An Assessment of DSS Design Science using the Hevner, March, Park, and Ram Guidelines

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Abstract
Design science has been an important strategy in decision support systems (DSS) research since the inception of the field in the early 1970s. Recent reviews of DSS research have indicated a need to improve its quality and relevance. DSS design science has an important role in this improvement as design science can engage industry and the profession in intellectually important projects. The 2004 publication of the Hevner, March, Park, and Ram (HMPR) Guidelines for the conduct and assessment of information systems design science provides a vehicle for assessing DSS design science. This paper presents research that used bibliometric content analysis to apply the HMPR Guidelines to a representative sample of DSS design-science papers in 14 journals. The analysis highlights issues that need attention, notably, evaluation, research design, strategic focus, and theorizing. Comments are also offered on the experience of applying the HMPR Guidelines to a large body of research.

1. Introduction

Decision support systems (DSS) is the area of the information systems (IS) discipline that is focused on systems that support and improve managerial decision-making terms of contemporary professional practice. Arnott and Pervan (2008) identified seven DSS types that are separated by technology, theory foundations, user populations, and decision tasks. These seven DSS types are:

- *Personal Decision Support Systems (PDSS)* are usually small-scale systems that are developed for one manager, or a small number of independent managers, to support a decision task. Perhaps the oldest DSS type, PDSS remains important in practice, especially in the form of user-built models and data analysis systems (Arnott, 2008).
- *Group Support Systems (GSS)* “consists of a set of software, hardware, and language components and procedures that support a group of people engaged in a

decision-related meeting" (Huber, 1984). GSS are typically implemented as electronic meeting systems (EMS) (Dennis et al., 1988) or group decision systems (GDS) (Pervan & Atkinson, 1995).

- *Negotiation Support Systems (NSS)* are DSS that operate in a group context but, as the name suggests, they involve the application of IT to facilitate negotiations (Rangaswamy & Shell, 1997). As the group members in NSS are opposing parties, NSS has had to be developed on a different theory foundation to that of GSS.
- *Intelligent Decision Support Systems (IDSS)* involve the application of artificial intelligence techniques to decision support. IDSS can be classed into two generations: the first involved the use of rule-based expert systems for decision support, and the second uses neural networks, genetic algorithms, and fuzzy logic (Turban et al., 2005).
- *Knowledge Management-Based DSS (KMDSS)* are systems that support decision making by aiding knowledge storage, retrieval, transfer, and application. KMDSS can support individual and organizational memory, and inter-group knowledge access (Burstein & Carlsson, 2008).
- *Data Warehousing (DW)* provides the large-scale data infrastructure for decision support. In general terms, a data warehouse is a set of databases created to provide information to decision makers (Cooper et al., 2000). In practice, data warehousing includes enterprise data warehouses, data marts, and applications that extract, transform and load (ETL) data into the data warehouse or mart (Watson, 2001).
- *Enterprise Reporting and Analysis Systems (ERAS)* are enterprise-scale systems that include executive information systems (EIS), online analytical processing systems (OLAP), business intelligence (BI), and, more recently, corporate performance management systems (CPM). BI tools access and analyze data warehouse information using predefined reporting software, query tools, and analysis tools (Nelson, Todd, & Wixom, 2005).

Over the nearly four decades of its history, DSS has moved from a radical movement that changed the way information systems were perceived in business, to a mainstream commercial IT movement that all organizations engage. During this time DSS has continued to be a significant sub-field of IS scholarship.

Design science is an alternative, or complement, to the natural science approach that is dominant in information systems research. In design science, the researcher "creates and evaluates IT artifacts intended to solve identified organisational problems" (Hevner, March, Park, & Ram, 2004, p. 77). March and Smith (1995) clearly draw a distinction between natural and design science: "Whereas natural science tries to understand reality, design science attempts to create things that serve human purposes" (p. 253). Design science is particularly relevant for contemporary IS research because it may help researchers confront two of the major challenges of the discipline: the role of the IT artifact in IS research (Orlikowski & Iacono, 2001) and the low level of professional relevance of many IS studies (Benbasat & Zmud, 1999). The terminology of design science is gaining momentum in IS. March and Smith (1995) was the first major use of the term in IS, although "design theory" was used earlier (Walls, Widmeyer, & El Sawy,1992). The landmark publication is Hevner et al. (2004) who proposed a set of seven guidelines to assess design-science research in IS. The publication of the guidelines in *MIS Quarterly* is particularly symbolic. A prescriptive design-science methods paper in the most cited IS journal will be influential with journal editors and reviewers, and it is also likely to be used by PhD examiners for IS design-science theses.

DSS research has a long history of using design-science strategies and many of the early DSS projects involved designing and implementing innovative IT-based systems (For example, Meador & Ness, 1974; Keen & Gambino, 1983). General reviews of DSS research have pointed to a need to increase the rigor of DSS design-science research (Arnott &

Pervan, 2005, 2008). One way to improve the quality of DSS design science, and to improve its contribution to general IS research, is to systematically review published projects and identify strategies for improvement. That is the goal of this paper.

2. Research Method and Design

There are two fundamental strategies for literature analysis. The first, thematic analysis, involves classifying and analysing papers according to themes that are relevant to the theory and practice goals of a research project (Webster & Watson, 2002). Thematic analysis is by far the most common form of literature review in journal papers and theses. The second fundamental strategy is bibliometrics, which involves the measurement of publication patterns. The two most common bibliometric methods are citation analysis (Osareh, 1996) and content analysis (Weber, 1990). In DSS literature analysis, Sean Eom's series of studies has used citation analysis, to analyse the intellectual structure of the field (Eom 1995, 1996, 1999, 2007; Eom and Lee 1990,1993). In bibliometrics, content analysis involves the coding and analysis of a representative sample of research articles. In this approach, data capture is driven by a protocol that can have both quantitative and qualitative aspects. This form of data capture is a very labour intensive process but it has the advantage that it can illuminate the deep structure of the field in a way that is impossible to achieve with other literature analysis approaches. This research adopted a content analysis method to help understand the nature of DSS design-science research, and to assess its strengths and weaknesses.

