# Collaborative Decision Support Systems for Facility Management

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## Abstract

Agent-based collaborative decision support is a methodology of utilizing domain specific intelligent systems, interacting in a common environment, to partner with one or more human decision makers to reach a consensus solution to a complex problem. An example is the recently developed Collaborative Infrastructure Assessment Tool (CIAT) that provides a collaborative planning facility management tool in support of military pier and port management. This methodology is applicable to many similar dynamic facility management problems where the complexity of issues and the number of decision makers result in the need for domain specific agents, a common view of the data, and the need to reach a consensus solution.

## Keywords

agents, collaborative planning, consensus solution, decision support, facilities management, infrastructure assessment, knowledge base, problem solving,

## Decision Support Data

Decision support is one of the most talked about and least implemented topics in the computer world today. It is generally built around a data warehousing component where corporate or institutional data are centralized and sanitized for general distribution. This is coupled with a variety of presentation programs that allow the slicing and dicing of data fields with the goal of providing users with every imaginable presentation option. The data collection and presentation process has unfortunately absorbed most corporate or institutional organizations and makes difficult their ability to evolve into decision support, whereby data are combined with operational rules and structured into a collaborative decision making system.

A recent survey of 700 information systems (IS) executives from a worldwide cross-section of large corporations found their foremost concern was not decision support but data and data movement, in particular, data hoarding, data compatibility among operating systems, and network performance for data movement. Particular concerns were "...critical information dispersed outside the data center, where it can't be easily accessed and managed, weakens customer service, lowers productivity and hurts a company's ability to compete.....most IS executives run into roadblocks when trying to share data because of the multitude of computer operating systems in use in their companies, and the impact that moving data over networks has on the performance of their main production systems" (The HP Chronicle, December 1997). Their focus is on data productivity and the perception that there is a direct relationship between the availability of data and the company "bottom line" (i.e., profitability).

For those reasons, industrial trends are for computer services to become more compatible and faster, and therefore will soon make feasible the direct dependence, in 'real-time', on the information buried in the huge piles of data these IS executives are worried about.

Unfortunately, their data concerns overshadow a much larger issue. As data become more readily available for operational and strategic purposes, users are demanding systems that allow help in understanding, interpreting, digesting, and incorporating the data into their decision making roles. In being consumed with the process of data collecting, IS executives seem not to be addressing appropriate data use and the decision making process. For example, in the area of facility management, what would it mean to have immediate access to 10 years of maintenance records for all air-conditioning equipment for an institution's 125 buildings. Maybe nothing. What would it mean to have fully detailed as-built drawings of every building for a large corporation and have them on a super computer-aided drawing system that is 'web' compatible and accessible to all employees both on an off their site. Maybe nothing. Unfortunately, many organizations are moving forward with weakly founded data collection plans hoping, as in the movie Field of Dreams, "build (pile) it and they will come (use it)".

## Decision Support Data Needs

Data should be viewed as one of two primary support components for decision making. The other being decision support rules. Decision making can occur when data are combined with rules. The result may then be called a knowledge base. Data that have no basis for use by rules should be archived and the expense of such data collection questioned. For example, one might have the rule that an air-conditioning system will be serviced after 8,000 hours of operation. That rule could then be part of a computer-based maintenance agent that tracks air-conditioning operational data. When service hours exceed a specified limit, the rule 'fires' and alerts the appropriate personnel. The maintenance agent could also anticipate when multiple buildings are to have their air-conditioning systems serviced and alert management of an impending workload crisis. Such service data have a reason for being and clearly would justify their existence.

A service agent is a rule-based computer program dedicated to monitoring and advising in a narrow domain. A 'real-time' example might be a weather agent monitoring weather data and advising, either a human decision maker or another agent, on appropriate precautions for building operations. A building use agent might monitor building activity levels and prepare for increases in maintenance needs. A maintenance agent might collaborate with the building use agent and propose a schedule of maintenance activities. A project scheduling agent might consider and advise on the time overlapping of trades and facility use needs. An agent is the domain specific 'engine' that combines rules and data. Groups of agents, including the human agents, form a Decision Making Team (DMT).

**Agent-Based Collaborative Decision Making (ICDM)**

Advances in agent-based software systems incorporating rule-based expert systems that assist human decision makers by monitoring user actions, evaluating consequences, proposing solution strategies, and inferring alternative solutions, represent a promising direction for assisting in the solution to complex facility management problems. In such distributed, cooperative systems, multiple intelligent agents collaborate among themselves and with the DMT to improve the quality of the planning effort.

