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Mapping the intellectual structure of research in decision support systems through author cocitation analysis (1971–1993)

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Abstract

This study applies factor analysis of an author cocitation frequency matrix derived from a database file that consists of a total of 23,768 *cited* reference records taken from 944 *citing* articles. Factor analysis extracted eleven factors consisting of six major areas of DSS research (group DSS, foundations, model management, interface systems, multicriteria DSS, and implementation) and five contributing disciplines (multiple criteria decision making, cognitive science, organizational science, artificial intelligence, and systems science). This research provides hard evidence that the decision support system has made meaningful progress over the past two decades and is in the process of solidifying its domain and demarcating its reference disciplines. Especially, much progress has been made in the subareas of model management such as representation, model base processing, model integration, and artificial intelligence application to model management leading towards the development of a theory of models. To facilitate the transition from the pre- to post-paradigm period in DSS research, this study has completed important groundwork.

Keywords: Decision support systems; Intellectual structure; Bibliometrics; Cocitation analysis; Factor analysis

1. Introduction

Since the term "decision support systems" (DSS) was coined in the early 1970s, DSS has been challenged and criticized. A notable criticism came from Naylor ([46], p. 94), who said that "DSS is not based on any formal conceptual framework, and this lack casts serious doubts on its substantive underpinning" and DSS "exists primarily in the minds of academic visionaries." In a reply to Naylor, Blanning ([6], p. 76) stated that "If DSS is a response to a change in the real world of information processing for which new research is required, it will survive temporary exuberance, and if not, the exuberance will bring it to an end quickly." Further, he suggested that the DSS area "must establish a research tradition that identifies researchable questions (that is, questions that both respond to the changes that are taking place in the market for information services and that are amenable to research)." Since then, a growing amount of research in the area of DSS over the past two decades has been reported (e.g., [21,27–29,33,57]).

More than 10 years ago, Peter Keen [38] stated that management information systems (MIS) re-

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search lacked a cumulative tradition. In his view, there was virtually no cumulative research tradition in the MIS area without "continued follow-up on interesting lines of inquiry." He defined a cumulative research tradition as one where researchers build on each other's and their own previous work and where definitions, topics and concepts are shared ([38], p. 13). As such, 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.

A number of studies have been conducted to assess the extent of progress towards building a cumulative research tradition in the DSS area. They include identification of leading institutions [22–24,26], faculty [23,24], and journals for DSS research [48]. Furthermore, curriculum trends and commercial products also reflect on the tradition.

Eom, Lee, and Kim [23] conducted an initial study to identify the intellectual structure of DSS, using factor analysis and multidimensional scaling of author cocitation analysis. Their study identified 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 tradition and intellectual structure.

This study overcomes the weakness of the earlier study by expanding the number of citing articles from 259 application articles to 944 articles. This study fosters a better understanding of the intellectual structure of the field by means of an empirical assessment of the DSS literature. Using factor analysis of author co-citation analysis, this study aims at:

(i) identifying the intellectual structure, research tradition, reference disciplines, and major themes in current DSS research;

(ii) identifying diffusion of ideas represented by these DSS research subfields to other disciplines or vice versa; and

(iii) providing important groundwork for future theoretical development in the DSS area and for future scientific inquiry.

2. Data

A database file was created consisting of a total of 23,768 *cited* reference records taken from the 944 *citing* articles in the DSS area over the past 23 years (1971–1993). Of these 944 articles 472 are collected from the following sources: 210 articles over the period of 1975 through 1985 from [21]; 157 articles over the period of 1969 through 1987 from [55]; 203 articles over the period of 1971 through 1988 from [28]. The additional 472 articles are included to cover the period the other articles did not cover, taken from the same source journals and selected using same selection criteria used by the three source articles [21,28,55].

Eom and Lee [28] used the following three criteria in deciding which papers to include in their survey of specific DSS applications. The article could be characterized as: (1) a description of a semistructured or unstructured decision; (2) a description of the human–computer interface and the nature of the computer-based support for decision makers' intuitions and judgements; and (3) a description of the data-dialogue-model system. The selection criteria of Elam, Huber, and Hurt [21] applied in the case of non-application articles. They selected an article 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. Sprague and Watson ([55], p. 403) chose 157 publications because they felt the chosen publications were "the most important, interesting, and accessible materials on DSS."

The following 16 journals represent 85% of the source articles. They are *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, Information Systems Research, Interfaces, Journal of MIS, Journal of Systems Management, Management Science, MIS Quarterly, Omega, Operations Research*, and *Sloan Management Review*. The other 15% of source articles come from 66 other journals including *Harvard Business Review, Academy of Management Review*, and *Academy of Management Journal*. Table 1 lists these 19 journals and the number of citing articles in each journal.

3. Research methodology

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" ([45], p. 111) (For an indepth overview and discussion of the continuing relevance of this topic, see [44,58]).

An important purpose of this study is an overall examination of the intellectual structure of the DSS area and the contributing disciplines. In doing so, it is critical to establish a diversified list of authors. McCain ([44], p. 433) states:

In the aggregate, this author set *defines* the scholarly landscape being mapped. If the authors are not chosen to capture the full range of variability in subject specializations, methodologies, political orientations, etc., these aspects of structure can not be determined.

To accurately and objectively examine the intellectual structure of the DSS field, the present study avoids personal judgment in selecting authors by objectively counting the frequency of each name from the data base file. To better understand the raw cocitation matrix used in this study, let's closely examine Tables 2 and 3, using

Table 1
A list of journals publishing citing articles

Journals	No. of citing articles	Proportion %	Cumulative %
Decision Support Systems	177	18.75	18.75
Interfaces	102	10.80	29.55
Information & Management	81	8.58	38.13
MIS Quarterly	72	7.62	45.76
Journal of MIS	64	6.78	52.54
Decision Sciences	48	5.08	57.63
EJOR	43	4.56	62.18
Management Science	40	4.24	66.42
IEEE Transactions on S, M, and C	37	3.92	70.34
Operations Research	32	3.39	73.73
Data Base	31	3.28	77.01
Omega	25	2.65	79.66
Communications of the ACM	18	1.91	81.57
Information Systems Research	15	1.58	83.16
Journal of Systems Management	11	1.17	84.32
Sloan Management Review	10	1.06	85.38
Harvard Business Review	5	0.53	85.91
Academy of Management Review	4	0.42	86.33
Academy of Management Journal	3	0.32	86.65
63 other Journals	126	13.35	100.00
Total	944	100.00	

IEEE Transactions on S, M, and C and *EJOR* stand for *IEEE Transactions on Systems, Man, and Cybernetics* and *European Journal of Operational Research*, respectively.

