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The intellectual structure of Decision support systems (1971–1989) *

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This study aims at identifying the intellectual structure of decision support systems (DSS), using factor analysis and multidimensional scaling of author cocitation frequency. Eight subsets of DSS research are identified; they are foundations, group DSS, routing DSS, data base management systems, multiple criteria DSS, marketing DSS, multiple criteria decision making, and management science. Earlier studies by Culnan reported that management information systems (MIS) have made significant progress toward a cumulative research tradition. This study extends the study of Culnan and examines a subspecialty of eight areas of MIS research identified by prior research. Contrary to the prior research, this research supports the theory of continuing fragmentation of DSS research and finds very little cumulative research tradition. Further, this study suggests that DSS research should be directed toward the improvement of organizational decision making.

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

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

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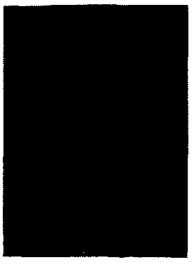

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1. Introduction

In the early 1980s, Keen [47] maintained that it was necessary for management information systems (MIS) research to clarify reference disciplines and to build a cumulative tradition to become a coherent and substantive field. To address some of Keen's issues, Culnan [19,20] and Culnan and Swanson [21] conducted an examination of the intellectual evolution and development of the MIS area using a citation analysis of published MIS research. In her landmark research, Culnan discusses the importance of the study of the intellectual development of a field of study [19, p. 156): "Researchers in any academic discipline tend to cluster into informal networks, or 'invisible colleges', which focus on common problems in common ways (Price 1963) [69]. 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. The history of exchanges between members of these subgroups in a discipline describes the intellectual history of the field. (...)

Researchers can benefit by understanding this process and its outcomes because it reveals the vitality and the evolution of thought in a discipline and because it gives a sense of its future. In a relatively new field such as MIS, this understanding is even more beneficial because it identifies the basic commitments that will serve as the foundations of the field as it matures.(...)"

Culnan's study, based on a factor analysis of author cocitation pattern, results in the identification of the following nine groups of MIS research subfields:

(1) foundations/management theory;
(2) systems science;
(3) computing impacts/local government;
(4) implementation (MIS/DSS);
(5) individual difference;
(6) human factors;
(7) computer conferencing;
(8–9) others (two clusters unnamed).

Out of nine subspecialties, the prior study suggests two areas of future research – MIS/DSS implementation and foundations. This study focuses on only DSS implementation, separated from MIS implementation.

There has been a growing amount of research in the area of DSS over the past two decades. For example, Elam et al. [25] examined the DSS literature published in the period 1975–1985. Their study presented an overall picture of the DSS area and provided a valuable source of knowledge concerning the type of DSS research (research vs. practice oriented) for academicians and practitioners in the DSS area. A study by Farhoomand [28] reports that DSS has been one of the five top research themes and has shown steadily increasing acceptance among information systems researchers in the last nine years (1977–1985). A recent survey, based on perceptions of a sample of MIS researchers, reports that almost one third of respondents were doing DSS research [79]. Additionally, Eom and Lee's recent studies [26,27] show that DSS application development research has increased significantly since 1985. Nonetheless, little research has been conducted to identify the intellectual development and structure of DSS.

The primary objective of this study is to identify: (i) the various subfields of DSS research; (ii) the contributing disciplines of DSS; and (iii) subsets of functional management which have influenced the development of specific DSS. This study also focuses on the issue of a cumulative tradition in the DSS field to answer important questions such as:

- Have decision support systems made any progress toward a cumulative research tradition?
- Who are the important people and which are the most influential (widely cited) articles in DSS research over the past two decades?
- What are the main themes in current DSS research?

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2. The research model

This research aims at identifying the underlying structure of DSS research by applying statistical methods to the references of source articles on specific DSS. Thus, we adapted a research framework of Wagner [82] as shown in fig. 1 to outline the interrelationships among the specific DSS application development, DSS theory, and contributing disciplines. The dark-colored arrows in fig. 1 show that the development and implementation of specific DSS are influenced by the following four areas of study:

(1) specific DSS applications;
(2) DSS theory;
(3) contributing disciplines;
(4) functional management theory such as financial management, marketing management etc.

This study is based on the assumptions that "bibliographic citations are an acceptable surrogate for the actual influence of various information sources" [21], and the cocitation analysis of a field yields a valid representation of the intellectual structure of the field [7,61,76]. The information sources are the cited references of the specific DSS articles, and each reference may consist of all of the above four areas. Therefore, applying statistical techniques such as factor analysis and multidimensional scaling (MDS) to the cocitation frequency matrix derived from the cited references of specific DSS may identify the influence of the four different fields of study on the development of DSS applications.

DSS applications development and implementation may be influenced directly (as arrow '*d*' indicates) by the research concerning DSS theory. The research regarding DSS theory, in turn, may also be influenced by contributing disciplines (arrow '*a*') such as management science (MS)/operations research (OR) (e.g., [49]) and organizational sciences (e.g., [4]), etc. Hence, the contributing disciplines can influence both the DSS theory and the design and implementation of specific DSS (arrows '*a*' and '*b*'). But our data do not include the references from the DSS theory paper, as indicated by arrows "a" and "c". Consequently, our research may identify only partial influence of the contributing disciplines on specific DSS.

3. Data

The primary data for this study consist of a total of 259 published articles related to specific DSS applications over the past 19 years (1971–1989). The majority of the source articles (203 articles out of 259) are taken from the previous studies [26,27], but these studies cover only the

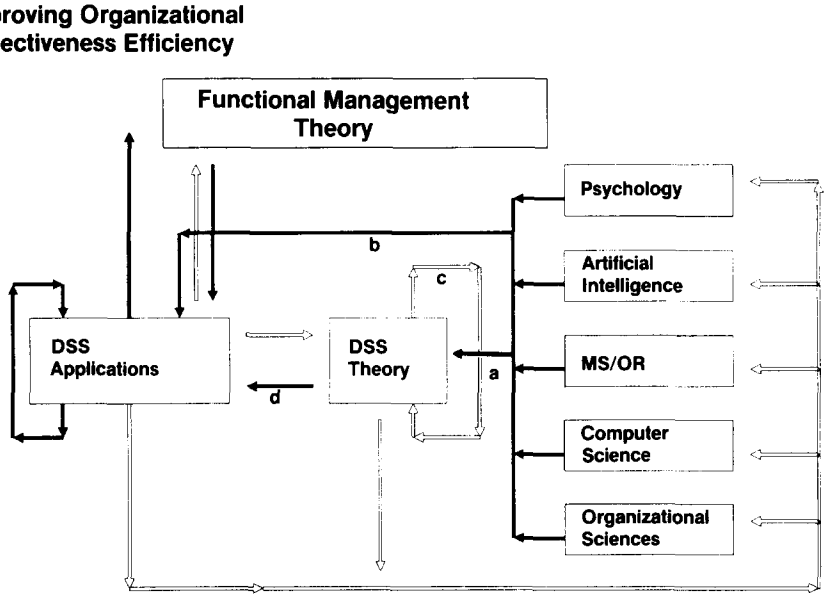

Fig. 1. Theory, applications, and contributing disciplines of decision support systems.

