Chapter 2: Review of Related Literature

By long practice the management of a flying machine
should become as instinctive as the balancing movements
a man consciously employs with every step in walking,
but in the early days it is easy to make blunders.

Wilbur Wright (1903)

(In McFarland, 1972)

Overview

The literature related to Aeronautical Decision-making (ADM) and judgement is extensive. This observation has been noted by numerous researchers (e.g., Hammond, 1988; Kaempf & Orasanu, 1997, etc.). For purposes of this study, therefore, pertinent literature will focus on research related to ADM. The concept of ADM is a relatively recent phenomenon. During the early years (1970s) much of the research centered on classical decision-making (CDM) techniques and models. In recent years many researchers (e.g., Cohen, Freeman and Thompson, 1997; Kaempf & Orasanu, 1997; Klein, 1997a, etc.) have advocated a more “naturalistic” approach.

Pertinent literature and concepts will be divided into three categories. These categories include: a. models and theories of decision-making; b. studies related to expert and novice judgement and c. a sample of General Aviation (GA), ADM studies. Each of these categories, will be addressed in turn.

Purposes to be Served by Review of Research Literature

The purpose of the literature review is to examine literature pertinent to my research question and to inform the reader of the rationale for the study. In addition, the literature review will provide the reader with a conceptual frame for the study. Finally, I will strive to show how my research will augment the existing body of literature.

I will trace the evolution of ADM research from its early days (during the 1970s) through research conducted up to and including the present. The major contributors to this research will be noted and their methods of conducting their studies will be examined. It is anticipated that this review will prove helpful in fully comprehending the depth and breath of the research topic.

Need for Study and Likelihood of Obtaining Meaningful and Significant Results

As mentioned earlier, there is little information regarding the teaching of ADM to student pilots. Most of the previous ADM studies were concerned with either licensed pilots, with considerably more experience than student pilots, or with commercial airline pilots. The data collected during this study should provide useful information to both student pilots and to individuals involved in teaching student pilots (e.g., ground school instructors and flight instructors). It is the researcher's position that the study has a high likelihood of providing information that will serve as a foundation for further research involving the presentation of ADM-related materials to student and low-time pilots.

Relevant Literature

Each of the categories previously mentioned will be reviewed. The volume of the literature related to each of these categories was immense. The researcher attempted, therefore, to provide a representative sample of the pertinent research in each of the subject areas.

Decision-making Theory and Models

The first body of knowledge involves information related to decision-making theory and models. Several researchers (Edwards, 1954; Lipshitz, 1994; Payne, Bettman & Johnston, 1988) provided information regarding decision-making theory along with general information related to decision-making. For example, Edwards (1954) explained that social scientists in a variety of disciplines studied decision-making. Specifically, he examined how economists developed theories of consumer decision-making. These theories, Edwards explained, centered on the subjective value of alternatives by decision makers. Edwards stated that these theories assumed that individual decision makers made rational decisions (i.e., decisions that will be beneficial).

Beginning in the 1980s the FAA conducted a series of studies related to teaching ADM to GA pilots. One such study conducted by Diehl, Hwoschinsky Lawton & Livak (1987) reviewed what the researchers termed the "conventional decision-making process." This process is depicted on the following page in Figure 4.

The authors stress that in the event of inadequate procedures or "headwork" (cognitive processes) accidents are likely to occur. The authors emphasized that a new model of ADM should be adopted that would build on the conventional model. The model they recommended was based on the conventional model but was modified to reflect what the writers felt were key elements vital to aviators. This "Aeronautical Decision-making Model" is depicted on page 23 in Figure 5.

Figure 4: Conventional Decision-making Process

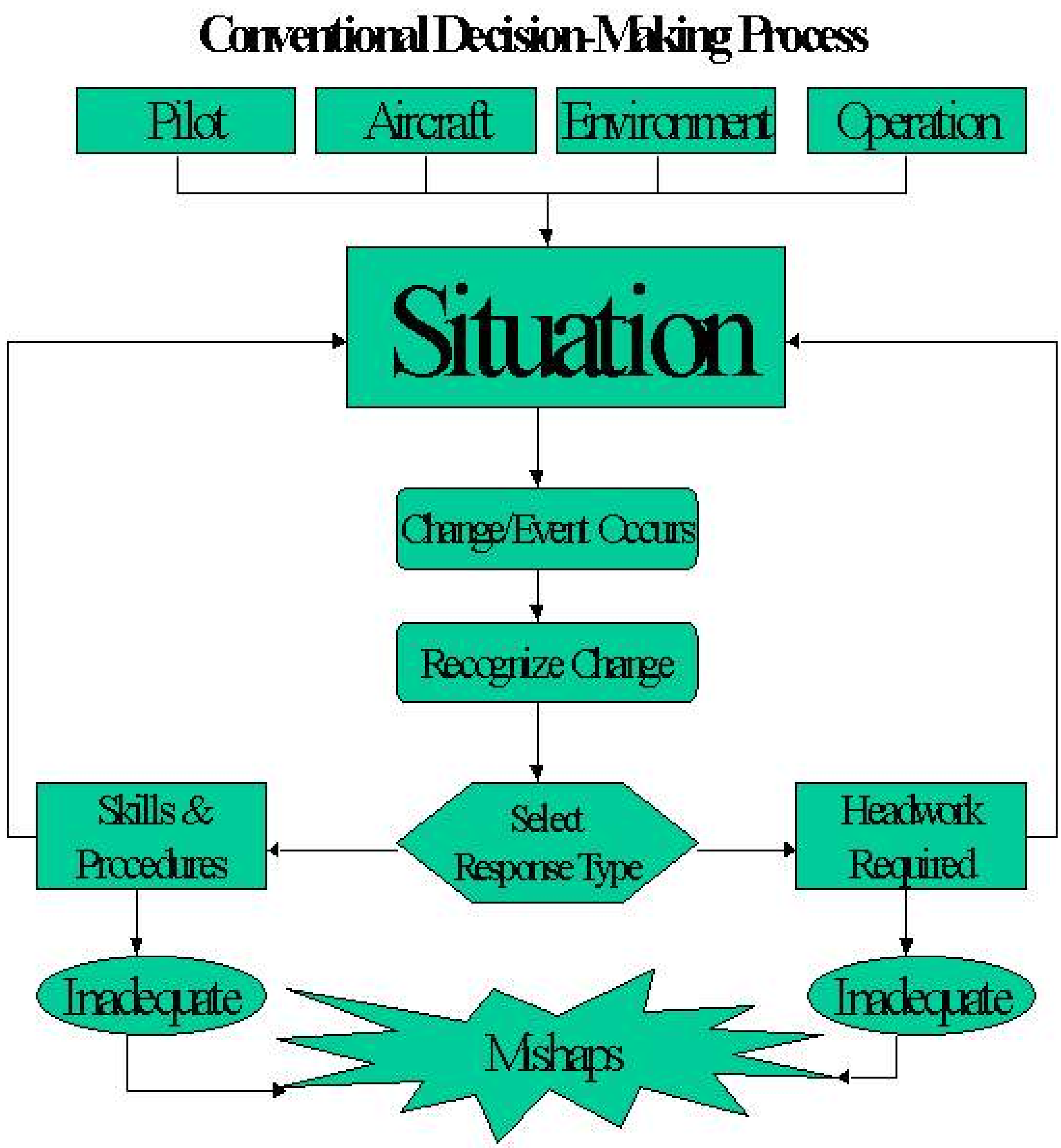
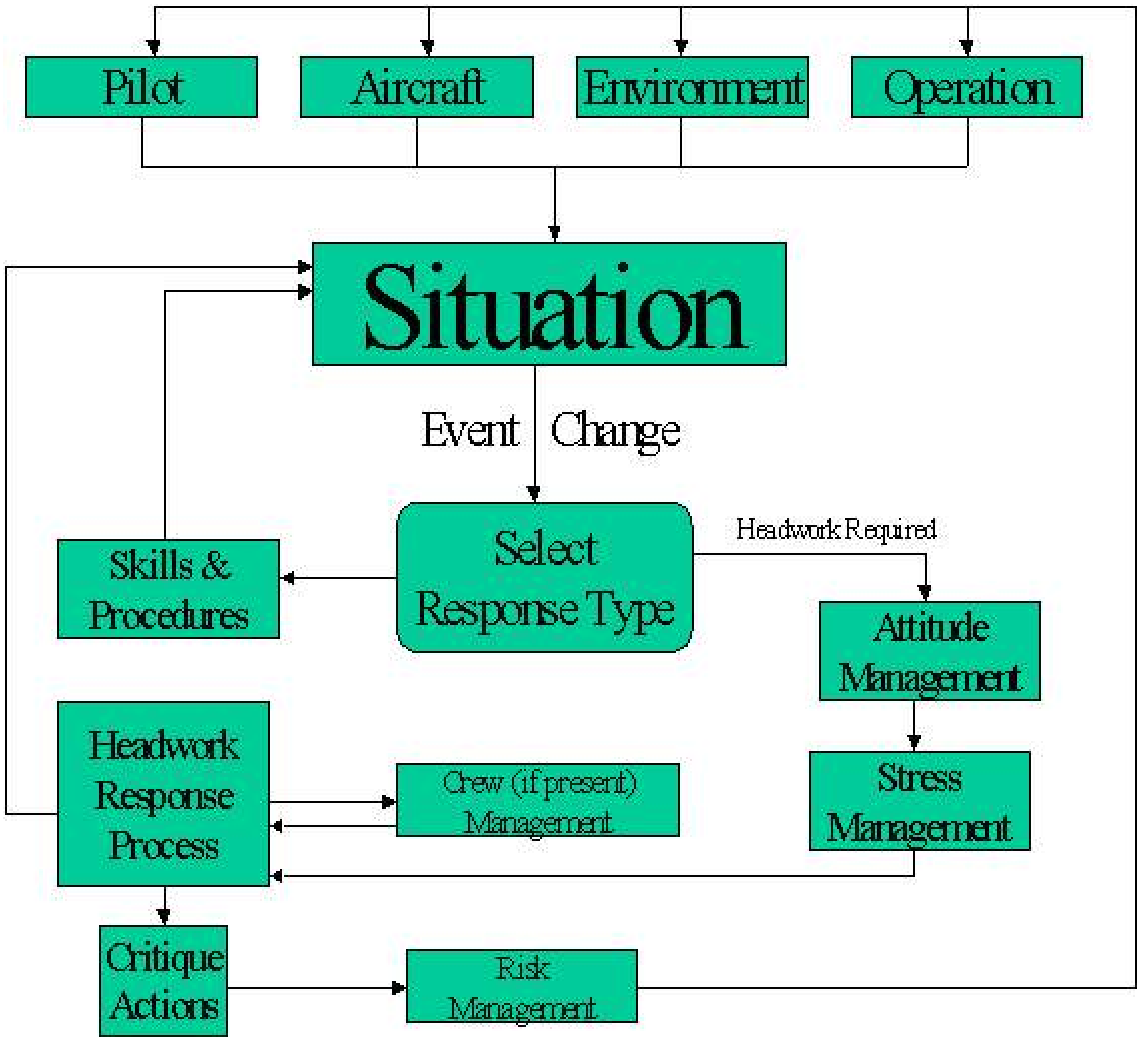