Table 2
References of citing papers

Refer. of paper #1	Refer. of paper #2	Refer. of paper #3
Ackoff	Ackoff	Ackoff
Bonczek	Ackoff	Ackoff
Bonczek	Applegate	Blanning
Blanning	Applegate	
Blanning	Whinston	
Blanning		
Whinston		

a hypothetical case of simplified sample cocitation matrix drawn from three citing reference papers which contain a total of 18 cited references as shown in Table 2. There is a difference in computing frequencies between the off-diagonal cells and the diagonal cells. The off-diagonal cells are filled with raw cocitation frequencies of row and column authors. In Table 3, the cell value 1 at the intersection of the first column (Ackoff) and the second row (Applegate) is the total cocitation count between these two authors that appeared in the citing paper shown in Table 2.

The term "author" in author cocitation analysis is neither an individual nor individuals. It refers to a body of writings by a person. Applying that definition, notice that the intersecting cell between the Ackoff column and the Applegate row in Table 3 contains a value of only "1" to indicate the frequency with which Ackoff's body of research is linked to Applegate's research, despite the fact that citing paper #2 contains two articles by each.

The underscored values of the diagonal cells were computed using the adjusted value approach, taking the three highest intersections for each author and dividing by two. [1] For example, the value of the diagonal cell (column 1, row 1) is computed by summing the three highest intersections involving the diagonal cell's row or column (2 + 2 + 1), and dividing by 2.

There are no structured ways of finding a candidate list of authors. McCain ([44], p. 435) discussed several different approaches to compiling a predetermined list of authors such as personal knowledge, consultation with researchers in the area to be studied, directories, etc. 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 (e.g., nine for 10 years of Social Scisearch [44] 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 citation and cocitations in initial retrieval trials.

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 term of size of records. Besides, the cocitation matrix generation system we developed gives access to co-authors as *cited* authors. Due to these differences, 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 the simplicity. Applying the mean cocitation criteria to our Lotus worksheet file (the output from the cocitation matrix generation system) involves too many computations. Whenever we delete/add an author to the final author set, we need to compute the mean cocitation rate of

Table 3
Sample cocitation matrix

	Ackoff	Applegate	Bonczek	Blanning	Whinston
Ackoff	*2.5*				
Applegate	1	*1*			
Bonczek	1	0	*2*		
Blanning	2	0	2	*3*	
Whinston	2	1	1	2	*2.5*

[1] In addition to the approach used in this study, McCain [[44], p. 435] discussed two other approaches — substituting the diagonal value with the highest off-diagonal cocitation counts for each author and treating the diagonal cell values as missing data. Her initial results indicate little difference berween these two. We also found little difference between the approach used here and the second approach of using the highest off-diagonal cell value.

each author again. Using the cocitation rate of 25 with himself/herself in the period (1971–1993), the initial set of 150 authors was reduced to 113 as the final author set for further analysis.

The raw cocitation matrix [2] of 113 authors is analyzed by the factor analysis program of SAS (statistical analysis systems) to ascertain the underlying structure of DSS research subspecialties. Through factor analysis of author cocitation frequency matrix, our aim is to group (condense) 113 selected variables (authors) into a smaller set of composite dimensions (factors) representing DSS research subspecialties and contributing disciplines. In doing so, each variable (cocitation frequency) is viewed as a dependent variable that is a function of a set of latent (underlying) factors. Factor loadings represent the correlations between the original variables and the underlying factors. An eigenvalue (latent root or extracted variance) represents the amount of common variance accounted by a factor. The percentage of total variation is an index to determine how the variables in each factor are related to each other. A high percentage variance means a high degree of interrelatedness among the variables with significant loadings.

Principal component analysis with the latent root criterion (eigenvalue 1 criterion) is applied to obtain the initial solution of 13 factors. The PROMAX rotation specification provides both orthogonal and oblique rotations with only one invocation of PROC FACTOR [52]. Out of the two major rotation options, this study chose an oblique rotation method. Compared to an orthogonal rotation method, the oblique factor rotation is "more desirable because it is theoretically and empirically more realistic" ([32], p. 245). It allows a more natural rotation without the imposition of orthogonal factors. Moreover, it generates additional information about the correlations between the factors.

The scree tail test indicates that only the first ten factors should be qualified. The scree tail test is an approach suggested by Cattell [7] to decide the optimum number of factors that can be extracted. 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 [32].

In addition to the two criteria of latent root and scree test, the ability to assign some meaning to the factors is an important consideration to finalize the optimum number of factors. For oblique rotation-based factor solutions, proper interpretation of a set of factors needs to examine the factor pattern (the weight matrix to calculate variable standard scores from factor standard scores), the factor structure (the correlations of the variables with the factors, and the reference structures (the correlations between the variables and the factors when the variance attributable to all other factors has been removed). Based on careful examinations of all three matrices, eleven factors resulted. The eleven extracted factors account for 84.97 percent of the total variances of the data set.

4. Results

Factor analysis extracted eleven factors consisting of six major areas of DSS research (group DSS, foundations, model management, interface systems, multicriteria DSS, and implementation) and five contributing disciplines (multiple criteria decision making, cognitive science, organizational science, artificial intelligence, and systems science). Table 4, Table 5, Tables 6 and 7 present the rotated factor structure (correlations) of the eleven-factor solution and all authors in each factor with factor loading at 0.40 or higher. The factor structure (correlations) is the matrix of correlations between variables and common factors. The larger the size of the correlation coefficients, the more significant the loading is in interpreting the factor matrix.