Table 1
Characteristics of cited references

Frequency	Number of records	%	Cumulative (%)
1	2757	87.94	87.94
2	256	8.17	96.11
3	69	2.20	98.31
4	21	0.67	98.98
5	14	0.45	99.43
6	5	0.16	99.59
7	4	0.13	99.72
8	2	0.06	99.78
9	1	0.03	99.81
12	1	0.03	99.84
13	1	0.03	99.87
15	1	0.03	99.90
17	1	0.03	99.93
27	1	0.03	99.96
38	1	0.03	99.99
Total	3135		

period 1970–March 1988. From April 1988 through December 1989, an additional 46 specific DSS articles were collected using the same source of reference as indicated in their study.

Next, we have created a database file of 3135 *cited* reference records taken from the 259 *citing* articles. Each record contains an article from journals, conference proceedings, or books in the citing references. Table 1 shows the frequency distribution of the cited references. The subsequent step was taken to identify names of most cited DSS researchers who are either single authors or one of multiple authors. Unlike the previous studies of Culnan [20,21], this study avoids personal judgment in selecting authors by objectively counting the frequency of each name from the data base file of 3135 cited references.

This stage yields a list of about 100 names, each of which occurs 10 times or more. The author cocitation analysis is conducted to prepare the matrix of the author cocitation frequency, an essential input to the factor analysis and multidimensional scaling. The next stage of screening is based on the number of cocitation frequency of five or more. The cut-off point of cocitation frequency is decided after a careful review of previous similar works [21,59,60,84].

The frequency itself may not be a useful measure because the total number of frequency, for example 10, should be interpreted as a '1' cocitation frequency with another author if '10' frequency of an author comes from only one journal article. Weak cocitation link of an author with respect to the other authors usually prevents him or her from loading in the final output of factor analysis. A total of 56 authors are identified, and each of them is paired with every other author. The cocitation frequency (cell value) of each pair is computed, using data base files and Dbase programming, to generate a 56 by 56 matrix of cocitation counts (appendix A). Each cell value in the cocitation matrix refers to the citation counts of paired author. The term "author" in this study is not an individual but a set of referenced articles in a source article ("a body of writings by a person"). In other words, appendix A is not the frequency of cocited documents by each person.

The first cell value 11 in appendix A, an intersection of the first column of Ackoff and the first row of Ackoff, is the total number of source articles (out of 259) which include one or more reference articles authored by Ackoff. Next cell, an intersection of Alter row and Ackoff column, represents the number of source journal articles (2 out of 259), containing one or more articles by Ackoff (a body of witting by Ackoff) and one or more articles by Alter in its references. This means if a source journal article includes 5 reference articles by Ackoff and 10 reference articles by Alter, the cocitation frequency (cell value) of appendix will be increased by 1. Our data set is restricted by a direction toward DSS applications, indicated by black colored arrows. The previous study of Culnan [20] used a total of 281 source articles which were published over the past 11 year-period (1972–1982) as opposed to our study, which involves 256 source articles.

4. Research methodology

The raw cocitation matrix of 56 authors is analyzed by the factor analysis program of SAS (statistical analysis systems) to ascertain the underlying structure of DSS research subspecialities. The principal component analysis with the latent root criterion (eigenvalue 1 criterion) is applied to obtain the initial solution of 11 factors (factor loadings greater than 0.40). In the initial solution, each of the factors 10 and 11 had only two significant variables, Belardo (0.42) and Wal-

lace (0.69), Ackoff (0.40) and Henderson (0.40), respectively. We could not easily assign relevant meaning to the factor 11. In the case of factor 10, the authors could be classified under the factor name of either routing DSS or emergency DSS. But in addition to two authors, several authors can be added to the factor. Thus, factors 10 and 11 were eliminated from further consideration. Subsequently, 4 more additional analysis were undertaken to determine the number of factors

Table 2
Author factor loading at 0.40 or higher (rotation method: Varimax; number of factor = 8).

Factor 1		Factor 2		Factor 3	
Fundamental theory		Group DSS		MCDM	
Alter	(0.91)	Turoff	(0.94)	Keeney	(0.87)
Carlson	(0.87)	Gallupe	(0.92)	Raiffa	(0.82)
Sprague	(0.85)	Gray	(0.90)	Geoffrion	(0.75)
Keen	(0.85)	DeSanctis	(0.89)	Zionts	(0.69)
Bennett	(0.83)	Hiltz	(0.87)	Zeleny	(0.66)
Scott-Morton	(0.83)	Huber	(0.83)	Dyer	(0.54)
Turban	(0.81)	Konsynski	(0.82)		
Meador	(0.75)	Courtney	(0.79)		
Henderson	(0.75)	Kraemer	(0.73)		
King, W.	(0.75)	Nunamaker	(0.71)		
Gorry	(0.71)	Delbecq	(0.68)		
Blanning	(0.70)	Ackoff	(0.67)		
Rockart	(0.69)	Bui	(0.62)		
Watson	(0.68)	Mitroff	(0.59)		
Schilling	(0.57)	Jarke	(0.52)		
Simon	(0.57)				
Holsapple	(0.55)				
Bonczek	(0.55)				
Whinston	(0.53)				
Delbecq	(0.51)				
Ackoff	(0.47)				
Dyer	(0.40)				
Eigenvalue	16.57		8.73		5.00
% Variance	29.59		15.59		8.93