Figure 5: Aeronautical Decision-Making Model



Diehl, Hwoshinsky, Lawton and Livak (1987) emphasized that the ADM Model depicted in Figure 5 enhanced the conventional decision-making process depicted in Figure 4 in several ways. Some of the more important additions that the ADM Model (Figure 5) included were a. identifying hazardous attitudes; b. learning how to cope with stress; c. appreciating how to assess and cope effectively with risk; d. considering all available resources and e. evaluating the effectiveness of one's ADM choices.

Lipshitz (1994) stated that decision-making required multiple perspectives. Based on reviews and analysis of the research of several writers (e.g., Beach, 1990; Klein, 1989; Quinn, 1980 etc.), she argued that different decision-making modes are effective under specific conditions and offered three examples. The first of the modes was what Lipshitz referred to as a *consequential choice.* This mode stressed the comparison of alternatives and the choosing of one over the other based on the anticipated better consequence. Lipshitz referred to the second mode as *matching*. In the *matching* mode, the decision maker bases a single decision specific criteria (e.g., if I have a fever, I will not fly). Matching differs from the *consequential choice* model in that the former is concerned with only one alternative at a time and the decision is not necessarily based on future consequences. Lipshitz referred to the third mode as *reassessment.* The reassessment mode involves a decision maker who reassesses a decision already made and chooses to revise the previously made decision. Lipshitz stressed that each of the modes may be appropriate in certain circumstances and that no one mode is best in all situations. According to Lipshitz, the *consequential choice* mode may be most applicable when one has access to comprehensive information and there are no time constraints. The *matching* mode, Lipshitz suggested, would be most beneficial when the decision maker has no particular precommitment to a particular course of action and the decision maker has access to pertinent personal experience or knowledge. The *reassessment* mode is useful if a previously made decision needs to be changed or altered due to a perceived threat or failure.

Each of these modes appears to have applications to student pilot ADM. Many of the ADM models (e.g., “PAVE,” “S-D-R-V” etc.) seem to stress the *consequential choice* mode of decision-making. There are times, however, that *matching* modes should be considered (e.g., when decisions must be made quickly). Finally, it would be wise to assure that students are aware that they do have the option to change their minds. In such situations the *reassessment* mode should be considered. Chapter Four and Five of this study will, in part, examine whether these modes were used by subjects in this study.

Payne, Bettman & Johnson (1988) stressed that judgement strategies selected by decision makers are based on a variety of variables (e.g., number of alternatives, time available to make decision, etc.). The authors examined how decision-making strategies are affected by variables and stated that “when faced with a decision task in which it is impossible or very difficult to process all information, the decision maker might use the information he or she has gained about the task to decide what information is less important and can be ignored" (p. 551). The researchers stressed that decision makers will often shift their decision strategies based on context changes. Other researchers (e.g., Newell & Simon, 1972) agreed and pointed out that the specific behaviors of individuals faced with problems are based upon both the problem environment and the behavior demanded by the specific situation.

The findings of these researchers have important applications to ADM. It is important for decision makers and in particular novice decision makers to comprehend fully that they are not necessarily bound to one specific decision-making method. Novice decision makers should comprehend that it may be advisable to shift their use of decision-making models based on the context and changing conditions of the problem at hand. Another group of researchers (Bechara, Damasio,Tranel & Damasio, 1997; Casner, 1994; Hammond, 1988; Johnston, & Maurino, 1995; Kirlik, Walker, Fisk & Nagel, 1996; Payne & Braunstein, 1978; Svenson, Edland, & Slovic, 1990) wrote about the variety of variables related to judgement and decision-making.

Bechara, Damasio, Tranel & Damasio (1997) conducted experiments involving a gambling task. The researchers determined that there was a nonconscious biasing step prior to the realization of which particular gambling strategy worked best. The writers concluded that "in normal individuals, nonconscious biases guide behavior before conscious knowledge does." (p. 1293). This research may prove applicable to student pilots. If Bechara and his colleagues are correct, perhaps the attitudes developed during a PPGS that stress *choosing safe alternatives* will affect future decisions of student pilots.

Hammond (1988) studied decision-making involved in dynamic tasks. Hammond concluded that in studying cognitive processes in dynamic tasks, there needs to be an in-depth diagnosis of the task itself. In addition, Hammond explained that the word "cognition" should be viewed as a continuum ranging from analysis to intuition. The researcher assumed, therefore, that intuitive cognitive processes would be more applicable to experienced pilots and have little application to novice aviators. In addition, numerous other writers (Brehmer, 1992; Busemeyer & Townsend, 1993; Cannon-Bowers, Silas, & Pruitt, 1996; Cohen & Freeman, 1996; Hunter, 1997a; Klein, 1989; Montgomery, 1983; Mosier, 1991; Samuelson, & Zeckhauser, 1988; Stokes & Kite, 1997; Svenson, 1992) wrote about a variety of decision-making models that could be related to aviation.

Brehmer (1992) discussed research regarding "dynamic problem solving" (decisions that are made in situations which require a series of decisions that are dependent on one another). Brehmer stated that his research revealed that we could expect that the performance of dynamic decision makers will often decline due to feedback delays. Problems resulting from feedback delays may be particularly relevant to student pilots. Anticipating and coping effectively with feedback delays, therefore, should be emphasized in a PPGS setting. Several of the ADM scenarios presented to student pilots during the PPGS (taught by the researcher) contain situations that reflect feedback delays (e.g., scenarios three and seven — see Appendix E). In addition, the researcher attempted to emphasize to PPGS students the importance of developing appropriate ADM tactics when faced with delays in obtaining feedback.

Busemeyer and Townsend (1993) studied the cognitive mechanisms that guide the deliberation process during conditions of ambiguity. They developed a decision-making theory known as *decision field theory*. The writers summarized the process by explaining that decision makers should be certain to evaluate all of the possible consequences for each alternative. They pointed out that this is often a time-consuming process. The writers concluded their report by emphasizing that ultimately decisions would be based on the amount of time available to make a particular decision. Busemeyer and Townsend stated:

> Present the decision maker with a choice between two alternatives, in which the first alternative has an advantage on the most prominent or salient dimensions, but the second alternative has an advantage on all of the remaining dimensions. Under short deadline time limit, only the most prominent dimension tends to be processed and the first alternative should be chosen more frequently. Under longer deadlines, the most prominent dimension is still processed first, but many additional dimensions are also processed, so that the second alternative should be chosen more frequently.
>
> p. 455.