The Integrated Cooperative Decision Making (ICDM) architecture developed jointly by the CAD Research Center (CADRC) at California Polytechnic State University and CDM Technologies, Inc., provides a distributed computer-based framework for cooperative decision support systems. It comprises a data-blackboard that is capable of interacting with multiple distributed agents, and addresses the support needs of a complex planning situation in terms of:

* A high level internal representation of real world objects that are commonly used by human decision makers in a particular application area.

* Databases containing factual technical information, reference data, and prototype models of knowledge that pertains to the problem under consideration.

* Expert agents capable of validating decisions and predicting the impact of solutions in one area on solutions in related areas.

The distributed agent computing model is capable of emulating and extending basic human problem solving strategies for the solution of complex planning problems. Human problem solving generally involves collaboration among DMT experts, such as building engineers, maintenance personnel, construction managers, and so on, depending on the particular problem. By encapsulating knowledge from human domain experts into computer-based agents and allowing these agents to interact with each other and with human users, and by allowing this interaction to occur in parallel through the use of computer networks, such systems can significantly increase the productivity of decision making. The CADRC and CDM Technologies, Inc. have implemented this ICDM methodology within a number of fielded projects (Pohl et al, 1997).

**A CIAT Implementation of the ICDM Model**

The Collaborative Infrastructure Assessment Tool (CIAT) is a collaborative planning facility management tool that provides support to a group of decision makers each with unique responsibilities but working for a common goal. The application to be discussed is a DMT in support of US Navy pier and port management.

Many US Navy ports are faced with the common problem of coordinating the movement and positioning of large warfare and support ships into selected berth locations. The issues of this problem go far beyond the simple matching of ships to available berths. Each naval pier facility has a unique set of characteristics including, utility availability, berth drafts, loading capability, width, scheduled maintenance activities, and so on. In addition, each pier has a unique relationship with port facilities based on location. For example, some may have more desirable access to parking, restaurants, recreational facilities, and so on. In addition, as ships prepare for arrival they transmit requests for services that may involve unexpected facility uses. These issues result in a complex problem solving situation, requiring a DMT, and a situation that is well suited to the collaborative planning environment as provided by the ICDM architecture.

CIAT is currently being used as the primary tool to place ships at the US Naval Station in San Diego, California. That facility has 14 piers and over 65 berths. It also has approximately 45 'home ported' ships and regularly caters to visiting US Navy ships and ships from foreign navies. The tempo involves ship movements monitored on an hourly basis, seven days a week, 24 hours per day.

After fielding an initial prototype version on the UNIX (HPUX) platform in September 1996, a Windows NT version was delivered in October 1997. This later version is a web-based application and runs under Internet Explorer. Current enhancements underway will provide additional agent functionality and connectivity to additional members of the DMT. CIAT is under consideration for use at a number of similar US Navy ports for management of port services.

The CIAT workstation (Figure 1) consists of service agents, a local semantic network, a graphical user interface, an agent status manager and agent kernel, reporting capabilities, a time manager, and a communications facility. The user interface module provides all of the functions required by the user to manipulate the system. It drives the logical inferencing capabilities of the agents based on user actions at any point in time. Users can initiate a ship arrival and departure request, select a berth, request hotel services, graphically move and delete ships and so on.

The user interface (Figure 2) component receives user requests. If a request requires a decision, it is sent to the agent kernel for processing. Agents process the requests and transmit violations to the agent status manager.

CIAT's main modes of service for ship placement operations are user scheduling and assisted scheduling. In user scheduling CIAT monitors user actions. In assisted scheduling CIAT receives a request for ship placement and offers appropriate solutions.

The agents consist of database knowledge and rules for manipulating this knowledge in application to specific domains. The databases contain information such as ship scheduling, pier and berth schedules and capabilities, maintenance and construction schedules, ship berthing histories, and cost information. Agents representing critical areas of expertise continuously assist the user in identifying and resolving conflicts.

For example, given a ship has been placed inappropriately through user scheduling (Figure 3), the agent responsible for monitoring the characteristics of piers and their utilization will provide an alert to the user indicating a violation.

A key planning element of CIAT is its ability to provide a variety of views of ship positioning and resource utilization information. These views are like trials or experiments for developing a reasonable positioning plan that are then sent to other members of the DMT for consideration and reply. Once a consensus has been reached among the DMT, a trial plan can be incorporated into the accepted planned view of the future and that view would then be available for the DMT to work from and for all others who utilize that information to consider. The 'viewer' web-based option is discussed below under Types of Users.

CIAT is meant to work in a web-based environment with multiple DMT team members involved in collaborative decision making. Each workstation is a single process, which is a client to a central server that consists of database, web, and communication servers. The components in a workstation are implemented as ActiveX controls (Li, 1997).

