The Methodological and Theoretical Foundations of Decision Support Systems Research

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Abstract

Decision support systems (DSS) is the part of the information systems (IS) discipline that is focused on supporting and improving managerial decision making. The field covers personal DSS, group support systems, negotiation support systems, intelligent DSS, knowledge management-based DSS, executive information systems/business intelligence, and data warehousing. Our long-term project on the intellectual foundations of DSS research has revealed a conservative field that needs to re-orient its research agendas to achieve greater quality and impact. This paper furthers this project and explores what we feel may be at the core of the field's problems — its methodological and theoretical foundations. A number of recommendations for improving the quality and relevance of DSS research are made. As DSS is a significant proportion of IS research, the lessons and recommendations from this study may be of use to all IS researchers.

Introduction

Decision support systems (DSS) is the part of the information systems (IS) discipline that is focused on supporting and improving managerial decision making. Essentially, DSS is about developing and deploying IT-based systems to support decision processes. It is perhaps the most buoyant area of contemporary IS practice (Graham, 2005) and the decisions made using these systems can fundamentally change the nature of an organisation. To help define the field, Arnott and Pervan (2005) presented a history of DSS that focused on the evolution of a number of sub-groupings of research and practice. These DSS types are:

- *Personal DSS*: usually small-scale systems that are normally developed for one manager, or a small number of independent managers, for one decision task;
- *Group Support Systems*: the use of a combination of communication and DSS technologies to facilitate the effective working of groups;
- *Negotiation support systems*: DSS where the primary focus of the group work is negotiation between opposing parties;
- *Intelligent DSS*: the application of artificial intelligence techniques to DSS;
- *Knowledge Management-based DSS*: systems that support decision making by aiding knowledge storage, retrieval, transfer and application by supporting individual and organisational memory and inter-group knowledge access;
- *Executive Information Systems/Business Intelligence*: data-oriented and model-oriented DSS that provide reporting about the nature of an organisation to management; and
- *Data Warehousing*: systems that provide the large-scale data infrastructure for decision support.

This paper arises from a long-term project investigating the intellectual foundations of the DSS field. The foundation of the project is the content analysis of 1,093 DSS articles published in 14 major journals from 1990 to 2004. The first, descriptive, results were presented in Arnott et al (2005b). Pervan et al (2005) presented a critical analysis of group support research from 1990 to 2003; Arnott et al (2005a) analysed the funding of all types of DSS research; Arnott and Pervan (2005) analysed published DSS research using a number of dimensions including journal publishing patterns, research paradigms and methods, decision support focuses, and professional relevance; Pervan and Arnott (2006) analysed data warehousing and business intelligence research; and Dodson et al (2006) investigated the role of the client and user in DSS research.

Our analysis of DSS research has revealed a conservative field that needs to re-orient its research agendas to achieve greater quality and impact. The practical relevance of DSS research is declining and it is underrepresented in 'A' journals (Arnott and Pervan, 2006). This means that it faces problems with both its key constituencies of industry and academe. Our paper addresses what we feel may be a major cause of these problems — the theoretical and methodological foundations of the field.

The paper is structured as follows: first, the project's research method and design is outlined. This is followed by an analysis of the article sample and discussion in terms of research paradigms, research design and methods, judgement and decision-making foundations, and discipline coherence. As DSS is a significant proportion of IS research, the lessons and recommendations from this study may be of use to all IS researchers.

Research method

The overall project aims to understand the nature of the DSS discipline using literature analysis. There have been a number of other critical reviews of DSS publications. Sean Eom's series of analyses have used bibliometric approaches, including co-citation analysis, to analyse the intellectual structure of the field (Eom, 1995, 1996, 1999; Eom and Lee, 1990, 1993). Other reviews have examined the content of articles but have usually concentrated on only one aspect of the field. For example, Benbasat and Nault (1990) examined empirical research while Pervan (1998) analysed group support systems. The literature analysis at the heart of this project included all DSS types. It involved the protocol-based content analysis of each paper in the sample. This form of data capture has the disadvantage that it is a very labour intensive process but, importantly, it has the advantage that it can illuminate the deep structure of the field in a way that is difficult with citation studies.