Cannon-Bowers, Salas & Pruitt (1996) discussed the study of *naturalistic decision-making* (NDM). The writers defined NDM as "decision-making as it occurs in the so-called real world under naturalistic conditions (p.193)." They suggested that a paradigm shift in the study of decision-making had occurred from a classical approach, in which research was based on "sterile, contrived decision-making situations with results that were of little consequence to real-world decision makers" (p. 195). The researchers cited Orasanu and Connolly (1993) who stated that "it is not feasible to apply classical decision-making research analysis to many real-life situations" because it considers neither the experience of the decision maker nor the demands of the natural environment" (p.19). Orasanu and Connolly identified eight factors that were characteristic of NDM. The factors are listed below in Table 3.

Table 3: Characteristics of Naturalistic Decision-Making

1. ill-structured problems
2. uncertain, dynamic environments
3. shifting, ill-defined or competing goals
4. multiple event-feedback loops
5. time constraints
6. high stakes
7. multiple players
8. organizational norms and goals that must be balanced against the decision makers' personal choice

Numerous other researchers (Casner, 1994; Cohen & Freeman,1996; Simon, 1981) agreed with Orasanu and Connolly and stressed that both the features of the environment and one's prior experiences in a particular domain contribute to one's ability to cope effectively with uncertainty and to develop sound decision-making practices. Cannon-Bowers, Salas & Pruitt (1996) stated that NDM can be viewed by three distinct sources of variables. The three sources of variables include those that are related to the decision, those that are related to the decision maker and those related to the environment in which the decision is made. Figure 6, on the following page, depicts the central features of NDM and how these features relate to the three sources of variables previously mentioned.

Cannon-Bowers, Salas & Pruitt (1996) reviewed the variables included in Figure 6. *Uncertainty, dynamic task*, the authors explained, involved a significant degree of ambiguity and uncertainty. The authors pointed out that although classical decision-making (CDM) theorists have included "uncertainty" in their research for years, the dynamic characteristics of specific decisions are more closely related to NDM.

Multiple event feedback loops, the authors stated, were also more attuned to NDM. The authors indicated that CDM theorists tended to focus on single decision events. NDM, on the other hand, often involved acting quickly and effectively with the consequences of decisions.

These consequences must be subsequently dealt with by the decision maker as their effects become apparent.

Figure 6: Central Features of NDM and How They Relate to Variable Sources

	Feature of			
Variable	Decision Task	Decision Maker	Environment	Comments
Uncertain, Dynamic Task	x			Perhaps the single most important feature of interest
Multiple Event Feedback Loops	x		x	Related to the dynamic nature of many naturalistic decisions
Meaningful Consequences	x	x		Can be related to the decision maker's motivation and/or to the nature of the task
Ill-Structured Decision	x			Structured decisions are not typically complex or in need of attention using "naturalistic" methods.
Multiple Goals	x		x	Multiple goals may or may not be shifting, competing or unclear.
Time Constraints	x		x	Time pressure affects the processes by which a decision is made and is a crucial NDM factor
Decision Complexity	x			Complex decisions are more interesting to investigate than simple ones in part because they pose greater challenges for aiding and training
Multiple Players	x			Multi-operator decisions are clearly of interest under NDM however, complex individual decisions are important as well.
Congruent - Organizational Norms & Goals		x	x	Congruence between the decision maker and the organization can make a decision more difficult; situations in which goals are compatible are of interest as well.
Quality of Information	x		x	Knowledge-rich environments present added challenges to decision makers; information overload is an important naturalistic feature
Level of Expertise		x		While a major goal of NDM is to look at the impact of expertise on decision-making, there is much to be gained by investigating processes employed across a wide range of expertise

Cannon-Bowers, Salas & Pruitt (1996) p. 198.

Meaningful consequences, according to the authors, are related to one's motivations. These motivations may be either internal or external. Naturalistic decision makers, in other words, should be concerned about the decisions they make and should strive to affect positive outcomes.

In addition, the authors stated that NDM research often involves *ill-structured tasks*, changing and often *multiple goals* and *time pressures*. Numerous writers (e.g., Benson, & Beach, 1996; BenZur & Breznitz, 1980; Cohen, Freeman & Wolf, 1996; Wright, 1974; Zakay & Wooler, 1984) discussed the effects of time constraints and time pressure on decision-making. Franklin & Hunt (1993) stated that time pressure, as it relates to ADM, is particularly significant and discussed the importance of creating effective simulations that can be used to train personnel in a variety of situations (e.g., air traffic controllers, emergency service dispatchers, etc.). Zakay (1985) also stressed the importance of time pressure in his study of decision-making among student nurses. Zakay found that *non-compensatory* decision-making strategies (i.e., the usefulness of only some of the attributes of an alternative are considered — as opposed to a compensatory process in which all of the attributes of an alternative are considered) are directly related to time constraints. Cannon-Bowers, et al. (1996) pointed out that NDM is also concerned with examining the complexity of the decision. Furthermore, NDM often involves *multiple players* as well as *competing goals* of the individual decision maker and the norms of an organization.

NDM also accounts for the increased stress levels inherent in natural settings. Although some writers (e.g., Gmelch, 1983) discussed how a degree of stress can be beneficial and provide individuals with "a competitive edge," numerous other researchers (Inzana, Driskell, Salas & Johnston, 1996; Keinan, 1987; Keinan & Friedland, 1984 & 1986; Stokes & Kite, 1997) discussed the negative effects of stress on performance. Several researchers (e.g., Krahenbuhl, Marett & Reid, 1978) reviewed the effects of simulator-based training in an attempt to reduce in-flight stress.

Cannon-Bowers, et al. (1996) indicated that NDM could and should be used to study those who have not achieved significant levels of competence. The writers stated that there are three reasons that this is so. First, it is often difficult to determine who are truly experts for specific tasks. Second, in naturalistic conditions, decisions are often made by those who are not experts. Finally, the authors stated "...examining how those who are less than expert on a task make a decision can provide necessary insight into the development of decision strategies. This is the case in studies aimed at investigating the impact of training on decision effectiveness" (p. 201). In other words, the authors indicated that NDM studies aimed at novices are capable of producing important data.

One specific type of NDM was discussed by Stokes, Kemper & Kite (1997). They looked at the effects of cue-recognition and expertise as they related to decision-making. The researchers indicated that experts were able to base decisions in part on the recognition of important cues that would assist them in making decisions. The cue-recognition was the result of experience — an important factor that novices lack.

Another type of NDM is what Klein (1997b) has termed Recognition-Primed Decision-making (RPD). Klein's model emphasizes that decisions can be made without attempting to choose from a set of alternatives but rather from intuitive knowledge and wisdom based on the accumulated experiences of the decision maker. Klein's model stresses the importance of experience and how experience is used to choose a course of action quickly and effectively. This particular type of NDM seems applicable to aviation and other types of naturalistic settings in which high stakes and stress levels as well as rapidly changing conditions, time constraints and high workloads are frequently experienced.

Numerous other researchers (e.g., Craig, 1998; Klein, 1997b) indicated that a paradigm shift has occurred in the study of decision-making from viewing ADM in a classical mode to more naturalistic settings. In the past, most decision-making studies centered primarily on participants choosing among alternatives — a classical decision-making approach. Today, according to these writers, a growing body of researchers is viewing and conducting studies related to decisions as they occur in dynamic and naturalistic environments. The authors concluded that although NDM research seems to be a more acceptable method of studying decision-making in aviation related contexts, we should not necessarily abandon CDM since it does have applications (particularly for novices). It seems probable, therefore, that germane ADM training for novice aviators could include a combination of both NDM and CDM tactics.

The concept of *cognitive maps* was first described by Tolman in 1948. These cognitive guides could be used to help pilots make decisions. Downs and Stea (1977) provided a definition of such maps:

> cognitive mapping is an abstraction covering those cognitive or mental abilities that enable us to collect, organize, store, recall and manipulate information about the spatial environment. These abilities change with age (or development) and use (or learning). Above all, cognitive mapping refers to a process of doing: it is an activity that we engage in rather than an object that we have. It is the way in which we come to grips with and comprehend the world around us. p. 6.

Csanyi (1993) discussed the biological basis for the formation of cognitive maps. Citing experiments with rats in the 1930s, Csanyi noted that following six to eight trial runs, rats were able to negotiate a maze quickly and obtain a reward. Csanyi noted that humans also formed cognitive maps. He explained that human cognitive maps are more complex than those of animals and are based in part on the recognition of features of a particular environment, actions of other people, cultural norms and linguistic cues.

Downs and Stea (1977) emphasized that cognitive mapping is based on desired outcomes. The writers stated that these desired outcome can take one of two forms. First, they can help to generate plans for solving problems. Second, the desired outcomes of our cognitive maps can help to establish frames of reference that could be used to comprehend our environment better.

Both of these factors are relevant to the decision-making processes of expert and novice pilots. Expert pilots, one could assume, have more thoroughly developed maps than do novices. Novice aviators, in contrast, are in the process of developing their respective maps and are unable to rely on them, to the extent of experts, in their decision-making processes. The development and use of cognitive maps, therefore, could play a key role in the acquisition of ADM capabilities of novices.