Factor 4		Factor 5		Factor 6	
Routing DSS		DBMS		MCDSS	
Bodin	(0.91)	Bonczek	(0.80)	Jelassi	(0.74)
Jaikumar	(0.89)	Whinston	(0.79)	Jarke	(0.67)
Fisher	(0.87)	Holsapple	(0.78)	Stohr	(0.67)
Belardo	(0.86)	Haseman	(0.66)	Schilling	(0.57)
Wallace	(0.75)	Blanning	(0.50)	Bui	(0.55)
		Nunamaker	(0.43)	Dyer	(0.44)
Eigenvalue	3.57		2.91		2.83
% Variance	6.38		5.20		5.05

Factor 7		Factor 8	
OR/MS		Marketing DSS	
Glover	(0.87)	Lodish	(0.87)
Charnes	(0.85)	Little	(0.83)
Dantzig	(0.83)	Lilien	(0.79)
Mulvey	(0.55)	Saaty	(0.49)
Eigenvalue	2.20		1.78
% Variance	3.93		3.18

to extract (6–9 factors). After careful analysis and interpretation of the outputs of 4 additional outcomes via the VARIMAX orthogonal rotation method, 8 meaningful factors were obtained as a terminal solution. The eight extracted factors account for 77% of the total variances of data set.

Multidimensional scaling was also applied to visualize the similarity and dissimilarity between each of DSS researchers. The author cocitation matrix in appendix A was used as an input to the nonmetric multidimensional scaling program PROC ALSCAL (alternating least squares multidimensional scaling) of SAS release 5.18. The multidimensional scaling technique helps us determine which authors are most similar (or dissimilar) to each other by representing the relative location of each author in a spatial map in which the distance between two authors may give some indications as to their similarity and dissimilarity. Furthermore, the spatial maps allow us to measure the similarity between each group (or factor identified by factor analysis) of researchers.

To test the acceptability of the multidimensional scaling output, the stress and R square (RSQ) values were examined for each dimension (two–six). Using the Kruskal's stress formula 1 [85], only the six dimensional solution had acceptable values of stress (0.200) and RSQ (0.385). This procedure generates 15 two dimensional map with all possible pairwise combinations of 6 dimensions such as dimensions 1 (horizontal) and 2 (vertical), 1 and 3,...,4 and 6, and 5 and 6.

5. Results

Factor analysis extracted eight meaningful factors consisting of six major areas of DSS research and two contributing disciplines. Table 2 presents each factor and all authors on each factor with

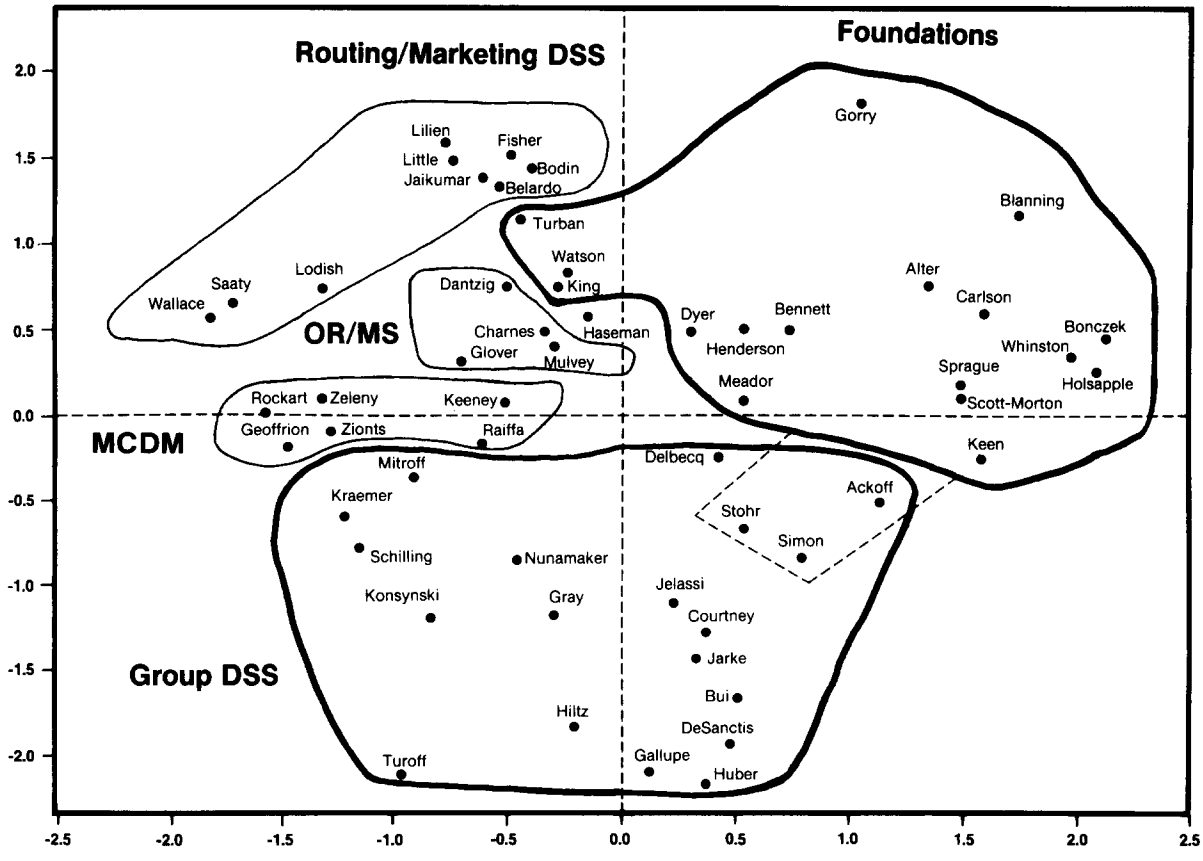

Fig. 2. Group DSS vs. Foundations.

factor loading at 0.40 or higher. 11 authors loaded on more than a single factor. They are Ackoff (factors 1 and 2), Blanning (factors 1 and 5), Bonczek (factors 1 and 5), Bui (factors 2 and 6), Delbecq (factors 1 and 2), Dyer (factors 3 and 6), Holsapple (factors 1 and 5), Jarke (factors 2 and 6), Nunamaker (factors 2 and 5), Schilling (factors 1 and 6), and Whinston (factors 1 and 5). A total of twelve authors from the previous study of Culnan [2]) also appeared in this study; they are Ackoff, Alter, Bennett, Carlson, Gorry, Hiltz, Keen, King, Kraemer, Mitroff, Rockart, and Turoff.