The sample of articles for this project is DSS research published between 1990 and 2005 in the 14 journals 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 (Alavi & Carlson, 1992; Benbasat & Nault, 1990; Pervan, 1998; Chen & Hirschheim, 2004). 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 we included five European information systems journals (*ISJ, EJIS, I&O, JIT, and JSIS*) in our sample. Following Chen and Hirschheim (2004), the classification of a journal as US or European is largely based on the location of the publisher.

The quality of journals was classified as 'A' level or 'Other'. This classification was based on publications that address journal ranking (Gillenson & Stutz, 1991; Hardgrave & Walstrom, 1997; Hirschheim, 1992; Holsapple, Johnson, Manakyan, & Tanner 1994; Mylonopoulo & Theoharakis, 2001; Walstrom, Hardgrave, & Wilson, 1995; Whitman, Hendrickson, & Townsend, 1999) and on discussions with journal editors and senior IS academics. Another indicator of journal quality is the Thomson ISI journal impact factor. The 2006 impact factors for 13 of the 14 journals in the sample are shown in Table 1. *Information & Organization* is not in the Thomson ISI index.

The selection of the journal sample was the first stage in arriving at the DSS design-science sample. An overview of the sampling process is shown in Figure 1.

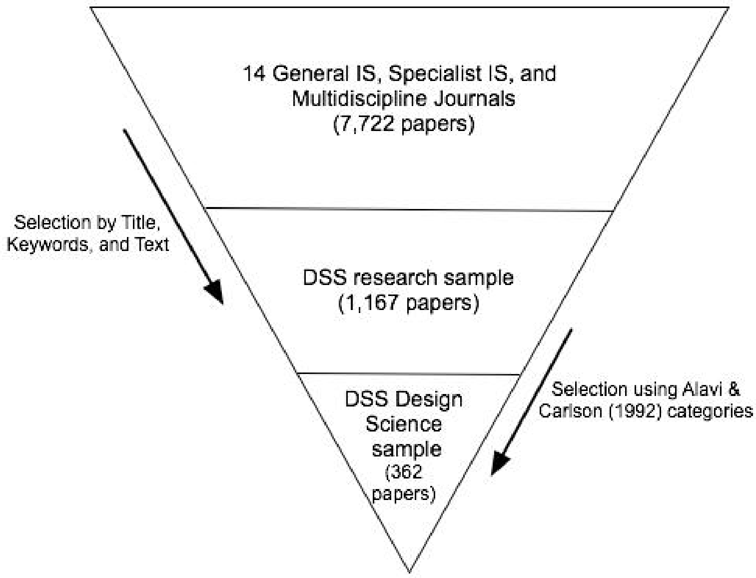

Figure 1. Arriving at the DSS Design-Science Sample

The first stage of article sampling was to identify the DSS articles in the 14 journals. The papers were initially 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 in terms of definition of DSS provided above. This procedure identified 1,167 DSS papers. Table 1 shows the distribution of the DSS papers in the sample by journal. Overall, 15.1**%** of published papers in the 14 journals between 1990 and 2005 were in the DSS field. When only the general IS journals in the sample are examined, the proportion of DSS articles increases to 18.9**%.** Each of these measures indicate that DSS is an important part of the IS discipline.

Table 1. DSS and DSS Design-Science Article Samples by Journal

Journal	Origin	Ranking (ISI Impact Factor)	Journal Orientation	No of DSS Articles Published	DSS Design-science Articles Published	DSS Design-science Articles as a Percentage of Published DSS Articles
Decision Sciences (*DS*)	US	A (1.620)	Multi-discipline	67	19	28.4
Decision Support Systems (*DSS*)	US	A (1.160)	General IS	500	247	49.4
European Journal of Information Systems (*EJIS*)	Europe	A (0.862)	General IS	25	5	20.0
Group Decision and Negotiation (*GD&N*)	US	Other (0.429)	Specialist IS	139	24	17.3
Information and Management (*I&M*)	US	A (2.119)	General IS	104	13	12.5
Information and Organization (*I&O*)	Europe	Other (not abstracted)	General IS	16	1	6.3
Information Systems Journal (*ISJ*)	Europe	A (1.543)	General IS	16	1	6.3
Information Systems Research (*ISR*)	US	A (2.537)	General IS	34	5	14.7
Journal of Information Technology (*JIT*)	Europe	A (1.239)	General IS	25	2	8.0

Journal of Management Information Systems (*JMIS*)	US	A (1.818)	General IS	84	18	21.4
Journal of Organizational Computing and Electronic Commerce (*JOC&EC*)	US	Other (0.500)	Specialist IS	73	12	16.4
Journal of Strategic Information Systems (*JSIS*)	Europe	Other (0.971)	General IS	8	1	12.5
Management Science (*MS*)	US	A (1.687)	Multi-discipline	41	13	31.7
MIS Quarterly (*MISQ*)	US	A (4.731)	General IS	35	1	2.9
Total				1,167	362	31.0

Each of the 1,167 papers was coded using the Alavi and Carlson (1992) taxonomy, as modified by Pervan (1998) to include action research and to distinguish between positivist and interpretive case studies. The result of this coding is shown in Table 2. The papers from the article types *Tools, Techniques, Methods, Model Application; Conceptual Frameworks and their Application; Description of Type or Class of Product; Technology, Systems etc.; Description of Specific Application, System etc*; and *Action Research,* were inspected by both researchers to see if they met the design-science research definition of Hevner et al. (2004). In particular, each paper was inspected for a focus on an innovative artifact, rather than providing a description of an existing commercial product. This yielded a DSS design-science sample of 362 papers. This sample shows the importance of design science to DSS scholarship, as design science is the strategy of 31% of DSS papers. To help identify trends in DSS design-science research we divided the sample into four four-year eras: 1990-1993, 1994-1997, 1998-2001, and 2002-2005.