How can we be assured, however, that cognitive maps are accurate? Downs and Stea (1977) stated that if by *accurate* one means a "total identity between the attributes and arrangements of the spatial environment and the attributes and arrangements of cognitive representations then the question is absurd. Such identity is impossible. " (pp. 99-100). The writers emphasized that the value of cognitive maps lies in their *utility* and that our objective should not be accuracy but rather "making the best use of our limited capacities for storing and handling information." (p. 101). They also pointed out that the usefulness of cognitive maps depended upon the problem-solving abilities and the acquisition of necessary information regarding a particular environment.

Expert and Novice Judgement

The second category of literature involves research and data related to expert and novice judgement. This category will be partitioned into three sections: a. defining expertise; b. comparisons between experts and novices and c. training designed to help novices acquire the skills of experts. Each of these sub-topics will be reviewed in turn.

Defining expertise.

Wiggins (1997) pointed out that historically, expertise was associated exclusively with recognized performance and successful results as defined by members of a particular group. For example, in athletic competition expertise was associated with winning contests. Likewise, in military aviation during World War II, Wiggins, citing Yeager & Janos (1986) stated that "...expertise, in terms of aeronautical performance, was generally associated with the number of enemy aircraft destroyed, or the number of combat missions which had been flown successfully" (p. 56).

Jensen, Kochan and Chubb (1994) conducted over one hundred interviews with experienced pilots. The interviews centered on the characteristics of expert GA pilots. Based on the responses of subjects, the researchers concluded that expert pilots shared nine characteristics. These characteristics are summarized below in Figure 7.

Figure 7: Characteristics of Expert Pilots

Characteristics	Remarks
Skill	high level of piloting skills and continually strives to improve those skills
Motivation	highly motivated to learn and update knowledge relative to flight domain
Ability to Focus	focuses on problem but can adjust focus when additional information warrants an adjustment
Keen Observer	ability to observe and comprehend the total flight environment (e.g., navigation, weather, communication with air traffic control, etc.)
Establishes Baseline for Normal Indications	has the ability to identify slight variations from normal conditions (e.g., sounds, vibrations, etc.)

Skeptical	makes contingency plans for unplanned events
Cognitive Skill	superior capacity for diagnosing and resolving problems
Communication Skills	can adapt communication skills to any pertinent situation
Aware of Limitations	tends to avoid situations that are beyond their comfort level

In a four part follow-up study sponsored by the FAA, Kochan, Jensen & Chubb (1997) interviewed highly experienced pilots. They concluded that expertise in general aviation pilots has little to do with acquired flight hours beyond a certain number "perhaps as low as 2,000 hours." (p. 26). The researchers stated that expert GA pilots share ten characteristics. These characteristics included all of the traits mentioned in the previous study (Jensen, Kochan & Chubb, 1994) and, in addition, the "...ego-strength to enforce his or her own limitations in every situation" (p. 26).

Wiggins (1997) cited several sources (Holsti, 1971; Keinan, 1987; Schvaneveldt, Durso, Goldsmith, Breen, Cooke, Tucker & DeMaio, 1985; Wright, 1974) who argued that the concept of *expertise*, as it relates to ADM, should include additional factors. These additional factors consisted of a combination of three mental and physical requisites that included: a. *psycho-motor skills* that demonstrate one's ability to perform demanding manual exercises or manipulations; b. *cognitive skills* that demonstrate one's ability to solve problems and make decisions and c. *managing stress and emotions* in a manner that will enhance the likelihood of a positive outcome.

Based on data acquired in his 1994 study and his years of research and involvement in aviation psychology, Jensen (1995) developed a model of the *expert pilot decision maker* (see Appendix A for diagram of this model). The model includes competencies in four areas. These areas include aviation experiences, risk management, attentional control and dynamic problem solving. Each of these four competencies include specific components and are listed below in Figure 8.

Figure 8: Expert Pilot Decision Maker; Competencies and Components

Competencies	Components
Aviation Experiences	- number: total flights as pilot in command - variety: types of flights taken (e.g., instruction, business, recreational, etc.) - meaningful: importance/significance of flight - relevant: the relevance of the flight to the pilot - recent: within past year/six months/3months
Risk Management	- values: extent to which the pilot's actions are consistent with the norms of his organization and/or society - hazardous attitudes: macho, anti-authority, invulnerability, impulsiveness and resignation
Dynamic Problem Solving	- feedback: obtaining information from a variety of sources - options: keeping safe alternatives open - satisficing: arriving at an adequate, if not the best, solution (due primarily to time constraints)
Attentional Control	- motivation: pilot does everything possible to attain a desirable outcome - expectations: to focus on relevant problems - perception: ability to discern between events and conditions that are/are not worthy of one's time and energy

Two other researchers (Endsley 1995; O'Hare, 1997) stressed that *situational awareness* is a key ingredient of expertise in aviation. O'Hare and Endsley developed instruments to measure situational awareness. O'Hare's instrument was administered to elite and experienced glider pilots. The elite pilots were chosen as a result of their successes in gliding competitions. Selection of experienced pilots were based on the amount of pilots' total flying time and their number of years as pilots. Their results suggested that higher levels of situational awareness were found in the elite pilots and that elite pilots scored higher in the test than did experienced pilots.

Shanteau (1992) developed a Theory of Expert Competence in which expert competencies were based on five factors. These factors included: a. grasp of domain knowledge;

b. psychological traits pertinent to a particular domain; c. cognitive abilities; d. acquisition of formal and informal decision-making strategies and e. task characteristics. Shanteau emphasized that *task characteristics* (the type and relevance of information used by experts and their abilities to perceive relevant patterns) were particularly significant when investigating their competencies.

The researchers previously mentioned identified a variety of characteristics, skills, and competencies shared by expert pilots. They are based on lessons learned over time and through experience. The expert pilots selected for inclusion in this study were selected in part because of their apparent acquisition of these traits as determined by the researcher in conversations with the subjects and, in the case of two expert subjects, during several flights.

Comparisons between experts and novices.

Federico (1995) contended that in naturalistic settings it is vital that individuals be able to assess situations and recognize similarities. His study was designed to measure how experts and novices recognized similar situations. Federico studied twenty-eight senior naval officers and fifty-two junior naval officers. He measured correlations intended to assess the ability of subjects to recognize and categorize tactical scenarios. Federico concluded that experts, more than novices, tended to create categories that were more dependent on context and circumstances that surrounded specific situations. His findings are consistent with the conclusions of other researchers (e.g., Klein, 1997b; Lipshitz, 1994; Mosier, 1991) who stressed the importance of context in decision-making in naturalistic settings.

Robertson (1996) conducted a study that focused on occupational therapists and the differences between expert clinicians and two groups of novices. Robertson surveyed a total of sixty-seven subjects. The subjects included fourteen second year occupational therapy students, thirty-one final year students and twenty-two practicing clinicians (experts). The surveys consisted of specific questions that related to the subjects' responses about a client they had worked with for a minimum of four weeks. The survey questions were used by the researcher to ascertain the degree to which each of the groups: a. focused on the problem; b. focused on the outcomes; c. elaborated about their responses and d. centered on the "human dimension" (relating the treatment procedures to the needs and concerns of a specific client).

Paired t-test comparisons were conducted across the three groups of subjects. The t-tests revealed several significant findings. First, Robertson concluded that with regard to their *focus* *on the problem,* there were no significant differences between the three groups. Second, the researcher reported that clinicians and more advanced students were significantly more *focused on outcomes* than were the less experienced students. Third, the clinicians received significantly higher *elaboration* scores (providing justification for their claims and a rationale for their decisions). Finally, the clinicians received a significantly higher score than did both groups of novices with regard to the *human dimension* (understanding and appreciation of personal concerns and apprehensions of their clients). Robertson concluded that while all groups had access to the same information, the experts were able to categorize and organize the information in a more efficient manner than did novices.

Many ADM decisions involve uncertain conditions along with time and stress pressures. Locke and Tan (1992) studied how experts and novices made decisions under conditions of uncertainty. Specifically, their study measured how experts and novices were affected by the framing of information. The researchers studied twenty-five experts and one-hundred-four novices. The study involved subjects evaluating fifty gambling scenarios. Half of the gambles were positively framed (probability of winning was presented) and half were negatively framed (probability of losing was presented). Each of the fifty gambles were presented to subjects by probability (of success or failure) and/or payoff information. The subjects were then asked to rank their likelihood of gambling in each scenario using a seven point scale.

The researchers found that both experts and novices were affected by the framing of the scenarios (i.e., the positively framed scenarios tended to be chosen more often than the negatively framed scenarios). Novices, however, attached more importance to chance information (probability of success) than did experts whose choices appeared only to be affected by positively framed scenarios. Locke and Tan also concluded that their study revealed no significant differences in the way experts and novices responded to complete and incomplete information. Perhaps their most pertinent finding of this study was that the framing of information can be a significant factor in determining how decision-makers will respond to specific ADM scenarios.

Another area in which differences appear between novices and experts is in their respective abilities to maintain *situational awareness.* For purposes of this paper the author will use a general definition developed by Endsley (1995). He defined situational awareness as "...the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future" (p. 36).