Factor 1 appears to define the *foundations* of DSS, represented by Keen and Scott-Morton [94], Bonczek, Holsapple, and Whinston [92], Sprague and Carlson [98], Alter [88,89], and Bennett [90]. They all authored/coauthored classic textbooks as shown in Appendix B. In addition, a group of authors who also appeared in the previous study of Culnan [21] include Ackoff, Gorry, King, and Rockart [1,2,50,71,72,93]. This study includes a growing number of DSS researchers who were excluded in Culnan's study, such as Blanning, Bonczek, Dyer, Henderson, Holsapple, Meador, Schilling, Scott-Morton, Simon, Sprague, Turban, Watson, and Whinston [12,14,15,23,24,44,62,95, 96,97,77,78,80,81,91]. Inclusion of authors who are not the first author is an important reason for the emergence of many new researchers in this study. For example, Scott-Morton, Whinston, Holsapple have coauthored many research papers as nonprimary (or first) authors.

Factor 2, *Group DSS*, is defined by Turoff, Gallupe, Gray, DeSanctis, Hiltz, Huber, Konsynski, Courtney, Kraemer, Nunamaker, Delbecq, Ackoff, Bui, Mitroff, and Jarke [16,29,30,32,38, 39,40,45,46,51,58,66,83,99,100,101,102]. A noticeable development in the DSS area since the mid-1980s is the growing importance of group DSS as a major research field. The emergence of GDSS as a major DSS research subspecialty could be interpreted as an evolution of factor 8 (computer conferencing) in Culnan's Study. As fig. 2 shows, Gallupe appears to be the central author of this group, followed by Huber, Hiltz, and DeSanctis. Jarke, Jelassi, Bui, and Stohr define the next important subgroup, characterized by the combination of Group DSS and multiple criteria decision making (MCDM) model embedded DSS. The next subgroup includes Nunamaker and Konsynski of the electronic meeting systems research.

Factor 3 seems to represent *multiple criteria decision making* (MCDM), defined by Dyer, Geoffrion, Raiffa, Keeney, Zeleny, and Zionts [31,70,87,103,104]. The importance of the synthesis of the MCDM into DSS research has been emphasized recently by Keen [48], who says that MCDM poses dilemmas or even crises of judgement and that the MCDM problem is at the core of decision support. Despite its powerful capabilities to deal with unstructured problems, many theoreticians such as Zeleny [86] in the MCDM area still think that "MCDM is rarely part of 'mainstream' OR/MS/DSS modeling." However, this study, along with another recent study [26,27], shows that the MCDM research has emerged as the third important factor that has influenced the development of specific DSS. Perhaps, the MCDM is indeed becoming a part of mainstream OR/MS/DSS research.

The fourth factor emerged in this research is *routing DSS* defined by Bodin, Jaikumar, Fisher, Belardo, and Wallace [5,6,10,11,105]. Currently, routing and marketing DSS are the predominant DSS application areas as they occupy about one third of all business applications of DSS [26]. The majority of routing and marketing DSS applications are network optimization model-based route selection and planning fleet configuration DSS. The predominance of routing area application of DSS may be largely attributable to the nature of routing decisions. In other words, routing and marketing decisions are better suited to OR/MS model-based DSS rather than heuristics based expert systems approach. Other areas of functional management such as production, accounting, and finance are actively developing expert systems (ES), rather than DSS. Thus, we predict that the routing/marketing area will continue to be a predominant DSS application field.

Factor 5 appears to represent *database management systems* (DBMS), as it is defined by Bonczek, Holsapple, Whinston, Haseman, Blanning, and Nunamaker [8,9,13,17,42,43,67]. In the previous study by Culnan, research in technology such as data base management systems was not identified as a subfield of information systems research.

Factor 6 appears to represent *multiple criteria decision support systems* (MCDSS), as it is defined by Bui, Dyer, Jelassi, Jarke, Stohr, and Schilling

[16,44,75,106,107]. The MCDSS is defined as an MCDM model-embedded DSS to solve various semistructured and unstructured decisions involving multiple attributes, multiple objectives, or both. The MCDM model embedded in the MCDSS can be used to further divide MCDSS into two subgroups. Stohr, Jarke, Jelassi, and Bui are characterized by the multiple attribute decision making (MADM) model embedded DSS subgroup. Dyer and Schilling represent another subgroup of the multiple objective decision making (MODM) model-based DSS. The MCDM (both MO0M and MADM) models utilize many MS/OR techniques such as goal programming, multiple objective linear programming, and multiple attribute utility theory, etc.

Factor 7 is defined by Glover, Charnes, Dantzig, and Mulvey and represents *management science / operations research* [18,22,35,36,37,108, 109,63,64]. This is one of the two reference disciplines identified, along with the factor 3 (MCDM). However, there have been many fields of contributing disciplines in DSS area such as economics, political science, psychology, and sociology and related applied disciplines such as computer science, and many functional management areas such as accounting and finance, MS/OR, and organizational behavior. Our research failed to identify most of these areas except MCDM and MS/OR.

The last factor, *marketing DSS*, is represented by Lodish, Little, Lilien, and Saaty [52,53,54,55, 56,110,111]. Care must be exercised when interpreting statistical output of citation analysis. A major source of problems in citation analysis is different types of citations [57]. In our research, although the output of the factor analysis indicates that Saaty should be a member of factor 8, he would rather be classified as a member of either factor 7 or factor 6. We believe Saaty's