The 362 DSS design-science papers were then coded using the protocol shown in Appendix A. The protocol was based on the guidelines proposed by Hevner et al. (2004). The time taken to code each article varied from 20 minutes to over one hour. To ensure coding validity each paper was coded by both researchers, disagreements in coding were discussed and resolved. An important aspect of coding validity is that the two researchers have decades of experience in the DSS area, are experienced journal reviewers and editors, and have published DSS design-science projects (for example, Arnott, 2004, 2006).

Table 2. The DSS and DSS Design-Science Samples by Article Type

		Article Type	DSS Papers		DSS Design Science		
			No.	% of Sample	No.	% of Sample	% of DSS
Non-Empirical	Conceptual Orientation	DSS Frameworks	53	4.5	0	0.0	0.0
		Conceptual Models	30	2.6	0	0.0	0.0
		Conceptual Overview	49	4.2	0	0.0	0.0
		Theory	22	1.9	0	0.0	0.0
	Illustrative	Opinion and Example	22	1.9	0	0.0	0.0
		Opinion and Personal Experience	5	0.4	0	0.0	0.0
		Tools, Techniques, Methods, Model Applications	148	12.7	92	25.4	62.2
	Applied Concepts	Conceptual Frameworks and Their Application	69	5.9	41	11.3	60.3
Empirical	Objects	Description of Type or Class of Product, Technology, Systems etc.	39	3.3	27	7.5	69.2
		Description of Specific Application, System etc.	215	18.4	199	55.0	92.6
	Events/	Lab Experiment	209	17.9	0	0.0	0.0
	Processes	Field Experiment	19	1.6	0	0.0	0.0
		Field Study	37	3.2	0	0.0	0.0
		Positivist Case Study	64	5.5	0	0.0	0.0
		Interpretivist Case Study	37	3.2	0	0.0	0.0
		Action Research	6	0.5	3	0.8	50.0
		Survey	77	6.6	0	0.0	0.0
		Development of DSS Instrument	4	0.3	0	0.0	0.0
		Secondary Data	28	2.4	0	0.0	0.0
		Simulation	34	2.9	0	0.0	0.0
Total			1,167		362		31.0

3. An Analysis of DSS Design-Science Research

In this section we present the analysis of the papers in the DSS design-science sample. First, some observations are made about the general nature of DSS design-science. This is followed by a detailed analysis of the sample using the guidelines proposed by Hevner et al. (2004), the “HMPR guidelines”.

3.1. “Design Science” in DSS Design Science

As mentioned in the Introduction, the term “design science” is relatively new to IS research. The definition used to identify DSS design-science research was taken from Hevner et al., (2004, p.77), who stated that the design-science researcher “creates and evaluates IT artifacts intended to solve identified organisational problems”. March and Smith (1995) argued that design science must be technology oriented.

In terms of this project, authors do not need to explicitly call their research “design science” for it to be retrospectively identified as design science. In our sample, only 6 papers (1.7%) mentioned the term “design science”. This means that the authors of 356 papers (98.3%) either were not aware of design science, or did not identify their work as design science. Where authors did identify an overall research strategy they mostly used terms such “description”, “development”, “design”, “implementation” as shown in Table 3. The term “development” was used in 18 of the 42 papers identified (either on its own or in combination with other terms, including “implementation”, “design”, “description”, “assessment”, and “validation”). “Description” was used in 13 papers (on its own, or with demonstration”, “implementation”, and “development”). “Design” was utilised in 6 papers, “implementation” in 4 papers, and ‘demonstration/demonstrate” in 3 papers.

Table 3. Non “Design Science” Descriptors in DSS Design-Science Research

	Frequency	Percent of Sample
Description	10	2.8
Development	7	1.9
Design	2	0.6
Development and implementation	2	0.6
Design and implementation	2	0.6
Design and development	2	0.6
Exploratory systems development	2	0.6
Action research	2	0.6
Description and demonstration	1	0.6
Description of implementation	1	0.3
Description of development	1	0.3
Design, development, and assessment	1	0.3
Development and validation	1	0.3
Systems development	1	0.3
Theory development and implementation	1	0.3
Implementation	1	0.3
Demonstration	1	0.3
Propose-present-demonstrate	1	0.3
Application of model and method	1	0.3
Case study	1	0.3
Decision analysis	1	0.3
	42	13.4

To further understand this issue we examined the citations in the sample to foundational design-science papers. The frequency of citation of these papers is shown in Table 4. This confirms the overall impression of the method identification statistics with only 3% of DSS design-science papers citing these foundational papers.

Table 4. Design-Science Citations in DSS Research

Reference	Frequency
Simon (1996 or earlier) *The Sciences of the Artificial*	3
Walls et al. (1992) *ISR*	3
Gero (1990) *AI Magazine*	1
Hevner et al. (2004) *MISQ*	1
March & Smith (1995) *DSS*	1
Nunamaker et al. (1991) *JMIS*	1
Whyte (1989) *Sociological Forum*	1
None	351 (97.0%)
Total	362

The literature analysis suggests that the term "design science" has had little impact in DSS research. Even papers authored by researchers that are leading the design-science movement in IS have not cited design-science reference works or mentioned design science as the method (for example, Berndt, Hevner, & Studnicki, 2003). This could be an artifact of journal reviewing practices where editors and reviewers prefer terms other than design science to describe a paper's overall research strategies.