Randel, Pugh and Reed (1996) studied situational awareness of experts, intermediates and novices. Their research was based on an analysis of twenty-eight U.S. Navy electronic warfare technicians in a naturalistic setting (simulated battle situation). A naturalistic setting, according to the authors, is one which included time limitations, dynamic environments, high stakes, ill-structured problems, stress and shifting or competing goals.

In such environments, Klein (1989) hypothesized that experienced decision makers base their decisions on experiences and patterns they recognize as being relevant to current problems. Klein termed decisions made in this manner “recognition-primed decisions” (RPDs). Klein hypothesized that decision-making by more experienced individuals is affected by their ability to place scenarios into recognized contexts with which they are familiar (rather than analyzing alternatives). According to Klein, experts are better able to recognize typical patterns and devote most of their decision-making energies into defining the context, understanding the situation and, ultimately, defining a reasonably good course of action (a process referred to by Jensen, 1995, as “satisficing”) based on their previous experiences.

The electronic warfare technicians were designated as either expert or novice based on their performance on a simulated tactical mission. “Intermediates,” included technicians whose scores were between those designated “expert” and “novice.” Randel, Pugh and Reed (1996) speculated that the major differences in the groups may have been in their differing abilities to recognize meaningful patterns and to react effectively to those patterns.

Randel, Pugh and Reed (1996) measured the situational awareness of the subjects by interviewing subjects and through the use of questionnaires after each scenario. Subject’s situational awareness were also evaluated during the scenario by asking them to draw what was on their radar screens on two occasions. The researchers stated that:

> The visual and several of the verbal measures of situation awareness indicate that experts are better than novices in sizing up the situation in a decision-making task. Experts have a better visual picture of the situation and they are able to verbalize the hostile platforms in the areas as well as information about the tactical situation. Experts also found the task less difficult and felt less time pressure than novices. p. 591.

The researchers concluded by stating that situational awareness appeared to be “...at least one determinant of superior decision-making.”(p. 594). They indicated that those involved in naturalistic decision-making would benefit from training that stressed situational awareness. Such training, the authors, emphasized, would ultimately result in better decision-making.

A variety of additional research has acknowledged the importance of both recognizing the above stated differences between novices and experts and developing programs that will help novices acquire the skills of experts. These studies represented a diverse array of disciplines (e.g., Benner, 1984 - nurses; McPhearson, 2000 - tennis players; Wiggins and Henley, 1997 - flight instructors). Such training programs, designed to help novices acquire the skills of experts, were well documented and will now be addressed.

Training designed to help novices acquire the skills of experts.

Several researchers (e.g., Benner, 1984; Dreyfus and Dreyfus, 1980, 1986) pointed out that the transition from novice to expert involves the accumulation of relevant experiences. For example, Dreyfus and Dreyfus (1986) studied the acquisition of skills in a number of domains (e.g., chess players, pilots, automobile drivers and adults who were learning a second language). They observed that there was a continuum of acquired skills common to all of these domains. They referred to this continuum as the "Five Stages of Skill Acquisition."

The first level of the Dreyfus' Model is the *novice* stage. In this stage the learner receives new skills through instruction. Rules are memorized and actions are based on facts, principles and guidelines presented by instructors. Relevant elements of a particular situation are specifically defined for the novice by instructors. Normally, the novice will recognize these elements without regard to the overall environment in which they occur. The researchers termed the recognition of such elements by novices as "context free." As an example of a "context free" feature the writers cited one learning to drive an automobile with a manual transmission. The learner develops the skills necessary to shift the transmission without developing an awareness of the context in which the skill is performed. In the novice stage, the researchers pointed out that performance was based on novices' perceptions of how well they followed rules and procedures.

Level two of the Dreyfus' Model was referred to as the *advanced beginner* stage. In this stage the learner has accumulated a significant degree of experience in managing relevant situations. The performance of the learner in this stage was, according to the authors, "marginally acceptable." In this stage learners began to draw on the experiences they encountered in specific situations. Beginning at this level, the *advanced beginner* makes use of both context free elements and situational experiences to make decisions.

The third level of the Dreyfus' Model is the *competence* stage. By this stage learners have accumulated an increasing number and variety of experiences relevant to their respective domains. The researchers pointed out, however, that despite the accumulation of experiences, learners appeared to lack "a sense of importance" and often tied decisions to the presence of specific elements. Typically, the writers indicated, learners in this stage adopted a linear sequence of decision-making steps that are based on a course of action that will address the factors that they perceive to be most relevant.

As the number and variety of experiences expand, individuals enter the fourth level of the Dreyfus Model, the *proficiency* stage. Individuals in this stage are able to discern between elements in a situation that are important and must be addressed with those that are irrelevant and can be ignored. The experiences of individuals in this stage serve as catalysts for action. Individuals at this level rely on their intuition (based on their experiences) to recognize and take actions that are most appropriate for any given situation. The proficient performer will continue to assess situations analytically and relies, therefore, on both intuitive and analytical competencies.

The final stage of the Dreyfus model is what the authors term *expertise*. In this stage individuals intuitively base actions on the large number and wide variety of their accumulated experiences. These experiences serve as a basis of developed skills and competencies which, in the expert, have become part of their being. The authors pointed out that while the actions of most experts are nonreflective, they will analyze situations if time permits. This analysis, however, differs from that of less experienced individuals. Analytical processes used by experts, the authors pointed out, are primarily concerned with reflecting upon their intuitions and contextual frameworks, as opposed to contemplating alternatives.

The stages of the Dreyfus model can be related to the evolution of novices into expert GA aviators. The researcher has witnessed numerous GA pilots progress through the stages described in the Dreyfus Model. The novice and expert subjects, upon which the researcher's study is based, can also be defined in terms of the Dreyfus Model. Based on the researcher's experiences as a flight instructor for the past twelve years, these stages, and their relationship to the experience levels of GA pilots, are depicted in Figure 9.

Figure 9: Relating Dreyfus' Stages to Experience Levels of GA Aviators

Stage	Features	GA Pilot Experience Level
Novice	actions based on adherence to rules and procedures	student pilots.
Advanced Beginner	actions based on both adherence to rules and recognition of previous experiences	licensed pilots who have acquired a minimum of 100 hours of total flying time
Competent	actions based on analysis of facts in which pilot begins to associate key facts with specific actions	licensed pilots who fly frequently (a minimum of 10 hours/month) and who have acquired a minimum of 250 hours of flying time
Proficient	actions based primarily on intuitive knowledge developed from past experiences but relies also on analytical skills	pilots with a variety of flight experiences who fly regularly (a minimum of 25 hours/month) and have acquired a minimum of 1,000 hours of flying time
Expert	actions based on intuitive knowledge and wisdom of relevant, context-based experiences — analysis is primarily concerned with identification of proper context	pilots with a variety of flying experiences who fly regularly (a minimum of 25 hours/month) and have acquired a minimum of 3,000 hours of flying time

The exposure to relevant experiences is an important component in the seasoning of novices. Throughout the literature numerous authors stressed the importance and necessity of such training. Many of these authors (e.g., Dreyfus, 1979; O'Bryne, Clark & Malakuti, 1997; Stepich, 1991; etc.) have offered suggestions related to how this training can best be accomplished.

For example, Stepich (1991) examined numerous studies (e.g., Chase and Simon, 1973; Larkin, McDermott, Simon and Simon, 1980; Schon, 1983; etc.) in attempting to develop guidelines for instructional designers who were concerned with the creation of programs aimed at helping novices acquire the skills and competencies of experts. Stepich considered the development of such training programs as they related to Gagne's internal and external conditions of learning. Gagne, (1985) stressed that effective training programs require both *internal* conditions (prerequisite information, comprehension and skills that must be known by the learner prior to the learning of something new) and effective *external* conditions (the type of instruction selected to facilitate learning). Stepich's training recommendations are summarized below in Table 4.

Table 4: Stepich's Training Recommendations For Helping Novices Acquire the Skills of Experts

- teach novices to recognize patterns and the proper actions associated with these patterns
- provide novices with as much practice (in recognizing patterns and taking proper actions) as time permits
- provide feedback to novices that will reinforce the recognition of patterns and emphasize proper responses (and correcting improper responses)
- present novices with an overview of the appropriate domain
- identify the relationship between pieces of information and their relationship to the domain
- provide novices with frequent reviews
- explain how, when and why specific strategies should be used
- provide examples to students of how specific strategies are used
- provide students with opportunities to apply principles and strategies to practical scenarios

O'Byrne, Clark and Malakuti (1997) attempted to develop training programs designed to help novices acquire expert competencies. Although the researchers limited their discussion to the training of counselors, their inquiry appears to have wider applications. Drawing on the studies of several researchers (e.g., Anderson, 1993; Skovholt and Ronnestad, 1992; etc.) the authors developed seven recommendations. These recommendations included teaching novices: a. basic facts, theories and principles (what the authors refer to as "declarative knowledge"); b. problem-solving procedures; c. in a manner that will not only develop a more in-depth knowledge of the domain, but will also enhance the motivation of novices; d. how to react appropriately to specific situations by arranging for internships so that novices can practice what they are in the process of learning; e. in a manner that will develop expertise (providing adequate amounts of time to learn and to receive feedback from teachers); f. in appropriate contexts and g. in a sequence that is conducive to understanding (from less difficult to more difficult) and in suspected order of application.