Tables 4—7 also show variance and percent of total variance (% variance) explained by each factor ignoring the effects of all other factors. Each of these variances is the sum of the squared elements of the correlations coefficients of each

[2] The cocitation matrix will be furnished upon request through email (C047BUM@SEMOVM.SEMO.EDU).

Table 4
Rotated factor structure (correlations) matrix (rotation method: oblique; number of factor = 11)

Factor 1 Group DSS		Factor 2 Foundations		Factor 3 Interfaces	
Gallupe	0.952	Keen	0.949	Lucas	0.926
R. Watson	0.947	Scott-Morton	0.937	Benbasat	0.925
Steeb	0.946	Alter	0.935	Dexter	0.912
Hiltz	0.944	Sprague	0.925	Lusk	0.908
Poole	0.942	Carlson	0.923	Zmud	0.897
Turoff	0.942	H. Watson	0.863	Ives	0.884
Zigurs	0.939	Ginzberg	0.853	Chervany	0.871
Vogel	0.932	Bennett	0.849	Bariff	0.831
Kraemer	0.929	Meador	0.835	Robey	0.817
J. King	0.927	Little	0.832	Remus	0.812
Applegate	0.923	Gorry	0.833	Huysmans	0.789
George	0.923	Donovan	0.819	Swanson	0.774
F. Lewis	0.922	Simon	0.812	Dickson	0.723
J. McGrath	0.921	Naylor	0.790	W. King	0.719
Jessup	0.920	Hackathorn	0.784	G. Davis	0.666
DeSanctis	0.919	W. King	0.778	Mason	0.665
Dennis	0.918	Wagner	0.775	Alavi	0.660
M.E. Shaw	0.915	Anthony	0.773	Mitroff	0.636
Nunamaker	0.907	Turban	0.767	M. Olson	0.635
Valacich	0.896	Stabell	0.757	Todd	0.626
Hackman	0.895	Rockart	0.731	Sanders	0.622
Beauclair	0.876	Ariav	0.727	Courtney	0.622
Connolly	0.872	Alavi	0.715	Keen	0.591
Johansen	0.866	Courtney	0.701	Ginzberg	0.582
Janis	0.853	Henderson	0.688	Simon	0.565
Kull	0.85	McLean	0.686	Mintzberg	0.554
Stefik	0.831	G. Davis	0.670	Scott-Morton	0.543
Delbecq	0.825	Stohr	0.642	Newell	0.533
Van de Ven	0.812	Sanders	0.636	Rockart	0.531
Huber	0.809	Hayes–Roth	0.625	Gorry	0.503
Jarvenpaa	0.791	Whinston	0.617	Hackathorn	0.503
Bui	0.777	Robey	0.611	Sage	0.502
Konsynski	0.72	Zmud	0.610	Ackoff	0.469
Gray	0.717	Sage	0.608	Jarvenpaa	0.469
Dickson	0.696	Bonczek	0.602	Alter	0.46
Daft	0.689	Bariff	0.590	McIntyre	0.454
McIntyre	0.588	Holsapple	0.586	McLean	0.432
Jelassi	0.449	Mintzberg	0.581	Einhorn	0.426
		Elam	0.567	Wagner	0.423
		Lucas	0.559	Sprague	0.421
		R. Davis	0.556	Huber	0.414
		Chervany	0.543	Meador	0.408
		Blanning	0.543	Hogarth	0.403
		Benbasat	0.540		
		Ackoff	0.524		
		M. Olson	0.513		
		Huysmans	0.511		
		Liang	0.503		
		Swanson	0.497		
		Dexter	0.486		
		Newell	0.476		
		Shortliffe	0.471		

Table 4 (continued)

Factor 1 Group DSS		Factor 2 Foundations		Factor 3 Interfaces	
		March	0.426		
		Churchman	0.410		
		Mason	0.407		
		Mitroff	0.402		
Variance	29.416		28.927		20.498
% Variance	26.031		25.599		18.139

Table 5

Rotated factor structure (correlations) matrix (rotation method: oblique; number of factor = 11) (cont.)

Factor 4 Model Management		Factor 5 MCDM		Factor 6 Cognitive Science	
Blanning	0.947	Wallenius	0.923	Einhorn	0.928
Dolk	0.924	Zionts	0.920	Hogarth	0.913
Whinston	0.916	Dyer	0.891	Tversky	0.847
Bonczek	0.915	Keeney	0.886	Todd	0.708
Elam	0.911	Raiffa	0.877	Newell	0.654
Holsapple	0.903	Geoffrion	0.538	Sage	0.560
Stohr	0.875	Jarke	0.490	Remus	0.556
Geoffrion	0.874	Shakun	0.456	Benbasat	0.538
Liang	0.857	Jelassi	0.408	March	0.529
Henderson	0.831			Stabell	0.504
Jarke	0.785			Simon	0.500
Turban	0.683			Lusk	0.444
R. Davis	0.673			Mintzberg	0.426
Konsynski	0.659			Raiffa	0.404
Sprague	0.652			Elam	0.403
Kottemann	0.628				
Carlson	0.627				
Donovan	0.591				
Naylor	0.584				
Simon	0.569				
Hayes-Roth	0.563				
H. Watson	0.547				
Bennett	0.546				
Courtney	0.530				
Buchanan	0.509				
McLean	0.506				
Sage	0.505				
Jelassi	0.501				
Meador	0.487				
Shortliffe	0.486				
Keen	0.475				
Scott-Morton	0.448				
Alter	0.417				
Stabell	0.407				
Ariav	0.399				
Variance	19.233		7.329		9.562
% Variance	17.020		6.485		8.461

Table 6
Rotated factor structure (correlations) matrix (rotation method: oblique; number of factor = 11) (cont.)