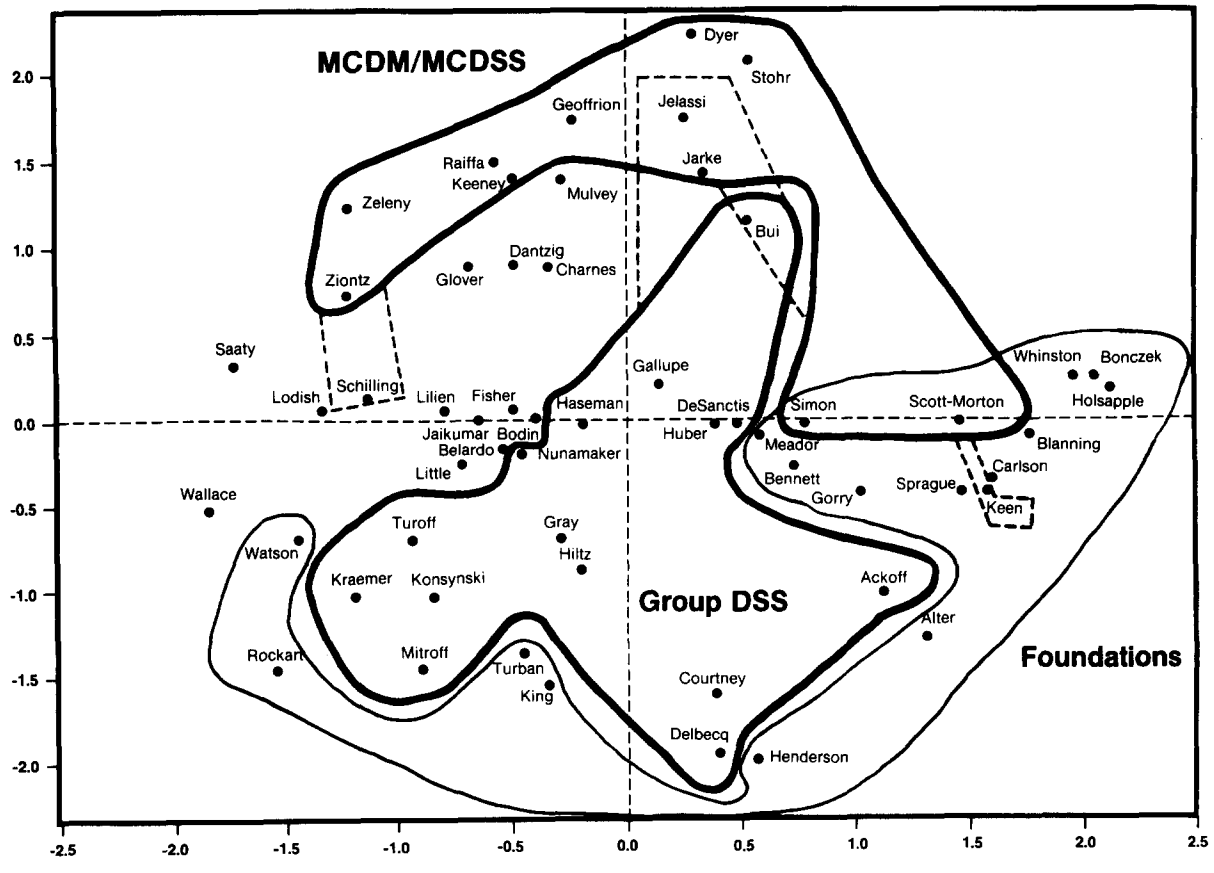

Fig. 3. Group DSS vs. MCDM/MCDSS.

work of the analytic hierarchical process [73,74] may have been frequently utilized by marketing researchers.

The MDS outputs, figs. 2 and 3, show the two dimensional maps of 56 authors, two of 15 MDS maps. The horizontal axis (dimension 1) of fig. 2 is used to represent the similarity of authors of group DSS. The vertical axis (dimension 2) shows the similarity of authors concerning the foundations of DSS. To understand the six dimensional solutions of the MDS outputs, one more factor analysis output is produced using six factor criterion (table 3). Each dimension of MDS output roughly corresponds to each factor of the factor analysis output. There are two major difference between tables 2 and 3. First, two factors (MCDM and MCDSS) in table 2 are merged into factor 3 of table 3. Second, all authors on marketing DSS (factor 8) fail to be loaded in any other groups. Therefore, all authors of factor 8 in table 2 are deleted. table 3 also includes several authors with factor loadings at 0.39 or slightly lower to show the closeness of the authors to a certain group.

Fig. 2 provides us with incomplete information on authors and their proximity in other dimensions (3–6). For example, information on MCDM

Table 3
Author factor loading at 0.40 or higher (rotation method: Varimax; number of factor = 6).

Factor 1		Factor 2		Factor 3	
Fundamental theory		Group DSS		MCDM/MCDSS	
Alter	(0.91)	Turoff	(0.92)	Keeney	(0.78)
Carlson	(0.87)	Gallupe	(0.90)	Zionts	(0.71)
Sprague	(0.85)	Gray	(0.92)	Dyer	(0.70)
Keen	(0.85)	DeSanctis	(0.87)	Stohr	(0.70)
Bennett	(0.82)	Hiltz	(0.87)	Zeleny	(0.70)
Scott-Morton	(0.82)	Huber	(0.78)	Jelassi	(0.69)
Turban	(0.81)	Konsynski	(0.87)	Jarke	(0.67)
Meador	(0.75)	Courtney	(0.81)	Geoffrion	(0.65)
Henderson	(0.75)	Kraemer	(0.78)	Raiffa	(0.62)
King, W.	(0.75)	Nunamaker	(0.73)	Bui	(0.58)
Gorry	(0.70)	Delbecq	(0.64)	Scott-Morton	(0.41)
Blanning	(0.69)	Ackoff	(0.62)	Simon	(0.40)
Rockart	(0.69)	Bui	(0.66)		
Watson	(0.68)	Mitroff	(0.59)	Schilling	(0.32)
Schilling	(0.57)	Jarke	(0.58)		
Simon	(0.57)	Jelassi	(0.46)		
Holsapple	(0.55)				
Bonczek	(0.53)	Simon	(0.35)		
Whinston	(0.53)	Haseman	(0.35)		
Delbecq	(0.47)				
Ackoff	(0.39)				
Dyer	(0.39)				
Eigenvalue	16.57		8.73		5.00
% Variance	29.59		15.59		8.93
Factor 4		Factor 5		Factor 6	
Routing DSS		DBMS		MS/OR	
Bodin	(0.89)	Bonczek	(0.80)	Glover	(0.73)
Jaikumar	(0.87)	Whinston	(0.79)	Charnes	(0.68)
Fisher	(0.85)	Holsapple	(0.77)	Dantzig	(0.65)
Belardo	(0.86)	Haseman	(0.68)	Mulvey	(0.49)
Wallace	(0.76)	Blanning	(0.51)		
		Nunamaker	(0.45)		
Eigenvalue	3.57		2.91		2.83
% Variance	6.38		5.20		5.05

and MCDSS appeared in part and information on DBMS did not appear at all. However, fig. 3 sharply contrast the interrelationships between the Group DSS and MCDM/MCDSS. There are several noticeable differences of fig. 3, when compared to fig. 2. First, the MCDM/MCDSS group clearly appears. Authors with factor loadings at 0.40 or higher in table 3 are circled with thick and wide lines. Thin dotted lines are used to indicate some authors that could be classified into two groups. For example, Jelassi and Jarke are classified as members of the MCDM/MCDSS group, but they can also belong to the GDSS group. Bui is a member of GDSS group, but can be a member of the MCDM/MCDSS group. This grouping is based on the value of factor loading in table 3. Second, the relative locations of all groups except the GDSS and MCDM/MCDSS are completely rearranged. For example, authors on foundations are now widely scattered, as compared to fig. 2. This indicates that fig. 3 is less meaningful to all other groups except the GDSS and MCDM/MCDSS group.