Dreyfus and Dreyfus (1979) analyzed three models of skill acquisition designed to assist aviators in emergencies . Citing the work of numerous psychologists (e.g., Posner, 1973; Schank

& Abelson, 1970; etc.), the researchers stated that only a model based on specific situational contexts would be useful in promoting effective emergency behaviors. Such a model would emphasize five abilities that included the capacity to: a. remember a large number of situations; b. associate a present condition with one of the remembered situations; c. comprehend that a remembered situation does not adequately represent a present condition; d. associate a different remembered situation with a present condition and e. recall an appropriate course of action for any specific remembered situation. The authors concluded by indicating that the situational model could serve to help novices recall relevant situations. They also indicated that this model could be used to help novices choose effective courses of actions.

Several writers (e.g., Cohen & Freeman, 1996; Connolly, 1990; Jensen, 1988; Ryder & Redding, 1993; Shebilske, Regian, Winfred & Jordan, 1992; Wiggins, 1997) discussed the value of teaching cognitive skills. Wiggins (1997), for example, emphasized that the teaching of cognitive skills are vital to the development of novice aviators. Wiggins cited the studies of several researchers (e.g., Edwards and Ryder, 1991; Harwood, Roske-Hofstrand and Murphy, 1991; Schlager, Means and Roth, 1990; etc.) who advocated the use of a strategy known as *cognitive task analysis* (CTA). According to Wiggins, CTA focuses on the inter-relationship between the procedural and cognitive demands of a task and can be used during training to enhance cognitive performance. CTA training techniques involve the application of a variety of tactics including protocol analysis (thinking aloud while performing or describing a task), error analysis, interviewing, etc. Wiggins indicated that CTA training could be used by instructors to enhance both the decision-making abilities of novices as well as their abilities to analyze risks, solve problems, and improve situational awareness.

Chappell (1991) reviewed the research of numerous investigators (e.g., Chase and Simon, 1973; Klein, 1989; Larkin, McDermott, Simon & Simon, 1980, etc.). She explained that pilot performance, including decision-making, could be enhanced both by improving training techniques and by perfecting the design of flight decks to promote pattern recognition. With regard to improvements in training, Chappell recommended programs that use three specific techniques. These techniques are listed on the following page in Figure 10.

Figure 10: Chappell's Recommended Training Techniques

Technique	Remarks
Part-Task Training	Divide tasks into their parts and assure students are familiar with each part. It is important, however, to provide students eventually with opportunities to combine these tasks into integrated actions.
Training for Monitoring	Students should be trained in the detection of anomalies under conditions of moderate stress.
Techniques for Transfer of Knowledge	Novices should be informed of how experts seek and apply information as well as how to determine information that is insignificant and should be disregarded.

Anderson and Henley (1997) offered a unique method to help novices acquire more advanced skills. The researchers used two groups of post-secondary aviation students to maintain reflective journals of their flight training experiences. One group consisted of novices (n=20) with little prior flight experience. The other group consisted of more advanced students (flight instructor trainees, n=30). Subjects in their study were asked to write about their actual experiences (recall) and to consider the meaning and application of their experiences (reflective thinking) in journals. The maintenance of journals, particularly by the novices, provided them with a vehicle through which they could receive feedback from instructors (experts). It also provided them with a medium through which they could reflect upon the transfer of theory to practical applications. The journal entry of one such novice, practicing a landing without flaps, reflects this process.

> The first two circuits were uneventful and I noticed the wind was blowing straight down the runway. I decided to make my approach speed about 5 knots faster than normal to compensate for the wind. I knew the approach speed for a flapless landing was a little bit faster than normal so on late downwind I did not pull the power as far back as normal. I didn't think that without flaps the aircraft would have very little drag and the airspeed could easily increase. I kept about 85 knots indicated airspeed on base but when I turned final the shallower approach which comes from a flapless approach seemed too low. I added power and climbed, not realizing I was already high and only seemed low due to the shallower approach angle. By the time I was on late final, I was very high and had a lot of power. I pitched the nose down towards the [runway] threshold and reduced the power. Over

> the threshold I was at the right height, but when I looked at my airspeed indicator it read over 100 knots. I cut the power, but because I was floating so much I did not hold off the flare as much as I should have. The aircraft hit the runway bouncing a number of times before coming to a stop at the end of the runway. I had used all of the runway more than double the runway length needed to land a Tomahawk [type of aircraft used primarily for training]. It was only after that I realized how fast I was really going and how close I came to running the aircraft off the runway. Looking back, I should have kept a constant speed throughout my approach and realized that different approach angle the aircraft has with a flapless approach. Ultimately I should have gone around [aborted the landing] when I realized my approach was bad. I was relaxed and so not concentrating on my approach and I think that is why my approach and landing were so bad.
> p. 1168.

The authors pointed out that students involved in the study actually created relevant knowledge based on their personal experiences. The journals, therefore, served to promote self-directed learning and lifelong learning that numerous adult educators (e.g., Boucouvalas, 1987; Knowles, 1990, etc.) have alluded to as fundamental tenets of the discipline. In addition, the authors stressed that students were provided with important feedback opportunities with instructors during which alternate solutions to problems were discussed and analyzed. The student journals not only provided subjects with opportunities through which they could analyze their actions and thought processes in a self-directed context, but also helped to facilitate the transfer of learning between experts and novices.

A Sample of General Aviation ADM Studies

The final section of the Literature Review will discuss studies of ADM. Some of the earliest ADM-related studies occurred during World War II. For example, Kelly and Ewart (1942) used the Purdue Scale for Rating Pilot Competency to measure, among other things, judgement. Beginning in the early 1970s and into the 1980s, many ADM researchers (e.g., Berlin, Gruber, Jensen, Holmes, Lau, Mills & O'Kane, 1982; Jensen & Benal, 1977 etc.) focused on the recognition of hazardous attitudes and the feasibility of teaching ADM to GA pilots. Current research has centered on the assessment of differences between groups of pilots based on age, experience levels, types of flying, etc. and determining methods to improving ADM skills.

Due to the volume of research in ADM, this section will be limited to a sample of pertinent research. The selection criteria were based on studies that were cited by prominent authors who have written extensively about ADM. The section will be divided into two subsections. The first subsection will examine research conducted prior to 1991. The second section will review more recent ADM studies.

ADM studies prior to 1991.

Jensen and Benal (1977) reviewed general aviation accidents between 1970 and 1974. Their analysis concluded that during that time period, improper judgements were involved in thirty-five percent of nonfatal GA accidents and fifty-two percent of fatal accidents. An analysis of the accidents convinced the researchers that judgement training could be taught and evaluated objectively. They also offered suggestions through which this training could be accomplished (e.g., classroom and simulator instruction).

Several years after the study by Jensen and Benal (1977) the FAA funded a study (Berlin, Gruuber, Holmes, Jensen, Lau, Mills & O'Kane, 1982) that was conducted at Embry-Riddle Aeronautical University (ERAU). The purpose of the study was to produce ADM training manuals for student and instructors and to develop a protocol for measuring pilot judgement. The researchers designed the ADM training materials and developed a simulator-based testing protocol in which subjects responded to events that required them to make decisions. The testing protocol was used to perform a limited validation study in which it was determined that the experimental group outperformed the control group.

In 1982, the FAA and the Canadian Air Transportation Administration conducted a joint project in which judgement training, using the ERAU training materials, was evaluated. Civilian air cadets comprised the subjects for this study. As was the case in the 1982 ERAU study, those who received the ADM training outperformed those who did not receive the training.

By 1985, the original ERAU training materials were revised and new manuals developed. In that same year, Lester, Diehl and Buch conducted a study among newly certificated private pilots (N=42) in "conventional flight school settings." The revised materials were provided to flight instructors who had received special training at ten fixed-base operations (FBOs). Subjects from the ten FBOs had received judgement training and comprised the experimental group (n=12). Subjects from the same ten FBOs were selected as members of a control group (n=30).

A test of judgement skill was developed that was based on an observation flight. During the observation flight, subjects were evaluated by highly experienced pilots who had accumulated between 5,000 and 10,000 hours of flying time. The role of the observers was to present twelve items (e.g., request subjects to fly into controlled airspace, request subjects to make non-standard traffic pattern entry for landing, etc.) that would require participants to make a decision and to record their performance. The performance of the subjects was rated as either “good” or “poor.”

The researchers concluded that those in the treatment group scored approximately 7% higher on the observation flight than did those in the control group. The authors pointed out that because of the relatively small size of the sample, their findings were tentative but that further research could help to establish the effectiveness of such programs in conventional flight school settings. They also stated that the improvement in pilot judgement skills in their study was less dramatic than what had been reported in previous studies.