3.2. HMPR Guideline 1 – The Design Artifact

The first HMPR Guideline concerns the design artifact. Hevner et al. (2004, Table 1), following the definitions of March and Smith (1995), state: "Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation." The coding of the DSS sample yielded 396 artifacts. Thirty-four papers contained significant secondary artifacts in addition to their primary products. The results of the coding are shown in Table 5.

Table 5. Design Artifacts in DSS Design-Science Research (Primary and Secondary)

Design Artifact	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Construct	0	0.0	0	0.0	1	1.2	1	0.9	2	0.5
Model	7	9.3	9	7.1	5	5.9	7	6.4	28	7.1
Method	12	16.0	34	27.0	18	21.2	39	35.5	103	26.0
Instantiation	56	74.7	83	65.9	61	71.8	63	57.3	263	66.4
Total	75		126		85		110		396	

Clearly, the focus in DSS research over all time periods has been on instantiations; they constitute close to two-thirds of all artifacts. High quality examples of these instantiation artifacts include R-EIS, a repository-based executive information system (Chen, 1995), and PUZZLE, a strategic business intelligence system (Rouibah & Ould-ali, 2002). However, in a positive sign of a maturing field, the development of methods has increased to 35.5% of design artifacts in the most recent time period. An example of a high-quality method artifact in this period is the multi-agent design for a DSS in Hall, Guo, Davis, and Cegielski (2005).

3.3. HMPR Guideline 2 – Problem Relevance

The second HMPR Guideline addresses problem relevance. Hevner et al. (2004, Table 1), define the second guideline as: "The objective of design-science research is to develop technology-based solutions to important and relevant business problems." Unfortunately, Hevner et al. provide no guidance on how to assess or categorize the "importance" and "relevance" constructs.

To operationalize "importance" in this project, we used the well-accepted concept of a hierarchy of management processes and activities (Anthony, 1965). Anthony's framework divides management activities into a hierarchy of importance to the organization from strategic, through tactical, to operational. Table 6 presents the primary focus of the DSS papers over time using Anthony's management activities. The Table reveals that the focus has varied a little over time and has been mostly at the operational level (75.7%). Overall, only 10.5% of papers involved artifacts that had a strategic focus or impact.

Table 6. The Importance of Business Problems in DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strategic	3	4.2	12	10.4	14	18.2	9	9.2	38	10.5
Tactical	14	19.4	15	13.0	10	13.0	11	11.2	50	13.8
Operational	55	76.4	88	76.5	53	68.8	78	79.6	274	75.7
Total	72		115		77		98		362	

Further analysis of importance across DSS types revealed that the operational focus was consistently high across personal DSS, GSS, ERAS, IDSS, and NSS. In contrast, however, KMS were mostly tactical (71.4%). An example of design-science research with a tactical impact is KNOVA, a knowledge-based DSS for radiologists (Holden & Wilhelmij, 1995-96). In concert with the general sample, few KMS were focused on the strategic level. A high-quality exception is an IDSS for strategic alignment in manufacturing (Kathuria, Anandarajan, & Igbaria, 1999).

The relevance of each paper was coded on a scale of high, medium, and low. The relevance of DSS design-science research was assessed with respect to two main target audiences: IS practitioners and managerial users. In coding "relevance", we erred on the generous side, that is, when a decision between categories was difficult, we coded the paper in the higher category of relevance. The result of the coding is shown in Tables 7 and 8.

Table 7. The Relevance of DSS Design-Science Research to IS Practitioners

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	3	4.2	5	4.3	2	2.6	5	5.1	15	4.1
Medium	19	26.4	29	25.2	28	36.4	26	26.5	102	28.2
Low	50	69.4	81	70.4	47	61.0	67	68.4	245	67.7
Total	72		115		77		98		362	

Table 7 shows that the relevance scores for IS practitioners have been relatively stable over time. IS practitioner relevance was mostly low in the first period (69.4% in the low relevance category) and has remained at that level over time. Very few articles (4.1% overall) were rated to be of high relevance to IS practitioners. The story for managerial users in Table 8 is a little better with 23.8% of the papers rated high in managerial relevance and 'only' 41.4% coded as low relevance. The levels of managerial relevance have also been quite stable over time. A further crosstabulation of IS practitioner relevance against managerial user relevance reveals that only 9 of the 362 papers were highly relevant to both groups. The repository-based EIS, R-EIS (Chen, 1995), is one example of this high scoring group.

A further analysis of IS practitioner relevance over the different DSS types showed better relevance ratings for ERAS (53.8% or 7/13 of low relevance), DW systems (25% or ¼ low relevance), and KMS (28.6% or 2/7 low relevance), although it should be noted that the number of papers of these types is quite small. A similar analysis of managerial user relevance revealed that papers on ERAS, KMS, and NSS were of greater relevance to managerial users than other types of DSS.

Table 8. The Relevance of DSS Design-Science Research to Managerial Users

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	14	19.4	28	24.3	21	27.3	23	23.5	86	23.8
Medium	24	33.3	33	28.7	30	39.0	39	39.8	126	34.8
Low	34	47.2	54	47.0	26	33.8	36	36.7	150	41.4
Total	72		115		77		98		362	

3.4. HMPR Guideline 3 – Design Evaluation

The third HMPR Guideline concerns the evaluation of the design artifacts. Hevner et al. (2004, Table 1), define this guideline as: "The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods." The coding of the DSS design-science papers for this guideline was based on the evaluation taxonomy presented by Hevner et al. (2004, Table 2). The result of this coding is shown in Table 9.

