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A Survey of Group Support Systems: Technology and Operation

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Abstract
Original working paper had no abstract. Broadly, this is a review of the state of GSS research up to 1995, with a focus on technical and operational aspects.

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A Survey of Group Support Systems: Technology and Operation

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1 INTRODUCTION

Group Support Systems, a relatively new technology that emerged in the early 1980s, can be seen as representing a progression from the longer established Decision Support Systems, the emphasis shifting from the single user to a group of users, all 'nominally' connected to each other. The exact topography of the connection varies according to the support system used, ranging from a local area network of terminals, through a number of groups of participants who may or may not all be in the same time zone and place. Equally, a group may be supported by a single terminal which is used (often by a professional meeting manager, facilitator or chauffeur) for data input and manipulation, graphical and statistical presentation.

A key aim of GSS is to improve group *performance*, whether it be of meeting productivity, the time taken to reach a decision, the degree of participation that is effected, the degree of satisfaction that is achieved and many other factors. This improvement is particularly significant, given that research has shown that some managers spend as much as 50%-60% of their time in meetings, though these meetings are not by any means as productive or effective as they might be (Hymowits, 1988; Mintzberg, 1973; Mosvick and Nelson, 1987). Groups themselves are pervasive and constitute an almost universal organizational structure. The rationale behind the superiority of the group over the individual lies in the fact that n+1 people are better at solving complex organizational problems than a single person. This is particularly true for problems that require multiskilled input, yet the idea of breaking work down into smaller, more manageable units can be traced back to Taylor's scientific management (Taylor, 1972). Furthermore, research has generally shown[1] that group judgement is superior to individual judgement (see, for example: Hill, 1981; Raman et al., 1992). This paper reviews the early history and development of Group Support Systems, before briefly reviewing laboratory experimentation and field studies. These sections are followed by an examination of:

- GSS tools and software;
- GSS Ergonomics, Environments and Interfaces;
- Facilitator and Chauffeur Support for the GSS Process;
- Task types.

2 EARLY STAGES OF GSS DEVELOPMENT: 1965-1980

While the development of Group Decision Support Systems (GDSS) is often portrayed in the literature (Raman et al., 1992; Hiltz et al., 1989; George et al., 1990; Lewis, 1987) as emerging in the early 1980s, underlying concepts that were to be incorporated into the development of early systems such as PlexSys[2] (Konsynski and Nunamaker, 1982), can in fact be traced back considerably further. 1965 saw the beginnings of the development of the Problem Statement Language/Problem Statement Analyzer (PSL/PSA) as part of the ISDOS (Information Systems and Decision Optimization System) project at the Case Institute of Technology (Teichroew and Hershey, 1982). Under Teichroew's direction, a number of software tools were developed by five doctoral students for automating the process of systems design. PSL/PSA was developed in three stages between 1965 and 1968 by Nunamaker (Nunamaker, 1974), Tremblay and Stephan. It also served as input for SODA[3] (Systems Optimization and Design Algorithm) - an analysis and design tool and was subsequently "used by well over 100 organizations for documenting and analyzing the set of requirements for an information system" (Teichroew et al., 1982; Dennis et al., 1988).

[1] See Janis (1972) for accounts of the perils of *groupthink* - situations where group judgements proved inferior to individual group members judgements.

[2] PLEXSYS is derived from the word plexus, meaning "an interwoven combination of parts or elements in a structure or system". 'Sys' is a contraction of system.

[3] SODA should not be confused with Strategic Options Development and Analysis, developed by Eden and Ackerman (1989) as an approach to group support using the COPE software.

As a result of working with end-users on a large US-Navy project in the mid-1970s, Nunamaker and Konsynski ascertained that there was a demand for a software tool which would help users to determine exactly what their requirements were and yet which would not involve them writing in PSL/PSA (Konsynski, 1976; Nunamaker et al., 1988). By 1979, it was realised that there was a need for a special meeting room where the end-user group, or their representatives, could meet. The room would have the specific function of not only displaying the "system flows, data structures and information requirements on a large screen projection system", but also permitting "each user seated at a workstation to interact with the set of requirements and the proposed design of the system" (Dennis et al., 1988). This PlexSys-84 system, "was a workbench/workstation environment for the system development team. A collection of integrated tools, procedures, transformations, and models were available to the systems developer to analyze and develop systems" (Dennis et al., 1988). At the time, it was expected that PlexSys would enable the length of the system development life cycle to be reduced. PlexSys itself was a *CASE*[4] tool - the system development process was not completely automated, and thus PlexSys supported that process.

3 EARLY FRAMEWORKS AND DECISION ROOMS: 1980-1984

The special meeting room adopted the generic name 'decision room' (Gray et al., 1981; Gray, 1983; DeSanctis and Gallupe, 1985, 1987; Zigurs, 1986; Aronson et al., 1987), although other terms were coined at different sites, notably the PlexCenter at the University of Arizona, the Decision Lab at the University of Minnesota, Colab at Xerox PARC and the Developmental Training Center (DTC) at the University of Louisville. These facilities provided the first foci for the wider dissemination of literature on what was initially known as Group Decision Support Systems (Huber, 1982). The first academic papers to be published in the 1980s were relatively few and far between: Huber (1984a, p.195) noted that "GDSS are rarely encountered today and published descriptions[5] are scarce". However, he also commented that the GDSS concept was not new (Keen and Scott Morton, 1978) and that a number

[4] As far as is known, the PSL/PSA tools were the first such *CASE* tools, developed under Teichroew at the Case Institute of Technology from 1965-1968. It is ironic that it was not until some fifteen years after the development of PSL/PSA that the term CASE tool was used formally.

[5] Gray et al., 1981; Gray, 1983; Kull, 1982; Steeb and Johnston, 1981.

of academic research bodies and private institutions had worked on the development of GDSS, These institutions included: EXECUCOM Systems Corporation (Gibson and Ludl, 1988; Kull, 1982); Cleveland State University; Georgia Institute of Technology; and Perceptive Decisions (Perceptronics).