The researchers also provided both instructors and subjects in the experimental group with questionnaires regarding the ADM materials and training. Based on the results of the questionnaires, the researchers concluded that those involved in the study gave high marks to the student manuals used during the study. Eighty percent of the students and ninety-eight percent of the instructors rated the student manuals as either “very useful” or “moderately useful.” Ninety percent of the flight instructors involved in the study rated the instructor manuals as either “very useful” or “moderately useful.” Perhaps this training could serve as a prototype for ADM tailored to student pilots.

Telfer (1987) divided Australian student pilot subjects into three groups. One group (*academic* group) was issued a decision-making manual. A second group (*experimental* group) received both a manual and ADM instruction. The third set of subjects consisted of a control group.

Subjects were measured first by a written pre-test and posttest. The tests measured subjects’ responses to situations involving two scenarios. Specifically, the written tests measured such items as: recognition of hazardous thoughts, recognition of good judgements, effects of hazardous thoughts and basic pilot judgement concepts. Telfer stated that the analysis of variance depicted no significant difference in performance of the three groups on the written test. He attributed this to the inadequacy of the written test itself. Telfer explained that there were two areas in which the written exam did seem to show a trend. The scores of both the experimental group and the academic group improved (pre-test and posttest scores) with regard to Critical and Emergency Decision making.

Subjects in Telfer's study were also provided with a flight test. The flight test was used to appraise subjects' judgement skills. Each of the subjects was evaluated by an experienced evaluator. Subjects were evaluated on numerous "judgement areas" including checking weather, hazards affecting aircraft, departure procedures, terrain and cloud clearance, infringement of controlled airspace, arrival procedures, etc. Telfer used t-tests to determine differences between the groups. He reported that the Experimental group outperformed the other groups and that the Academic group performed second best. He stated that "the difference between the Experimental Group and the Control group was significant ($t=2.48$, $p<.05$), but that there were no significant differences between the Experimental and Academic, and the Academic and the Control groups" (p. 268). Telfer concluded by stating that although there were concerns about the testing procedures, his study served to provide substantial support to the studies previously mentioned.

Jensen (1988) sought to develop training programs to improve pilot judgement. In an attempt to help less experienced pilots acquire such skills, Jensen asked "What does a pilot learn during the hours 300 to 1000 that make him or her safer?" (p. 1). Based on his previous analysis of experienced pilots (Jensen and Marsh, 1976), Jensen surmised that one of the important distinguishing feature between experienced and inexperienced pilots were the differences in their decision-making skills.

Jensen (1988) indicated that judgement training must address two vital components: a. discrimination or "headwork" (the perceptual and cognitive abilities to "...detect, recognize and diagnose problems, to determine available alternatives and to determine the risk associated with each alternative." — p. 2) and b. motivation (an attitude which stresses safety and the norms of the organization for which pilots fly). Jensen's study involved the creation and evaluation of a decision-making training program. The ADM training vehicle selected by Jensen was the "DECIDE" model.

The DECIDE model consists of a simple acronym that can be used to help pilots make decisions that require the use of their cognitive abilities. It was demonstrated to be effective (Benner, 1975) in the training of fire fighters. The components of the DECIDE model are listed on the following page in Figure 11.

<u>Figure 11: The DECIDE Model</u>

D	-	Detect	the decision maker detects a change that requires attention
E	-	Estimate	the decision maker estimates the significance of the change
C	-	Choose	the decision maker chooses a safe outcome
I	-	Identify	the decision maker identifies actions to control the change
D	-	Do	the decision maker acts on the best options
E	-	Evaluate	the decision maker evaluates the effects of the action

p. 3.

Jensen's (1988) study used detailed analyses of accident cases as a vehicle to teach the DECIDE model. The subjects in the study consisted of ten pilots from the Columbus, Ohio area. Five of the subjects received the DECIDE model training. The remaining five subjects received no such training. All of the pilots had similar levels of flight experience and training.

Following the instruction, both groups received instruction in the use of a Frasca 141 flight simulator. Subjects were provided with all necessary aeronautical charts and checklists. Following a familiarization flight in which subjects were encouraged to ask questions, the subjects took the experimental flight. Audio and video recordings were made of all subjects during each of the flights. Subjects were told that the purpose of the simulator flight was to evaluate the Frasca 141.

The experimental flight consisted of a trip from Port Columbus, Ohio to Frederick, Maryland. The flight was designed to present the subjects with three unexpected conditions that would require decisions to be made. The three unexpected conditions were presented to subjects in the following order: a. failure of the attitude indicator (an instrument that displays the position of the aircraft relative to the ground); b. carburetor ice (could cause the engine to stop if not dealt with effectively) and c. deteriorating weather conditions.

The results of the study were obtained during a structured debriefing following the experimental flight. The structured debriefing attempted to acquire all pertinent cognitive processes of the subjects in terms of the DECIDE model. In addition to the structured debriefing, a review of the experimental flights indicated that all of the experimental group members who chose to fly (four of five) eventually landed safely. All of the control group members who chose to fly (three of five), however, eventually crashed.

Jensen (1988) concluded that although his study did not provide overwhelmingly positive results (due to lack of time and funding), it did show that the DECIDE model had "great potential" as a tool to teach judgement to inexperienced pilots. He pointed out that the experimental group seemed to show a greater concern for the safe outcome of their flights than did the control group. He also stressed that the study demonstrated the suitability of simulators in teaching judgement skills to novices.

Connolly (1990) randomly assigned twenty-nine subjects to either a control group (n=13) or a treatment group (n=16). All of the subjects were enrolled in a *Principles of Flight* course at ERAU and held private pilot licenses. The treatment group received a total of eight hours of ADM training (four hours of classroom instruction and four hours of training in a simulator). The two groups were evaluated before and after the ADM training on a simulated VFR cross-country flight.

During the pre-test and post-test evaluations, subjects were presented with three events that required a response during a simulated flight in a Singer-Link GAT-1 two-axis simulator. The pre-tests and posttests of all subjects were evaluated through the use of two measurements. First, subjects were presented with a ten item checklist related to decisional activities they had completed during the flight. Second, each subject's record was evaluated by five raters. All of the raters were either CFIs or FAA designated examiners.

The scores of the raters were compared to the scores on the checklist. The author determined a high correlation ($r = +0.86$) between the two measurements. Connolly also determined that there was no significant difference in the pre-test scores of both groups. The posttest measurements revealed significant differences between the two groups on both checklist scores ($t = 7.39$, $df = 27$) and ratings by experts ($t = 5.14$, $df = 27$). The writer concluded that his experiment demonstrated the effectiveness of simulator-based ADM training. A summary of this, and previously mentioned studies that were conducted prior to 1991, is depicted on the following page in Figure 12.

Figure 12: Sample of ADM Studies Prior to 1991

Researchers	Subjects	Data Collection Techniques	Validation of	Key Results
Lester, Diehl & Buch 1985	N=42 Control n=30 Experimental n=12	Questionnaires and author - created "observation flight items" for Flight Test	Berlin, Gruber, Holmes, Jensen, Lau, Mills & O'Kane (1982)	Researchers stated that preliminary flight test results showed a modest improvement in decision-making skills for subjects in the experimental group. Questionnaire responses demonstrated high regard for ADM manuals and training program by both subjects and instructors.
Telfer 1987	N=20 Control n=6 Academic n=6 Experimental n=8	Written pre-test and posttest based on author-created scenarios and Flight Test	Diehl, (1983) Buch and DeBagheera, (1985) Jensen and Adrion, (1985) Diehl, Austin and Buch, (1986)	Researcher claimed "statistical substantiation" p. 268. of other studies (i.e., treatment group demonstrated superior performance in some areas)but expressed concerns with testing procedures
Jensen 1988	N=10 Control n=5 Experimental n=5	Simulator based scenario Audio and Video data were obtained for each of the subjects	Benner (1975)	Researcher found that those in the experimental group performed better (all simulated flights ended in safe outcomes) than those in the control group. Researcher concluded that the DECIDE-based training program shows promise but further research is necessary to perfect judgement training, and evaluation techniques.
Connolly 1990	N=29 Control n=13 Experimental n=16	Pre-test and Posttest simulator based evaluation created by author	Buch & Diehl, (1984)	Researchers reported a significant difference between experimental and control groups and claimed that this demonstrated the effectiveness of simulator-based ADM training.

Recent ADM studies.

In a study conducted by Stokes, Kemper & Kite (1997) the writers evaluated the information processing characteristics of twenty-four pilots flying in simulated instrument conditions. The researchers analyzed the short-term and long-term memory information processing traits of the subjects. Twelve of the pilots were classified as *high-time* aviators (had acquired over 1,500 hours of flying time, held an instrument rating and a commercial or airline transport pilot certificate). The remaining twelve pilots were classified as *low-time* pilots (had acquired less than fifty hours of instrument flying and held a private pilot's license). The two groups responded to a computer-based decision-making program.

Each of the subjects was presented with a series of scenarios during a simulated flight. Following each scenario, the subjects responded either to multiple choice decisions or an open-ended decision. The simulated flight required approximately two hours and, according to the authors, "every effort was made to avoid making the flight an implausible assemblage of unlikely catastrophes; rather, the intention was to simulate a realistic (if eventful) experience" (p. 189).