Each workstation (Figure 4) utilizes TurboCAD as its graphics engine. ActiveX agents are written in a combination of Java, C++, and Clips (Giarratono, 1989), an expert system language. Reporting functions utilize VBGrid. ActiveX data objects utilize ODBC (Open Database Connectivity). The ODBC driver implements the communication layers and access methods to the databases. Communications utilize standard TCP/IP protocols. The blackboard ActiveX control is an object that maintains the state of global objects. As blackboard data changes in the database server, triggers are fired in the database that inform the blackboard control that it needs to update its data. The web server utilizes the standard HTTP (HyperText Transfer Protocol) which is an applicati level protocol for distributed, collaborative, hypermedia information systems (Lemay, 1996).

### Types of Users

CIAT serves two types of users. First, members of the DMT as described abo These are the primary decision-makers and those who have the authority to make changes and modify data. A second important group of users are thos that require viewing of the scheduled data. Viewers are those implementing a judging the decisions of the DMT. For example, viewers might be food servic and maintenance personnel, ships at sea reviewing possible berth requests, a naval management both on and off the base monitoring base decisions.

Information viewers (Figure 5) do not require the graphics and agent function of a DMT workstation. Viewers require only inter- or intra-net (depending on security level) access and viewer software is configured to run under a stand web browser. Viewers look only at the single planned view or the past view c the ship berthing information and can take advantage of the date change fun to view that which is planned for any day in the future or what has occurred ir past. The viewer functionality provides decision visibility to all involved in po operations.

### Summary

Decision support systems are generally built around a data-warehousing component where corporate or institutional data are centralized and sanitize general distribution. As data become more readily available for operational a strategic purposes, users are demanding systems that allow help in understanding, interpreting, digesting, and incorporating the data into their decision making roles. This naturally leads to the creation of knowledge bas

Agent-based collaborative decision support is a methodology of utilizing knowledge based domain specific intelligent systems, interacting in a comm environment, to partner with one or more human decision makers to reach a consensus solution to a complex problem. An example is the recently devel Collaborative Infrastructure Assessment Tool (CIAT) that provides a collabo planning facility management tool in support of military pier and port management. This methodology is applicable to many similar dynamic facil management problems where the complexity of issues and the number of decision makers result in the need for domain specific agents, a common view of the data, and the need to reach a consensus solution.

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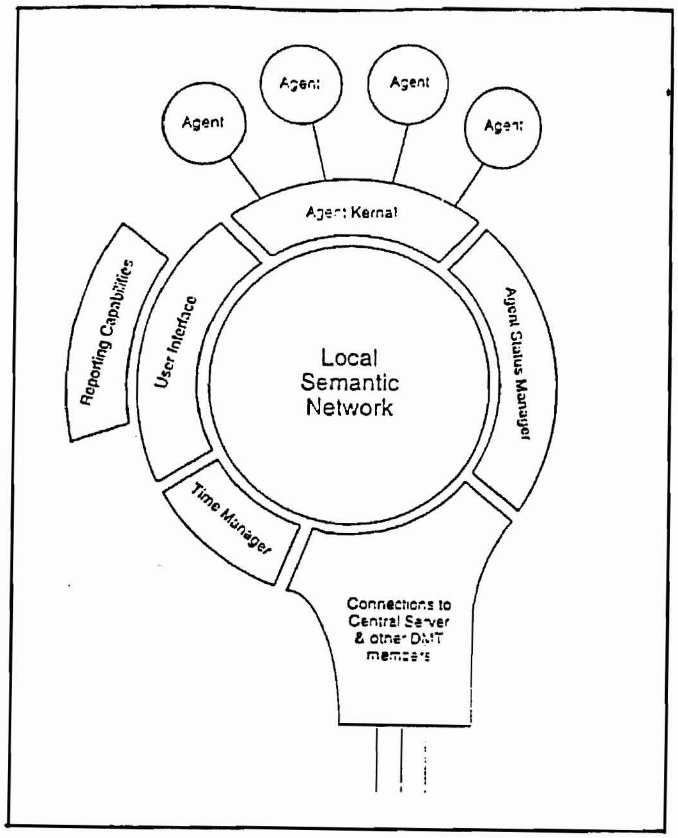