Before going further into the nature of GDSS research, some definitions are in order. Although, as Huber (1984b) has indicated, early decision rooms were relatively rudimentary in nature, a body of literature has been devoted to the ongoing design and functionality of decision rooms. DeSanctis and Gallupe's (1987) study is often cited in this respect. They observed that "A GDSS combines communication, computing, and decision support technologies to facilitate formulation and solution of unstructured problems by a group of people" (p.589). They elaborated: "A GDSS aims to improve the process of group decision making by removing common communication barriers, providing techniques for structuring decision analysis, and systematically directing the pattern, timing, or content of discussion" (ibid.). The term group is used here to mean two or more people who have come together with a common purpose, if not a common perspective. A number of tools and techniques have been devised which can be used to improve the process of group decision making. Equally, there are a number of outcomes that can be measured so as to give an appreciation of what may be termed the *effectiveness* of the GDSS.

Gray's research (Gray et al., 1981; Gray, 1983; Aronson et al., 1987), conducted at Southern Methodist University is more significant than might be gleaned from Huber's (1984a) somewhat cursory descriptions. Thirteen executive MBA students undertook a variety of group decision support exercises which involved such tasks as: long range planning, operations management and capital budgeting, using the Interactive Financial Planning System (IFPS) for modeling. Participants, mostly middle level managers aged 30-55, observed "the critical importance of being able to challenge assumptions immediately and of finding out the implications of proposed alternatives" (Aronson et al., 1987, p.430). The researchers drew a number of conclusions from the experiments, viz.:

- The group decision support tools aided in focusing the argument;
- It was possible not only to introduce new alternatives into the discussion but also for competing groups to examine them on-line;
- ...the need for equipment reliability is even more critical for Group DSS than it is in individual DSS (Aronson et al., 1987, p.430).

Thus kindled, research interest in GDSS grew with a plethora of articles appearing in existing scholarly journals such as *Management Science, MIS Quarterly* and the *European Journal of Operational Research* as well as in other journals that were established in the mid-1980s such as *Decision Support Systems* and *Journal of Management Information Systems.*

Although empirical research was to take off in the mid-1980s, this was not the end of the research that looked at design and system architecture issues. Papers devoted to theories, models and architectures have continued to be published throughout the 1980s and indeed up to the present time (Bui and Jarke, 1986; Lewis and Keleman, 1986; Nunamaker et al., 1987; Jelassi and Beauclair, 1987; DeSanctis and Poole, 1993). DeSanctis and Gallupe's (1987) paper is seminal in its treatment of the GDSS domain, and in the theories and structures it proposes. Furthermore, the number of activities supported by GDSS grew to include many more than pure decision making. These activities spawned new acronyms, viz.:

- negotiation support systems - *NSS* - (Bui, 1993; Jelassi and Foroughi, 1989; Anson and Jelassi, 1990);
- group communication support systems - *GCSS* - (Pinnsoneault and Kraemer, 1990);
- organisational decision support systems - *ODSS* - (Huber, 1988; Vogel et al., 1988; Lee et al., 1988);
- strategic group decision support systems - *SGDSS* - (Finlay and Marples, 1992);
- distributed group decision support systems - *DGDSS* - (Jacob and Pirkul, 1992).

As a consequence of this, a new acronym emerged in the late 1980s to include all of the above processes: GSS - Group Support Systems (Jessup and Valacich, 1993). It is this acronym that will be used for the rest of this paper, except where particular emphasis is laid on one or other of its forebears, or in citations, or references to citations, since it is widely used and accepted in the literature today.

Partly because of the multifaceted nature of GSS's forbears, GSS itself is a somewhat nebulous term. Very broadly, however, GSS is used to mean "computer-based information systems used to support intellectual collaborative work" (Jessup and Valacich, 1993. p.5). Incorporating a complex set of support systems, GSSs vary in their appearance and internal workings, as will be discussed later in this article.

4 LABORATORY EXPERIMENTS and FIELD STUDIES

As GSS became an increasingly well established research topic, so it moved into the realm of empirical research. A number of universities allocated, or were awarded, funds to develop GSS facilities and most of the research (Buckley and Yen, 1990) was concentrated round these same sites, including: the Universities of Arizona, Indiana, Minnesota, Louisville, Texas and Claremont Graduate School. From the end of the 1980s, interest in GSS extended outside North America and Europe to such places as Singapore and Hong Kong.

A common feature of laboratory based experiments was their predominant use of student subjects. The limitations of using students as participants, or surrogates for managers - for this was often the case - had been recognised long before (Lorge et al., 1958), yet the case was very often that it was simply too difficult to persuade real managers to participate in GSS sessions. Howsoever the case, students were used in a wide range of experiments that tested the various features of GSS including brainstorming, assumption surfacing and voting.

By the late 1980s, researchers were becoming increasingly aware of the fact that not only did there need to be a wider application for GSS, but that this application must come through studies validated not with students but "real people". Indeed, *recommendations for future research* often included exhortations to conduct field studies, noting the lack of research in this area and re-echoing the non-generalizability problems inherent in the use of students as participants, as expressed by Lorge et al. (ibid.). Connolly et al. (1990, p.701), are not untypical in this regard: "questions of external validity must always be raised in experimentation of this sort" [i.e. using students]. Galliers and Land's (1987, p.900) general comment "although the experimental design of such IS research may well be academically acceptable and internally consistent, ... all too often it leads to inconclusive or inapplicable results" is singularly apt. However, field experimentation was much slower to get moving.

Buckley and Yen (1990, p.116) attribute this slow take up, at least in part, to the "tremendous cost required to develop these systems. Another reason is the shortage of available human skill in this relatively new area. ... Most installations thus far are in financial, computer service, and government organizations" (Straub and Beauclair, 1988).

Dennis et al. (1989, p.301), defining GSS field study research as including "the use of GDSS technology by specific business groups (public or private) addressing problems of their own choosing, whether in a GDSS facility at their organization or another institution" were only able to locate six published papers presenting such field research: Applegate et al. (1986), Dennis et al. (1988), Heminger (1989), Martz (1989), Nunamaker et al. (1987), Vogel and Nunamaker (1988). They observed, however, that "not all field research is formally documented and submitted for publication". This is a critical point to bear in mind given Buckley and Yen (1990)'s comment above concerning the costs involved to build systems. That there were systems available is not questioned, but few research findings were published by non-academic institutions.