Table 9. Evaluation Methods in DSS Design-Science Research

		1990-	1993	1994-	1997	1998-	2001	2002-	2005	Total	
		No.	%	No.	%	No.	%	No.	%	No.	%
Observational	Case study	6	8.3	10	8.7	13	16.9	13	13.3	42	11.6
	Field study	1	1.4	0	0.0	3	3.9	3	3.1	7	1.9
Analytical	Static	0	0.0	0	0.0	1	1.3	0	0.0	1	0.3
	Architecture	0	0.0	1	0.9	0	0.0	0	0.0	1	0.3
	Optimization	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Dynamic	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Experimental	Controlled experiment	1	1.4	4	3.5	5	6.5	5	5.1	15	4.1
	Simulation	14	19.4	17	14.8	17	22.1	26	26.5	74	20.4
Testing	Functional	0	0.0	2	1.7	0	0.0	2	2.0	4	1.1
	Structural	0	0.0	0	0.0	0	0.0	1	1.0	1	0.3
Descriptive	Informed argument	0	0.0	3	2.6	2	2.6	2	2.0	7	1.9
	Scenarios	13	18.1	21	18.3	8	10.4	15	15.3	57	15.7
None		37	51.4	57	49.6	28	36.4	31	31.6	153	42.3

Surprisingly, overall, 42.3% of papers were coded as "None". This means that the focus of the paper was the presentation and description of an artifact without any attempt of establishing its worth, effectiveness, or usefulness. This large proportion of un-evaluated projects is a major problem for DSS design science. Over time the situation is improving, from 51.4% coded as "none" in first period to 31.6% in the most recent period. However, 31.6% "none" is still a very poor result for the discipline. A further analysis of evaluation method against DSS type revealed that "None" was coded noticeably more often for GSS (54.9%) but less often for IDSS (29.8%).

Of the papers that did include an evaluation of the artifact, three approaches dominate, simulation at 20.4% of the sample, scenarios at 15.7%, and case study at 11.6%, with another, controlled experiment, significant at 4.1%. The other evaluation approaches identified by Hevner et al. (2004) are either hardly used, or not used at all. Interestingly, only 13.5% of papers evaluated their artifacts in the field. A further analysis of evaluation method by DSS type was performed but was limited to studies where an evaluation was actually undertaken. This analysis showed that:

- PDSS were mostly evaluated by simulation (37.1%) (e.g., Hall et al., 2005), scenarios (28.9%) (e.g., Balbo & Pinson, 2005), and case studies (18.6%) (e.g., Tavana & Banerjee, 1995);
- GSS were mostly evaluated by case studies (34.8%) (e.g., Dennis, Carte, & Kelly, 2003; and de Vreede & Dickson, 2000[1]), controlled experiments (21.7%) (e.g., Zhang, Sun, & Chen, 2005), and scenarios (17.4%) (e.g., Moreno-Jiminez, Joven, Pirla, & Lanuza, 2005);
- From the three ERAS papers from the eight evaluated used scenarios (e.g., Chen, 1995)
- For DW, only one study was evaluated and it used a case study (Sen & Sen, 2005);
- IDSS were mostly evaluated by simulation (50%) (e.g., Walczak, 2001) followed by scenarios (14.2%) (e.g., Kathuria et al., 1999);
- KMS (only 4 papers) were all evaluated by case studies (e.g., Holden & Wilhelmij, 1995-96);
- NSS (only 6 papers) were evaluated by scenarios (66.7%) (e.g., Kuula, 1998) or case studies (33.3%) (e.g., Noakes, Fang, Hipel, & Kilgour, 2005).

The HMPR Guideline 3 stresses rigor in evaluation via well-executed methods. Table 9 and the associated analysis by DSS type shows the presence or absence of evaluation, but not the quality of evaluation. To analyse the quality of evaluation, each paper that undertook some form of evaluation was first coded for the appropriateness of the evaluation method to the objects of the study and the nature of the artifact. Secondly, the quality of the execution of the evaluation method in each paper was assessed on a scale of high, medium, and low. Like the coding strategy used for Tables 7 and 8, evaluation method choice and execution quality were assessed generously. Tables 10 and 11 contain these assessments for those DSS papers where an evaluation method was used.

Table 10. The Choice of Evaluation Method in DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Highly	16	45.7	25	43.1	36	73.5	38	56.7	115	55.0

[1] Note that this paper actually used an action research approach for evaluation but had to be classified as case study because the HMPR guidelines did not include action research as an evaluation method.

Appropriate										
Adequate	18	51.4	32	55.2	12	24.5	28	41.8	90	43.1
Poor	1	2.9	1	1.7	1	2.0	1	1.5	4	1.9
Total	35		58		49		67		209	

In each era, when evaluation did occur, the level of appropriateness of the evaluation method choice was at least "adequate". This indicates that researchers who evaluate artifacts are making reasonable choices in terms of method. Over time the quality of the choice of evaluation method has been a little variable, but there is no significant trend in the coding.

Table 11. The Quality of Evaluation Execution in DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	5	14.3	16	27.6	13	26.5	23	34.3	57	27.3
Medium	17	48.6	24	41.4	26	53.1	34	50.7	101	48.3
Low	13	37.1	18	31.0	10	20.4	10	14.9	51	24.4
Total	35		58		49		67		209	

Table 11 shows that in each era, when evaluation was conducted, the quality of evaluation was mostly medium to high. This indicates that those researchers are doing a reasonable job in conducting the evaluation. Further, the proportion of low quality execution has steadily decreased from 37.1% in 1990-1993 to only 14.9% in 2002-2005.

The overall picture in relation to evaluation is that, surprisingly, over 40% of DSS design-science projects do not undertake formal evaluation of the artifacts. When artifact evaluation is performed, researchers generally make an appropriate choice of method. Further, the quality of the execution of evaluation is steadily, and significantly, improving.

