Introduction.

Decision making is still one of the most critical and central activities performed in organizations (Simon, 1960; 1997; Ackoff, 1962). Any effort that improves the effectiveness and efficiency of the process is likely to have positive impacts on organizational intelligence and performance (Huber, 1990; Mora & Cervantes, 1999). Computer Based Information Systems (CBIS) have been used to support operational, management and decision making activities. Transaction Processing Systems (TPS) are useful to support operational tasks and the automation of highly structured decisions. Management Information Systems (MIS) are useful to support the management of operational activities and the decision making process for routine structured decisions (Kroeber & Watson, 1988; Davis & Olson, 1990). These systems, however, are insufficient to support modern complex, semi and ill structured business decision problems. The gap in requisite support has stimulated the development of additional information systems called Decision Making Support Systems (DMSS) (Forgionne, Mora, Cervantes & Kohli, 2000).

DMSS are systems designed to support all phases of the decision making process from intelligence, through design, choice and implementation (Simon, 1997; Forgionne et al, 2000). The main stand-alone DMSSs are Decision Support Systems (DSS) (Gorry & Scott-Morton, 1971; Sprague, 1982), Executive Information Systems (EIS) (Rockart & Tracy, 1982) and Expert Systems & Knowledge Based Systems (ES/KBS) (Feigenbaum, McCorduck & Nii, 1989). Benefits obtained from the stand-alone system usage, the desire for complete and integrated decision making support, and the potential syngery from integration has stimulated the formulation of integration strategies that combine the functions of the stand-alone systems. These integrated DMSSs include: (a) Executive Support Systems (ESS), for systems that are integrated by an EIS and a DSS (DeLong & Rockart, 1986); (b) Expert Decision Support Systems (EDSS) for systems that are integrated by DSS and ES/KBS, and (c) integrated DSS (Turban & Watkins, 1989; Klein & Methlie, 1990) and Integrated Decision Making Support Systems (IDMSS) for systems composed of an EIS, a DSS and a ES/KBS (Turban & Watson, 1989; Forgionne, 1991; Forgionne & Kholi, 1995). Currently, new information technology (IT), such as intelligent agents, data warehousing, and data mining, are being used to enhance DMSS, and in turn, improve the decision making process.

The relevance of DMSS has motivated the proposal of frameworks to gain a better understanding of how DMSS can enhance the DMP. These frameworks account for some of the following dimensions: types of decisions (Simon, 1960, 1997); types of managerial decision levels (Anthony, 1965); types of decision vs types of managerial decision levels (Gorry & Scott-Morton, 1971); types of decision phases vs types of CBIS (Sprague, 1980; Turban & Watson, 1989); types of decision steps vs types of CBIS (Forgionne, 1991); types of tasks (Alter, 1980; Elam & Konsyinski, 1987); types of density of intelligence (Dhar & Stein, 1997) and types of decisions and managerial levels vs types of CBIS (Turban & Aronson, 1998). All of the frameworks have generated valuable findings to identify the right IT for some characteristics of the overall DMP. However, the literature has reported few, if any, frameworks that account for the main structural components of these IT and their relationship with key characteristics of the DMP, such as types of decisions, types of phases of decisions and types of CBIS. A framework with these characteristics is useful to identify how current IT is supporting the DMP and where new advances of future IT are needed.

This paper presents a new framework to help identify the role of IT in the support of the DMP. We first review the phases of the decision making process. Then, the characteristics of IT specialized to support this process are discussed. Next, an analysis of the role of these ITs in
The decision making process is presented. In this analysis a taxonomy of the structural components of DMSS is used as a framework to identify trends and required future enhancements (Mora, Forgionne & Cervantes, 2000; Mora, 2001). Finally, conclusions about the specialized IT support are presented and directions for further research are given.

The Decision Making Process.