Since Dennis et al.'s (1989) paper, a number of other field studies have been published (Eveland and Bikson, 1988; Jarvenpaa et al., 1988; Nunamaker et al., 1988; Ellis et al., 1989; Hiltz et al., 1989; McCartt and Rohrbaugh, 1989; Nunamaker et al., 1989b, 1989c; Smith and Vanacek, 1989; Beauclair and Straub, 1990; Dennis et al., 1990a, 1990b; Vogel and Nunamaker, 1990; Vogel et al., 1990; Valacich et al., 1991; Dennis et al., 1993; DeSanctis and Poole, 1993; DeSanctis et al., 1991, 1994; Lyytinen et al., 1993; Maaranen et al., 1993). A number of these involve cooperation between academia and industry - a relatively new trend, but one that is important for the continuing publication of field studies that involve a non-academic element. Furthermore, statistics indicating how widely GSS are used in the field have been compiled. Beauclair and Straub (1990, p.213) report that from a survey of 135 randomly-selected organizations that belonged to the Data Processing and Management Association, 45 organizations were making use of 78 GSS between them. This surprisingly high number of GSS will be referred to when different GSS systems and environments are discussed below. Overall, Beauclair and Straub (1990) found that GSS were slowly being introduced and supported by IS departments.

McCartt and Rohrbaugh (1989) and Phillips (1988) point to what they term 'decision conferencing': "Decision conferencing employs a portable single-user computer system to support groups of managers and executive teams working face-to-face on a wide variety of organizational problems" (McCartt and Rohrbaugh, 1989, p.244). They illustrate the widespread use of this tool with the Decision Techtronics Group (DTG) at the State University of New York (SUNY). From 1982 to 1989, the "DTG has hosted approximately 60 decision conferences for private and public sector organizations located throughout the United States" (ibid., p.245). DeSanctis and Poole (1993) describe the field studies undertaken using the SAMM (Software-Aided Meeting Management) tool. The first field study was carried out in 1989 by the Manhattan District of the Internal Revenue Service. Second and third studies which are currently ongoing involve Texaco Inc. In 1989, six non-academic sites had SAMM software usage licenses.

PlexSys and more recently GroupSystems, both developed by the University of Arizona, have been widely used in field studies, both on site at the University of Arizona and at company sites. Nunamaker et al. (1991) give examples of some of the more than 150 organizations that have used the GSS facilities at the University of Arizona since 1985. Nunamaker et al. (1989b, 1991), Martz (1989) and Heminger (1989) describe a series of field studies carried out at IBM. These studies were part of a two-year programme examining "the implementation, operational use, and evaluation of the EMS [Electronic Meeting System][6] at six IBM corporate sites" (Nunamaker et al., 1991). The objective of this longitudinal study was to evaluate both how the technology worked under 'normal operating conditions' and to what extent the technology could be successfully transferred from an academic environment to a corporate one.

As companies began to use GSS on a more regular basis, for normal meetings rather than as a means to evaluate the technology, so evidently a further shift has taken place, away from research and into actual usage, which is much less published. This shift has been accompanied by a technology expansion - to the sites where it is to be used (Campbell, 1990). This shift is further evidenced by the fact that, increasingly, corporate institutions have their own software licenses and electronic meeting facilities (Martz, 1989; Heminger, 1989; DeSanctis and Poole, 1993). Raman et al. (1992) report that GroupSystems is used in almost 200 industrial and academic sites around the globe, including 33 IBM sites. According to

[6] Electronic Meeting Systems is a term used by researchers at the University of Arizona to refer to what they see as the next step beyond GSS, incorporating more communication technologies. This will be referred to in greater detail later in this chapter under GSS Models and Theories.

Grohowski et al. (1990), more than 15,000 IBM participants, representing all levels of management, have used those facilities.

5 TOOLS AND SOFTWARE

Laboratory experiments often did not examine the wide range of software tools that were becoming available, with many concentrating primarily on brainstorming for idea generation and voting/ranking of alternatives.

The number of tools offered by different decision rooms varies considerably, with some offering only a couple of features, such as the DTC lab at Louisville - brainstorming and voting/ranking - (Beauclair, 1987), and the MCC system at the University of Texas (Jarvenpaa et al., 1988). Indeed, early GSSs tended to be task-driven, i.e. they were "designed to meet the needs of one group performing one task. ...one early GDSS was designed specifically to assist in labor-management negotiation and could not be used for any other task" (Kersten, 1985, cited in Dennis et al., 1988). The PlexSys system at the University of Arizona, however, provided a whole toolbox of functions. George (1989) reports that it offered some 25-30 different tools which could be used individually or in combination, on demand or in a pre-requested order. These tools include both the frequently encountered Electronic Brainstorming and Voting, and also the more specialised Questionnaire and Policy Formation. Any review of tools must necessarily make reference to the system that provides the tools, as there are often no generically accepted names for tools. All tools listed in this section are provided by GroupSystems, the most widely used GSS today, unless otherwise stated.

5.1 Electronic Brainstorming

Brainstorming was conceived of by Osborn (1957), its author claiming that a "group could generate more ideas than the same number of individuals working separately without communicating" (Dennis and Valacich, 1993). However, since Taylor et al.'s (1958) study testing Osborn's claim, dozens of such studies have been undertaken (see Mullen et al. (1991) for a meta-analysis) and the evidence is clear: "Individuals working separately generate many more, and more creative (as rated by judges) ideas than do groups... The difference is large, robust and general" (McGrath, 1984, p.131, original emphasis). Where electronic brainstorming is concerned, however, research indicates different results. The key to Osborn's original claim is synergism: each group member contributes a uniqueness in terms of knowledge and experience. The diversity of the group eases problem definition, alternative generation and evaluation, and solution identification (Buckley and Yen, 1990). In electronic brainstorming, group members use computers to interact and exchange ideas.

Electronic Brainstorming is often considered to be one of the core elements of a GSS, one that most GSS will provide. It has also been most frequently used in empirical experiments (Jessup et al., 1990a; Dennis et al., 1993). Comparisons have often been made between face-to-face and dispersed, electronic and manual (i.e. using writing materials) brainstorming (George et al., 1990; Jessup and Tansik, 1991; Zigurs et al., 1988; Tan et al., 1993b). In face-to-face mode, the group members can see each other and so communicate non-verbally, and, depending on the experimental operationalisation, may be permitted to verbally converse as well (Zigurs et al., 1989). In dispersed mode, group members are separated, either by partitions or by being located in different rooms (Tan et al., 1993b). While text-based communication is provided through the communication network, verbal communication is eliminated. In manual brainstorming groups, electronic interaction is not provided at all. Group members, in this necessarily face-to-face mode, generate issues verbally.