Factor 7 A.I.		Factor 8 Org. Science		Factor 9 Systems Science	
Shortliffe	0.966	Cyert	0.851	Mitroff	0.858
Buchanan	0.953	March	0.833	Mason	0.840
R. Davis	0.932	Mintzberg	0.714	Churchman	0.837
Hayes–Roth	0.773	Simon	0.671	Ackoff	0.779
Whinston	0.677	Newell	0.669	Mintzberg	0.621
Holsapple	0.674	Ackoff	0.635	Huysmans	0.563
Bonczek	0.665	G. Davis	0.633	Sage	0.490
Stohr	0.533	Anthony	0.617	Simon	0.484
Bennett	0.532	M. Olson	0.597	Gorry	0.430
Sprague	0.529	Rockart	0.517	Newell	0.428
Naylor	0.525	Churchman	0.511	Scott-Morton	0.428
Turban	0.514	Gorry	0.508	March	0.427
Carlson	0.514	Scott-Morton	0.497	Tversky	0.420
Elam	0.514	Tversky	0.470	Keeney	0.418
Blanning	0.495	Keen	0.467	Chervany	0.406
Donovan	0.494	Mitroff	0.438	Cyert	0.400
Henderson	0.474	Mason	0.425		
Simon	0.460	Daft	0.415		
Jarke	0.460	McLean	0.400		
Keen	0.429				
Scott-Morton	0.429				
Dolk	0.428				
H. Watson	0.421				
Little	0.417				
Meador	0.412				
Geoffrion	0.407				
Stabell	0.406				
Liang	0.402				
McLean	0.402				
Variance	12.158		10.929		10.649
% Variance	10.759		9.671		9.423

factor column. According to McCain ([44], 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 [3].

[3] Some questions may arise as to the potential factors that may influence the result of this study such as the selection of source articles and the selection of authors. Since this study is primarily based on the analysis of author cociation frequency, we believe the most important factor may be to the selection of authors as discussed earlier. The selection of source articles may have negligible impacts.

Factor 1 appears to define *Group DSS*. Since the mid-1980s we have witnessed an emerging DSS research theme: group decision support systems [15,31,40,47] and [61,62,63,64,65,66,67,68, 69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85, 86,87,88,89,90]. Earlier works by Delbecq, Van de Ven, and Gustafson [62] 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 1980's.

Turoff and Hiltz [88] 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.

In the early stages of GDSS development, several descriptive research papers were cornerstones for subsequent GDSS empirical research. Huber [73] provided a comprehensive definition and purposed an architecture of GDSS. Further, alternative GDSS design strategies were examined to conclude that an activity-driven design strategy is superior to either a task-driven or techniques-driven strategy. His analysis of group activities led to another important conclusion that textual and relational information (PERT network, or organizational chart) is relatively more important for GDSS than it is for single user DSS.

Another landmark paper is the result of the work of DeSanctis and Gallupe [63]; it presents an overview of GDSS, discusses the potential impact of GDSS on group processes and outcomes, and proposes a multidimensional taxonomy of GDSS, based on the four dimensions: group size (smaller, larger); member proximity (dispersed, face-to-face); task type (6 types); and GDSS tool type (levels 1, 2, and 3).

Kraemer and King [77] 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, The 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 major comprehensive reviews of empirical GDSS research [3,17,49] and [65]. Dennis et al. [65] identified at least four streams of research under the broader label of experimental GDSS research to compare: Local Area Decision Nets (LADNs) to Decision Rooms, LADNs to no computer support, Decision Rooms to no computer support, and two different configurations of the same Decision Room. Gallupe, DeSanctis and Dickson [67] added one more value of task type (group problem finding) to the dimension III of the GDSS cabinet and conducted an empirical investigation of group problem finding (smaller group, face-to-face, level 1, problem finding). Jarke, Jelassi, and Bui seem to define an important field of GDSS — multiple criteria decision making (MCDM)-model embedded group decision support systems [61]. The next subgroup includes Nunamaker, Applegate, George, Konsynski, and Vogel of the electronic meeting systems research [40] and [65,81]. The taxonomy of EMS environments presented by Dennis et al. [65] added a new time dimension (dimension VI: synchronous and asynchronous meetings) and another value (multiple group sites) to the dimension II of the DeSanctis and Gallupe taxonomy.

Factor 2 seems to represent *Foundations* of DSS [91,92,93,94,95,96,97,98,99,100,101,102,103, 104,105,106,107,108,109,110,111,112,113,114,115, 116,117,118,119,120,121,122,123]. Most authors in this factor conducted descriptive research to provide definitions, concepts, architectures, taxonomies, development and evaluation of DSS. Some authors clearly pinpointed a need for another type of business computing systems to relieve managers' suffering from an "over abundance of irrelevant information" (Ackoff, [91]) and, therefore, Gorry and Scott-Morton [104] claimed that "Information systems should exist only to support decisions." Anthony [95] classified all managerial activities into three categories: strategic planning, management control, and operational control. This taxonomy combined with that of Simon [117] — which classified all decisions into structured, semistructured, and unstructured provided a simple schema for classifying organizational decisions to be best supported by transaction processing systems, MIS, and DSS. Little [113] 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

Table 7
Rotated factor structure (correlations) matrix (rotation method: oblique; number of factor = 11) (cont.)

Factor 10 MCDSS		Factor 11 Implementation	
Jelassi	0.862	Courtney	0.785
Shakun	0.795	Sanders	0.778
Jarke	0.771	Swanson	0.667
Bui	0.639	M. Olson	0.653
Stohr	0.561	Alavi	0.646
Stefik	0.460	Sage	0.641
Turban	0.454	G. Davis	0.634
Liang	0.443	McLean	0.625
Beauclair	0.419	Zmud	0.607
Keeney	0.413	Meador	0.584
Ariav	0.404	Robey	0.583
		Ginzberg	0.572
		Rockart	0.571
		Mintzberg	0.558
		Henderson	0.544
		W. King	0.534
		H. Watson	0.519
		Keen	0.518
		Simon	0.512
		Lucas	0.504
		Ives	0.502
		Ackoff	0.485
		Sprague	0.485
		Ariav	0.477
		Newell	0.469
		Huber	0.463
		Churchman	0.456
		Chervany	0.444
		Carlson	0.434
		Alter	0.427
		Scott-Morton	0.422
		Hackathorn	0.413
		Stabel	0.399
Variance	8.220		13.735
% Variance	7.274		12.154

characteristics for DSS (*simple, robust, easy to control, adaptive, complete on important issues, easy to communicate with*). Sprague and Carlson [119] examined the necessity of including decision models in an integrated MIS and emphasized that there is a need for a systematic way of embedding decision support models into MIS to support managers' decision making processes.

