Design of Support Systems for Cognitive Work in Airline Operations

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This paper examines design of support systems for airline operations. Previous studies found that cognitive work which includes activities such as judgment and decision making varies with context such that a single method of supporting cognitive work can not apply in many situations. Specifically, time constraints have been found to be a major factor in the both the decision strategies adopted by individuals and in the contextual control mode individuals operate in. An approach is presented to incorporate the Contextual Control Model into the design of a cognitive work support system to address the issue of varied time constraints . Specific examples are given for support systems for airline decision makers operating in the Strategic, Tactical and Opportunistic Contextual Control Modes.

I. Introduction and Motivation

US airlines play a large role in the efficient operation of the national air transportation system, not only due to strategic scheduling decisions made by airlines, but also in the daily implementation of these strategic decisions.[1,2] The safe and efficient management of an airline is a complex cognitive task, involving many individuals working in close coordination. In particular, Airline Operation Managers (AOMs) of typical major U.S. airlines are responsible for the daily operation of large regions or fleets of aircraft, often with 40-50 flights departing every hour. They oversee daily operations that are often disrupted by weather, ATC delays and unscheduled maintenance and are responsible for implementing flight delays, cancelations, "aircraft swaps" and the use of reserve crews to minimize the impact of such disruptions.

Thus, both AOMs (like Air Traffic Managers) operate in an environment in which:

- The overall goal of the work is to regulate some dynamic system
- A series of activities are required to reach/maintain the overall goal
- Individual activities are dependent on the outcome of previous activities
- Task parameters are continuously changing in response to changes
- Must be 'accomplished in real time

This type of environment is typical of a dynamic environment which Brehmer defined as those requiring a series of actions, including decisions, judgments, etc, to reach or maintain the overall goal, being dependent on the previous action outcomes, having a system which is continuously changing, and requiring that actions be made in real time'.[3]

The AO work domain is particularly interesting as a dynamic system because of the current interest in expanding the use of optimization techniques in airlines to aid in day-to-day operations in addition to long-range planning. Specifically, there has been much interest in the operations research community on using mathematical programming to improve airline recovery from irregular operations.[4] The aim of these algorithms is, first, to generate a set of feasible solutions, and, second, select the solution that optimizes some aspect of the operation, be it aircraft utilization, the number of passengers stranded or a composite function of revenue generation based on the problem description that it is given. With over 10% of daily

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operations considered to be irregular, even small performance improvements in the work of AOMs could potentially translate into significant revenue.

What is lacking is a coherent support system in which to implement these algorithms. To date, most support systems have been fielded in static or slowly evolving dynamic environments. In these environments the challenges facing support system designers include how to deal with uncertainty in situation assessments. Dynamic environments add to these challenges a wide range of time constraints within which actions must be taken, as well as interdependence between subsequent decisions.

In addition to the challenges posed to the design of support systems by the dynamic nature of the work environment, there are further questions imposed by human operator, which include:

- Which activities should the support system aim to support?
- What model of decision making, judgment, etc should the system aim to support?
- How should the work be split between the human operator and the support system?
- How should the human and the support system interact?

Traditionally, support systems have been designed to facilitate the decision making process by comparing multiple decision alternatives over a set of decision attributes. These systems have been based on a model of rational decision making, and were thus dubbed Decision Support Systems. Sophisticated DSS can allow for the weighting of attributes and the automatic calculation of the "best" rational choice according to these weightings.

In the field of airline operations, there has been much interest in creating a DSS with the capability to present the user with the "best" solution to approve and implement. This can create an 'authority' responsibility double-bind, where the user has responsibility for the decision but may not have the resources to evaluate and improve the solution's efficacy and to catch any problems. Additionally, as DSS are currently designed, this advanced solution generation capability takes time, suitably formatted information and expertise. Unfortunately, time and suitably formatted information are not always available in dynamic environments such as AO. Often, necessary information is not known, not known precisely enough, or only known in a form difficult to enter into a DSS. Further, traditional support systems have been designed to primarily support the activities of decision making and information gathering. Based on a model of rational decision making, the designer has to split the work such that the human serves as an automation translator and monitor, and limits interaction between the humans and support systems.

Previous research by the authors has employed an ethnographic technique, called contextual inquiry as described by Beyer & Hotzblatt,[5] to model the work performed by AOMs.[1] The contextual inquiry revealed that AOMs' approaches to their work can vary widely. On a busy travel day with major disruptions, the AOM may resort to broad measures such as operating the entire fleet an hour behind schedule. Alternatively, on days with few disruptions the AOM may consider many possible alternatives to minimize flight delays. He may consult his colleagues, generate several alternatives and choose between them. These variations lead the authors to hypothesize that any tool intended to support an AOM's work process should to be capable of accommodating the range of behaviors observed in the contextual inquiry.

In summary, the current models and assumptions upon which support systems are designed are not appropriate for dynamic work environments such as AO, and are not consistent with the activities observed there. For example, present AO support systems focus on supporting decision making behavior alone, when information gathering may play an equally important role. Further, DSS design based on a model of rational decision making, where the required decision making strategy is assumed to follow that predicted by theories of rational decision making,[6] is inadequate to meet the needs of individuals operating in dynamic environments.