5.2 Anonymity

An additional feature that is often associated with brainstorming is anonymity (Connolly et al., 1988, 1990; Jessup et al., 1987, 1988, 1990a, 1990b; Jessup and Tansik, 1991; Valacich et al., 1989, 1992a, 1992b). Essentially, anonymous communications in the Electronic Brainstorming context means that meeting participants can generate their ideas without being identified. Equally they can see the comments generated by others without knowing the others' identities. When anonymity is enabled, even the facilitator cannot see who the author of a particular comment is. Anonymity is not a compulsory feature, nor is it necessarily desirable (Lyytinen et al., 1993). It is possible to identify participants in a number of ways, including by their real names (Hiltz et al., 1989), by pen-names (Hiltz et al., 1989), and by sub-group identification (Ventana Corporation, 1994). When anonymity is disabled, each comment that a participant sees will have the identification tagged on beside it. In the same way, a time stamp can be tagged on, indicating when the comment was written.

Most GSS packages, including PlexSys/GroupSystems (Dennis et al., 1990a), SAMM (DeSanctis et al., 1987), SAGE (Software Aided Group Environment, a Macintosh based derivative of SAMM) (Raman et al., 1992; Wei et al., 1992), and Chinese SAGE (Wei and Tan, 1993) do support both identified and anonymous communications. When group interaction is anonymous, group members are subject to much less influence from their peers or seniors. The issues of anonymity and influence are dealt with in more detail in Davison (1995).

5.3 Evaluation

There are a number of different ways in which evaluation can be carried out electronically. GroupSystems provides a wide range of options: ranking, multiple choice, yes/no, true/false, agree/disagree, 10-point scale and allocation - each item on a list can have a figure allocated to it (Ventana Corporation, 1994). The results of the evaluation can be accumulated and presented to the group as a whole (Nunamaker et al., 1989a). Thus, for example, when group participants have been ranking items, they can receive, as feedback, their own ranking compared to the ranking of the group as a whole. Statistical and graphical analysis can also be presented.

5.4 Other Tools

A **Session Director** tool guides the meeting manager in the selection of software for the session and provides a default agenda that may be modified (Vogel and Nunamaker, 1990). SAMM and SAGE also provide an *Agenda* function. This permits group members, as well as the meeting manager, to generate the agenda, unlike GroupSystems (Raman et al., 1992).

An **Issue Analyzer** tool helps participants "identify and consolidate" (ibid.) those main items produced in brainstorming or idea generation (SAGE).

A **Stakeholder Identification and Assumption Surfacing (SIAS)** tool is used "to support systematic evaluation of the implications of a proposed policy or plan. Stakeholders' assumptions are identified, scaled and graphically analyzed" (ibid.; Vogel et al., 1987; Campbell, 1990; Easton et al., 1989, 1992; cf. also Mason and Mitroff, 1981 and Rowe et al., 1981 for descriptions of manual precursors to this electronic tool). SIAS has elements in common with SAMM's *Problem Definition* tool (Zigurs, 1989), and SAGE's *Decision Aids* (Raman et al., 1992).

"An **Alternative Evaluator** tool provides multi-criteria decision making support. A set of alternatives can be examined under flexibly weighted criteria to evaluate decision scenarios and tradeoffs" (Nunamaker et al., 1989a). An *Idea Evaluation* tool is also present in SAMM and SAGE (Zigurs, 1989; Raman et al., 1992).

Additional GroupSystems tools include:

- Issue Prioritization;
- Group Dictionary (a data dictionary);
- tools which allow group members to provide written input to a document, such as
  - Group Writer,
  - Policy Formation;
- tools that provide more specific brainstorming functions such as:
  - Topic Commenter,
  - Group Outliner,
  - Idea Organization,
  - Categorizer;
- and other miscellaneous tools such as
  - Questionnaire, which "elicits responses to various types of questions";
  - Group Matrix, which permits participants "to establish relationships between two sets of items in a matrix format";
  - Survey, which permits expression of opinions on a variety of pre-selected topics;
  - and Briefcase, which "is a set of memory resident utilities designed to be 'popped up' during sessions to provide a supportive environment for the use of GroupSystems". These utilities include:

- a text editor,
- a clipboard,
- a quick voting tool,
- a calendar
- and a calculator

(Ventana Corporation, 1994; Dennis et al., 1988).

SAMM and SAGE have a similar set of utilities for performing quick votes, determining the mood of the meeting, writing public and private notes to other group members, etc. (Raman et al., 1992).

Clearly there is a wide range of tools available to both the meeting manager or facilitator and participants. The selection of which tools to use and in what order must be approached with care, so as to ensure that the maximum benefit is derived from the meeting. This is particularly true for real-life business decision making situations, where a meeting often has wide-ranging significance. It is notable that most laboratory based research thus far has concentrated on brainstorming and voting tool use. This rather restricted use of the available tools has clear implications for any wider generalization to business situations, in that we do not have a complete store of data relating to meetings using other tools.

5.5 Commercially Available Software

When considering only recently published research, it could seem at first sight that there are only two or three GSS in existence: GroupSystems (and its precursor PlexSys), SAMM and SAGE. SAMM runs on the Unix platform and has been around since the late 1980s (DeSanctis et al., 1987), when it was developed to support experimental work. It still performs that function and tests theories "of how groups use GSSs and of the effects of GSSs on group interaction and outcomes" (DeSanctis and Poole, 1993). SAGE (Wei et al., 1992) and Chinese SAGE (Wei and Tan, 1993) derivatives of SAMM, offer almost identical functionality. Developed for the Macintosh, SAGE is able to take advantage of the "information organising and user interface capabilities of HyperCard" (Raman et al., 1992) and so provides a more user friendly interface. PlexSys/GroupSystems was developed in 1985, and runs on most DOS platforms (Dennis et al., 1988). A Windows version

(GroupSystems for Windows) was released early in 1995 with a much improved interface though at the time of writing, only a limited set of tools are available.