Keen and Scott-Morton [106] 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 judgment; and improve the effectiveness of decision making rather than its efficiency." Most founding fathers of DSS areas including Keen and Scott-Morton have provided a set of filing cabinets with many drawers. Three sets of filing cabinets (of design, implementation, and evaluation of DSS from an organizational perspective) were provided by Keen and Scott-Morton [106]. Sprague and Calson [119] added several important cabinets of data, model, dialogue, and decision makers, which can be termed a DSS architecture. In addition, Sprague [120] created another cabinet that stores an important and widely accepted definition and concept termed specific decision support systems.

Through the analysis of 56 implemented specific DSS, Alter [92,93,94] classified all DSS into seven distinct types and added several folders into the implementation drawers: patterns, risk factors, and strategies of DSS implementations. In the early 1980s, Wagner ([123], p. 77) maintained that "If the DSS concept has a valid core, it must be secured against adulteration and overburdening by *evidence drawn from actual practice*" and the valid core of the DSS concept is to provide "interactive support for the thought processes of one or more executives in their principal function of making decisions." Others suggested theoretical models. King and Rodriguez [112] suggested an evaluation process model for evaluating MIS and DSS, which measures attitude, value perception, information usage, and decision performance in every stage of the system development life cycle in a simulated environment.

Several of these authors began to conduct empirical studies in an attempt to build a DSS theory. Among them, Ginzberg's earlier work [30], 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 DSS should be viewed in the broader context of organizational change. Therefore 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. Sanders and Courtney [51] 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) on DSS implementations.

The third factor that emerged in this study is *User Interface/Individual Differences* [124,125, 126,127,128,129,130,131,132,133,134,135,136,137, 138,139,140,141]. The initial investigation of this topic was begun by the earlier work of Mason and Mitroff [138], who hypothesized that "What is 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" ([138], p. 478). Bariff and Lusk [124] 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 users' cognitive styles. Benbasat and Dexter [127,128] 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" ([127], p. 8).

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). They include Chervany and Dickson [129] and Dickson et al. [131]: comparison of the decision impacts of detailed reports with summarized reports; Lusk and Kersnick [135], Lucas and Nielson [136], and Lucas [137]: comparison of tabular with graphics; and DeSanctis [130]: comprehensive investigation of previous research in this area up to 1984.

Despite the numerous previous research reports, results are confusing and inconclusive: "the extravagant claims favoring graphic presentation formats may be considerably overstated" ([34], p. 21), "a picture may *not* be worth a thousand words" ([130], p. 482) and there are no differences between tabular and graphical reports in terms of decision quality [128]. Jarvenpaa, Dickson and DeSanctis [134] argued that numerous equivocal findings could be attributable to the various tasks used in these experiments and the match between the task and presentation method as well as the lack of a sound taxonomy for classifying data extraction tasks. They recommended the development of some type of taxonomy of tasks as a basis of interpreting the impact of the graphical presentation format.

After over a decade of cognitive styles and individual difference research, Huber ([133], 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."

Very recently Tan and Benbasat [56] have provided taxonomies for classifying various tasks and for classifying information presentation methods and concluded that "the task and presentation notion of matching provides a way to explain the conflicting results by showing that information presentation methods can not be evaluated outside the given task context in which they are applied" ([56], p. 168).

Factor 4 appears to represent *Model Management* [142,143,144,145,146,147,148,149,150,151, 152,153,154]. 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 [5]. In the model structure and representation area, the structured modeling approach by Geoffrion [151] 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 [148,152] developed the model abstraction structure for representing models as a feasible basis for developing model management systems. Dolk [19] attempts to connect both artificial intelligence and database management to evolve a theory of model management via model integration relying heavily upon the relational database theory. In the model processing area, Blanning [143] 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, Holsapple, and Whinston [144,145,146,147] suggested the use of artificial techniques for determining how models and data should be integrated in response to a user query. Elam, Henderson and Miller [149] 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. 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 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."

Dolk and Kotteman [19] further believe that model management needs to see some effective implementations, much like relational theory needed ORACLE and other commercially viable products. The expense of building such systems is high, however, and it is not clear that there is market support for such a product. No one has yet achieved a breakthrough in this regard. Comprehensive literature reviews on model management can be found in [5,8,19].

Factor 5 seems to represent *Multiple Criteria Decision Making (MCDM)* [60] and [155,156]. MCDM deals with semistructured and unstructured decisions involving multiple attributes, multiple objectives, or both. As reported by Dyer and others [20], numerous individuals have contributed to give rise to the field of MCDM. Among them, Keeney and Raiffa [156] have provided us with an excellent and complete overview of multiple attribute utility theory, along with numerous examples of practical application. By the nature of multiple criteria decision making, usually there are numerous nondominated solutions in MCDM problems. To single out a decision alternative, Geoffrion, Dyer, and Feinberg [155] suggested interactive procedures for multiple criteria optimization.

Factor 6 seems to represent *Cognitive Psychology/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. Einhorn and Hogarth [157] have proposed a variety of mechanisms that influence strategy selection. 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 [158] 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 [158] 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" [133]. Further, to ameliorate human cognitive limitations, integration of DSS and expert systems is suggested [50].

Factor 7 represents *Artificial Intelligence* (AI) [16,54] and [159]. 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 [159], and the development of model and data management systems. Over the past few years, AI techniques have been increasingly integrated into DSS research to form a new hybrid system of knowledge-based DSS [4].