The time period of published research chosen for analysis in this project is 1990 to 2004 (although some of the earlier papers that reported on parts of the project ended their analysis in 2002 or 2003). The start of this analysis period is marked by two much-cited reviews: Eom and Lee (1990) and Benbasat and Nault (1990). Both of these reviews covered the DSS field from its inception to the late 1980's. A third review paper focusing on DSS implementation (Alavi and Joachimsthaler, 1992) provides a further anchor for the starting date of our analysis, as does the TIMS/ORSA and National Science Foundation sponsored discipline assessment (Stohr and Konsynski, 1992). The period 1990 to 2004 also marks an interesting period in the development of the information systems discipline because it witnessed a significant growth in the use of non-positivist research methods. Also, in industry, the analysis period saw the deployment of several new generations of DSS, especially the large-scale approaches of executive information systems (EIS), data warehousing (DW), and business intelligence (BI). To help identify trends in DSS research, the sample was divided into three five-year eras: 1990-1994, 1995-1999, and 2000-2004.

The sample of articles used in the project is shown in Table 1. We adopted a large set of quality journals as a basis of the sample because we believe that this best represents the invisible college of DSS research. Previous analyses of information systems research have used a similar sampling approach (Benbasat and Nault, 1990; Alavi and Carlson, 1992; Pervan, 1998). Alavi and Carlson (1992) used eight North American journals for their sample. However, Webster and Watson (2002) have criticised the over emphasis on North American journals in review papers. In response to this criticism, we included four European information systems journals (*ISJ, EJIS, JIT,* and *JSIS*) in our sample. The quality of journals was classified as 'A' level or 'Other'. This classification was based on a number of publications that address journal ranking (Gillenson and Stutz,

1991; Hardgrave and Walstrom, 1997; Holsapple et al., 1994; Mylonopoulos and Theoharakis, 2001; Walstrom et al., 1995; Whitman et al., 1999) and on discussions with a number of journal editors. The articles were selected electronically by examining key words and titles. A manual check was performed of the table of contents of each issue of each journal. In addition, the text of each potential article for analysis was examined to verify its decision support content.

Journal	Journal Area and Ranking	Journal Orientation	No. of DSS Articles Published	Total No. of Articles Published	DSS Articles as a Percentage of Published Articles
Decision Sciences (*DS*)	US 'A'	MS/OR	64	665	9.6
Decision Support Systems (*DSS*)	US 'Other'	Specialist DSS	466	857	54.4
European Journal of Information Systems (*EJIS*)	Europe 'A'	General IS	24	348	6.9
Group Decision and Negotiation (*GD&N*)	US 'Other'	Specialist DSS	122	321	38.0
Information and Management (*I&M*)	US 'Other'	General IS	98	818	12.0
Information and Organization (*I&O*)	US 'Other'	General IS	16	169	9.4
Information Systems Journal (*ISJ*)	Europe 'A'	General IS	15	183	8.2
Information Systems Research (*ISR*)	US 'A'	General IS	34	303	11.2
Journal of Information Technology (*JIT*)	Europe 'Other'	General IS	22	378	5.8
Journal of Management Information Systems (*JMIS*)	US 'Other'	General IS	80	523	15.3
Journal of Organizational Computing and Electronic Commerce (*JOC&EC*)	US 'Other'	General IS	71	225	31.5
Journal of Strategic Information Systems (*JSIS*)	Europe 'Other'	General IS	8	240	3.3
Management Science (*MS*)	US 'A'	MS/OR	39	1,807	2.1
MIS Quarterly (*MISQ*)	US 'A'	General IS	34	347	9.8
Total			1,093	7,184	15.2

Table 1: Article sample by journal.

The sample comprised 1,093 papers that concern the development and use of IT-based systems that support management decision-making. Table 1 shows the distribution of these papers by journal as well as identifying the percentage of papers in each journal that were classified as DSS. Overall, 15.2% of published papers between 1990 and 2004 were in the DSS field. When only the general IS journals are examined, the proportion of DSS articles is still a healthy 11.4%. Each of these measures indicate that DSS is an important part of the IS discipline.

The protocol used to code each paper appears in Arnott and Pervan (2005). Some papers, termed 'example articles', were selected as being representative of the various article types. To calibrate the coding process, the example articles were coded independently and compared. A small number of changes to the initial assessments were made. The remaining articles were then coded by the two

authors and a research assistant working independently. The time taken to code each article varied considerably, ranging from over an hour for large, complex papers, to ten minutes for the straightforward coding of a known paper. In coding each paper the emphasis was on the dominant attribute of each factor for each paper. For consistency, the coding of articles by the research assistant was reviewed by the first author. The coded protocols were entered into an SPSS database for analysis by the second author, who also performed statistical consistency checks on the coding.