The Decision-Making Process (DMP) can be defined as the steps developed by a decision-maker to identify a problem, propose and evaluate alternative solutions, select the most preferred alternative, and finally implement the choice (Simon, 1960, 1997; Ackoff, 1962; Huber, 1986; Sage, 1981). A DMP model, based on the seminal model proposed by Simon, consists of the following 4 phases (Forgionne and Kohli, 1995; Forgionne et al, 2000): (i) intelligence, where an organizational problem or opportunity is detected, qualitative and quantitative data are gathered, and objectives of the decision process are formulated; (ii) design, where a model with the pertinent decision alternatives, uncontrollable events, and associated outcomes is formulated; (iii) choice, where alternatives are evaluated in terms of their effects on the decision criteria, and the action that best achieves the decision objectives is selected; (iv) implementation and monitoring, where commitment of financial, human and material resources in an implementation plan is established, and monitoring activities to control the implementation of the decision are developed. According to the DMP literature, decisions can be classified as: (i) structured, where there is a well defined procedure to make a decision; (ii) semi-structured, where one of the phases of the DMP is ill-structured; and (iii) non-structured, where there is no previous procedure to act on (Gorry & Scott-Morton, 1971). MIS are oriented to support type I decisions. DMSS, in turn, are focused on support for type II and III decisions. In next sections, we will discuss such support.

IT to Support the Decision Making Process.

DSS.

Gorry & Scott-Morton (1971) proposed the use of a special kind of information system that was oriented specifically to support the DMP. They called this system a Management Decision System (MDS). Gorry and Scott-Morton defined a MDS as: “an interactive computer-based system which helps decision makers utilize data and models to solve unstructured problems”. Later, the MDS term was changed to Decision Support Systems (DSS) (Sprague, 1980). A DSS offers the following capabilities: (i) what-if analysis of scenarios; (ii) goal-seeking analysis and (iii) sensitivity analysis of variables. A DSS is usually used for staff personnel in organizations, top managers and executive decision makers. A survey of DSS applications reported from 1998 to 1994 (Eom et al, 1998), pointed out that the main areas of use are: Production/Operation, Marketing, Finance and Strategic Management. Various sources report successful cases of DSS implementations (Turban et al, 1995; Sprague & Watson, 1995; Eom et al, 1998)

EIS.

An Executive Information Systems (EIS), according to Rockart & Tracy (1982): “... is a computer based system which lets the user access a common core of data covering key internal and external business variables by time and by business unit.” Rockart & Tracy discovered in the early 80’s that top executives (i.e. CEO’s, CFO’s, etc) were independently using special information systems which let them monitor and track key performance indicators of the company. From these facts, they coined the term EIS. The capabilities typical of an EIS are: (i) access to summarized information on internal and external key performance indicators, usually through graph and text-table displays; (ii) analysis through drill-down, roll-up, slice and dice and pivoting operations and (iii) networking communications to bulletin boards. The literature also reports successful cases of EIS usage (Rockart & Treacy, 1982; Watson, Rainer & Koh, 1991; Turban & Aronson, 1998).

ES/KBS.

An ES/KBS, according to several researchers in the field (Feigenbaum et al, 1989; Jackson, 1990; Ignizio, 1991, Mora & Padilla, 1998), is a computer based system which exhibits, in a specific domain, a high degree of expertise in problem solving that is comparable to that of a human expert. An ES/KBS offers the following capabilities: (i) intelligent advice; (ii) qualitative reasoning; (iii) problem-solving assistance and (iv) explanation of advice. Successful cases of ES/KBS are reported from several sources (Feigenbaum et al, 1989; Liebowitz, 1989; Cantu, 1991). The difference between an ES and a KBS (Barr, 1990) is that the former contains the knowledge of a recognized expert in the field and the second contains only knowledge valuable for the organization.
Furthermore, Turban & Aronson (1998) identify the potential usage of other AI-based technologies, including Genetic Algorithms (Goldberg, 1989), Fuzzy Logic Systems (Zadeh, 1998), Neural Networks (Kosko, 1992), and Case-Based Reasoning (Kolodner, 1990), in Knowledge-Based Systems (KBS).

HYBRID SYSTEMS: ESS, EDSS & IDMSS.

The first proposal to integrate DSS, EIS and ES/KBS was developed by Turban & Watkins (1986). Their proposal was to integrate a DSS with an ES. The main objective was to add the qualitative modeling capabilities of ES to enhance a DSS. Other researchers also suggest enhancements such as why-analysis (King, 1992) and access to knowledge bases in order to effectively support decision makers in complex and ill-structured tasks (Klein & Methie, 1990). The integration of a DSS with an EIS was proposed by Delong & Rockart (1986). In these formulations, DSS analytical capabilities were added to EIS, and the time frame of analysis was extended from past and present to future data. Finally, Turban & Watson (1989) and Forgionne (1991) posed the integration of DSS, EIS and ES/KBS. The main focus of this integration was to support all phases of the decision making process, a task that was not being performed by any stand-alone system. Turban & Watson developed a conceptual model about how this integration could occur. Using this conceptual model, Forgionne and Kohli (1995) developed an IDMSS and tested the system’s effectiveness and efficiency versus stand-alone systems in an experiment. They found that an IDMSS, in general, helped to generate better user decisions. Additional evidence was reported by Forgionne and Kohli (2000).