However, there are other examples of GSS software. Meetingware (Lewis, 1989, 1992) offers similar functionality to GroupSystems and SAMM, and is a Windows based application. A second example is Option Finder. This "is a portable, keypad-based GSS which consists of a general purpose vote collection and analysis software, a ten-button keypad for each group member, an IBM-compatible PC and a public screen" (Option Technologies, 1990). Option Finder can support up to 100 keypads and provides four different forms of voting. It is a highly portable program and simple to set up in a variety of environments (Raman et al., 1992). Co-oP (Bui, 1987), ObjectLens (Lai and Malone, 1988).

Beauclair and Straub (1990), through questionnaire analysis, found that some 78 different GDSS were being used by the companies in their sample. While they do not list all 78 GDSS, they do indicate that at least some of these systems are electronic mail systems. Electronic mail is more of a group *communication* support system than a group *decision* support system, providing asynchronous dispersed communications, rather than the synchronous, often face-to-face communication found in Decision Rooms. This study does, however, reveal that to consider the Decision Room to be the only form of GSS environment is a fallacy. Another type of GSS which Beauclair and Straub allude to is teleconferencing - remote, yet probably synchronous, communications. Asynchronous communications and teleconferencing will be considered in further detail under GSS Environments.

6 ENVIRONMENTS

Dennis et al. (1988) provide a clear taxonomy of GSS environments, noting that there are three dimensions: group size (small, medium, large); participant proximity (local, remote); and time synchronicity (synchronous or asynchronous). Group size is considered separately in the sister working paper (Davison, 1995). When considering group proximity, the assumption is that a single 'logical' group is involved and that the group's members are addressing the same task. Group participants need not, however, be physically in the same location, either room, building or country. Dennis et al. (1988) provide three categories of dispersion:

- Multiple Individual Sites

"- the individual members of the group are physically separate, working in their individual offices or workstations";

- One Group Site

"- all members of the group are physically together in one room";

- Multiple Group Sites

"- members of the group meet in separate locations in subgroups, and then these multiple subgroup meetings are interconnected through EMS [Electronic Meeting Systems]".

Where time synchronicity is concerned, meetings have traditionally been held at the same time, i.e. synchronously. Tan et al. (1993a, 1993b) have conducted experiments comparing the multiple individual sites and one group site categories, using partitions to separate participants from each other. Cass et al. (1991a, 1991b) and Gallupe and McKeen (1988, 1990) also report usage of GSS in remote versus face-to-face (one group site) locations. The one group site category corresponds to the use of a single decision room for a meeting. This is the type found in the vast majority of experiments, both laboratory and field, that have been conducted thus far. Synchronous multiple sites meetings are typically addressed by teleconferencing, as indicated by Beauclair and Straub (1990). At each site, participants essentially have the same software tools as in a decision room, but with the additional support of a network that can provide "electronic, voice, and video communication between the different sites" (Dennis et al., 1988). A "local area decision net" (LADN) can be provided for multiple individual sites where participants work from their offices or workstations. In practice this may not differ substantially from the set-up of a decision room, in that decision rooms also use LADNs, if on a geographically smaller scale. However, consideration will need to be paid to the capacity of both the network and the server that runs the software.

Examples of asynchronous meeting technologies are electronic mail (DeSanctis and Gallupe, 1987; Jelassi and Beauclair, 1987) and computer conferencing, such as that offered through electronic discussion lists. People subscribe to a conference which they want to participate in. When they send (email) a comment/message to the listserver software that runs the system, the listserv(er) sends out that same comment/message to all of the other conference members. This exemplifies not only asynchronous communications and multiple individual sites, but also identified communications. It is possible to send messages anonymously to computer conferences, but only as a registered user and through the services of a special server such as anon@penet.fi. Asynchronous communications with multiple group sites (where multiple means more than one) is best illustrated with teleconferencing, though very little research has been conducted in this area. Burns et al. (1987), Rathwell and Burns (1985) and Thomas and Burns (1982) discuss some cases of geographically remote groups that have to meet at different times, sometimes because of time zone differences. Essentially, the subgroups work as complete entities and send off the whole of their work to the other remote sites for inclusion in their own discussion sessions. Mashayekhi et al. (1993) describe an "inspection environment that lets geographically distributed inspection participants 'meet' with people in other cities through workstations at their desks". The inspection they envisage is one of software code and documentation. Mashayekhi (1993) clarifies their vision of the inspection system thus:

> We envision participants who are distributed over Metropolitan and Wide Area Networks. Note that the wider the distribution of the participants, the greater the benefits of supporting their interaction. For instance, if we have two programming teams in the U.S. and Hong Kong working on the same software development project, we are not only spread across space, but time zones. A software inspector system (and for that matter any meeting support system) must provide support for the participants' interaction across both time and space axes.
>
> There exist limitations in our network technology today, but they are fast disappearing. Soon we will have high speed, low latency, guaranteed bandwidth for our communication needs.

This clarification draws out another issue related to the environment - the nature of the network between participants. In non-remote meetings, a LAN (LADN) is perfectly adequate for the task, but in dispersed meetings, more stringent network criteria will need to be applied, particularly if the meeting is to be synchronous. If a LAN is dedicated to the meeting and no other traffic is present, then this will make matters easier, but if the network is shared by a number of other utilities and users, traffic speed is likely to suffer causing lag times that may become intolerable. This is less likely to be a problem for local multiple decision sites and more likely to be a problem for remote multiple decision sites, whether they be group or individual. Jacob and Pirkul's (1992) concept of a distributed GDSS relates directly to this problem, in that they envisage replacing meetings with a system which allows "group members to exchange information and expertise on a continuous basis rather than only during meetings" (Jacob and Pirkul, 1992).

7 ERGONOMICS

The Ergonomics of GSS design is a field that has not been paid much attention in the literature, yet clearly GSS facilities have been designed and developed and presumably not with total disregard for ergonomic issues. The design approach adopted by the PlexCenter at the University of Arizona has evolved, the second generation design drawing upon lessons learnt from the first. Their first generation facility, opened in March 1985 saw 16 terminals arranged around a large U-shaped table, the terminals recessed into the table in front of the participants. This design enables all participants to see the public screen at the front of the room and also facilitates group interaction. The facility includes four 'break-out rooms' at the sides of the main room for small group discussion (Vogel et al., 1987; Dennis et al., 1988).