This paper proposes that the dynamic nature of the ATM and AO work encompasses a broad set of activities, such as decision making, judgment, coordination, information gathering, solution generation, decision execution, and defined here as cognitive work. Cognitive work leads to specific challenges for the design of support systems that cannot be met through the use of traditional DSS systems. These challenges include supporting a variety of activities concurrently, supporting activities over a range of time horizons for task completion,[6] and supporting multiple activities with varying amounts of information.

II. Designing for Cognitive Work in Dynamic Environments

The different decision strategies seen in the contextual interview of AOMs appear to correspond to contextual factors such as the decision maker's perception of the variable time constraints and knowledge of situation. The Contextual Control Model (COCOM) devised by Erik Hollnagel provides a useful framework to view the changes in cognitive work in response to contextual features such as time limit and information availability,[7] as it includes both a model of competence and a model of control.

The model of competence consists of the set of possible actions (action set) available to person to implement at any moment in time and the patterns for carrying out the actions (template set). The patterns defined in the template set, "may be plans (pre-defined or produced during the task), procedures, rules, guidelines (heuristics), strong associations, or in fact any thing else that may serve as a guide for performance".[7]

In the COCOM the pattern selected is determined by the model of control. Control in this model is conceptualized as planning what to do in the short-term and within the time horizon of the system with which the human is interacting.[8] The control model consists of a continuum of control, where at one end there is little to no control, and at the other there exists a high degree of control.

To describe this continuum of control, Hollnagel has developed a classification of CCMs that describe how humans organize their activities. The classification contains the following four modes that are characterized by the seven performance characteristics shown in Table 1:[7]

Scrambled control "denotes the case where the choice of next action is completely unpredictable or random... This type of performance is thus, paradoxically, characterized by the lack or absence of any control"[7](p168). Examples of scrambled control include individuals in a state of panic or complete indecision.

Opportunistic control "corresponds to the case when the next action is chosen from the current context alone, and mainly based on the salient features rather than on more durable intentions or goals"[7](p169-170). In this mode planning and anticipation are limited often because of limited constructs or limited time.

Tactical control "is characteristic of situations where the person's performance is based on some kind of planning, hence more or less follows a known procedure or rule. The person's event horizon goes beyond the dominant needs of the present, but the possible actions considered are still very much related to the immediate extrapolations from the context"[7](p170).

Strategic control "means that the person is considering the global context, i.e., using a wider event horizon and looking ahead at higher level goals"[7](p170).

Importantly, COCOM included the idea that individuals will transition between CCM to maintain control over a changing situation.[9,10] Hollnagel states that, "The change between control modes is determined by a combination of situational and person (or internal) conditions, – in other words by the existing context,"[7] p194. Thus, the control mode are chosen to be appropriate for the context and, as context changes, an individual's CCM can change too.

Using the examples given previously, on a day with few disruptions the AOM may operate in a Strategic CCM. He may consider many possible alternatives to minimize flight delays, may consult his colleagues, generate several alternatives and choose between them. He is likely to coordinate with many of his colleagues and iterate many times before choosing a course of action. Additionally when operating in a strategic mode, the AOM may work on the problem for a long period often stopping to work on other problems. Alternatively, on a busy travel day with major disruptions, the AOM may operate in an Opportunistic CCM and may resort to broad measures such as operating the entire fleet an hour behind schedule. The AOM may resort to solving problems in isolation with little input from colleagues and limited iteration. The AOM's CCM will not necessarily last for an entire shift, and will most likely vary with contextual features of the work such as workload, time available, and availability of extra aircraft and crews. The variations witnessed during the contextual inquiry lead the authors to hypothesize that any tool intended to support AOM's work process would need to be capable of accommodating the range of behaviors observed in the contextual inquiry.

The framework provided by the COCOM allows many different ways of approaching a high level task, including many different ways of organizing human activities. COCOM does not prescribe the order of activities necessary to accomplish a task or goal, but instead accommodates multiple patterns of activity,

Table 1. COCOM Contextual Control Modes, reprinted from Hollnagel, 1993 p. 193[7]

	Strategic	Tactical	Opportunistic	Scrambled
Number of Goals	Several	Several (limited)	One or two (competing)	One
Subjectively Available Time	Adequate	Adequate	Just adequate	Inadequate
Selection of Next Action	Prediction based	Procedural	Association based	Random
Evaluation of Events	Elaborate	Normal details	Concrete	Rudimentary
Event horizon	Extended	Normal	Narrow	None
Plans Available	Pre-defined or generated	Available and used	Negligible or limited	None
Execution mode	Mix of subsumed and feed-back	Feedback (with comparison to expected outcome)	Feedback (with observation of effects on system)	Subsumed

broadly grouped into CCMs. This breadth is necessary because of the wide variety of approaches AOMs use in accomplishing their overall goal of schedule adherence, including which methods of information seeking, communication, and coordination, which decisions to make, and when and how to apply these actions. Using the framework provided by the COCOM suggests that a CWSS could be tailored for specific CCMs.[11–13]