The MDS output can provide the following additional information. First, it shows the respective location of each group. The routing DSS group and marketing DSS group are located nearest in this map as well as the MCDM group vs. MS/OR group. Second, the MDS map also indicates the proximity of authors within groups, such as in the cases of Bonczek, Holsapple, and Whinston, Keen and Scott-Morton, DeSanctis and Gallupe, and Keeney and Raiffa. Third, it represents the proximities of authors across group boundaries. For example, Ackoff loaded in factors 1 and 2 in our previous output (tables 2 and 3). In figs. 2 and 3, the location of Ackoff is approximately in the middle of the group decision support systems group and foundations group. He, therefore, can be classified in either one of the two groups. Fourth, the MDS map shows centrality and peripherality of authors. Dimension 2 of fig. 2 appears to represent foundations group. The shorter distances of authors from the horizontal axes are indicative of an author's centrality. Keen, Scott-Morton, and Sprague seem to be more central than Gorry, Blanning, and Turban. Finally, the MDS outputs may indicate the centrality and peripherality of groups with respect to the overall field. From the standpoint of foundations and GDSS groups, the next similar groups appear to be the MCDM and OR/MS groups. The location of the marketing group also indicates its peripherality in relation to the GDSS and foundation groups.

6. Conclusion

This research has identified several subspecialties of the DSS area such as foundations, group DSS, multiple criteria DSS, marketing and routing DSS, and database management systems. However, several active DSS research areas were not represented by the factors we identified. For example, as Ginzberg and Stohr [34] pointed out earlier, model management systems (MMS) have been undoubtedly considered an important DSS research area over the past decade. Unfortunately, this research failed to identify the MMS field as an established research area. Despite the continuing active research in the MMS area over the past decade, this research may indicate that the MMS research has had little influence on the design and implementation of specific DSS applications. Perhaps, the MMS research is becoming too theory-oriented with little relevance in improving effectiveness of organizational decision making.

This study could provide a valuable guideline for evaluating and prioritizing the relative importance of each DSS research subfield. Many earlier studies (e.g., [3,88]) note that in order for any specific DSS to be successful, it requires substantially greater organizational changes than do conventional systems. The organizational changes include the manager's view of his or her tasks and the way the tasks are accomplished. All these organizational changes, however, must be directed toward improving organizational decision making. The improvement of organizational decision making, in turn, has to be measured by the degree of contribution in achieving organizational goals such as profit, market share, and improving customer relationships. The concept of "value chain" suggested by Porter [68] can be a useful tool for evaluating the contribution of DSS to the achievement of organizational goals. Doing DSS research that may not result in measurable improvement of decision making may not be the first priority of DSS researchers.

We also addressed the issue of the cumulative tradition in the DSS area. In the early 1980s, Keen [47] maintained that a cumulative tradition did not exist in the information systems area. This research shows a clear evidence of fragmentation of research in this field. Almost 90% of the references are cited just once. On the other hand, only about one percent of the references are cited 5 or more times. A comparison of the size of the source references of this study (259 articles) and Culnan's study (281 articles) shows that this study lists only 6 references that were cited 10 or more times, while the study of Culnan includes 34 references with same citation frequencies. This can be seen as a direct evidence that, when compared to MIS in general, the DSS field has failed to build a cumulative research tradition.

Thus, we have had conflicting assessment as to the existence of a cumulative research tradition in the MIS area. Some believe that significant progress has been made toward a cumulative research tradition in MIS [20]. Others perceive that MIS researchers feel that there is an overemphasis on transient topics and continuing evidence of fragmentation and lack of cumulative research tradition in MIS field [79]. Another study of Farhoomand [28] concludes that "the rather insignificant scientific progress of MIS can be attributed, to a large degree, to the fact that MIS *lacks articulated theories of its own*" and "MIS will not make significant progress as a *scientific field of study* until it can both explicate its disciplinary matrix through development of its *own theories* and enhance its exemplars so that they can be applied to a wider and more precise set of applications." Our research also strongly supports the idea that DSS research over the past two decades has failed to develop its own theory that can be applied to specific DSS applications and finds very little evidence of a cumulative tradition in DSS research areas.

We hope this research has shed some light on this issue of the cumulative tradition in the DSS area. This study has attempted to provide answers to the questions raised earlier as to important themes in DSS research, and important people and articles in this field that have influenced the intellectual structure of the DSS field. Nevertheless, some research questions raised by the earlier study of Culnan [19] were not answered in this study. Due to the restrictive nature of our data set, we failed to identify all of DSS reference disciplines and diffusion of ideas represented by these subfields to other disciplines. Consequently, future research may be needed to answer those questions.

