEE Computer 17*, No. 7, 89–97 (15 citations).

86. Geoffrion AM (1987) An introduction to structured modeling. *Management Science 33*, No. 5, 547–589 (43 citations).

87. Jones C (1990) An introduction to graph-based modeling systems, part I: overview. *ORSA Journal on Computing 2*, No. 2, 136–151 (15 citations).

88. Krishnan R (1990) A logic modeling language for automated model construction. *Decision Support Systems 6*, No. 3, 123–152 (16 citations).

89. Muhanna W and Pick R (1988) Composite models in SYMMS. *Proceedings of the 21st HICSS*, IEEE Computer Society Press II pp. 418–427 (16 citations).

90. Murphy FH and Stohr EA (1986) An intelligent system for formulating linear programs. *Decision Support Systems 2*, No. 1, 39–47 (24 citations).

91. Saaty TL (1980) *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. McGraw-Hill, New York (21 citations).

Factor 3: Implementation (3 articles and 1 book)

92. Alter SL (1980) *Decision Support Systems: Current Practice and Continuing Challenges*. Addison-Wesley, Reading, MA (26 citations).

93. Houdeshel G and Watson H (1987) The management information and decision support (MIDS) system at Lockheed-Georgia. *MIS Quarterly 11*, No. 1, 127–140 (15 citations).

94. Sanders GL and Courtney JF (1985) A field study of organizational factors influencing DSS success. *MIS Quarterly 9*, No. 1, 77–93 (16 citations).

95. Sharda R, Bar SH, McDonnell JC (1988) Decision support system effectiveness: a review and empirical test. *Management Science 34*, No. 2, 139–159 (20 citations).

Factor 4: Design (11 articles and 2 books)

96. Aldag RJ and Power DJ (1986) An empirical assessment of computer-assisted decision analysis. *Decision Sciences 17*, No. 4, 572–588 (17 citations).

97. Ariav G and Ginzberg MJ (1985) DSS design: a systemic view of decision support. *Communications of the ACM 28*, No. 10, 1045–1052 (17 citations).

98. Cats-Bail WL and Huber GP (1987) Decision support systems for ill-structured problems: an empirical study. *Decision Science 18*, No. 3, 350–372 (16 citations).

99. Daft RL and Lengel RH (1986) Organizational information requirements, media richness, and structural designs. *Management Science 32*, No. 5, 554–571 (16 citations).

100. Eom HB and Lee SM (1990) Decision Support systems applications research: a bibliography (1971–1988). *European Journal of Operational Research 46*, No. 3, 333–342 (15 citations).

101. Eom HB and Lee SM (1990) A survey of decision support system applications (1971-April 1988). *Interfaces 20*, No. 3, 65–79 (15 citations).

102. Gorry GA and Scott Morton MS (1971) A framework for management information systems. *Sloan Management Review 13*, No. 1, 55–70 (26 citations).

103. Keen PGW (1981) Value analysis: justifying decision support systems. *MIS Quarterly 5*, No. 1, 1–16 (23 citations).

104. Keen PGW and Scott Morton MS (1978) *Decision Support Systems: An Organizational Perspective*. Addison-Wesley, Reading, MA (49 citations).

105. Turban E and Watkins PR (1986) Integrating expert systems and decision support systems. *MIS Quarterly 10*, No. 2, 121–136 (16 citations).

106. Silver MS (1990) Decision support systems: directed and nondirected change. *Information Systems Research 1*, No. 1, 47–70 (18 citations).

107. Sprague RH Jr. (1980) A framework for the development of decision support systems. *MIS Quarterly 4*, No. 4, 1–26 (32 citations).

108. Sprague RH and Carlson ED (1982) *Building Effective Decision Support Systems*. Prentice-Hall, Englewood Cliffs, NJ (74 citations).

Factor 5: Cognitive science (4 books)

109. Newell A and Simon HA (1972) *Human Problem Solving*. Prentice-Hall, Englewood Cliffs, NJ (29 citations).

110. Payne JW (1976) Task complexity and contingent processing decision making: an information search and protocol analysis. *Organizational Behavior and Human Performance 16*, No. 2, 366–387 (15 citations).

111. Simon HA (1960) *The New Science of Management Decision*. Harper and Row, New York, NY (29 citations).

112. Tversky A and Kahneman D (1982) *Judgment Under Uncertainty: Heuristics and Biases*. Cambridge University Press, London pp. 1124–1131 (15 citations).

Factor 6: Unnamed factor (1 article)

113. Stefik MG, Foster DG, Bobrow K, Khan K, Lanning S and Suchman L (1987) Beyond the chalkboard: computer support for collaboration and problem solving in meetings. *Communications of the ACM 30*, No. 1, 32–47 (27 citations).

Factor 7: Organizational science (1 article and 2 books)

114. Mintzberg H, Raisinghani D and Theoret A (1976) The structure of "unstructured" decision processes. *Administrative Science Quarterly 21*, No. 2, 246–275 (19 citations).

115. Mason RO and Mitroff II (1981) *Challenging Strategic Planning Assumption*. John Wiley and Sons, New York (15 citations).

Factor 8: Multiple criteria decision making (1 book)

116. Keeney RL and Raiffa H (1976) *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. John Wiley and Sons, New York (27 citations).

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