III. Impact of Contextual Control Modes on CWSS Design

By using the Strategic, Tactical and Opportunistic CCMs as descriptors of effectivehuman behavior under different contextual conditions, we can begin to think about how activities might change under different contexts. For example, we can postulate that an AOM operating in an opportunistic mode, where the choice of next action is often heavily influenced by the salient features of the problem, may want their CWSS, to highlight a limited number of the most relevant information available from the environment and then facilitate task execution (such as identifying any flights which are predicted to be delayed due to late arriving aircraft and providing 'one-click' mechanisms to delay or cancel it). AOM operating in a tactical mode may instead want their CWSS to support a common procedure for planning and double checking their task solution. Different still, an AOM operating in a strategic mode may want their CWSS support solution comparison along a specified objective function (such as the number of passengers disrupted, number of aircraft disrupted, or overall economic impact) in addition to the support with task execution and solution checking. The following sections will present sketches of an interface of one aspect of a CWSS for AO for each of these different CMMs to further illustrate the ideas.

A complete CWSS would be comprised of a number of different focus areas designed to support a specific function combinations. In order to identify which focus areas are required by a CWSS it was necessary to identify key functions that were required and to determine the role of both the Human and the CWSS for each. To better organize these functions, we have used Sheridan, Parasuraman and Wickens[14] four stages of problem solving behavior. as a general classification: information acquisition, coordination, analysis, and action. Tables 2 and 3 list the different roles for both the human operator and the CWSS for each of the functions. The tables are further divided into the different CCM design modes as the roles for the Human and CWSS may vary across modes. The roles are defined below:

Alerter: tries to draw attention
Authorizer: authorizes the implementation of an action
Clerk: copies and pastes data from one place to another
Compiler: selects information to be used (usually from a pre-existing set)
Decision maker: chooses between options
Implementer: implements an action

Informer: informs the necessary parties about a decision, action, problem, etc.
Interrogator: questions either the human or computer agent
Judge: determines potential actions from an environmental attribute
Manager: decides what to do with an action or how to modify a process
Mediator: helps two or more agents agree on a course of action
Monitor: monitors system for potentially problematic situations
Organizer: organizes information in a useful format
Presenter: presents information in a useful manner
Stenographer: transcribes what they hear

Tables 2 and 3 illustrate that, for the Information Acquisition and Action phases of problem solving, there are very few differences in the roles of either the human or the CWSS; however, for the Coordination and Analysis stage large differences are expected.

A. Prototype CWSS Description

To better illustrate the impact of designing CWSS to support multiple CCMs, this paper presents an example of CWSS designs for different contextual control modes so that the CWSS supports the human's CCM appropriate to and, as context changes, an individual's CCM can change too. the immediate context. The different features of the CCMs and illustrations of some of these features on the design of the CWSS will be addressed in turn in the following subsections.

A complete CWSS would be comprised of a number of focus areas designed to support specific function combinations. Using the information gathered previously during a contextual inquiry, resultant work models,[11] and the information about the different roles used by both the CWSS and its human operator, a diagram of the envisioned focus areas has been created for each of the CCMs, presented in the following subsections. Additionally, a specific focus area will be singled out to better illustrate the impact of using CCMs to guide the design of a CWSS.

Figures 1- 5 illustrate the main focus areas for the CWSS in a specific CCM. Each of the boxes in the figure represent a single focus area, and each of the lines between the focus areas represent links between the focus areas. Some of the links are labeled to indicate which function will take the user from one focus group to another. The dashed lines indicate a link which may be used by multiple functions within the focus area the first time they are called, but will be ignored by those functions upon subsequent use. Some focus areas will be the same across two or three CCMs, but others will be tailored for specific CCMs. Within each, boxes indicate which CCM the focus area is customized for.

B. Strategic CWSS Design

The Strategic CCM is the highest level of control, and is often the mode for which CWSS have traditionally been designed. It has a long resolution time horizon (RTH)[a] and thus the AOM will perceive a more-than-adequate subjectively available time limit. In this CCM the AOM has time to fully assess the situation, without the need for much information filtering. Consequently, in the strategic mode the amount of information sought and coordination required between individuals are also expected to be extensive, as the AOM seeks to integrate information from a large number of sources and individuals.

In this mode AOMs can develop multiple feasible solutions in conjunction with the CWSS. AOMs will also be able to compare multiple feasible solutions and iterate several times to make the "best" decision possible. Further, the AOM should have the time and information available to ask the CWSS to compute "optimal" solutions for the current problem along many different dimensions. For example, the support system may compute "optimal" solutions to minimize passenger delay, maximize aircraft usage, etc as directed by the AOM. In the strategic mode the time for iteration and the desire to find the absolutely best alternative will be high, leading to a large number of iterations with the support system.

Figure 1 illustrates the functional areas and functional area links envisioned for a CWSS for the Strategic CCM. The extensive linkages allow iteration solutions. The probable path for an AOM using this interface in a strategic CCM is to start with the Case Viewer and then to enter data about each case into the Case Pad to log it into the CWSS. From here the AOM can either choose to examine the case immediately, to send it out for consultation, or to wait and address it later. Once the AOM chooses to examine the case she

[a]The amount of time allowable to resolve the problem, which is independent of the time required to resolve the problem.