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Appendix A. Raw cocitation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Ackoff	11																	
2 Alter	2	22																
3 Belardo	0	0	8															
4 Bennett	0	4	0	9														
5 Blanning	0	4	0	2	8													
6 Bodin	0	0	3	0	0	7												
7 Bonczek	3	5	0	4	6	0	22											
8 Bui	1	0	0	2	1	0	3	8										
9 Carlson	2	13	1	6	5	2	11	2	32									
10 Charnes	0	0	0	0	0	0	0	0	0	7								
11 Courtney	4	2	0	0	2	0	1	3	1	0	6							
12 Dantzig	0	0	1	0	0	1	1	0	0	5	0	9						
13 Delbecq	3	2	0	0	0	0	2	1	4	0	2	0	7					
14 DeSanctis	3	0	0	0	1	0	2	4	1	0	3	0	2	9				
15 Dyer	0	1	0	0	0	0	1	1	5	0	0	0	0	0	8			
16 Fisher	0	0	3	0	0	5	0	0	1	0	0	1	0	0	0	7		
17 Gallupe	2	0	0	0	0	0	2	4	1	0	2	0	2	6	0	0	7	
18 Geoffrion	0	0	0	0	1	0	0	1	2	1	0	1	0	0	4	0	0	8
19 Glover	0	0	0	0	0	0	0	0	0	4	0	5	0	0	2	1	0	2
20 Gorry	0	5	0	2	1	0	4	0	5	0	0	0	0	0	1	0	0	0
21 Gray	2	0	0	0	0	0	0	3	1	0	2	0	2	5	0	0	5	0
22 Haseman	1	0	0	0	0	0	3	1	0	0	1	0	0	1	0	0	1	0
23 Henderson	3	4	0	2	3	0	4	2	5	0	3	0	3	3	0	0	1	0
24 Hiltz	3	1	0	0	0	0	1	4	2	0	4	0	3	5	0	0	5	0
25 Holsapple	3	6	0	4	6	0	19	3	11	0	2	0	2	4	2	0	2	1
26 Huber	4	3	1	0	0	0	3	4	4	1	3	1	4	8	1	0	7	1
27 Jaikumar	0	0	3	0	0	5	0	0	1	0	0	1	0	0	0	7	0	0
28 Jarke	1	0	0	2	0	0	3	8	4	0	3	0	1	4	2	0	4	1
29 Jelassi	1	0	0	2	1	0	3	7	3	0	2	0	0	3	2	0	3	1
30 Keen	6	17	1	8	7	0	10	8	20	0	6	0	5	4	4	0	4	1
31 Keeney	0	0	0	0	0	0	0	2	2	0	0	0	1	1	2	0	1	3
32 King	1	3	0	1	1	0	1	0	4	1	0	1	0	0	0	0	0	0
33 Konsynski	3	0	1	0	2	0	1	2	0	0	3	0	2	4	0	0	3	0
34 Kraemer	1	1	0	0	0	0	0	3	2	0	2	0	1	3	0	0	2	0
35 Lilien	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36 Little	2	1	4	0	0	2	0	0	1	0	0	1	0	0	0	2	0	0
37 Lodish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38 Meador	2	3	0	2	2	0	2	1	4	0	2	0	1	1	2	0	0	0
39 Mitroff	2	1	0	0	1	0	1	1	2	0	2	0	1	2	0	0	1	0
40 Mulvey	0	1	0	0	0	0	1	0	4	1	0	1	0	0	5	0	0	1
41 Nunamaker	2	0	1	0	0	0	2	2	1	0	2	0	2	3	0	0	3	0
42 Raiffa	2	0	0	0	1	0	1	2	3	0	1	0	1	4	2	0	1	3
43 Rockart	1	2	0	1	0	0	0	0	2	0	0	0	1	0	0	0	0	0
44 Saaty	0	2	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	1
45 Schilling	1	2	0	1	0	0	0	1	3	0	1	0	2	0	1	0	0	0
46 ScottMorton	3	14	1	7	6	0	10	7	17	0	2	0	3	3	5	0	3	2
47 Simon	3	3	0	3	3	0	4	4	7	0	3	0	2	4	3	0	3	1
48 Sprague	5	14	2	6	3	2	13	5	28	0	3	0	4	3	4	1	3	1
49 Stohr	1	0	1	2	1	0	5	5	3	0	0	0	1	2	2	0	2	1
50 Turban	0	3	1	4	2	1	2	0	5	0	1	0	0	0	0	1	0	0
51 Turoff	3	1	0	0	0	0	1	4	2	0	4	0	3	5	0	0	5	0
52 Wallace	0	1	5	0	0	2	0	0	1	0	0	1	1	0	0	1	0	0
53 Watson	1	2	0	2	1	0	0	1	4	0	2	0	0	0	1	0	0	0
54 Whinston	3	6	0	4	6	0	21	3	11	0	1	0	2	4	2	0	3	1
55 Zeleny	0	0	0	0	2	0	3	2	2	0	1	0	0	1	3	0	0	3
56 Zionts	0	1	0	1	1	0	2	2	2	0	0	0	0	0	2	0	0	1

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
12																		
0	13																	
0	0	6																
0	0	1	5															
0	1	2	0	10														
0	0	4	1	1	6													
0	3	0	1	4	1	22												
1	0	5	1	0	6	3	15											
0	0	0	0	0	0	0	0	7										
0	1	3	1	0	4	3	4	0	14									
0	0	2	1	0	2	3	4	0	7	9								
0	5	3	1	7	5	11	7	0	8	4	51							
0	0	1	0	0	1	0	1	0	3	2	4	10						
1	2	1	0	3	0	1	2	0	0	0	4	0	8					
0	0	3	1	1	3	1	3	0	3	1	2	0	0	6				
0	0	0	1	1	4	0	1	0	3	2	2	1	1	2	5			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5		
0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4	18	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	6
0	2	0	0	1	1	2	1	0	1	1	6	0	0	1	0	0	1	0
0	0	1	0	2	2	1	2	0	1	0	3	0	2	2	2	0	0	0
4	1	0	0	0	0	1	0	0	1	1	2	0	0	0	0	0	0	0
0	0	3	4	0	3	2	3	0	3	1	2	0	0	4	2	0	0	0
0	0	0	0	1	1	1	2	0	2	1	5	7	0	1	1	0	1	0
0	1	1	0	2	1	0	1	0	0	0	3	0	2	0	1	0	1	0
0	1	0	0	0	0	1	1	0	0	0	1	2	1	0	0	0	2	2
0	0	0	0	1	1	0	1	0	2	3	4	0	0	1	0	0	0	0
0	10	2	0	4	3	10	6	0	9	4	39	4	4	2	3	0	2	0
0	4	2	0	3	3	4	4	0	5	5	9	1	2	3	2	0	2	0
0	4	3	1	5	3	13	6	1	5	4	27	2	3	2	0	0	3	0
0	0	1	0	0	0	5	3	0	7	7	5	3	0	2	0	0	1	0
0	2	1	0	1	0	2	0	1	0	0	5	0	2	0	1	0	1	0
0	0	4	1	1	6	1	6	0	3	2	5	1	0	3	4	0	0	0
0	0	0	0	1	0	0	1	2	0	0	2	0	0	1	0	0	3	0
0	1	1	0	2	0	0	1	0	1	1	5	0	2	2	2	0	0	0
0	4	2	4	4	1	22	5	0	3	3	12	2	2	0	0	0	0	0
0	1	0	0	1	0	3	2	0	3	2	2	2	0	0	0	0	0	0
0	1	0	0	1	0	2	1	0	3	3	4	3	1	0	0	0	0	0

Appendix A (continued)