[4] Some would contend that all DSSs are based on the representation and processing of one or more types of knowledge (e.g., [98]).

Factor 8 appears to represent *Organizational Sciences* [160,161,162,163,164,165,166]. 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" ([106], 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 by Cyert and March [161] stressing the compartmentalization of the various units in any organization; (3) the satisficing model by Simon and his colleagues [164,165,166] which finds an acceptable, good enough solution, reflecting "bounded rationality"; and (4) other models.

Factor 9, *Systems Science*, seems to represent a contributing discipline to deal with complexity through the application of the systems approach. The systems approach aims at better understanding the organization as a system and predicting future states of the organization through model building. Based on the work of Hegel and Singer, Churchman [9–11] suggested a methodology called "dialectical design" by examining a situation completely and logically from two different points of view. Mitroff and Mason [42,43] and [167] further extended Churchman's ideas into a rigorous methodology (assumption analysis) for uncovering (surfacing), analyzing the effect, and challenging key policy assumptions in dealing with ill-structured problems.

Factor 10, *Multiple Criteria DSS / Negotiation Support Systems*, represents MCDM model-embedded decision support systems [36] and [168]. Bui, Jarke, Jelassi, and Shakun have contributed to forge new branches of DSS research — multiple criteria DSS and negotiation support systems (For a detailed discussion of various contributions of MCDM to the evolution of DSS subsystems, See [25]). Negotiation support systems support negotiations involving multiple decision makers [36].

Factor 11, *Implementation*, is the last factor that emerged in this study. Several researchers in the DSS implementation area [1] and [170,171]

Table 8
Interfactor correlations

Factor	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	−0.11	1									
3	0.07	0.45	1								
4	0.06	0.49	0.10	1							
5	−0.08	0.21	−0.00	0.25	1						
6	0.06	0.19	0.31	0.29	0.15	1					
7	−0.05	0.47	0.05	0.55	0.13	0.24	1				
8	0.09	0.39	0.30	0.14	0.21	0.17	0.14	1			
9	0.17	0.32	0.30	0.18	0.13	0.22	0.09	0.45	1		
10	0.21	0.24	−0.01	0.36	0.28	0.12	0.26	−0.04	−0.05	1	
11	0.12	0.42	0.42	0.23	0.05	0.13	0.09	0.39	0.35	0.14	1

Factor 1: Group Decision Support Systems.
Factor 2: Foundations.
Factor 3: Interfaces.
Factor 4: Model Management.
Factor 5: Multiple Criteria Decision Making.
Factor 6: Cognitive Science.
Factor 7: Artificial Intelligence.
Factor 8: Organizational Science.
Factor 9: Systems Science.
Factor 10: Multiple Criteria DSS.
Factor 11: Implementation.

have attempted to systematically identify the implementation success factors and the relationship between user-related factors (cognitive style, personality, demographics, and user-situational variables) and implementation success.

Beyond the foregoing identification of eleven factors, this research provides an avenue for assessing the degree of diffusion of ideas among DSS research subfields and the interdependency among factors. This is accomplished through a macro-level examination of inter-factor correlations among the eleven factors that emerged (Table 8). For instance, the highest correlation of 0.551 indicates that factor 4 (model management) has been strongly influenced by factor 7 (artificial intelligence).

The foundations of DSS research have been influenced by three contributing disciplines: artificial intelligence (factor 7), organizational sciences (factor 8), and systems science (factor 9) and are also strongly related to the research subspecialties of user interface (factor 3), model management (factor 4), and implementation (factor 11). As the first column of Table 8 indicates, the GDSS factor has a negative correlation with the foundation factor and shows very low correlations with all other factors. Making an analogy between the field of DSS and a tree, our study shows that DSS can be compared to the grafted tree where GDSS is inserted into the main stem (foundation) of the DSS tree. The grafted tree has four branches (model management, Interfaces, MCDSS/Negotiation support systems, and implementation) from the main stem and a GDSS branch grown from the bud inserted into the stem.

5. Discussion

A cocitation analysis is valid only as a partial analysis and presents only an *archival* view of a field. We have to account for the ongoing changes in its "disciplinary matrix" before we can make solid conclusions about the maturity of the field. In future research to trace the complete and dynamic dimensions of the intellectual history of the DSS field, we intend to present some longitudinal results by partitioning our database into several periods so that we can identify the several key events in the DSS field as well as the dynamic dimension of DSS research areas — emerging, stagnant, continuously growing, and dying areas.

A review of the major works of Kuhn [41], Kaplan [37], and Cushing [14] describes the process by which an academic discipline becomes establishment in terms of four steps:

(1) Consensus building among a group of scientists about the existence of a body of phenomena that is worthy of scientific study [41];

(2) Empirical study of the phenomena to establish a particular fact or a generalization [37];

(3) Articulation of theories to provide a unified explanation of established empirical facts and generalizations [41]; and

(4) Paradigm building to reach a consensus on the set of elements possessed in common by practitioners of a discipline such as shared commitments, shared values, and shared examples (exemplars) [41].

The MIS research frameworks of Mason and Mitroff [138] and Ives, Hamilton, and Davis [35] have played important roles in facilitating and solidifying the consensus building process on the body of phenomena that is worthy of scientific study by MIS scholars. Previous studies have attempted to determine the degree to which the other steps have been achieved. Culnan [12,13] and Cushing [14] conducted examinations of the intellectual evolution and development of the MIS area. These studies concluded that significant progress had been made toward a cumulative research tradition in MIS and identified several groups of MIS research subfields.

The research reported here provides hard evidence that decision support systems have made meaningful progress over the past two decades. As a field of study, DSS is in the process of solidifying its domain and demarcating its reference disciplines. The current state may be summarized as follows:

(1) Several areas of DSS research subspecialties that emerged in this study provide us with concrete evidence as to the existence of a cumulative DSS research tradition. A cumulative research tradition, however, is only a prerequisite

to the scientific progress of an academic discipline.