3.5. HMPR Guideline 4- Research Contributions

The fourth HMPR Guideline concerns the research contributions of design science. Hevner et al. (2004, Table 1), define this guideline as: "Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies." Each paper in the DSS sample was examined for its primary research contribution according to the HMPR definition. Secondary contributions were also recorded where they occurred. Among the 362 papers, the design artifact was the primary research contribution in 360 cases, with only one paper having design foundations, and one having design methodologies as their primary research contribution. Only eight papers had a secondary research contribution: one in the design artifact, six in design foundations, and one contribution to design methodologies.

There were a number of examples of high-quality research contribution through a design artifact. These included a repository-based executive information system (Chen, 1995), a strategic business intelligence system (Rouibah & Ould-ali, 2002), and a knowledge-based DSS for radiologists (Holden & Wilhelmij, 1995-96). Two notable contributions to design foundations were a design theory for systems that support emergent knowledge processes (Markus, Majchrzak, & Gasser, 2002), and a groupware-based business process re-engineering process (Dennis et al., 2003). An example of a high-quality contribution to evaluation methodologies is DeSanctis, Snyder, and Poole (1994), who developed a method for conducting a preliminary evaluation of an EMS. In particular, their method assessed the match between user and designer perspectives on system interface, functionality, and holistic attributes.

3.6. HMPR Guideline 5 – Research Rigor

The fifth HMPR Guideline concerns the rigor of design-science research. Hevner et al. (2004, Table 1), define this guideline as "Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact."

We operationalized this guideline using two constructs: the rigor of the theoretical foundations of the research, and the rigor of the research methodology. Each construct was coded on a scale of strong, adequate, or weak. As with other HMPR guidelines, the coding was generous with respect to assessments at category boundaries.

The rigor of theory foundations was coded by considering the use of appropriate reference theory, and in particular argument as to why the reference theory is appropriate. The effective use of theory in evaluation and the discussion was coded highly, as was consideration of the limitations or weaknesses of the theory foundations. The result of the coding for the rigor of theory foundations is shown in Table 12. Over 80% of papers were coded as either adequate or strong. This has been fairly consistent over time and represents a good result for the DSS discipline. A crosstabulation of the rigor of theory foundations with DSS type found that the data in Table 12 were fairly consistent across DSS type.

Table 12. The Rigor of the Theoretical Foundations of DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strong	20	27.8	41	35.7	26	33.8	38	38.8	125	34.5
Adequate	38	52.8	47	40.9	42	54.5	46	46.9	173	47.8
Weak	14	19.4	27	23.5	9	11.7	14	14.3	64	17.7
Total	72		115		77		98		362	

The result of the coding of the rigor of research methodologies in the sample is shown in Table 13. The results are extremely disappointing, with 75% of papers in the weak category and only 3.3% coded as strong. Most of the papers in the "weak" set did not mention research method and design at all. The time trend in the sample is for the less rigorous category to decrease substantially over time, a positive result for the field. Unfortunately, the improvement has been in the adequate category, and not in the strong.

Table 13. The Rigor of the Research Methodologies of DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strong	0	0.0	6	5.2	2	2.6	4	4.1	12	3.3
Adequate	10	13.9	21	18.3	18	23.4	31	31.6	80	22.1
Weak	62	86.1	88	76.5	57	74.0	63	64.3	270	74.6
Total	72		115		77		98		362	

Table 14 contains a crosstabulation of the rigor of the theoretical foundations against the rigour of the research methodologies. It reveals a strong association between the constructs (a correlation of 0.408, which is significant at the 0.1% level). Also, the table reveals the direction of the association. In the 64 design-science DSS cases where the theoretical foundations are weak, all 64 are weak in their research methodologies. This means that DSS design-science researchers who are not rigorous with their theoretical foundations pay little attention to research methodology issues.

Table 14. Theoretical Foundations versus Research Methodologies

Research Methodologies	Theoretical Foundations							
	Strong		Adequate		Weak		Total	
	No.	%	No.	%	No.	%	No.	%
Strong	10	7.9	2	1.2	0	0.0	12	3.3
Adequate	52	41.3	28	16.3	0	0.0	80	22.1
Weak	64	50.8	142	82.6	64	100.0	270	74.6
Total	126		172		64		362	

3.7. HMPR Guideline 6 – Design as a Search Process

The sixth HMPR Guideline concerns the iterative search process that is characteristic of high quality design. Hevner et al. (2004, Table 1), define this guideline as: "The search for an effective artifact requires utilizing available means to reach desired ends wile satisfying laws in the problem environment."

Thirty-seven papers (10.2% of the sample) decomposed the design problem into sub-problems, 23 papers (6.4% of the sample) displayed iteration from the sub-problem solution to the overall problem solution, and 10 papers (2.8% of the sample) used satisficing to decide on the solution convergence point. This analysis shows little support for an evident search process in DSS design-science research.

3.8. HMPR Guideline 7 – Communication of Research

The seventh, and final, HMPR Guideline concerns the communication of research. Hevner et al. (2004, Table 1), define this guideline as: "Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences."

The effectiveness of communication was coded on a scale of high, medium, and low, with the "generous" approach of the coding of other constructs. Both coders have significant technical and managerial experience. The result of the coding is shown in Tables 15 and 16.