	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
1 Ackoff																			
2 Alter																			
3 Belardo																			
4 Bennett																			
5 Blanning																			
6 Bodin																			
7 Bonczek																			
8 Bui																			
9 Carlson																			
10 Charnes																			
11 Courtney																			
12 Dantzig																			
13 Delbecq																			
14 DeSanctis																			
15 Dyer																			
16 Fisher																			
17 Gallupe																			
18 Geoffrion																			
19 Glover																			
20 Gorry																			
21 Gray																			
22 Haseman																			
23 Henderson																			
24 Hiltz																			
25 Holsapple																			
26 Huber																			
27 Jaikumar																			
28 Jarke																			
29 Jelassi																			
30 Keen																			
31 Keeney																			
32 King																			
33 Konsynski																			
34 Kraemer																			
35 Lilien																			
36 Little																			
37 Lodish																			
38 Meador	7																		
39 Mitroff	1	6																	
40 Mulvey	2	0	8																
41 Nunamaker	0	1	0	7															
42 Raiffa	1	2	0	0	15														
43 Rockart	0	1	0	0	0	6													
44 Saaty	0	0	0	0	1	0	7												
45 Schilling	2	0	1	0	0	1	0	5											
46 ScottMorton	5	1	3	2	5	3	2	3	45										
47 Simon	2	2	0	2	4	1	1	1	13	20									
48 Sprague	4	2	0	2	3	3	1	3	20	8	41								
49 Stohr	1	0	1	1	3	0	0	2	8	4	6	11							
50 Turban	1	1	0	0	0	1	0	0	5	2	5	0	8						
51 Turoff	1	2	0	3	1	1	0	1	3	3	3	0	0	6					
52 Wallace	0	0	0	1	0	1	0	1	1	0	4	1	0	0	6				
53 Watson	0	1	0	0	1	2	0	0	3	2	7	1	2	0	0	8			
54 Whinston	2	1	1	4	4	0	1	0	10	7	13	5	2	1	0	2	24		
55 Zeleny	0	0	0	0	2	0	1	0	2	0	2	2	0	0	0	1	2	7	
56 Zionts	0	0	0	0	4	0	0	0	4	4	2	0	0	0	0	1	2	3	7

Appendix B. Publications receiving 5 or more citations by co-citing factor

Factor 1. Foundations

[88] S.L. Alter, Decision Support Systems: Current Practice and Continuing Challenges (Addison-Wesley, Reading, MA, 1980). (17 citations).

[89] S.L. Alter, A Taxonomy of Decision Support Systems, Sloan Management Review 19, No. 1 (Fall 1977) 39–56. (7 citations).

[90] J.L. Bennett, Ed., Building Decision Support Systems (Addison-Wesley, Reading, MA, 1983). (7 citations).

[91] R.W. Blanning, The Functions of a Decision Support System, Information & Management 2, No. 3 (1979) 87–93. (5 citations).

[92] R.H. Bonczek, C.W. Holsapple and A.B. Whinston, Foundations of Decision Support Systems (Academic Press, New York, 1981). (15 citations).

[93] G.A. Gorry and M.S. Scott-Morton, A Framework for Management Information Systems, Sloan Management Review 13, No. 1 (Fall 1971) 55–70. (8 citations).

[94] P.G.W. Keen and M.S. Scott-Morton, Decision Support Systems: An Organizational Perspective (Addison-Wesley, Reading, MA, 1978) (38 citations).

[95] M.S. Scott-Morton, Management Decision Systems: Computer Based Support for Decision Making Division of Research, (Graduate School of Business Administration, Harvard University, Cambridge, MA, 1971). (6 citations).

[96] H.A. Simon, The New Science of Management Decision (Harper and Row, New York, 1960) (13 citations)

[97] R.H. Sprague, Jr. A Framework for the Development of Decision Support Systems, MIS Quarterly 4, No. 4 (Dec. 1980) 1–26. (12 citations)

[98] R.H. Sprague, Jr. and E.D. Carlson, Building Effective Decision Support Systems (Prentice-Hall, Englewood Cliffs, NJ, 1982). (27 citations).

Factor 2. Group DSS

[99] 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, Glenview, IL, 1975) (5 citations)

[100] G. DeSanctis and B. Gallupe, Group Decision Support Systems: A New Frontier, Data Base 16, No. 2 (Winter 1985) 3–10. (5 citations)

[101] G. DeSanctis and B. Gallupe, A Foundation for the Study of Group Decision Support Systems, Management Science 33, No. 5 (May 1987) 589–609. (5 citations)

[102] G.P. Huber, Issues in the Design of Group Decision Support Systems, MIS Quarterly 8, No. 3 (Sept. 1984) 195–204. (9 citations)

Factor 3. Multiple criteria decision making

[103] R.L. Keeney and H. Raiffa, Decisions with Multiple Objectives: Preferences and Value Tradeoffs (Wiley, New York, 1976). (7 citations)

[104] M. Zeleny, Multiple Criteria Decision Making, (McGraw-Hill, New York, 1982). (5 citations)

Factor 4. Routing DSS

[105] W.J. Bell, L.M. Dalberto, M.L. Fisher, A.J. Greenfield, R. Jaikumar, P. Kedia, R.G. Mack and P.J. Prutzman, Improving the Distribution of Industrial Gases with an On-Line Computerized Routing and Scheduling Optimizer, Interfaces 13, No. 6 (1983) 4–23. (5 citations)

Factor 5. Data base management systems

None

Factor 6: Multiple criteria decision support systems

[106] T.X. Bui, "Building Effective Multiple Criteria Decision Support Models: A Decision Support System Approach, Systems. Objectives. Solutions 4, No. 1 (1984) 3–16. (5 citations)

[107] M.T. Jelassi, M. Jarke and E.A. Stohr, Designing a Generalized Multiple Criteria Decision Support System, Journal of Management Information Systems 1, No. 4 (Spring 1985) 24–43. (6 citations)

Factor 7: MS / OR

[108] A. Charnes and W.W. Cooper, Management Models and Industrial Applications of Linear Programming, Vols. 1 and 2 (Wiley, New York, 1961). (5 citations)

[109] F. Glover and D. Klingman, Network Applications in Industry and Government, AIIE Transactions 9, No. 4 (Dec. 1977) 363–376. (6 citations)

Factor 8. Marketing DSS

[110] J.D.C. Little, Models and Managers: The Concepts of a Decision Calculus, Management Science 16, No. 8 (April 1970) B466–B485. (8 citations)

[111] J.D.C. Little, Decision Support Systems for Marketing Managers, Journal of Marketing 43, No. 2 (Summer 1979) 9–26. (7 citations)