Table 2. Work Functions and Role of User and CWSS

	Opportunistic		Tactical		Strategic	
Functions	Human	CWSS	Human	CWSS	Human	CWSS
Information Acquisition						
Problem from phone call	stenographer	organizer	stenographer	organizer	stenographer	organizer
Problem from conversation	stenographer	organizer	stenographer	organizer	stenographer	organizer
Problem from computer program	manager, clerk	monitor, alerter, organizer	manager, clerk	monitor, alerter, organizer	manager, clerk	monitor, alerter, organizer
Problem from instant message	manager, clerk	monitor, alerter, organizer	manager, clerk	monitor, alerter, organizer	manager, clerk	monitor, alerter, organizer
Problem from CWSS	manager	monitor, alerter, organizer	manager	monitor, alerter, organizer	manager	monitor, alerter, organizer
Weather monitor	manager, clerk	monitor, alerter	manager, clerk	monitor, alerter	manager, clerk	monitor, alerter
Coordination						
Consult with colleagues face to face or over phone	informer	–	informer, interrogator, presenter, mediator	–	informer, interrogator, presenter, mediator	–
Consult with colleagues electronically	informer, interrogator	presenter	informer, interrogator, presenter, mediator	presenter	informer, interrogator, presenter, mediator	presenter
Send colleagues information electronically	authorizer, compiler	presenter	authorizer, compiler	presenter	authorizer, compiler	presenter
Receive response from colleagues electronically	authorizer, compiler	presenter	authorizer, compiler	presenter	authorizer, compiler	presenter

Table 3. Work Functions and Role of User and CWSS

	Opportunistic		Tactical		Strategic	
Functions	Human	CWSS	Human	CWSS	Human	CWSS
Analysis						
Evaluate	compiler, authorizer	analyzer, presenter	compiler, authorizer	analyzer, presenter, organizer	compiler, authorizer	analyzer, presenter, organizer
Double Check	compiler, authorizer	analyzer, presenter	compiler, authorizer	analyzer, presenter, organizer	compiler, authorizer	analyzer, presenter, organizer
Modify	–	–	–	–	manager, authorizer	organizer
CWSS Suggest	–	–	compiler, authorizer	creator, organizer, presenter	manager, authorizer	creator, organizer, presenter
Compare	–	–	compiler, authorizer	analyzer, presenter, organizer	manager, compiler, authorizer	analyzer, presenter, organizer
Human Suggest	creator	organizer, presenter	creator	organizer, presenter	creator	organizer, presenter
Action						
Execute	authorizer	informer, implementer	authorizer	informer, implementer	authorizer	informer, implementer
Choose	judge	organizer, presenter	decision maker	organizer, presenter	decision maker	organizer, presenter

will open the Case Viewer from the Case Organizer. In the case viewer the AOM will be able to examine all data pertinent to the case including all affected aircraft, personnel, passengers, stations, etc.

From here they can choose to consult, work on the case later, or to use the CWSS to develop an optimized solution via the Computer Assisted Solution Suggestion Criteria (CASSC) focus area. If the AOM decides to develop an optimized solution he will then specify the optimization criteria in the CASSC focus area. In the Strategic CWSS mode the CASSC requires that the AOM specify metrics of interest and the relative weightings of each of these metrics; the CWSS then produce an optimized solution and open the Solution Viewer focus area. The Solution Viewer focus area provides descriptive information about the solution selected and allows the AOM to modify, create a new solution from scratch, specify new solution criteria, evaluate, compare or double check the solution.

If the AOM chooses to analyze one or more solutions then he must first specify the evaluation criteria in the Solution Evaluation Criteria focus area. The information in this focus area must only be specified once, but can be altered at any time. All subsequent analysis will use the information supplied the last time the analysis was invoked unless specifically modified. The CWSS will run the requested analysis and display the results in the Solution Evaluation Viewer.

Once in the Solution Evaluation Viewer focus area an AOM in a Strategic CCM will most likely choose to iterate on the solution. He may choose to change the optimization criteria specified, modify the solution by hand, consult with colleagues or create his own solution by hand. He can also choose to execute the solution immediately, but it is doubtful that an AOM in a Strategic CCM would execute a solution without at least one round of iteration and consultation.

In the strategic CCM the solution alternatives will be compared more thoroughly than in any other mode. Strategies which describe how an individual chooses between alternatives are often referred to as decision strategies. It is hypothesized that the decision strategies which best describe the alternative comparison used in the Strategic CCM are a set of rational decision making strategies which range from weighted additive derived strategies to the equal weight strategy.[15] The Strategic CWSS mode should, therefore, support rational decision making strategies by providing a comparison tool which is capable of generating optimal solutions from an objective function specified by AOM. Figure 2 illustrates a sketch of the prototype Computer Aided Suggestion Criteria functional area (labeled 9 on Figure 1). In this sketch the AOM will be able to construct an objective function either by ranking the decision attributes of interest or weighting them. The ranking method will give priority to certain decision attributes, and the weighting method will allow the AOM a greater level of control over the specific weighting assigned to each decision attribute.