Table 15. The Effectiveness of Technology-oriented Communication in DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	17	23.6	29	25.2	28	36.4	41	41.8	115	31.8
Medium	43	59.7	61	53.0	41	53.2	48	49.0	193	53.3
Low	12	16.7	25	21.7	8	10.4	9	9.2	54	14.9
Total	72		115		77		98		362	

Table 16. The Effectiveness of Management-oriented Communication in DSS Design-Science Research

	1990 -	1993	1994 -	1997	1998 -	2001	2002 -	2005	Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	0	0.0	2	1.7	3	3.9	0	0.0	5	1.4
Medium	10	13.9	8	7.0	14	18.2	16	16.3	48	13.3
Low	62	86.1	105	91.3	60	77.9	82	83.7	309	85.4
Total	72		115		77		98		362	

The effectiveness of technical communication was reasonable with 85.1% of papers coded as medium or high. Further, the proportion of papers with high effectiveness is increasing with each time period. The effectiveness of management communication is the reverse of technical communication with 85.4% of DSS papers coded as low effectiveness. Further, there is no significant improvement in the percentage of “low” papers over time. Unfortunately, only 1.4% of papers have high effectiveness in managerial communication.

The picture that emerges in Tables 15 and 16 is a discipline with a strong technical focus and one whose papers are unlikely to influence managerial activities. Table 16 goes a long way to explain the perceived lack of relevance in DSS (and IS) research. Perhaps the Table is a reflection of the nature of academic journals, where the rigor of theory base, design, and execution is rewarded by publication. The Table is also influenced by the nature of the DSS design-science sample. There are no premier professional journals in the sample as the object of this paper was to assess the quality of DSS design-science research. Had the *Harvard Business Review*, *Sloan Management Review*, and *MIS Quarterly Executive* been in the sample, the statistics for the effectiveness of managerial communication may have been more encouraging. On the other hand, we suspect the number of DSS articles in these premier professional journals could be small.

3.9. Summary of the HPMR Guideline-based Analysis

Using the HPMR Guidelines has provided an evidence-based understanding of the nature of DSS design-science research. The analysis shows that design science as a term has had little usage in DSS research and the current debate on design science is yet to impact published DSS research. Despite this, design science is the strategy of 31% of published DSS research since 1990. The focus in DSS design-science research over all time periods has been on instantiations; they constitute close to two-thirds of all research artifacts. Methods are around a quarter of DSS design-science artifacts. The “artifact” is the major contribution of most DSS design-science papers with few making design foundations or methodology contributions. DSS design-science addresses problems at the lowest level of managerial impact – operational management support is the focus of 75% of papers. The assessment of relevance shows that two-thirds of papers are of low relevance to IS partitioners. The assessment of relevance to managers is significantly better. Evaluation is major problem area for DSS design science with 42% of papers not undertaking any form of evaluation. The rigor of the theory foundations of DSS design science is reasonable, but many papers do not explicitly address research design. In terms of the communication of results, the analysis shows a discipline with a strong technical focus and one whose papers are unlikely to influence managerial activities.

4. Strategies for Improving DSS Design-Science Research

The analysis in the previous section provides a basis for considering how to improve the quality and impact of DSS design-science research. A word of caution is warranted before proceeding. Our aim is to identify major areas that can be improved in DSS design-science research. This identification can paint an overly negative impression of the field, which is not our intention. Further, the standard of IS research has improved significantly since 1990 and an assessment of older research from a 2008 perspective may be biased. It is important to remember that DSS design-science research has progressed over the 16 years of the sample period without the assistance of an agreed set of guidelines for what constitutes quality in design-science research. Nevertheless, the analysis in the previous section has highlighted four major areas that need serious attention. The areas identified overlap considerably and represent different levels of abstraction about the problems of DSS design-science research.

4.1. Evaluation

Evaluation is the biggest weakness in DSS design-science research. The focus of many papers is the description of an instantiation without any attempt at evaluation. The presence of rigorous and convincing evaluation is an important separator of consulting, professional design, and design research. Some form of convincing evaluation should mandatory for design-science research.

The analysis in this paper shows that those researchers who have performed some form of evaluation usually choose an appropriate strategy but the quality of the execution of the evaluation needs significant improvement.

There is also a need to broaden the base of evaluation methods and techniques. Three methods currently dominate DSS research, simulation, scenarios, and case studies, with experiments also significant. This is a very narrow methodological base. Other evaluation approaches in Hevner et al. (2004, Table 2) may be relevant, and methods not in this table should be considered. These could include qualitative methods like focus groups.

4.2. Research Foundations and Methodologies

The next major area of concern is with the theoretical foundation and research methodology of DSS design science. These are surprising concerns and are not explained by an averaging effect where, for example, poor foundations early in the sample are offset by strong foundations in papers later in the sample. The most disappointing result in the analysis was that 75% of papers were identified as being "weak" with respect to research methods. Most of these papers did not mention research design at all. While the rigor of research methods was low, the effectiveness of managerial communication (Guideline 7) was even worse with 85% of papers coded in the poorest category. This implies that there is no trade-off between rigor and relevance in DSS design-science research.

We believe that researchers should focus on improving the rigor of all aspects design-science research. It is the rigor of academic research that is most valued by practitioners. A greater focus on quality in research foundations and methods will also help build to a cumulative tradition in DSS design-science. Although not covered by the HMPR guidelines, we noticed during the coding, principally through the citation of DSS work, that there is no general sense of published research building on previous DSS design-science projects.

4.3. Strategic Focus

The analysis under Guideline 2, problem relevance, showed that 75% of DSS design-science research has been focused on operational management problems. If DSS design science is going to have a major impact on the way managers work and make decisions, then researchers need to increase the organizational importance of the tasks that are targeted. This is particularly important as the business intelligence movement has raised the visibility of, and demand for, decision support by senior managers and executives.

4.4. Theorizing

The final major area of DSS design-science that we believe needs significant improvement is the level and quantity of theorizing in published papers. This finding builds on the previous discussion regarding research foundations and methodologies. It is not related to a particular HMPR guideline but emerges from the overall analysis in Section 3.