The second generation facility at the University of Arizona, opened in November 1987, represents a shift from the first design in terms of size (it can now accommodate some 48 people, 2 per terminal) and layout - there are now two concentric, tiered rows of workstations. Furthermore, gallery seating for eighteen people at the back of the room is also provided. Whilst the design of the room is formal, group verbal interaction across the room is also possible. The room is equipped with a number of technical and other features designed to improve the quality of both the local environment and to enable a high standard of group support. These features include: audio microphones and video cameras; a high resolution video projector and two large screens, which can be used to display a variety of images, such as video, laser disc, transparencies, slides, computer graphics and other publicly available materials (Dennis et al., 1988). Both the first and second generation rooms have sound proofing and air conditioning installed (Dennis et al., 1990a).

Future generations of GSS facilities at the University of Arizona are likely to concentrate on a devolvement of the meeting process to participants' offices (Dennis et al., 1988) - it is not necessary for all participants to be in the same place at the same time, though evidently there are advantages to such face-to-face meetings, such as verbal interaction and access to the public screen. Dennis et al. (1988, pp.611-612) give detailed descriptions of considerations that can be made when designing: the floor plan, the public information display, workstation design, ergonomics of heating, lighting, sound and air conditioning, general aesthetics and other support features.

Mantei (1989) discusses ergonomic issues in some detail in her review of the Capture Lab, a GSS facility of the Electronic Data Systems (EDS) Corporation located at the University of Toronto. The Capture Lab supports a maximum of eight Macintosh terminals running over the Appletalk network (Mantei, 1989). The monitors are recessed into the table top, so that they rise no more than four inches above the surface. The keyboards and mice lie on the table surface in front of the monitors. All the lights are fluorescent and located around the sides of the room so as to minimise glare on the public screen at the front and on the monitors. Three video cameras gather data on meetings from behind one-way mirrors. Six microphones which pick up meeting conversations are embedded in the walls of the meeting room (Mantei, 1989).

When the Capture Lab was being designed, three different seating configurations were proposed. The finally accepted design allows participants to interact, whilst directing their terminals towards the front of the room. A semi-circular design, as used in the PlexCenter facilities, was rejected as not being "conducive to eye contact, non-verbal exchanges and verbal interaction" (Mantei, 1989), exchanges documented by Krauss et al. (1977) as being important for communication. The oval shaped conference table that was selected was deemed to be more conventional for most meeting participants in that it symbolized a typical meeting environment (Mantei, 1989). The design also includes a 'power position', which is the seat furthest from the public screen. From this position, the person who wants to control the meeting can see all other participants. Mantei (1989) observed in her research that the manager of a meeting would quickly establish that this position was the most influential and would always sit there. If no seat was available, the manager would leave the meeting deliberately to find a chair. He would then sit between the two group members at the base of the table and instruct them to enter his comments (Mantei, 1989). This kind of room design obviously lends itself to such a power position to a far greater extent than that used in the PlexCenter, where all participants have more or less equal lines of sight, and all can easily view both their fellow participants and the public screen.

Gray and Olfman (1989) show awareness of cultural considerations in ergonomics and apply these to a comparison of the COLAB facilities at Xerox PARC (Stefik et al., 1987a, 1987b), SAMM at Minnesota, the Claremont Graduate School facilities and Arizona's PlexCenter. They note, for example, that Japanese people would dislike a U-shaped arrangement, as found at Minnesota, because they would like to be physically opposite one another. Another problem associated with the U-shaped design, is that some people are close to the screen and others are further away. This may create problems with angle of vision, blurring, etc.

Lyytinen et al. (1993) also address ergonomic issues in their design considerations for the CSCE (Conference on Security and Cooperation in Europe). Bearing in mind principles of how diplomats interact and what software is needed to support that interaction, Lyytinen and colleagues, in collaboration with the Helsinki University of Industrial Arts, developed and built the Helsinki Prototype system (Maaranen et al., 1993). The facility was designed to support some twenty delegates. Ergonomic design and layout of the meeting room, i.e. its tables, chairs and the various configurations (see also Lewe and Krcmar, 1990; Olson and Atkins, 1990) was a critical issue, since the design would impact on most of the meeting behaviour. "The shapes of tables were chosen in a way that helps to establish eye contact, as tables did not arrange delegates into straight rows. Tables would [not] draw attention to specific power positions" (Lyytinen et al., 1993; cf. Mantei, 1989). Small lap-top computers, embedded into the table, were chosen as they would minimise impairment of delegates' visual fields and so encourage less constrained verbal interaction. An additional advantage of using lap-tops was that they generate less heat and noise than PCs. As the lap-tops can fold away inside the table top, traditional meetings with no computer presence are easy to arrange (Lyytinen et al., 1993).

Clearly GSS designers have very different notions of how best to arrange participants in a group meeting situation, and what facilities are necessary to support those groups (cf. Lyytinen et al., 1993 and Dennis et al., 1988, 1990a). These notions depend to a considerable extent on the characteristics of the group itself, yet it is not practical for a GSS site to have an infinite number of fixed settings, if only for reasons of space. It seems likely that as further field studies are carried out in future, so the number of settings will continue to increase.

8 INTERFACES

As with Ergonomics, interface design for GSS is not a field that has received substantial attention in the literature. While Stohr and White (1982) looked at more general DSS design, Gray and Olfman (1989) have conducted a thorough review of GSS interface design. They cite Bennett's (1983) three questions about DSS interface design

1. What does the user *see* at the terminal?
2. What must the user *know* about what he sees at the terminal?
3. What can the user *do* with the system in order to accomplish the purpose of using the system?

as being fundamental to the issue of GSS interface design. They then add five more features that have to be considered:

1. The design of the "public screen(s)".
2. The interaction between the public screen and the individual screen.
3. The design of the individual's workstation in the group environment.
4. Cognitive style differences among participants.
5. Cultural differences among participants.