Based on schemes reported by Forgionne et al (2000) and Mora (2001), this section presents a framework that identifies the structural components of DMSS. We claim that this scheme is useful to categorize the functional support that the different DMSS offer for decision making. The framework has two main structural components: data and process. The data component, in turn, is classified by levels of structural complexity. These levels are:

- I: Unidimensional Data Bases.
- II: Multidimensional Data Bases.
- IV: Knowledge Bases.
- V: Networking of Knowledge Bases.

With regard to the process component, the levels vary by the degree of embedded intelligence in the system. These levels are:

- I: Access to massive data.
- II: Summarization of massive data.
- III: Query.
- IV: Numerical Pattern Recognition.
- V: Conceptual Pattern Recognition.
- VI: Estimation of Numerical data (heuristics)
- VII: Estimation of Qualitative data (inferences).
- VIII: Intelligence (complex problem solving).

Figure 1 presents the relation of the data and process as structural components of DMSS, the types of DMSS, and the types of decisions supported. In Figure 1, we can observe that the lowest level of complexity, i.e. structured decisions, require IT with lower levels of data and process complexity, namely transaction processing (TPS) and management information (MIS). It must be noted that TPS is highly useful to automate routine decisions. The next level of decision complexity, i.e. semi-structured decisions, is supported by DMSS that require more complex data and process components. Multidimensional data bases combined with capabilities of massive data summarization, query and numerical pattern recognition, are the base for EIS and DSS augmented with Data Warehousing and Data Mining capabilities. Also, the addition of numerical models to DMSS with query capabilities are supported by ESS. In turn, ill-structured decisions, the highest level of complexity, requires ES, KBS, EDSS, and IDMSS mainly. These DMSS are based on numerical and qualitative estimations using numerical models, knowledge bases, and networks of knowledge bases. It can be argued that the deployment of networks of knowledge bases will be necessary to offer the full intelligence capability used in guiding decision makers through an analysis of ill-structured tasks.

Figure 2 presents the relationship between structural components of DMSS, the types of DMSS, and the phases of the DMP. Phase I of the DMP, i.e. intelligence, can be supported by EIS, ESS, DSS+DM, DSS+DW and EDSS. In this phase, these DMSS help summarize data, perform queries, and recognize numerical and conceptual patterns. Multidimensional data bases and numerical models are used to help decision makers identify potential problems. Phase II, i.e. design, is one of the most difficult tasks to be supported. It implies the formulation of the
model, identification of alternatives, scenarios, and criteria and the estimation of potential outcomes from actions. The framework proposed suggests that current DMSS do not offer meaningful support for this phase. Future IDMSS will have to offer capabilities of full intelligence and usage of networking of knowledge bases to support the design phase adequately. Phase III and phase IV, i.e. evaluation and implementations, are less complex than phase II. For phase III, DSS, EDSS, ES/KBS and IDMSS are suggested as the appropriate support systems. These DMSS, with the capabilities of numerical and qualitative estimations and the usage of numerical models and knowledge bases and multidimensional data bases, are able to assist decision makers in evaluating alternatives and in suggesting the preferred alternative. Finally, phase IV, or implementation, is supported by EIS, DSS+DW, and traditional MIS.

Conclusions.

A framework of structural components of DMSS has been reported. It has 2 dimensions: data and process. We show how this framework is useful to identify the role of different kinds of DMSS to support the different phases of the DMP for different types of decisions. It was argued that traditional TPS and MIS are not adequate to directly support the DMP. Therefore DMSS must be deployed in organizations for this managerial goal. As the DMP is still a critical managerial activity, any effort to improve it will have positive impacts on competitive intelligence and organizational performance. We suggest extending the research of this framework to specify procedures to identify the level of data and procedures used by a DMSS. Another potential area of investigation is to find real cases of DMSS and validate empirically the theoretical results reported in this study.

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Figure 1. Relation between Data, Process, Types of Decisions and Types of DMSS.
Figure 2. Relation between Data, Process, Phases of DMP and Types of DMSS.