It is clear from the Strategic CWSS diagram that it supports iteration for individuals in the strategic mode, as they are more likely to iterate before executing solution, than individuals in either the Tactical or Opportunistic mode. Similarly, it is clear comparing with Figure 5 that not all of the strategic focus areas are available in the Opportunistic mode; specifically, the Computer Assisted Solution Suggestion Criteria focus area, is only available in the Tactical and Strategic modes because it supports a computerized optimization algorithm to create solution.

C. Tactical CWSS Design

The Tactical CCM is the intermediate level of control characterized by actions being determined according to some general established pattern of activity, such as a procedure. It has a RTH and subjectively available time limit which are “adequate”. In this CCM the AOM has time to assess the situation and use a procedure or heuristic to solve the disruption, possibly generating multiple feasible solutions along the way. The amount of information sought in a tactical control mode is expected to be beyond what is immediately observable, but may be limited to what routine procedure requires. Coordination is expected to be formulaic as the AOM restricts information seeking to a limited set of required sources and individuals.

Figure 3 illustrates the functional areas and functional area links envisioned for a CWSS for the Tactical CCM. From this diagram the linkages which will allow for limited iteration on solutions can be seen. The probable path for an AOM in a tactical CCM is very similar to that for a strategic CCM. However, in a tactical CCM the AOM will probably not loop through the solution evaluation focus area as often as in the strategic CCM, nor will the AOM seek as extensive coordination effort. These differences are best seen in Figure 4 with the Computer Assisted Solution Suggestion Criteria focus area for the tactical CCM.

In a tactical CCM, the AOM has enough time and information to allow the support system to compute ”optimal” decision alternatives along some predetermined dimensions as a part of the procedure, but may not have adequate time to fully evaluate the resultant alternatives for several reasons. First, the large number

