# Decision Support System

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## Abstract:

**In this paper we introduce Decision support systems which are gaining an increased popularity in various domains, including business, engineering, the military, and medicine. They are especially valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker and in which precision and optimality are of importance. Decision support systems can aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, and aiding the process of structuring decisions. They can also support choice among well-defined alternatives and build on formal approaches, such as the methods of engineering economics, operations research, statistics, and decision theory. They can also employ artificial intelligence methods to address heuristically problems that are intractable by formal techniques. Proper application of decision-making tools increases productivity, efficiency, and effectiveness and gives many businesses a comparative advantage over their competitors, allowing them to make optimal choices for technological processes and their parameters, planning business operations, logistics, or investments.**

## I. INTRODUCTION:

While it is difficult to overestimate the importance of various computer-based tools that are relevant to decision making (e.g., databases, planning software, and spreadsheets), this article focuses primarily on the core of a DSS, the part that directly supports modeling decision problems and identifies best alternatives. We will briefly discuss the characteristics of decision problems and how decision making can be supported by computer programs. We then cover various components of DSSs and the role that they play in decision support. We will also introduce an emergent class of normative systems (i.e., DSSs based on sound theoretical principles), and in particular, decision analytic DSSs. Finally, we will review issues related to user interfaces to DSSs and stress the importance of user interfaces to the ultimate quality of decisions aided by computer programs.

## II. DECISIONS AND DECISION MODELING:

### Types of Decisions:

Simple view of decision making is that it is a problem of choice among several alternatives. A somewhat more sophisticated view includes the process of constructing the alternatives (i.e., given a problem statement, developing a list of choice options). A complete picture includes a search for opportunities for decisions (i.e., discovering that there is a decision to be made). A manager of a company may face a choice in which the options are clear (e.g., the choice of a supplier from among all existing suppliers). She may also face a well-defined problem for which she designs creative decision
Options (e.g., how to market a new product so that the profits are maximized). Finally, she may working a less reactive fashion and view decision problems as opportunities that have to be discovered by studying the operations of her company and its surrounding environment (e.g., how can she make the production process more efficient). There is much anecdotal and some empirical evidence that structuring decision problems and identifying creative decision alternatives determine the ultimate quality of decisions. Decision support systems aim mainly at this broadest type of decision making,

and in addition to supporting choice, they aid in modeling and analyzing systems (such as complex organizations), identifying decision opportunities, and structuring decision problems.

## Human Judgment and Decision Making:

Theoretical studies on rational decision making, notably that in the context of probability theory and decision theory, have been accompanied by empirical research on whether human behavior complies with the theory. It has been rather convincingly demonstrated in numerous empirical studies that

Human judgment and decision making is based on intuitive strategies as opposed to theoretically sound reasoning rules. These intuitive strategies, referred to as judgmental heuristics in the context of decision making, help us in reducing the cognitive load, but alas at the expense of optimal decision making. Effectively, our unaided judgment and choice exhibit systematic violations of probability axioms (referred to as biases).

One might hope that people who have achieved expertise in a domain will not be subject to judgmental biases and will approach optimality in decision making. While empirical evidence shows that experts indeed are more accurate than novices within their area of expertise, it also shows that they also are liable to the same judgmental biases as novices and demonstrate apparent errors and inconsistencies in their judgment. Professionals such as practicing physicians use essentially the same judgmental heuristics and are prone to the same biases, although the degree of departure from the normatively prescribed judgment seems to decrease with experience. In addition to laboratory evidence, there are several studies of expert performance in realistic settings, showing that it is inferior even to simple linear models (an informal review of the available evidence and pointers to literature can be found in the book by Dawes). For example, predictions of future violent behavior of psychiatric patients made by a panel of psychiatrists who had access to patient records and interviewed the patients were found to be inferior to a simple model that included only the past incidence of violent behavior. Predictions of marriage counselors concerning marital happiness were shown to be inferior to a simple model that just subtracted the rate of fighting from the rate of sexual intercourse (again, the marriage counselors had access to all data, including interviews with the couples). Studies yielding similar results have been conducted with bank loan officers, physicians, university admission committees, and so on.