**Figure 1: CIAT Workstation**


**Figure 2: Basic Screen**

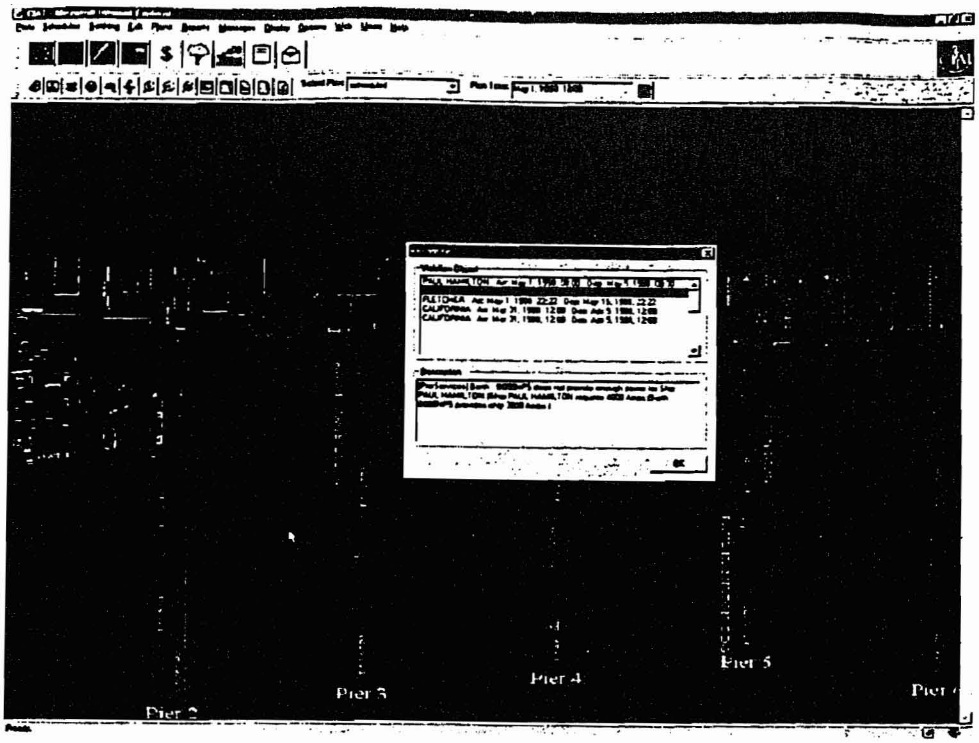


**Figure 3: Screen with Violation**

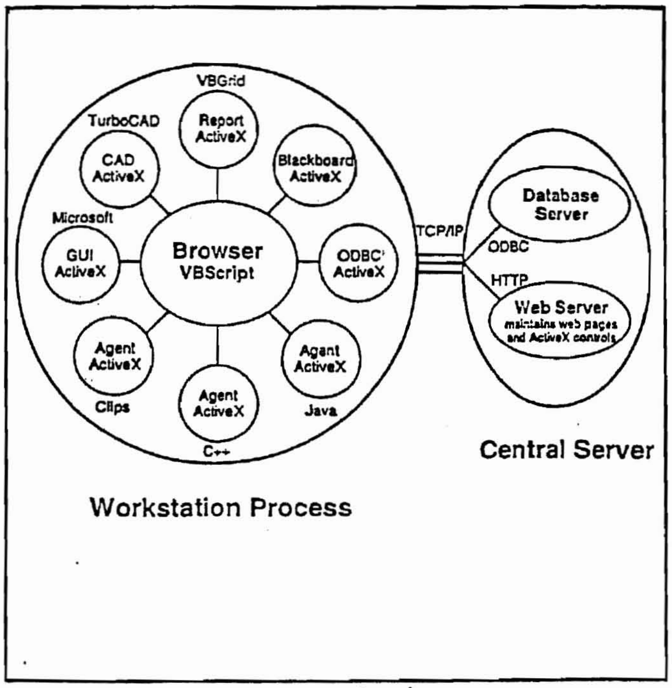


**Figure 4: Workstation-Server**

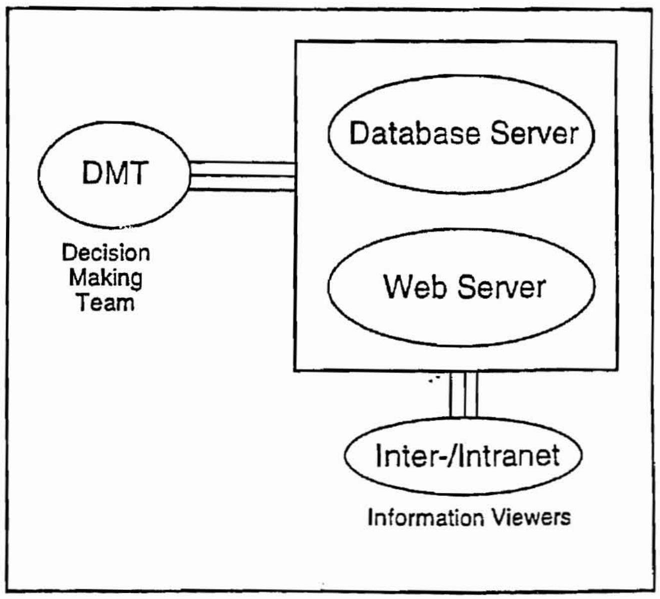


**Figure 5: Types of Users**