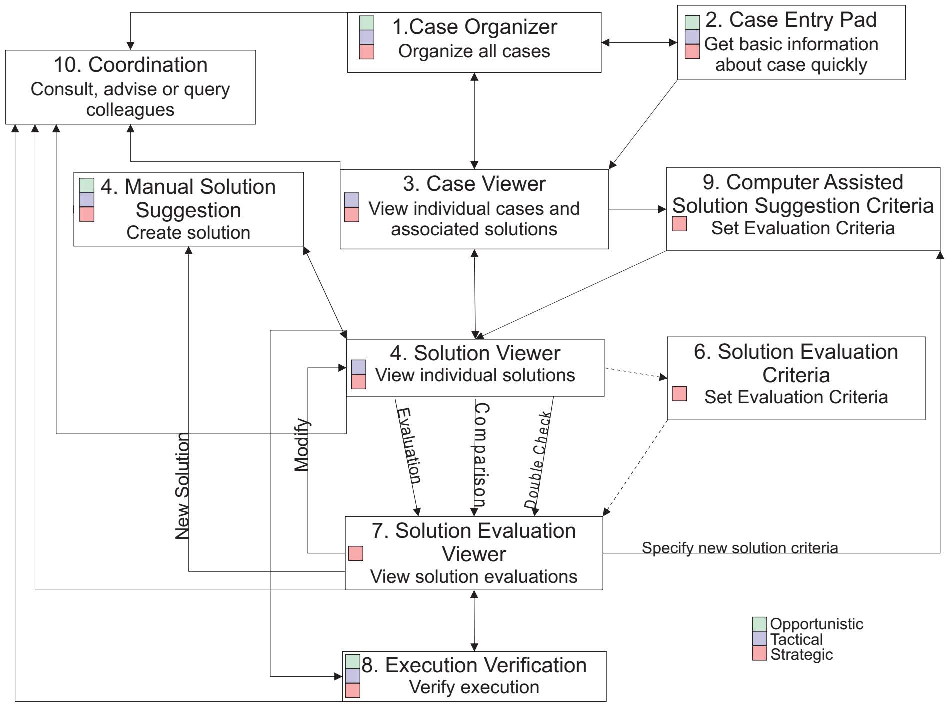

Figure 1. CWSS focus area and link diagram, Strategic CCM

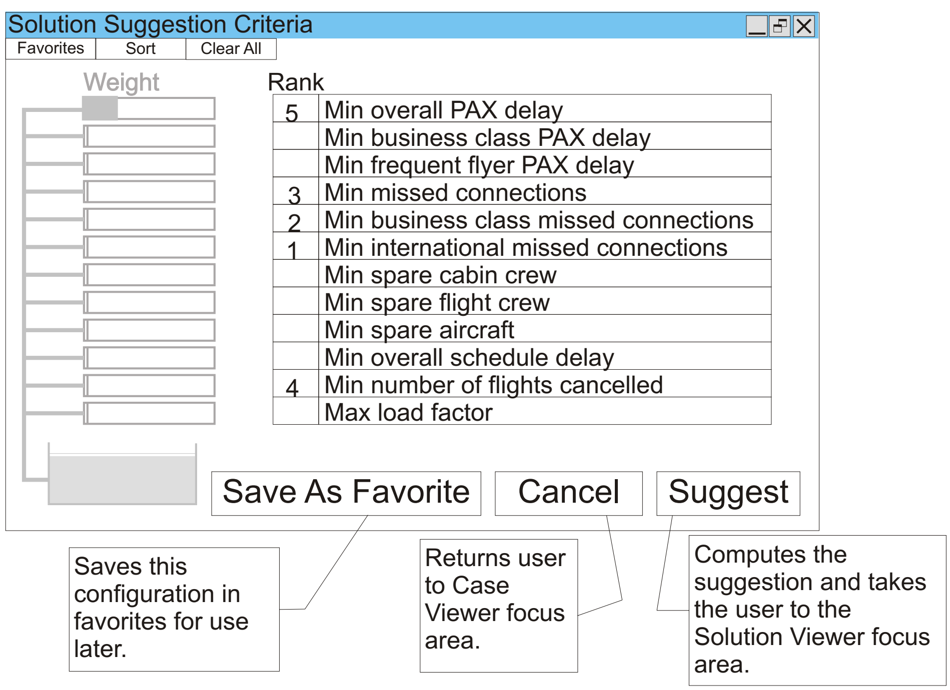

Figure 2. Computer Aided Solution Suggestion Focus Area, Strategic CCM

of attributes evaluated by the CWSS to generate a solution is likely to be larger than the small number of attributes that the AOM will be able to consider, which may lead the AOM to dismiss any solutions that she does not understand. Second, the AOM may not have time to iterate with the support system to create an appropriate solution for the attributes that the AOM is interested in satisfying. This does not mean that solutions generated by the support system are valueless, just that their utility may be limited in this CCM, and that perhaps less optimal, but more transparent, solutions may be preferred. To combat this tendency, instead of requiring the AOM to create a complex objective function comprised of multiple decision attributes (either weighted or ranked), the AOM will instead simply specify the decision attributes of interest and then set a maximum or minimum allowable range. The CWSS will then compute multiple solutions (one maximizing or minimizing each attribute) while holding all of the other specified attributes within their desired ranges. This should provide the transparency required in the tactical CCM.

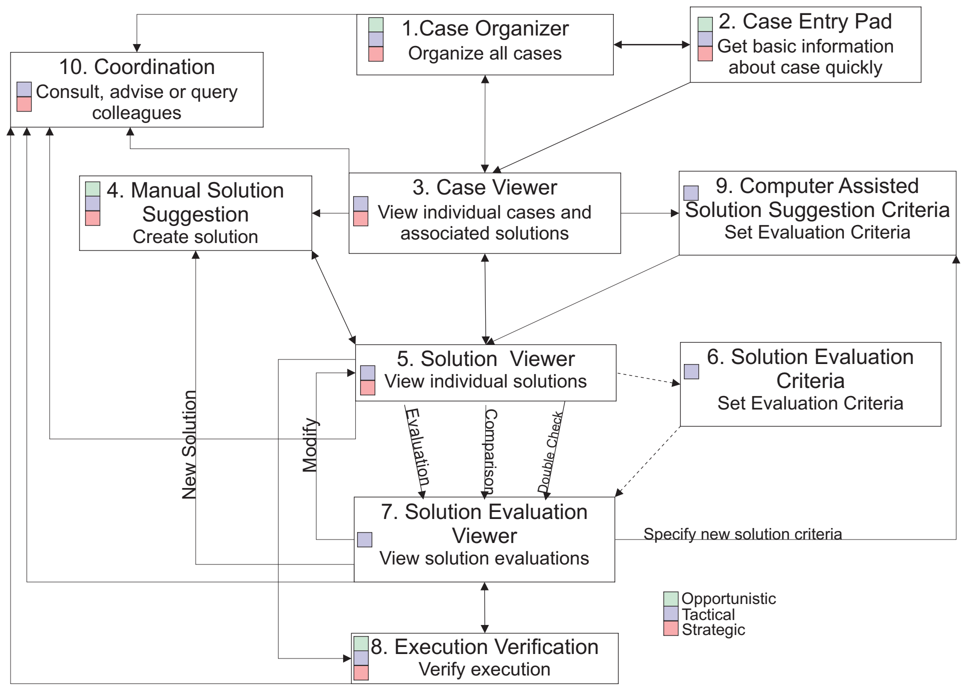

Figure 3. CWSS focus area and link diagram, Tactical CCM

D. Opportunistic CWSS Design

Finally the Opportunistic CCM is the lowest level of control that can be supported by a support system. It has a RTH which is tight, and subjectively available time characterized by Hollnagel as "just adequate". In this CCM, the AOM is not able to fully assess the situation, often having difficulty finding and assessing relevant aspects of the environment.

The Opportunistic CCM is characterized by a person's actions revolving around the most salient cues. Correspondingly, both information seeking and coordination are limited to necessary and salient information. In an opportunistic mode iteration will be limited to cases in which solutions generated by the AOM fail to meet minimum criteria. Unlike the Strategic CCM, AOMs in the Opportunistic CCM will not have the time required to thoroughly specify the situation in the CWSS, nor will they have the time necessary to double check any CWSS-generated solutions. As both time and information are scarce in the Opportunistic CCM, the aspects of the task which are appropriate for automation are those which are well defined, such as solution evaluation and execution.