Research methods and paradigms

Table 2 shows the empirical papers in the sample coded for research paradigm. The papers were coded as positivist, interpretivist, critical, or mixed. We followed the approach of Chen and Hirschheim (2004) and only coded empirical papers for paradigm. Only one paper, in Personal DSS, was coded as mixed. Surprisingly, no DSS paper in the sample adopted a critical paradigm. The analysis period saw a significant increase in non-positivist research in IS with an increasing presence of interpretivist case studies in the highest quality journals. Table 2 shows that DSS research is overwhelmingly dominated by the positivist paradigm with 92.3% of empirical studies following that approach. Chen and Hirschheim's (2004) study of general IS research from 1991 to 2001 reported that 81% of papers had a positivist orientation with 19% using an interpretivist approach. Thus, DSS research is more dominated by positivism than general IS research and DSS researchers have been more conservative than their general IS colleagues in embracing philosophical diversity.

	Positivist		Interpretivist		Total
	No of Articles	% of Type	No of Articles	% of Type	No of Articles
Personal DSS	250	96.5	8	3.1	259
Group Support Systems	202	87.4	29	12.6	231
EIS/BI	50	83.3	10	16.7	60
Data Warehouse	11	78.6	3	27.4	14
Intelligent DSS	86	98.0	1	1.1	87
Knowledge Mgt-based DSS	14	87.5	2	12.5	16
Negotiation Support Systems	17	94.4	1	5.6	18
Many	31	96.9	1	3.1	32
Total	662	92.3	54	7.5	717

Table 2: DSS types by research paradigm.

Arnott and Pervan (2005) found that only 9.6% of DSS papers were of high or very high professional relevance. One strategy for improving the relevance of DSS research is to increase the number of case studies, especially interpretive case studies. Put simply, a field that is so removed from practice needs case study work to ensure that the questions it is addressing are both relevant and important. Interpretive case studies can illuminate areas of contemporary practice in ways that natural science-like studies such as laboratory experiments and surveys

cannot (Cavaye, 1996; Eisenhart, 1989). Importantly, they can inspire researchers to focus on issues of current importance and build lasting links between academics and senior professionals, a process that will assist with grant funding as well. Table 2 shows that data warehousing and EIS/BI have the highest proportion of interpretivist studies (although the number of DW papers is probably too small to make firm conclusions), while intelligent DSS and personal DSS have almost ignored non-positivist paradigms. It is interesting that the more modern types of DSS are being researched with a more contemporary mix of paradigms than older types of DSS. Further analysis of the interpretivist studies reveals that almost all are focused on the theory development stage of research, thus confirming their importance in developing new theory in DSS.

Table 2 also shows the dominance of the oldest types of DSS in the agendas of researchers. While DW and EIS/BI have been mainstream in practice since the mid 1990s they only account for 9% of empirical papers (8.4% of all papers). Arnott and Pervan (2006) confirmed this dominance of the oldest aspects of the field.

	Article Type	Number	%
Non-Empirical			
Conceptual	DSS Frameworks	51	4.7
	Conceptual Models	28	2.6
	Conceptual Overview	48	4.4
	Theory	22	2.0
Illustrative	Opinion and Example	22	2.0
	Opinion and Personal Experience	5	0.5
	Tools, Techniques, Methods, Model Applications	126	11.5
Applied Concepts	Conceptual Frameworks and Their Application	65	5.9
Empirical			
Objects	Description of Type or Class of Product, Technology, Systems etc.	36	3.3
	Description of Specific Application, System etc.	194	17.7
Events/Processes	Lab Experiment	204	18.7
	Field Experiment	19	1.7
	Field Study	36	3.3
	Positivist Case Study	58	5.3
	Interpretivist Case Study	39	3.6
	Action Research	4	0.4
	Survey	73	6.7
	Development of DSS Instrument	4	0.4
	Secondary Data	26	2.4
	Simulation	33	3.0

Table 3: Sample by article type.

Table 3 shows an analysis of the sample using the IS research classification developed by Alavi and Carlson (1992) and revised by Pervan (1998). The highest level of the classification divides papers into empirical and non-empirical categories. The lowest level addresses research designs and methods. Table 3 shows that around one-third (33.6%) of DSS research is non-empirical, with the remaining two-thirds (66.4%) being empirical. Chen and Hirschheim's (2004) analysis of overall IS research reported a different split between non-empirical (40%) and empirical (60%) research, showing that DSS research has significantly more empirical research than general IS. The most popular single research method since 1990, using the Alavi and Carlson (1992) taxonomy, has been the laboratory experiment. This, in part, reflects the methodological focus of North American business schools.