For the purpose of the study, Gray and Olfman assume that they are senior executives, and so the criteria that they use for design necessarily reflect this assumption. They also incorporate the possibility, mentioned rarely elsewhere in the literature (see Park et al., 1990; Park, 1990; Gray et al., 1988), that participants may not all be of the same nationality or be speaking/writing the same language, and thus cultural constraints or misunderstandings may arise. Hence, in a multicultural setting, group members should be able to work in their own language, regardless of the language that is displayed on the public screen. Where cognitive style, i.e. the way that individuals understand information, is concerned, "it is arrogant for the designer to assume that all users of a GDSS have the same [style] and that they come from the same cultural and language background" (Gray and Olfman, 1989). This can be exemplified by the fact that some people prefer data to be presented in tabular format while others prefer charts. In terms of input mechanism, some prefer command language and others prefer to use a mouse, key-pad, touch-screen, etc. They comment: "a thoughtful designer will create interfaces that allow the user to select the form of presentation". Where screen design is concerned, it should be recognized that different icons may have different meanings for different nationalities and cultures. Where translation is concerned, several more problems arise. If only one pair of languages is to be used in the meeting, then translation is relatively simple, though it may be necessary to provide different kinds of translation facilities for different communication modes, i.e. verbal and textual. If six working languages are to be used, as in the UN, or nine, as in the EEC with its 72 translation pairs, then the issue becomes considerably more complex.

Wei and Tan (1993) describe the interface design of the Chinese SAGE program, paying particular attention to the problems encountered in Chinese language input. Chinese SAGE has a multi-windowing facility, allowing two windows to be maintained on the screen. One of these is a private window, used to invoke the functions of the software; the second is used for the display of group ideas and evaluations (Wei and Tan, 1993). Wei et al. (1992, p.17) describe the interface of SAGE. "The main dialogue styles are menus and direct manipulation. The functions of SAGE can be invoked with simple clicks on the mouse. ... The keyboard is used solely for textual input. ... Since human memory for icons is better than human memory for words (Shephard, 1967), the use of familiar icons to represent functions eases the process of learning and using SAGE". SAGE has extensive on-line help facilities and a consistent icon layout. It also permits the display of information in multiple concurrent windows, so that "a problem can be viewed together with its alternative solutions and its criteria for evaluating solutions, through a number of windows... SAGE is able to present the results of evaluation in tabular form and in a variety of graphical forms..." (Wei et al., 1992, p.18). While GSS applications are clearly moving towards the Windows platform, with four packages currently offering Windows interfaces[7], a caveat associated with Windows use is detailed by Mashayekhi et al. (1993), who found that their users tended to be confused when more than four windows were open simultaneously.

[7] GSS for Windows, SAGE, Chinese SAGE and Meetingware.

9 FACILITATOR AND CHAUFFEUR SUPPORT FOR THE GSS PROCESS

As well as examining the nature and level of communication support, there is also the issue of group-management support that is provided for meetings. Some studies conducted into GSS usage have looked at the effect that a facilitator and/or a chauffeur has on the decision making process (Anson et al., 1991; Dickson et al., 1989, 1993).

The role of a *facilitator* is to direct "the group members as to what GSS features to use and when to use them" (Dickson et al., 1993). Normally, the facilitator is not a member of the group, and so does not participate in the actual brainstorming, voting, etc. However, the facilitator often takes on the role of a coordinator. Thus the facilitator must have an excellent working knowledge of the system, as well as an understanding of the issues being discussed in the meeting, a cooperative relationship with the participants in and organiser(s) of the meeting, and so an appreciation of the most appropriate way to organise discussion. Some of the tools, such as meeting agenda, room configuration, view participant sign-in, save and print meeting data, provided by software such as GroupSystems, are only for the facilitator, who uses them during the course of running the meeting and for post meeting file management.

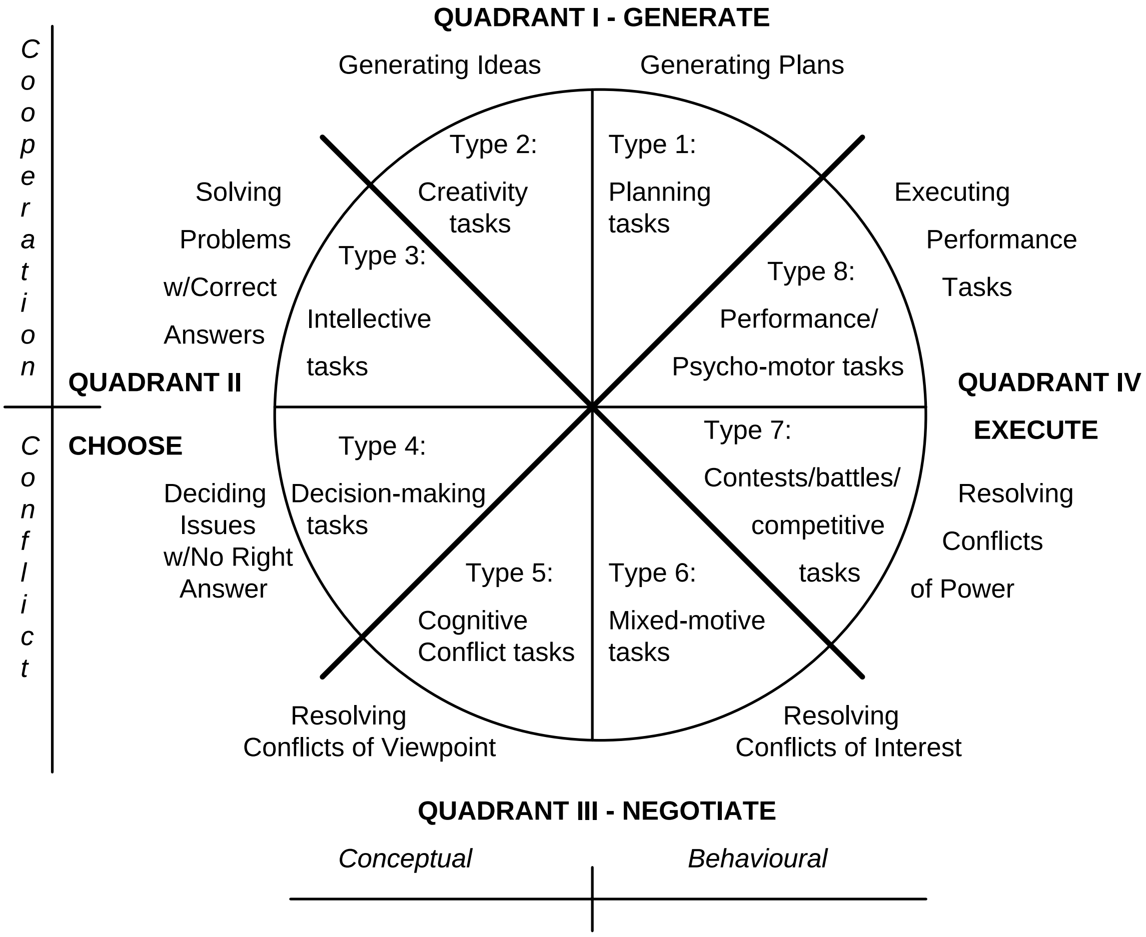
The role of a *chauffeur*, on the other hand, is to implement features of the system for the group and only at its request (Jarvenpaa et al., 1988). In this way, the chauffeur does not direct, but merely obeys. The chauffeur should, however, be able to answer questions posed by the participants regarding which tools are suitable to use for different activities. The differences between facilitator and chauffeur become more distinct when comparing how they behave in the situation when the users ask for advice on how the meeting should work. A facilitator would direct the process, whereas a chauffeur should only do what he is asked to do, i.e. should not make constructive suggestions. Evidently there will be occasions, particularly for larger groups, when both facilitator and chauffeur are present. The facilitator works with the group and makes suggestions. These are communicated to the chauffeur who then implements them (Dickson et al., 1993). The advantage of this system is that there is a person who can handle queries and problems relating to how the software functions and can best be used, as well as a separate person responsible for the actual implementation.