(2) There have been a number of assumed reference disciplines in the DSS area. This study identified the weak influence of organizational sciences, artificial intelligence, systems science, cognitive science, and multiple criteria decision making on the development of DSS research subspecialties.

(3) Despite the cumulative research tradition, we have accumulated conflicting and/or inconsistent results from numerous empirical studies in the areas of GDSS, user interface, and implementation. Nevertheless, there are encouraging signs of scientific progress toward the development of theory in these areas [3,56].

(4) Over the last two decades (1970–1993), DSS research has mainly concentrated on DSS components (e.g., data, model, dialogue, decision maker). Two of Keen and Scott-Morton's suggested areas of DSS study (design and evaluation of DSS) have not been shown to be substantive DSS research subspecialties.

(5) In the area of model/data 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. Some researchers in model management areas believe a theory of models is imminent [2,19].

(6) A previous study [29] shows an increasing proportion of empirically based DSS research. Nevertheless, this accelerating rate of DSS research publication and the steady transition from non-empirical to empirical studies have not resulted in DSS theory building. To facilitate the transition from the pre- to post-paradigm period in DSS research, this study has completed important groundwork.

6. Implications and directions for future research

We are now in a better position to address the following issues: what should the DSS community do to facilitate the transition from the pre- to post-paradigm period, who should do it, and how should it be done?

WHAT: Future DSS research should redirect its attention to underdeveloped subspecialties to provide useful guiding principles for practitioners in the integrated processes of design, implementation, and evaluation. The important question still remains to be answered: What DSS theories concerning design, implementation, and evaluation have been developed for the practitioner? For example, researchers in the DSS implementation area have attempted to systematically identify the implementation success factors and the relationship between user-related factors and implementation success. Nevertheless, Alavi and Joachimsthaler [[1], p. 95] concluded that "Although information systems implementation has been a topic of interest to researchers over the past two decades, the extent to which the existing body of research reflects substantial and cumulative development is not entirely clear" based on a meta-analysis of 144 findings.

WHO: This research identified a group of influential and responsible DSS researchers who represent major forces that have charted and perhaps will chart the future directions for DSS research and redirect DSS research efforts toward a common paradigm. "Any study of paradigm-directed or of paradigm-shattering research must begin by locating the responsible group or groups" ([41], p. 242).

HOW: DSS as an applied discipline should be evaluated by its impact on practice and applications. This research has provided some evidence that the DSS research areas are struggling to demarcate themselves from reference disciplines and solidify their domain. However, the considerable amount of empirical research in GDSS, user interface/individual differences, and implementation has produced conflicting, inconsistent results due to methodological problems, lack of a commonly accepted causal model, different measures of dependent variables, hardware and software designed under different philosophies, etc. [3,49,59] and [65,134].

Some researchers abandoned their efforts to develop context-free DSS theories and suggested that future DSS research should focus on modeling the specific "real world" target environment which is characterized in terms of organizational contexts, group characteristics, tasks, and EMS environments [18]. Other empirical researchers continue their efforts to integrate the seemingly conflicting results of empirical experiments [4].

The fundamental questions every DSS researcher should ask are: *Have we developed theories, concepts, frameworks, methods, techniques, and tools that are being applied in practice? Has our DSS research been relevant to meet the needs of managers*? The increasing level of DSS implementation in organizations over the past two decades is strong evidence to show DSS is indeed a viable and well-accepted managerial tool [27]. Most DSS applications have resulted in substantial financial and nonfinancial benefits in many organizations as evidenced by the prestigious Franz Edelman Awards for Management Science Achievement, sponsored by The Institute of Management Science. Nevertheless, a focal question remains to be answered. *What have been the contributions of DSS researchers in achieving numerous significant benefits*? Close examination of the Franz Edelman Award Papers in special issues of *Interfaces* over the past 10 years (1985–1994) reveals that none of the DSS papers claims that significant DSS benefits are attributable to the application of theory/techniques/concepts developed by the DSS researchers.

DSS research will not make significant contributions unless we find common ground between researchers and practitioners. To quote Murphy ([53], p. 5), developing DSS theory for practice depends on "maintaining a constructive tension between the immediate needs of managers and the research interests of professors." But researchers have often ignored this simple truth. If we cannot develop our own articulated DSS theory for practice, we will face a serious dilemma. Only *articulated DSS theories* will provide the DSS community with its *raison d'etre*.

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Appendix A. Publications receiving 15 or more citations by co-citing factor (84 articles and 26 books)

A.1. Factor 1: Group DSS (24 articles and 7 books)

[61] T.X. Bui and M.A. Jarke, Communication Requirements for Group Decision Support Systems, Journal of Management Information Systems 2, No. 4 (Spring 1986) 8–20 (16 citations).

[62] A.L. Delbecq, A.H. Van de Ven and D.H. Gustafson, Group Techniques for Program Planning: A Guide to Nominal Group and Delphi Processes (Scott, Foresman and Company, Glenview, IL, 1975) (20 citations).

[63] G. DeSanctis and B. Gallupe, A Foundation for the Study of Group Decision Support

Systems, Management Science 33, No. 5 (May 1987) 589–609 (86 citations).

[64] G. DeSanctis and B. Gallupe, Group Decision Support Systems: A New Frontier, Data Base 16, No. 2 (Winter 1985) 3–10 (34 citations).

[65] A.R. Dennis, J.F. George, L.M. Jessup, J.F. Nunamaker, Jr. and D.R. Vogel, Information Technology to Support Electronic Meetings, MIS Quarterly 12, No. 4 (December 1988) 591–624 (43 citations).

[66] A.R. Dennis, A.R. Heminger, J.F. Nunamaker, Jr. and D.R. Vogel, Bringing Automated Support to Large Groups: The Burr–Brown Experience, Information & Management 18, No. 3 (March 1990) 111–121 (17 citations).

[67] R.B. Gallupe, G.L. DeSanctis and G.W. Dickson, Computer-Based Support for Group Problem Finding: An Experimental Investigation, MIS Quarterly 12, No. 2 (June 1988) 277–298 (29 citations).