Figure 5 illustrates the functional areas and functional area links envisioned for a CWSS for the Opportunistic CCM. The largest change from the Tactical and Strategic CCMs is the elimination of the Computer Assisted Solution Suggestion Criteria focus area. The probable path for an AOM using this interface in

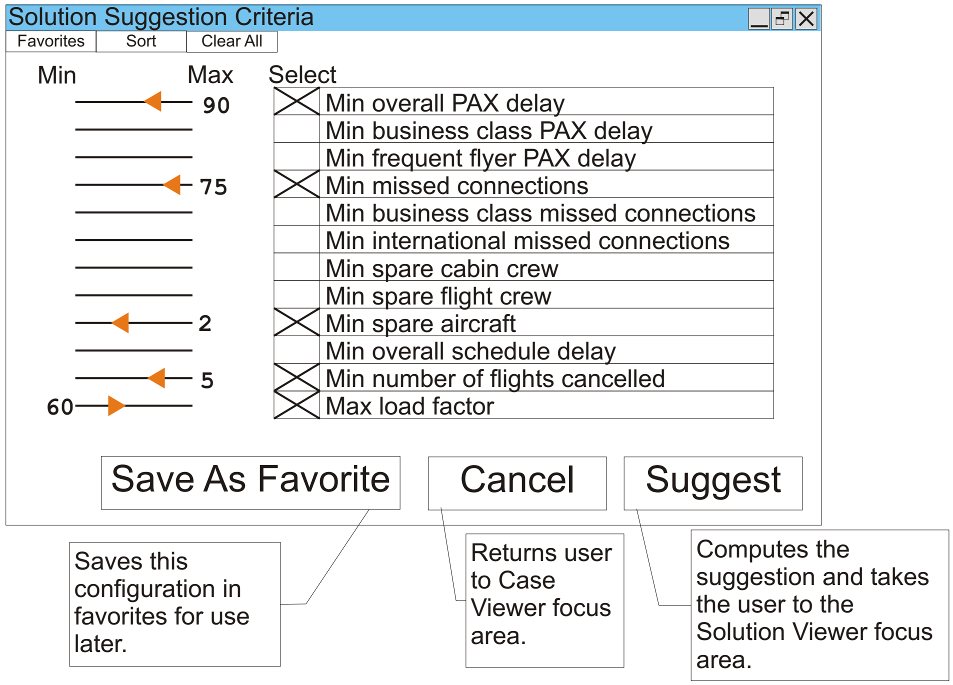

Figure 4. Computer Aided Solution Suggestion Focus Area, Tactical CCM

a opportunistic CCM is to start with the Case Viewer visible and then to enter data about the case into a streamlined Case Pad and log that case into the CWSS. The CWSS will fill in any missing information from the airlines' scheduling and crew assignment databases. From here the AOM will be taken to the Case Viewer focus area, where she will be able to examine all data pertinent to the case including all affected aircraft, personnel, passengers, stations, etc.

From here she can choose to advise or query colleagues, or generate a solution via the Manual Solution focus area. A sketch of this focus area is shown in Figure 6. The top portion of the focus area organizes the information and helps the AOM keep a clear picture of the solution being generated, while the the terminal located at the bottom of the focus area allows the AOM to manually enter a full or partial solution. The *Complete* button will have the CWSS suggest the rest of a partially specified solution. For example the CWSS may then suggest a solution which includes delaying the flight and swapping aircraft to minimize delay. Or, as depicted in Figure 6 the AOM may choose to cancel a flight and swap two others. The CWSS may then suggest a solution which incorporates both of those requests plus adds in the additional cancelation necessary to correctly position the aircraft. Once the solution has been saved the Solution Viewer focus area will be brought up for the AOM. The Solution Viewer focus area provides descriptive information about the solution selected and allows the AOM to modify, create a new solution from scratch, evaluate, or double check the solution.

If the AOM chooses to analyze a solution then he must first specify the evaluation criteria in the Solution Evaluation Criteria focus area. The information in this focus area need only be specified once, but can be altered at any time. All subsequent analysis will use the information supplied the last time the analysis was invoked unless specifically modified. The CWSS will run the requested analysis and display the results in the Solution Evaluation Viewer. Once in the Solution Evaluation Viewer focus area an AOM in a Opportunistic CCM will most likely choose to execute the solution (assuming it meets some minimum criteria). If a change does need to be made, the AOM will most likely make the change manually and then choose the double check function to verify that it meets a set of preset minimum criteria before being executed.