To date there has been little research into the issue of "how users are supported in their interaction with the GDSS technology and the nature of the support process" (Dickson et al., 1993). However, it is a critical area since the results that we see emerging from GSS literature may depend to a certain, as yet unknown, extent on the type of support made available to users. While we have considered facilitator and chauffeur supported variants, some GSS permit user-driven discussion, i.e. with no external or internal support.

10 TASK TYPE

"Virtually all group researchers agree that group performance cannot be studied generically without regard to task, and that an individual's performance is without question affected by the type and characteristics of the task" (McGrath,1984). The issue of task is not as simple as might be otherwise thought. This is illustrated by McGrath's (ibid.) circumplex (see Fig. 1) that depicts a taxonomy of 8 task types. This is useful as a reference point for task selection in GSS experimental design, as well as for specification or identification of real tasks, i.e. in field settings. However, it does not address the issues of task complexity or duration.

Fig. 1 Task Circumplex (McGrath, 1984)



A proportion of GSS empirical research has focused on the effect that a GSS has on group processes and the contributing effects exerted by anonymity, typically involving brainstorming with non-specific idea generating tasks (Gallupe et al., 1992; Jessup et al., 1990a; Ellis et al., 1989; Connolly et al., 1990). The limits of these idea generating tasks are only governed by the imagination of the decision makers (Vogel et al., 1987). More recently, studies have examined the nature of the task that the group undertakes and contrasted the different task-types with other group process outcomes, the levels of consensus reported among group members, and the degree to which group members have been able to exert influence over the group as a whole (Zigurs et al., 1988; Tan et al., 1991, 1993a, 1993b; Huang et al., 1993; Raman et al., 1993; Watson et al., 1988). Gallupe (1985) looked specifically at the impact that task difficulty had on the use of a GSS.

There is the general understanding that a task has to be of sufficient complexity to make it worth using a GSS in the search for a solution. Tasks that are too simple will undermine the effective use of the GSS (Vogel et al., 1987). Bui and Sivasankaran (1990) have argued that highly complex tasks lend themselves to GSS use simply because the tools available provide functions such as memory, structure and various forms of analysis which enable participants to assess the impacts likely to be caused by the solution to the task. They found that as task complexity increases, so the effectiveness of GSS-supported groups becomes more apparent when compared to groups that do not have GSS support.

It is also noteworthy that there is a difference between the task type usually undertaken by business groups in field settings and by student groups in laboratory settings. Most tasks used for student, experimental sessions are single-session tasks (see Zigurs et al. (1989) for a longitudinal student study), and the complexity of the tasks is normally considerably less than that experienced by business groups (Dennis et al., 1989). Mason and Mitroff (1981) characterize these business problems as hydra-like in their entangling complexity. These may not be single-session tasks but may involve longitudinal continua of sessions. They may not have an end, and the task may not be completed. "While these tasks are common in field studies, they have typically not been studied in experiments - for obvious reasons! However, *these tasks are particularly appropriate for GDSS support*" (original emphasis, Dennis et al., 1989).

It was perhaps with such task appropriateness in mind that a number of researchers examined tasks along the informational-normative continuum (Huang et al., 1993; Raman et al., 1993; Tan et al., 1991, 1993a, 1993b), proposed by Davis et al. (1976), also used by Kaplan and Miller (1987) and Laughlin and Earley (1982), specifically intellective and preference tasks (types 3 and 4 in McGrath's circumplex). The intellective task lies towards one end of the continuum, while the preference task lies towards the other. While, intellective tasks have, or are considered to have, "demonstrably correct answers", preference tasks involve "behavioural, ethical, or aesthetic judgements for which there are no demonstrably correct answers" (Huang et al., 1993). "In terms of solution multiplicity, the former yields [a] single solution and the latter ... yields multiple solutions" (Benbasat and Lim, 1993). Both task types involve activities of a higher degree of complexity than simple idea generation, since intellective tasks may involve multiple criteria (Bui, 1987, 1993; Yu, 1985; Zigurs, 1987; Zigurs et al., 1988) and preference tasks will yield more than one solution as the solutions should reflect individual participant preferences (Watson, 1987; Watson et al., 1988).

11 SUMMARY

In this paper we have undertaken an extensive review of the GSS literature. This includes charting the development of GSS from its origins to the present day and presenting detailed accounts of other significant operational factors such as GSS facilitation, ergonomic design considerations, and interface design. The intention of this paper has not been merely to establish a working vocabulary of terms that are used in the GSS field. Rather, we have attempted to provide a comprehensive and detailed foundation for more analytical, applied work in the GSS domain. In this respect, it is complemented by its sister working paper (Davison, 1995), which examines socio-psychological aspects of group processes as they relate to GSS.

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