## Components of Decision Models:

While mathematically a model consists of variables and a specification of interactions among them, from the point of view of decision making a model and its variables represent the following three components: a measure of preferences over decision objectives, available decision options, and a measure of uncertainty over variables in using the decision and the outcomes. Preference is widely viewed as the most important concept in decision making. Outcomes of a decision process are not all equally attractive and it is crucial for a decision maker to examine these outcomes in terms of their desirability. Preferences can be ordinal (e.g., more income is preferred to less income), but it is convenient and often necessary to represent them as numerical quantities, especially if the outcome of the decision process consists of multiple attributes that need to be compared on a common scale. Even when they consist of just a single attribute but the choice is made under uncertainty, expressing preferences numerically allows for trade-offs between desirability and risk. The second component of decision problems is available decision options. Often these options can be enumerated.

The third element of decision models is uncertainty. Uncertainty is one of the most inherent and most prevalent properties of knowledge, originating from incompleteness of information, imprecision, and model approximations made for the sake of simplicity. It would not be an exaggeration to state that real-world decisions not involving uncertainty either do not exist or belong to a truly limited class.1 Decision making under uncertainty can be viewed as a deliberation: determining what action should be taken that will maximize the expected gain. Due to uncertainty there is no guarantee that the result of the action will be the one intended, and the best one can hope for is to maximize the chance of a desirable outcome. The process rests on the assumption that a good decision is one that results from a good decision-making process that considers all important factors and is explicit about decision alternatives, preferences, and uncertainty. It is important to distinguish between good decisions and good outcomes.

## III. DECISION SUPPORT SYSTEMS:

Decision support systems are interactive, computer-based systems that aid users in judgment and choice activities. They provide data storage and retrieval but enhance the traditional information access and retrieval functions with support for model building and model-based reasoning. They support framing, modeling, and problem solving. Typical application areas of DSSs are management and planning in business, health care, the military, and any area in which management will encounter complex decision situations. Decision support systems are typically used for strategic and tactical decisions faced by upper-level management decisions with a reasonably low frequency and high potential consequences in which the time taken for thinking through and modeling the problem pays of generously in the long run. There are three fundamental components of DSSs

- Database management system (DBMS).

A DBMS serves as a data bank for the DSS. It stores large quantities of data that are relevant to the class of problems for which the DSS has been designed and provides logical data structures (as opposed to the physical data structures) with which the users interact. A DBMS separates the users from the physical aspects of the database structure and processing. It should also be capable of informing the user of the types of data that are available and how to gain access to them.

- Model-base management system (MBMS).

The role of MBMS is analogous to that of a DBMS. Its primary function is providing independence between specific models that are used in a DSS from the applications that use them. The purpose of an MBMS is to transform data from the DBMS into information that is useful in decision making. Since many problems that the user of a DSS will cope with may be unstructured, the MBMS should also be capable of assisting the user in model building.

- Dialog generation and management system (DGMS).

The main product of an interaction with a DSS is insight. As their users are often managers who are not computer-trained, DSS need to be equipped with intuitive and easy-to-use interfaces. These interfaces aid in model building, but also in interaction with the model, such as gaining insight and recommendations from it. The primary responsibility of a DGMS is to enhance the ability of the system user to utilize and benefit from the DSS.

## IV. DECISION-ANALYTIC DECISION SUPPORT SYSTEMS:

An emergent class of DSSs known as decision-analytic DSSs applies the principles of decision theory, probability theory, and decision analysis to their decision models. Decision theory is an axiomatic theory of decision making that is built on a small set of axioms of rational decision making. It expresses uncertainty in terms of probabilities and preferences in terms of utilities. These are combined using the operation of mathematical expectation. Decision analysis is the art and science of applying decision theory to real-world problems. It includes a wealth of techniques for model construction, such as methods for elicitation of model structure and probability distributions that allow minimization of human bias, methods for checking the sensitivity of a model to imprecision in the data, computing the value of obtaining additional information, and presentation of results. (See, for example, Ref. for a basic review of the available techniques.)These methods have been under continuous scrutiny by psychologists working in the domain of be behavioral decision theory and have proven to cope reasonably well with the dangers related to human judgmental biases.

The approach taken by decision analysis is compatible with that of DSSs. The goal of decision analysis is to provide insight into a decision. This insight, consisting of the analysis of all relevant factors, their uncertainty, and the critical nature of some assumptions, is even more important than the actual recommendation. Decision-analytic DSSs have been successfully applied to practical systems in medicine, business, and engineering. As these systems tend to naturally evolve into three not necessarily distinct n classes, it may be interesting to compare their structure and architectural organization.