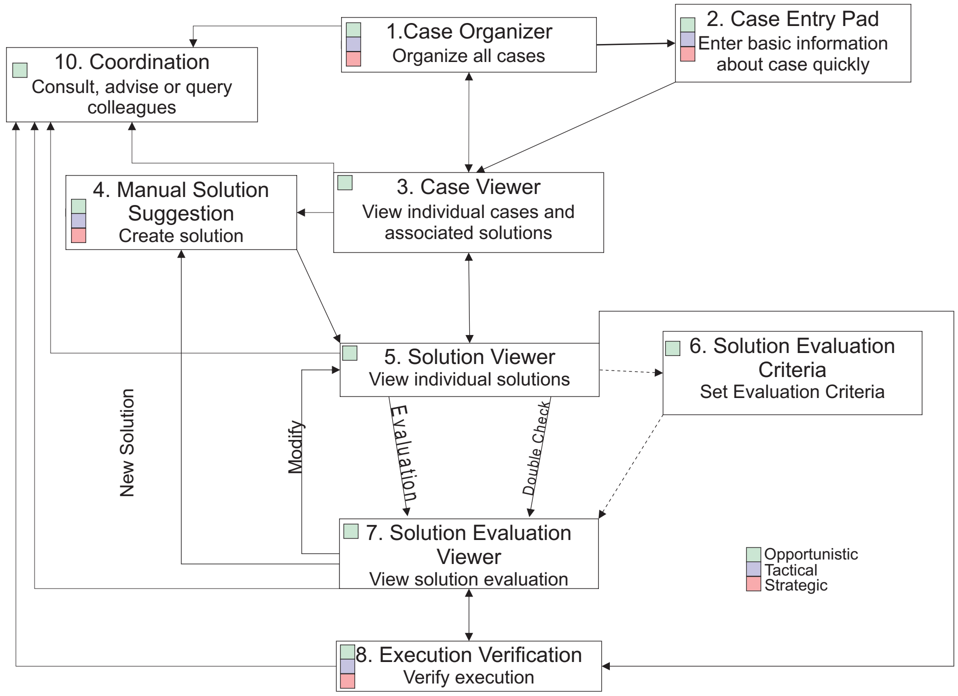

Figure 5. CWSS focus area and link diagram, Opportunistic CCM

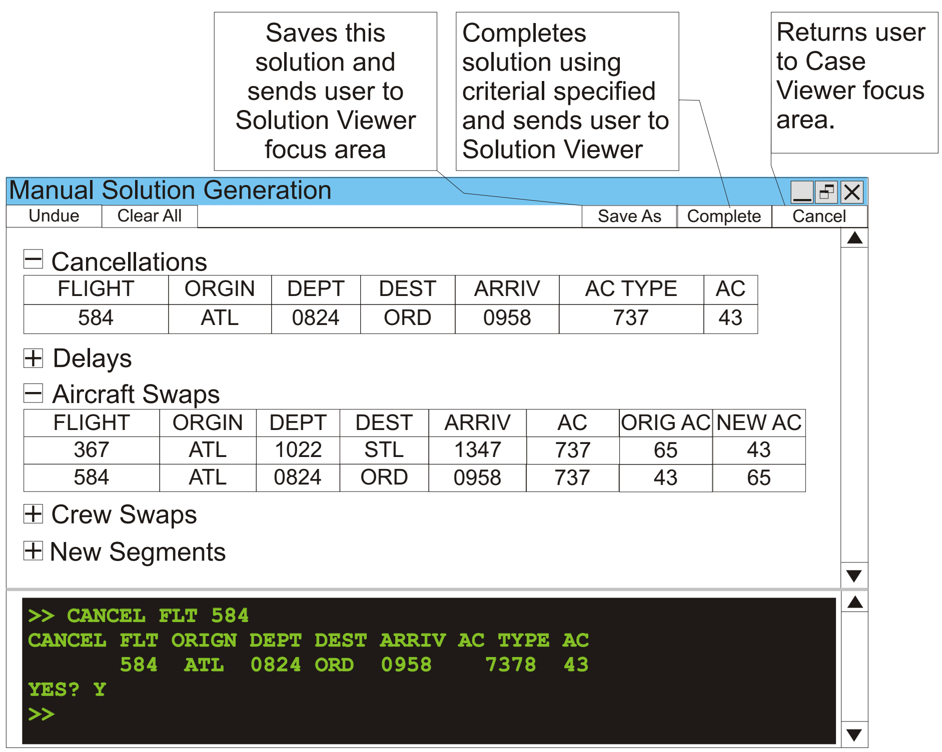

Figure 6. Manual Solution Generation Focus Area, Opportunistic CCM

IV. Discussion and Conclusion

The safe and efficient management of an airline is a complex cognitive task involving many individuals working in close coordination. As current AO modernization efforts attempt to further increase productivity and efficiency, increasingly support systems are being designed to aid the airline operations personnel. Historically, these support systems have often been specifically designed to support a single pattern of human activity, strategic. This paper has presented an argument that cognitive work support systems would benefit from incorporating multiple patterns of activity. Specifically the idea that cognitive work support systems could be designed around Hollnagel's Contextual Control Modes. The implications on CWSS design for each CCM have been discussed and specific examples have been presented for each CCM. CWSS designed for the Strategic and Tactical CCMs have been shown to have more links and focus areas to facilitate iteration and incorporation of optimization algorithms into the solution generation process. CWSS designed for the Opportunistic CCM has been shown to have fewer links to help the AOM focus on the salient information and not to become overwhelmed by information and choices. The paper has also presented examples of two distinct focus areas to aid the AOM with solution generation, the Computer Assisted Solution Suggestion Criteria and the Manual Solution Generation focus areas.

Cognitive work support system design is not limited to Airline Operations, but could also be used in Air Traffic Management, as both environments have many similarities. Specifically they are both dynamic environments where the worker's context is continually evolving. They are both environments where decisions must be made in real time and often with limited knowledge of the situation at hand. As air traffic continues to increase there is increasing pressure to introduce support systems into the ATC work practices. It is important to make sure that the support systems put in place not only support Strategic CCMs but also Tactical and Opportunistic CCMs as necessary to fully support the controller's work.

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