What is noteworthy in Table 3 is the 21% of papers in the empirical-objects categories. DSS was founded on the development of experimental systems for managers and has a long history of publication of descriptions of DSS applications that are novel or important. This is part of what is now called design science (Hevner et al., 2004). There could also be a significant amount of design-science research in the 'Tools, Techniques, Methods, Model Applications' and 'Conceptual Frameworks and Their Application' article types. As a result, design science could be the largest major category of DSS research. DSS researchers have much to offer the current debate on IS design science methodologies; it may even be the most significant contribution that DSS can make to its parent discipline.

Judgement and decision making foundations

It is axiomatic that research in DSS should be grounded in quality judgement and decision-making (JDM) research since it is focused on supporting and improving management decision making. In coding and analysing this JDM grounding, special care was taken to distinguish between merely citing reference theory in introductory or focussing discussion and using reference theory in the design of the research and interpretation of results. Only the second, integral, use of reference theory was coded in this project. Surprisingly, the result was that 47.8% of papers did not use any reference research in judgement and decision-making. Further, the percentage of papers that explicitly use JDM reference research is falling slightly over time. Table 4 shows the mean number of citations to JDM reference research per paper for each type of DSS. Group and Negotiation Support, and Personal DSS have the most reference citations, with the current professional mainstream of data warehousing having the poorest grounding.

	No of Articles	Mean	Standard Deviation	Median
Personal DSS	389	2.15	3.72	0.00
Group Support Systems	319	2.62	3.15	2.00
EIS	76	1.55	2.84	0.00
Data Warehouse	16	0.00	0.00	0.00
Intelligent DSS	160	0.73	1.61	0.00
Knowledge Management Based DSS	22	1.82	3.11	0.00
Negotiation Support Systems	43	2.33	2.61	1.00
Many	68	2.71	4.68	1.00
Total	1,093	2.04	3.31	1.00

Table 4: Cited judgement and decision making references by DSS type.

Another aspect of the intellectual structure of a field is the degree of coherence between different sub-fields. Arnott and Pervan (2005), using an historical analysis, characterised DSS as a set of partially connected sub-fields. The 'partially connected' descriptor hints at a field that may not be as coherent as may be imagined. Table 5 shows the top five judgement and decision-making reference articles for each DSS type. The total number of references per type is shown in the left column and the right column shows the reference ranking and reference frequency for each type. The 'many' classification in KM-based DSS and NSS indicates a large number of reference articles with one or two citations in the sample. These 'many' articles are different to those cited elsewhere in the table. This analysis of the JDM foundation citations can provide an indication of the coherence of the field. If the key references across different DSS types are similar then the discipline has a high level of coherence.

What immediately stands out in the table is the major disconnect between the grouping of GSS and Negotiation Support Systems, and the other DSS types; there are no common key references between these two groupings. This suggests that they may even be considered as separate academic fields, a notion that is supported by the conduct of separate specialist conferences and the publishing of separate specialist journals. The lack of any JDM references in data warehousing research indicates that it could also be regarded as a separate academic field. Data structures, data quality, and information delivery seems to be this DSS type's core concerns. Another interesting observation is the integrating nature of Simon's behavioural theory of decision making across Personal DSS, EIS/BI, Intelligent DSS, and KM-based DSS. The strength of this referencing does indicate intellectual coherence among these DSS types.

DSS Type	Key Reference Articles — Frequency
Personal DSS	1. Simon (1960) — 30
(389 papers, 828 references)	2. Newell & Simon (1972) — 22
	3. Keeney & Raiffa (1976) - 17
	4. Tversky & Kahneman (1974), Mintzberg et al. (1976) — 15
Group Support Systems	1. DeSanctis & Gallupe (1987) — 82
(319 papers, 834 references)	2. McGrath (1984) — 35
	3. Daft & Lengel (1986) — 19
	4. Nunamaker et al. (1991) — 16
	5. Steiner (1972) — 15
EIS/BI	1. Mintzberg (1973), Isenberg (1984) — 5
(76 papers, 117 references)	2. Newell & Simon (1972), Simon (1957), Mintzberg et al. (1976), Cyert & March (1963)
Data Warehouse	No key references
(16 papers, 0 references)	
Intelligent DSS	1. Newell & Simon (1972), Saaty (1980) — 5
(160 papers, 115 references)	2. Keeney & Raiffa (1976) — 4
	3. Simon (1960), Simon (1977) — 3
KM-based DSS	1. Newell & Simon (1972) — 3
(22 papers, 40 references)	2. Many — 1
Negotiation Support Systems	1. Raiffa (1982) — 5
(43 papers, 101 references)	2. Shakun (1988), Mumpower (1991) — 4
	3. DeSanctis & Gallupe (1987) — 3
	4. Many — 2

Table 5: Key reference articles per DSS type.