- Systems with static domain models.

In this class of systems, a probabilistic domain is represented by a large network encoding the domain's structure and its numerical parameters. The network comprising the domain model is normally built by decision analysts and domain experts. An example might be a medical diagnostic system covering a certain class of disorders. Queries in such a system are answered by assigning values to those nodes of the network that constitute the observations for a particular case and propagating the impact of the observation through the network in order to offend the probability distribution of some selected nodes of interest (e.g., nodes that represent diseases). Such a network can, on a case-by-case basis, be extended with decision nodes and value nodes to support decisions. Systems with static domain models are conceptually similar to rule-based expert systems covering an area of expertise.

- Systems with customized decision models.

The main idea behind this approach is automatic generation of a graphical decision model on a per-case basis in an interactive effort between the DSS and the decision maker. The DSS has domain expertise in a certain area and plays the role of a decision analyst. During this interaction, the program creates a customized inuence diagram, which is later used for generating advice.

- Systems capable of learning a model from data.

The third class of systems employs computer intensive statistical methods for learning models from data [1, 11, 12, 21, 26]. Whenever there are sufficient data available, the systems can literally learn a graphical model from these data. This model can be subsequently used to support decisions within the same domain.

The first two approaches are suited for slightly different applications. The customized model generation approach is an attempt to automate the most laborious part of decision making, structuring a problem, so far done with significant assistance from trained decision analysts. A session with the program that assists the decision maker in building an inuence diagram is laborious. This makes the customized model generation approach particularly suitable for decision problems that are infrequent and serious enough to be treated individually. Because in the static domain model approach an existing domain model needs to be customized by the case data only, the decision-making cycle is rather short.

## V. USER INTERFACES TO DECISION SUPPORT SYSTEMS:

While the quality and reliability of modeling tools and the internal architectures of DSSs are important, the most crucial aspect of DSSs is, by far, their user interface. Systems with user interfaces that are cumbersome or unclear or that require unusual skills are rarely useful and accepted in practice. The most important result of a session with a DSS is insight into the decision problem. In addition, when the system is based on normative principles, it can play a tutoring role; one might hope that users will learn the domain model and how to reason with it over time, and improve their own thinking.

- Support for Model Construction and Model Analysis

User interface is the vehicle for both model construction (and model choice) and for investigating the results. Even if a system is based on a theoretically sound reasoning scheme, its recommendations will be as good as the model they are based on. Furthermore, even if the model is a very good approximation of reality and its recommendations are correct, they will not be followed if they are not understood. Without understanding, the users may accept or reject a system's advice for the wrong reasons and the combined decision-making performance may deteriorate even below unaided performance. A good user interface should make the model on which the system's reasoning is based transparent to the user.

- Support for Reasoning about the Problem Structure

While numerical calculations are important in decision support, reasoning about the problem structure is even more important. Often when the system and its model are complex it is insightful for the decision maker to realize how the system variables are interrelated. This is helpful in designing creative decision options but also in understanding how a policy decision will impact the objective.

- Support for Both Choice and Optimization of Decision Variables

Many DSSs have an inexible structure in the sense that the variables that will be manipulated are determined at the model-building stage. This is not very suitable for planning of the strategic type when the object of the decision-making process is identifying both the objectives and the methods of achieving them. For example, changing policy variables in a spreadsheet-based model often requires that the entire spreadsheet be rebuilt. If there is no support for that, few users will consider it
as an option.

## VI. CONCLUSIONS AND FUTURE WORK:

Decision support systems are powerful tools integrating scientific methods for supporting complex decisions with techniques developed in information science, and are gaining an increased popularity in many domains. They are especially valuable in situations in which the amount of available information is prohibitive for the intuition of an unaided human decision maker and in which precision and optimality are of importance. Decision support systems aid human cognitive deficiencies by integrating various sources of information, providing intelligent access to relevant knowledge, aiding the process of structuring, and optimizing decisions.

Because DSSs do not replace humans but rather augment their limited capacity to deal with complex problems, their user interfaces are critical. The user interface determines whether a DSS will be used at all and if so, whether the ultimate quality of decisions will be higher than that of an unaided decision maker.

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