The researchers surmised that low-time pilots, due to their lack of experience, were forced to rely on short-term memory cues. High-time pilots, the writers pointed out, also relied on short-term memory cues but, in addition, associated scenarios with experiences stored in long-term memory. The study also determined that high-time pilots were able to select more relevant cues than were the low-time pilots and that the high-time pilots were able to cite more alternatives than the low-time pilots. The study concluded that:

> The data from this analysis also suggest that pilot training could be improved by explicitly building the experiential repertoires of students. Ground school training classes could therefore be modified to include or emphasize event-based learning in conjunction with traditional fact and rule-based training. p. 194.

Driskill, Weissmuller, Quebe, Hand and Hunter (1997) studied the ADM reactions of GA pilots to varying weather and terrain conditions in a single engine aircraft that was operating in VFR conditions. The writers used a mail-out-and-return protocol to collect data. Of the twelve hundred packages that were mailed to randomly selected (from FAA records) licensed pilots, the researchers received three hundred twenty-six responses. An analysis of the data corroborated earlier research (Driskill, Weissmuller, Quebe, Hand, Dittmar & Hunter, 1997) that was limited to one geographic area. The authors concluded that pilots tended to associate acceptable ceiling levels (lowest layer of clouds), visibility and precipitation with the terrain over which they fly. In addition, the writers stated that pilots appeared to use a *compensatory* ADM strategy in which poor conditions in one variable (e.g., ceilings lower than ideal) were weighed with improved conditions in other variables (e.g., good visibility, no turbulence). The researchers also pointed out that a number of pilots employed personal weather minimums that would make them less likely to fly under certain conditions.

Kochan, Jensen & Chubb (1997) conducted research aimed at developing a new model of ADM -- the “Expertise” model. Their study centered on the development of such a model and on three specific sub-goals: a. to determine the characteristics of expert pilots; b. to determine how expert pilots acquired their skills and competencies and c. to develop training strategies by which “competent” pilots can acquire the skills of experts. The researchers selected GA pilots who flew fairly complex aircraft (Cessna P-210 Centurions and Beechcraft 58-P Barrons). The author’s research consisted of four studies.

The purpose of the first study was to develop a definition of an “expert” pilot. The first study collected data via questionnaires and semi-structured interviews. The interviews and questionnaires were administered to ten exceptionally experienced pilots (average number of years flying was 32.5 and average number of flying hours was 13,500). Subjects in this study provided data used to develop a definition of an “above average” pilot. The subjects stressed that such a pilot needed to possess certain skills, knowledge, confidence, motivation and effective learning and performance strategies.

The purpose of the second study was to develop further the evolving definition of an expert pilot by determining the “cognitive processes and learning strategies of the above average pilot.” Subjects for this study included thirty experienced pilots (average number of flying hours was over 5,000). A structured interview was used to collect data. Information from this study indicated that expert pilots: a. were motivated to learn; b. were able to focus their attention on required tasks; c. were confident in their piloting skills; d. were consistently aware of the total environment (situational awareness); e. were attuned to their aircraft and any anomalies; f. were vigilant for anything out of the ordinary; g. possessed superior cognitive abilities to diagnose and solve problems; h. were able to communicate effectively; i. were knowledgeable of their limitations and did not attempt to exceed those limitations and j. were able to enforce their personal limitations in all situations.

Following an analysis of the data from this study, the authors hypothesized that there were three primary distinctions between "expert" and "average" pilots. First, the quantity and quality of information obtained by expert pilots exceeded that of average pilots. Second, expert pilots made more and better decisions than did average pilots. Third, expert pilots communicated more effectively and with more relevant sources than did average pilots.

The third study was based on the development of a realistic scenario created from data obtained from NTSB accident reports. The authors compiled seven events into their flight scenario. Six experienced pilots served as subjects for this study. Data gathered during this study were used to refine further the authors definition which now consisted of several major components: knowledge, skills, behavior and motivation.

The fourth study collected data from six experienced pilots (none of whom was involved in the third study). Subjects were presented with the same scenario as were subjects in the third study. The responses of subjects were recorded and transcribed. The transcriptions were then coded into specific categories for analysis. The researchers were able to identify several trends based on their analysis: a. experts expeditiously sought more quality information; b. in attempting to resolve problems, experts tended to make decisions in a progressive manner and c. experts tended to communicate more often than did non-experts and were apt to use all relevant and available resources.

The researchers concluded that general aviation expert pilots can be characterized by the ten items previously mentioned in the second study. They pointed out that these items could readily fit into Jensen's (1995) Expert Pilot Model (see Appendix A) and could be described in terms of the major headings of that model (i.e., aviation experiences, risk management, dynamic problem solving and attentional control). Finally, the authors indicated that expertise was not necessarily a factor of accumulated hours of flying but, rather, the acquisition of judgement skills and characteristics that promote effective, efficient and safe flying.

In a 1998 study, Driskill, Weissmuller, Quebe, Hand and Hunter evaluated the decision-making skills of GA pilots. The writers developed fifty-one ADM written scenarios. Twelve of these ADM scenarios were, in some cases, modified and used by the researcher in this study as examples for students and to collect data (see Appendix E). Those designated as *Expert* pilots were asked to rank the alternatives for each scenario. The responses of private pilot subjects were then compared to the responses of experts.

The authors concluded that overall, the expert and novice pilots agreed on alternatives that were judged to be important to flight safety. They pointed out, however, that further analysis revealed that two factors appeared to be relevant to the judgement tendencies of private pilot subjects. Younger pilots, the researchers noted, tended to choose alternatives that involved a higher degree of risk than did older pilots. In addition, the authors noted that the private pilots with more flight time appeared to be less conservative in their responses than private pilots with less flight time. The authors concluded that those pilots who seem to be most at risk are those who are young and have a considerable amount of flying time. They also noted that their findings are tentative since the study involved pencil and paper responses to scenarios. The authors pointed out that what one would actually do in an emergency situation (in a truly naturalistic setting) may be vastly different from alternatives chosen on the ground.

As was previously noted, the volume of studies related to ADM was large. The studies presented in this section were meant to provide the reader with a representative sample of such research. Recent ADM studies, reviewed by the author, are summarized in Figure 13 (p. 55).

Summary

The purpose of the literature review was to provide the reader with relevant data underpinning the current research. In addition, the researcher attempted to provide the reader with a relevant sampling of the immense amount of research data related to decision-making, experts and novices, and ADM studies. Pertinent information was divided into three major categories for convenience and to promote organizational clarity.

The researcher continued to acquire data related to the major categories until each became “saturated” (i.e., same authors and articles were being cited). The shear volume of data, therefore, resulted in this literature review being selective rather than comprehensive. Throughout the review of the literature there was little that specifically related to ADM and GA student pilots. Much of the pertinent literature was the result of studies involving more experienced pilots conducted primarily during the 1980s and 1990s; therefore, a gap in the knowledge exists. It is the intention of this study to help fill that gap.

Figure 13: Sample of Recent ADM Studies

Researchers	Subjects	Data Collection Techniques	Validation of	Key Results
Stokes, Kemper & Kite 1997	N=24 12 high time pilots and 12 low time pilots	Responses to multiple choice and open-ended questions based on simulated flight	Barnett (1989) Stokes, Belger, & Zhang (1990)	Low-time pilots were forced to rely on short term memory cues. High time pilots relied on both short-term and long term memory cues. In addition, high-time pilots were able to think of more alternatives and more relevant cues than were low-time pilots
Driskill, Weissmuller, Quebe & Hand 1997	N=326 mean age: 52	Authors employed a mail-out-and-return protocol	Driskill, Weissmuller, Quebe, Hand, Dittmar & Hunter (1997)	The terrain over which they flew affected the weather-related ADM of licensed pilots. Many pilots used a *compensatory* approach, weighing unfavorable weather variables with more favorable variables. Some pilots had established personal weather minimums that made them reluctant to fly under certain conditions.
Kochan, Jensen & Chubb 1997	Study 1: N=10 Study 2: N=30 Study 3: N=6 Study 4: N=6	Studies 1&2: Structured interviews and questionnaires. Study 3: Scenario Study 4: Scenario	Jensen (1995)	Researchers developed a definition of GA pilot expertise. They concluded that expertise was not necessarily a matter of accumulated flight hours but, rather, the acquisition of specific characteristics.
Driskill, Weissmuller, Quebe & Hand 1998	Expert Pilots: N=31 mean flying time: 4,995 hours ――― Private Pilots: N=246 mean flying time: 589 hours	Package including the 51 Scenarios were mailed to 1000 Private Pilots. Packages were hand delivered to those designated as Experts.	Driskill, Weissmuller, Quebe, Hand, Dittmar & Hunter (1997)	Older private pilots tended to chose alternatives that were more conservative than those who were younger. Private pilots with more flight experience tended to choose less conservative alternatives than did those with limited flight experience. The authors concluded that younger pilots with high amounts of flying time appeared to be more willing to take risks.