This analysis of Table 5 indicates that the DSS field is fragmented with marked disconnects between important sub-fields. In terms of judgement and decision-making reference theory, there appears to be three disjoint groups of DSS research:

- GSS and Negotiation Support Systems;
- Personal DSS, EIS/BI, Intelligent DSS, and KM-based DSS;
- Data Warehousing.

A further aspect of Table 5 is the relative age and scope of the reference research. Although the article sample spans 1990 to 2004, the major references are quite old and many are from the 1970s; only two frequently cited references are from the 1990s. This is another aspect of discipline conservatism. In particular, the early behavioural decision theory associated with Herbert Simon is dominant. This could be a negative consequence of Simon's Nobel Prize and it could be that the academic standing of Nobel Prize winning theory has prevented or discouraged the search for other reference theory. An author is unlikely to be criticised for basing their research on Nobel Prize winning theory. More contemporary theory is often the subject of vigorous debate and can be a riskier prospect with journal editors and reviewers. Daniel Kahneman won a Nobel Prize in 2002 for his behavioural decision theory based on heuristics and biases and the effect of this more recent prize may be to counteract the evident Simon-based conservatism of DSS research.

Conclusions

DSS has a long history of success in scholarship and practice. BI and Personal DSS systems are now an integral part of most managers' work and DSS scholars have contributed significantly to IS theory in areas such as evolutionary systems development, multi-dimensional data structures, critical success factors, group processes, and managerial information behaviours. Despite this history of achievement, the discipline is at an important turning point. It is increasingly removed from practice, is relatively unsuccessful in major competitive grant funding, and does not have the presence in 'A' journals that it should. The analysis of the methodological and theoretical foundations of DSS provided in this paper gives important insight into the field's underperformance.

A major theme of our analysis is the conservatism of the field. The evidence for this lies with:

- The small proportion of non-positivist research;
- The relatively low proportion of non-empirical research;
- The continuing dominance of Personal DSS and Group SS in research agendas; and
- The reliance on an aging and narrow reference foundation in judgement and decision making.

This evidence provides the foundations for our major recommendations. First, DSS must embrace more contemporary reference theory in judgement and decision making. This applies to research on all types of DSS. DSS researchers should look for this reference research not only in psychology, but in business and other social science fields as well. Second, researchers should shift their objects of study toward data warehousing and EIS/BI. In effect, such a shift would move researchers from a well accepted, well established comfort zone to the messy reality of current practice. The fundamental research questions of DSS that relate to how to support managers in important decision tasks would need little change. Third, DSS researchers need to embrace more diversity in epistemology and methodology. In an applied field struggling for professional relevance, a significant amount of theorising and exploratory research needs to be undertaken. This research should be focused on concepts and theory that will lead to the reshaping of the ideas and methods of influential professionals (Lyytinen, 1999). This attention to research with fundamental and long lasting effect on practice is much more important than orienting projects towards the short term concerns of CIOs.

The design science heritage of DSS is very important for IS as a whole since the parent discipline shares DSS's problem of declining professional relevance, albeit to a lesser extent (Benbasat and Zmud, 1999; Argarwal and Lucas, 2005). One aspect of the relevance decline has been the pursuit of research rigor; another

has been a decline in the number of quality studies that address systems development. A number of influential IS researchers have called for greater attention on the IT artifact in research designs and the greater use of quality design-science designs (Orlikowski and Iacono, 2001; Markus et al., 2002). DSS's long experience with design science can inform its increasing application in general IS. For example, in the landmark *MIS Quarterly* paper on the conduct of design science research in IS (Hevner et al., 2004) two of the three exemplar studies analysed were from DSS. Importantly, design-science research can link researchers to practitioners in creative and influential ways.

Related to the analysis in this paper, two further investigations of the intellectual foundations of DSS are under way. The first is a critical review of DSS design-science research using the guidelines developed by Hevner et al. (2004). The aim of this analysis is to provide prescriptions for improving the rigor and relevance of DSS design science research. The second project is a more detailed analysis of the judgement and decision-making foundations of DSS research with a special emphasis on the role Simon's theory of behavioural decision-making has played in shaping the field.

We finish this paper with a call-to-arms to other IS researchers. The IS discipline faces a critical period in its development. There has been a significant downturn in IS-related IT activities and spending in OECD countries. There are also serious questions over the direction and relevance of IS research (Benbasat and Zmud, 2003). An important aspect of understanding our current situation and developing research agendas for the future is the rigorous analysis of high-quality published research. The literature analysis project described in this paper can support DSS disciplinary development. Other branches of IS scholarship need to follow this lead.

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