[68] R.B. Gallupe, The Impact of Task Difficulty on the Use of a Group Decision Support System, Ph.D. Dissertation, University of Minnesota, 1985 (19 citations).

[69] P. Gray, J.S. Aronofsky, N.W. Berry, O. Helmer, G.R. Kane and T.E. Perkins, The SMU Decision Room Project, Proceedings of the Second International Conference on Information Systems, Cambridge, MA (December 7–9, 1981) 122–129 (19 citations).

[70] S.R. Hiltz and M. Turoff, The Network Nation: Human Communication via Computer (Addison-Wesley, Reading, MA, 1978) (18 citations).

[71] G.P. Huber, Group Decision Support Systems as Aids in the Use of Structured Group Management Techniques, in: G. Dickson (ed.), DSS-82 Transactions: 2nd International Conference on DSS, San Francisco, CA, June 14–16, 1982, pp. 96–108 (27 citations)

[72] G.P. Huber, The Nature and Design of Postindustrial Organizations, Management Science 30, No. 8 (August 1984) 928–951 (21 citations).

[73] G.P. Huber, Issues in the Design of Group Decision Support Systems, MIS Quarterly 8, No. 3 (September 1984) 195–204 (73 citations).

[74] I.L. Janis and L. Mann, Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment (Free Press, New York, NY, 1977) (21 citations).

[75] I.L. Janis, Victims of Groupthink: A Psychological Study of Foreign Policy Decisions and Fiascoes (Houghton Mifflin, Boston, MA, 1972) (19 citations).

[76] S.L. Jarvenpaa, V.S. Rao and G.P. Huber, Computer Support for Meetings of Groups Working on Unstructured Problems: A Field Experiment, MIS Quarterly 12, No. 4 (December 1988) 645–665 (24 citations).

[77] K.L. Kraemer and J.L. King, Computer-Based Systems for Cooperative Work and Group Decision Making, Computing Surveys 20, No. 2 (June 1988) 115–146 (29 citations).

[78] D.J. Kull, Group Decisions: Can Computers Help?, Computer Decisions 14, No. 5 (May 1982) 70–76, 81–84, 160 (18 citations).

[79] F.L. Lewis, II, FACILITATOR: A Microcomputer Decision Support Systems for Small Groups, Unpublished Ph.D. Dissertation, University of Louisville, KY (1982) (26 citations).

[80] J.E. McGrath, Groups: Interaction and Performance (Prentice-Hall, Englewood Cliffs, NJ, 1984) (30 citations).

[81] J.F. Nunamaker, Jr., L.M. Applegate and B.R. Konsynski, Facilitating Group Creativity: Experience with a Group Decision Support System, Journal of Management Information Systems 3, No. 4 (Spring 1987) 5–19 (29 citations).

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[84] M.E. Shaw, Group Dynamics: The Psychology of Small Group Behavior, 3rd ed. (McGraw-Hill, New York, 1981) (17 citations).

[85] J.V. Siegel, S. Dubrovsky, S. Kiesler and T.W. McGuire, Group Processes in Computer-

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[87] M.G. Stefik, D.G. Foster, K. Bobrow, K. Khan, S. Lanning and L. Suchman, Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings, Communications of the ACM 30, No. 1 (January 1987) 32–47 (29 citations).

[88] M. Turoff and S.R. Hiltz, Computer Support for Group Versus Individual Decisions, IEEE Transactions on Communications COM30, No. 1 (January 1982) 82–92 (43 citations).

[89] R. Watson, G. DeSanctis and M.S. Poole, Using a GDSS to Facilitate Group Consensus: Some Intended and Unintended Consequences, MIS Quarterly 12, No. 3 (September 1988) 463–478 (21 citations).

[90] I. Zigurs, M.S. Poole and G. DeSanctis, A Study of Influence in Computer-Mediated Group Decision Making, MIS Quarterly 12, No. 4 (December 1988) 625–644 (16 citations).

A.2. Factor 2: Foundations (22 articles and 11 books)

[91] R.L. Ackoff, Management Misinformation Systems, Management Science 14, No. 12 (December 1967) B147–B156 (28 citations).

[92] S.L. Alter, Decision Support Systems: Current Practice and Continuing Challenges (Addison-Wesley, Reading, MA, 1980) (79 citations).

[93] S.L. Alter, A Taxonomy of Decision Support Systems, Sloan Management Review 19, No. 1 (Fall 1977) 39–56 (30 citations).

[94] S.L. Alter, A Study of Computer Aided Decision Making in Organizations, Unpublished Ph.D. Thesis, MIT, 1975 (19 citations).

[95] R.N. Anthony, Planning and Control Systems — A Framework for Analysis, Division of Research (Graduate School of Business, Harvard University, Cambridge, MA, 1965) 13–43 (40 citations).

[96] G. Ariav and M.J. Ginzberg, DSS Design: A Systemic View of Decision Support, Communications of the ACM 28, No. 10 (October 1985) 1045–1052 (21 citations).

[97] J.L. Bennett (ed.), Building Decision Support Systems (Addison-Wesley, Reading, MA, 1983) (26 citations).

[98] R.H. Bonczek, C.W. Holsapple and A.B. Whinston, Foundations of Decision Support Systems (Academic Press, New York, 1981) (77 citations).

[99] E.D. Carlson, An Approach for Designing Decision Support Systems, Data Base 10, No. 3 (Winter 1979) 3–15 (21 citations).

[100] G.B. Davis and M.H. Olson, Management Information Systems: Conceptual Foundations, Structure, and Development, 2nd ed. (McGraw Hill, New York, 1985) (26 citations).

[101] J.J. Donovan, Database System Approach to Management Decision Support, ACM Transactions on Database Systems 1, No. 4 (December 1976) 344–369 (15 citations).

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[106] P.G.W. Keen and M.S. Scott-Morton, Decision Support Systems: An Organizational Perspective (Addison-Wesley, Reading, MA, 1978) (190 citations).

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