We need to move beyond an instantiation as the primary focus in DSS design science. Gregor and Jones (2007) divide design artifacts into material or abstract artifacts. They argue that the abstract artifacts - constructs, models, and methods - are theory, or components of theory. One of the strongest findings in Section 3 was that 66% of design artifacts in DSS research are instantiations. It is clear that the DSS field needs to urgently emphasize theory and theorizing in design-science projects. A key aspect of this improvement should be the explicit consideration of information systems design theory in manuscripts (Walls et al., 1992, Gregor & Jones, 2007).

5. Comments on the Hevner, March, Park, and Ram Guidelines

It is clear from the Thomson ISI citation count that the HMPR guidelines will be a major reference work for IS design-science researchers. In this section we reflect on the effectiveness of the guidelines in assessing a large sample of design-science papers.

In general, the guidelines were relatively easy to apply. The major difficulty in the design of the content analysis was the lack of definition of the constructs for some guidelines. As described above, we operationalized these opinion-based constructs on three-point scales. This proved to be an effective approach to coding and there were few disagreements between the coders. We did find that it was important to keep rereading Hevner et al. (2004) during the coding process in order to remain calibrated to their definitions, constructs, and meanings.

It was very difficult to assess Guideline 6, which relates to design as a search process, from the published papers. By their nature, journal papers are written in a linear style. Often the research design and the project description can appear more ordered, and more structured, than was actually the case. This is not a criticism of these papers; it is an artifact of the publishing process. It does, however, create a problem for the assessment of the iterative search process of a piece of design-science research. As a result, the assessment of papers for HMPR Guideline 6 is difficult or biased unless the search process is explicitly addressed by the authors.

In response to one of the concerns in the previous section, we believe that Guideline 4, which relates to the research contributions of a paper, could be broadened to include an explicit contribution to theory.

Hevner et al. (2004, p 82) state “Following Klein and Myers (1999) we advise against mandatory or rote use of the guidelines.” Following the analysis of DSS design science, we believe that some of the guidelines should be mandatory, namely, Guideline 1, the design artifact; Guideline 2, problem relevance; Guideline 3, evaluation; and Guideline 5, research rigor.

Not withstanding these concerns, using the HMPR Guidelines to analyse a large set of DSS design-science papers did provide a clear idea of the state of the field. More importantly, they provided a clear idea of the areas that need significant improvement.

6. Concluding Comments

This study is subject to a number of limitations. The first concerns the representativeness of the sample. The use of the Alavi & Carlson categories as the filter for the DSS design-science sample could underestimate the sample size as the coding was based on the focus or dominant method of the paper. Some papers that were coded as experiments could be have really been design science but the published papers paid cursory attention to artifact construction. In particular, the journal reviewing practices early in the sample could have encouraged this style of write-up. Fortunately, the sample is large and this effect should be diluted.

The second limitation concerns the subjective nature of some of the coding. This is inevitable when interpreting guidelines that do not have well-defined constructs. We believe that researchers with considerable experience in DSS research and design science who used our protocol on our sample would generate similar data.

This study shows that design science is an important part, perhaps the major part, of DSS research. The lessons learned from the application of the HMPR Guidelines should help to significantly improve DSS research. Our further research into the nature of DSS design-science research includes the use of the HMPR Guidelines to develop a "balanced scorecard" that will provide a quality measure of a piece of design-science research. A second strand of further research will attempt to distil the general design theories that have been used for DSS design science.

The stakes are high for DSS design science. If we get design science right, if it is relevant and rigorous, then we will have increased influence in industry and the profession, much like what occurs in medicine. If we get it wrong, the disconnect between academe and practice will be amplified.

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8. Appendix

Article Coding Protocol

Guideline 1 – The Design Artifact
1.1 Type of Artifact 1 Construct 2 Model 3 Method 4 Instantiation
1.2 What was the artifact?

Guideline 2 – Problem Relevance

2.1 Importance of business problem	1 Strategic	2 Tactical	3 Operational
2.2 Relevance to IS practitioners	1 High	2 Medium	3 Low
2.3 Relevance to managerial users	1 High	2 Medium	3 Low

Guideline 3 – Design Evaluation
3.1 Type of evaluation

Observational	1 Case study	2 Field study		
Analytical	3 Static	4 Architecture	5 Optimization	6 Dynamic
Experimental	7 Controlled experiment	8 Simulation		
Testing	9 Functional (black box)	10 Structural (white box)		
Descriptive	11 Informed argument	12 Scenarios		
	13 None			

3.2 Choice of evaluation method	1 Highly Appropriate	2 Adequate	3 Poor Choice
3.3 Quality of execution of evaluation	1 High	2 Medium	3 Low

Guideline 4 – Research Contributions
4.1 Contribution Area 1 The design artifact 2 Foundations 3 Design Methodologies

Guideline 5 – Research Rigor

5.1 Theoretical Foundations	1 Strong	2 Adequate	3 Weak
5.2 Research Methodologies	1 Strong	2 Adequate	3 Weak

Guideline 6 – Design as a Search Process

6.1 Decomposition into sub-problems	Yes	No
6.2 Iteration from sub-problem solution to overall problem solution	Yes	No
6.3 Satisficing used to decide on solution convergence point	Yes	No

Guideline 7 – Communication of Research

7.1 Effectiveness of tech-oriented presentation	1 High	2 Medium	3 Low
7.2 Effectiveness of mgt-oriented presentation	1 High	2 Medium	3 Low

8.1 Did the paper mention "design science"? Yes No
8.2 If "No" what did it call it? or "Nothing"

9. Design Science Reference Citations
1 March & Smith (1995) *DSS*
2 Markus et al. (2002) *MISQ*
3 Nunamaker et al. (1991) *JMIS*
4 Simon (1996 or earlier) *The Sciences of the Artificial*
5 Walls et al. (1992) *ISR*
6 Hevner et al. (2004) *MISQ*
7 Other:
8 None

10. Free text comments on the paper: