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THESIS

MODELING HUMAN ELEMENTS OF DECISION-MAKING

by

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Combat models attempt to represent the various factors that can influence combat outcomes. The most difficult of these factors to define and represent are the purely human inputs into the combat equation. These include factors such as personality, emotion, and level of expertise, which vary from individual to individual. The process of decision-making during combat is one of the most problematic modeling challenges. Traditional models of human decision-making do not adequately address the factors listed above. This thesis addresses this issue by proposing an influence diagram, which builds on traditional utility theory to include the human element in combat decision-making. The model is examined by application to three historical case studies. The results show that the outputs of the model are consistent with the end-state of the three historical battles.

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MODELING HUMAN ELEMENTS IN DECISION-MAKING

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Combat models attempt to represent the various factors that can influence combat outcomes. The most difficult of these factors to define and represent are the purely human inputs into the combat equation. These include factors such as personality, emotion, and level of expertise, which vary from individual to individual. The process of decision-making during combat is one of the most problematic modeling challenges. Traditional models of human decision-making do not adequately address the factors listed above. This thesis addresses this issue by proposing an influence diagram, which builds on traditional utility theory to include the human element in combat decision-making. The model is examined by application to three historical case studies. The results show that the outputs of the model are consistent with the end-state of the three historical battles.

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EXECUTIVE SUMMARY

Models of combat situations can provide valuable insights to military leaders at all levels. These models attempt to represent the various factors that can influence combat outcome. The human inputs into these models are difficult to define and represent. The high level of technology available to the U.S. military does not eliminate these elements. On the contrary, the rapid pace and information-rich nature of modern combat increases the complexity of decision-making for commanders and results in a greater need to take into account the human element.

Research in human behavior indicates that a variety of internal and external factors have the potential to impact the decision maker. Some of these issues such as training, experience and level of fatigue can be directly impacted by outside influences, e.g., orders from a senior commander to require additional training or a rest period. While many of these factors are purely environmental and vary with the given situation, others are more constant and are part of the decision maker's own personality. Other factors such as emotional characteristics and values are inherent to the decision maker.

In 1998 the National Research Council released the report of the Panel on Modeling Human Behavior and Command Decision-Making (Pew and Mavor, 1998). Convened at the request of the Department of Defense, the panel identified several problem areas with the modeling of human behavior in current combat models. The panel's recommendations included a framework for improved model development of human behavior.

Previous thesis work has attempted to include the impact of the human aspects of decision-making on combat situations. In June of 2001, a thesis submitted by Maj. Sergio Posadas provided a clear argument for the need for a stochastic decision-making model that can be used in combat simulations such as Combat XXI (Posadas, 2000). Major Posadas developed and tested a model based on a typical command and control scenario. Current efforts at the Army Training and Doctrine Command, Analysis Center (TRADOC) seek to further explore methods to accurately represent human decision-making in established combat models.

A variety of disciplines have explored the process of human decision-making and have developed models accordingly. These models range from rational choice theories such as utility theory, to more descriptive psychological models that focus more on the process of decision-making. Within these theories a variety of factors have been identified that have the potential to impact the decision choice. The model proposed in this thesis draws on several theories and attempts to provide a balance, capitalizing on the strengths of each.

The challenge is to blend these factors into a comprehensive model that can be easily adapted for use in combat simulations. Like Posadas' model, the model developed by this thesis looks at a single operational decision made by a commander during combat operations. In addition to the factors discussed previously, the model must include reasonable inputs that would be available to a military commander in the situation. A modified influence diagram is proposed as an appropriate graphical representation of the commander’s decision-making process with nodes assigned to represent individual factors.

This general model is evaluated using three case studies. The Task Force Smith example examines the ability of the model to represent how a decision maker's decision may change over time as the situation changes. The Battle of Midway example illustrates the effects of expertise on the decision maker's risk tolerance. Finally the Battle of Kursk example demonstrates how the model can be adapted to decisions on a strategic level as well as to decision at the tactical or operational levels.

The suggested model provides a framework for future thesis students to build upon by collecting data and validating the model for various warfare communities throughout the Department of Defense.

I. BACKGROUND

A. INTRODUCTION

Models of combat situations can provide valuable insights to military leaders at all levels. These models attempt to represent the various factors that can influence combat outcome. The capabilities and attributes of various units and weapons systems, such as accuracy and range, are documented and readily available for incorporation into such models. More difficult to define and represent are the purely human inputs into the combat equation. The high level of technology available to the U.S. military does not eliminate these elements. On the contrary, the rapid pace and information-rich nature of modern combat increases the complexity of decision-making for commanders and results in a greater need to take into account the human element.

Research in human behavior indicates that a variety of internal and external factors have the potential to impact the decision maker. Some of these issues such as training, experience, and level of fatigue can be directly impacted by outside influences, e.g., orders from a senior commander to require additional training or a rest period. While many of these factors are purely environmental and vary with the given situation, others are more constant and are part of the decision maker's own personality. Other factors such as emotional characteristics and values are inherent to the decision maker.

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B. HUMAN DECISION-MAKING IN COMBAT MODELS

The U.S. Military uses combat models and simulations for a variety of purposes. These purposes include training, mission rehearsal and analysis. In each of these cases the human element must be included for the model to be accurate. With this in mind, in 1996 the Defense Modeling and Simulation Office (DMSO) requested that the National Research Council study the representation of human behavior in military simulation. As a result, the Panel on Modeling Human Behavior and Command Decision-making conducted an eighteen-month study that directed attention to human behavior representation in models.

> The modeling of cognition and action by individuals and groups is quite possibly the most difficult task

> that humans have yet undertaken. Human behavior representation is critical for the military services as they expand their reliance on the outputs from models and simulations for their activities in management, decision-making and training (Pew and Mavor, 1998).

The Panel reported three overall concerns regarding the role of human behavior in combat simulation.

1. Human behavior representation is essential to successful applications in both wargaming and distributed interactive simulation.

2. Current models of human behavior can be improved by building on what is already known in the behavioral science, social science, cognitive science, and human performance modeling communities.

3. There is great potential for additional progress through the funding of new research and the application of existing research in areas of knowledge the panel explored. (Pew and Mavor, 1998)

A key element of the panel's report was its discussion of decision-making in combat simulations. The panel found that most combat simulations do not allow for any variability in decision-making, usually relying on scripted or deterministic decision-making processes. This inaccurate modeling results in simulations that lack the realism needed to be effective. According to the panel:

> Under Secretary of Defense for Acquisition and Technology has set an objective to "develop authoritative representations of individual human behavior"...Yet...users of military simulations do not consider the current generation of human behavior representations to be reflective of the scope or realism required for the range of applications of interest to the military (Pew and Mavor, 1998).

The panel found three serious problems with the representation of human decision-making in military simulations. One, as mentioned previously, these representations are too rigid and lack the flexibility and adaptability normal to the decision-making process. Two, the process does not incorporate factors such as fatigue, attitude towards risk, emotions and experience. These factors vary greatly from individual to individual and situation to situation. Lastly, these representations do not take into account biases or judgment errors. The panel proposed that correcting these discrepancies is an important goal for all combat models.

The OneSAF Modeling Infrastructure Team and TRADOC have an ongoing research project that supports modeling decision-making (i.e., command entity behaviors) for future military simulation and decision support. They are attempting to move beyond a traditional rational choice model to a more realistic model that includes elements of naturalistic decision theory and represents human factors. TRADOC has indicated an interest in the model proposed by this thesis as a possible component of this effort.

In his 2000 thesis, Major Posadas sought to represent the randomness inherent in human decision-making with a stochastic decision model. His work was an effort towards accomplishing the first overarching goal stated by the NRC Panel by creating a representation of human behavior. However, Major Posadas did not expand beyond the military perspective by incorporating what is already known in other fields about decision-making. While he did introduce randomness into the process he did not represent many of the other factors that can affect the process nor did he account for biases or judgment errors. This thesis will address these issues.

C THE ORIGINAL MODEL

The goal of Major Posadas' thesis was to develop an analytical model to represent a commander's decision process for command and control. In order to move past the traditional deterministic model, he developed an influence diagram (Figure 1) of the process that took into account the commander's attributes, and his or her perception of the situation.

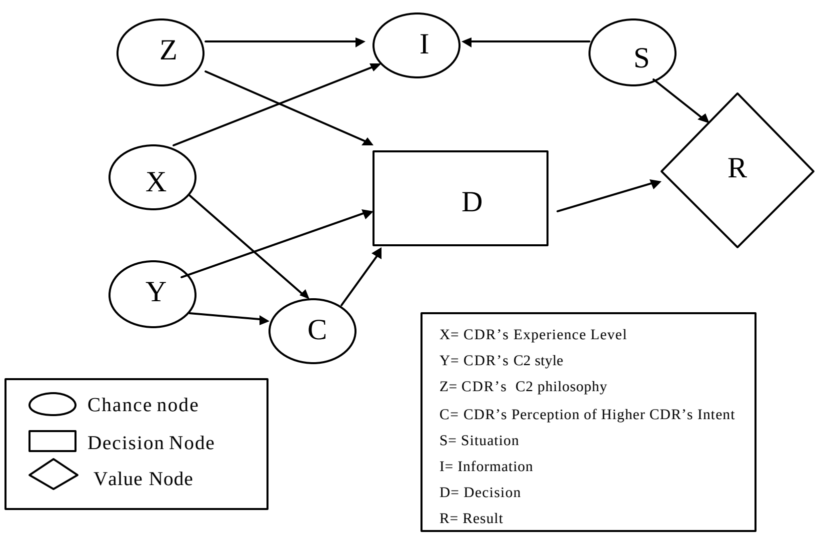

Figure 1-1 Influence Diagram of a Decision-Making Process

Major Posadas states:

> The influence diagram is ordered in time from left to right...The directed arcs indicate possible conditional dependence. The absence of an arc between

two nodes indicates possible conditional independence (Posadas, 2000).

In this diagram, first the commander's attributes are modeled. The commander's style impacts the probability of certain types of actions in a given situation. This style can range from aggressive to conservative. The commander's philosophy looks specifically at how the commander views command and control (C2). If the commander has more of a mission focus, he or she is more likely to make a decision without waiting for direction from a higher command. A commander's style and philosophy are combined to create a probability of a specific action. The third attribute in the model, experience, is an indicator of the time it takes the commander to make a decision. A less experienced commander is expected to take longer to process available information and reach a conclusion.

Once the commander's attributes are determined, the next factor in the model is the commander's perception of the higher command's intent. The basis for this factor is the tactical commander's reliance on their superior commander's intent to both focus their own decision-making goals and to assess the effectiveness of their decisions. The final factor that feeds into the commander's decision is his or her perception of the situation. The decision in Posadas' model was derived from the above factors using stochastic processes.

In addition to the model discussed above, Major Posadas tested a simple Bayesian network that did not include any of the commander's attributes. This model focused on the assessment of the situation, and consisted of three decision factor states. These included the condition of own forces, condition of enemy forces and the environment relative to own mission.

Major Posadas implemented his model in Java and evaluated it using a test scenario. Three measures of effectiveness (MOEs) were used. 1) Does the model arrive at realistic decisions? 2) Do the decisions support the higher commander's intent? 3) Is tactical decision-making represented realistically? The first MOE was purely subjective and Major Posadas evaluated model realism by comparing model outcomes with decisions typically made by tactical commanders. To evaluate the model's ability to represent higher commander's intent, Major Posadas compared the battle force ratio at the end of each simulation run with the stated commander's goal of a 1:3 ratio. To examine the realism of the model's representation of tactical decision-making, he considered the battle force ratio's relationship with the time required to complete the mission.

D. THESIS GOALS

This thesis will expand on the ideas in Major Posadas' model by:

1. Developing a model of the commander's decision-making process that addresses the issues raised by the Panel on Modeling Human Behavior and Command Decision-Making;
2. Providing a more detailed representation of the various factors involved in human decision-making; and
3. Justifying these factors with previous research from a variety of disciplines.

II. LITERATURE REVIEW

A variety of disciplines have explored the process of human decision-making and have developed models accordingly. These models range from rational choice theories such as utility theory, to more descriptive psychological models that focus more on the process of decision-making. Within these theories a variety of factors have been identified that have the potential to impact the decision choice. The model proposed in this thesis draws on several theories and attempts to provide a balance, capitalizing on the strengths of each.

A. THEORIES

The approach to decision-making that is most familiar to operations analysts is the concept of expected utility. Multi-attribute Utility Theory attempts to choose among alternatives with multiple attributes through a mathematical process. Two parameters are crucial to this theory, the conditional probability of the outcome of the alternative given the decision and the utility of the outcome to the decision maker. Using basic probability the "expected utility" of each option is evaluated. This assessment assumes the decision maker will correctly calculate this value and will logically choose the option that maximizes utility (Hammond et al, 1980).

A major weakness of this theory is the underlying assumption of decision maker rationality, as it does not allow for misperceptions or judgment errors (Hammond et al, 1980). If this assumption could be validated, there would be little need for development of additional models for combat simulations. The program could simply calculate the expected utility for a commander's choices and assume that the commander will always make the optimal choice. However, we know this assumption is not valid. The model proposed in this thesis attempts to minimize this issue by taking into consideration a variety of factors that have the potential to skew the decision maker's rationality. Expected utility theory does have advantages that are useful in developing a realistic model of decision-making that can be incorporated into combat simulations. Expected utility theory restricts its scope to the individual making a single decision at a single moment of time. This focus provides a framework that can be expanded upon by adding and modifying parameters that will result in a predictive model.

At the other end of the spectrum of decision-making theories are the "naturalistic theories". These theories focus more on how decision makers formulate an understanding of the problem situation and arrive at a chosen course of action. A unique aspect of the Naturalistic Decision-Making (NDM) theories is that they incorporate intuition and are based on observations of human decision-making in the real world, versus controlled conditions.

One example of a naturalistic decision theory is the Recognition Primed Decision Model (RPD) proposed by Klein in 1997. This model describes how experts make decisions under stressful situations, perhaps due to time pressure or rapidly changing environments. The decision maker uses expertise and experience to quickly assess the situation and to come up with an acceptable course of action. They then "play out" the course of action using mental simulation to see whether it is feasible or requires modification. If the first choice does not work, they will go back, select another option, and reevaluate the decision.

In RPD, experience allows a decision maker to see a situation, even a non-routine one, as an example of a prototype so that he or she knows the typical course of action right away. Experience allows a decision maker to identify a reasonable course of action as the first option considered. A good example is an infantry commander faced with an enemy assault. He will quickly recognize what to do and act accordingly, although the situation may change rapidly. He will have to stay on top of the situation, perhaps changing priorities on the fly. One aspect of RPD is that the expert can quickly rule out unimportant information or unusable solutions, almost on a subconscious level, whereas a novice would need much more time to explicitly think through all possibilities.

Some characteristics of RPD include:

1. Most of the time is spent in situation assessment until possible responses are defined;
2. RPD relies heavily on expertise;
3. The decision maker uses knowledge from previous experience in similar situations to infer behaviors or attributes from the observed cues; and
4. As long as uncertainty is minimal, decision-making takes place by simple pattern matching (Klein, 1997).

RPD and the other naturalistic decision-making theories are descriptive in nature. Because of their descriptive nature, they provide a more realistic representation of human decision-making than the rationally based models. However these models do not provide quantitative results that can easily be incorporated into a combat model. In addition the treatment of risk in RPD models is very abstract.

B. FACTORS

There is a vast body of research that looks at the impact that various factors have on the decision-making process. Some of these factors are in place long before the time of the decision. These can be internal attributes such as personality or cultural values. Others are external, such as expertise, and have been developed throughout the commander's career. Of course, situational factors also have an important role to play. Situational factors can include stress response factors such as the personal environment and information flow, or internal factors such as a commander's emotional state.

Figure 2-1 provides a classification of these various factors.

	Internal Factors	**Externally Influenced Factors**
Inherent to the decision maker	Personality traits	Professional factors
Determined at the time of event	Emotions	Environmental /Stress factors

Figure 1. Division of Factors

1. Factors Inherent to the Decision Maker

a. Internal Factors- Personality

One of the most difficult challenges in psychology is the measurement of personality. The major problem is that there is no clear consensus as to what defines personality. Having a single validated scale to measure personality is difficult if not impossible. Various researchers have proposed different definitions and scales. There seems to be an agreement that personality can be modeled as a five-factor scale, but which particular five factors varies from theorist to theorist. One popular version that has been validated in a variety of settings is the five-factor scale used by Barrick and Mount in 1991. Originally designed for use in job placement, their scale cites five factors that can be used to define personality and predict an individual's success in a particular job. These five factors are listed below.

Openness is a measurement of curiosity, creativity and original thinking.

Conscientiousness deals with an individual's ability to be organized, reliable, dedicated and self-disciplined.

Extrovertism is a measure of social behavior and includes traits such as talkative, optimistic and fun loving.

Agreeableness measures how good-natured and trusting an individual is.

Neuroticism is a scale for nervousness and worrying behavior. (Barrick and Mount, 1991)

In his ***Crucial Decisions: Leadership in Policy Making and Crisis Management (1989),*** Irving Janis suggests that in the case of command behavior, only three of the five traits are needed for understanding and prediction. He argues that openness, conscientiousness, and neuroticism can explain most executive decision-making and that an individual's scores in these areas can predict weaknesses in their leadership. The trait of extrovertism might indicate how charismatic a leader is, but does not play a role in the decision process. Likewise agreeableness can give some indication of how well the decision maker relates with others, but it may have little impact on a commander's choice during combat operations (Janis, 1989).

Janis hypothesizes that someone who scores low in conscientiousness has a tendency to miss warning signs of a potential problem. On the other hand, a decision maker with a high score on the conscientiousness scale tends to accurately perceive potential risk. A low score in openness results in a decision maker who tends to stick to routine or established procedures. An open decision maker tends to make decisions based on the situation at hand. Neuroticism indicates the level of self-confidence of a decision maker. A person scoring high on Neuroticism has the potential to ignore risk while a low scorer may avoid risk at all cost.

b Cultural Values

Many behavioral scientists that have studied military issues believe that cultural values have an important impact on behavior. Unfortunately, most of the research in the area of cultural values does not apply to modern military operations. Most military-specific studies of cultural values focus on pre-industrial societies, while more modern studies of cultural values tend to focus on commercial operations or educational settings. The Panel on Modeling Human Behavior and Command Decision-Making concluded that at this time there is not enough evidence to define a clear effect of cultural values on modern military decision-making (Pew and Mavor, 1998).

c. Intuition

A variety of sources discuss the concept of intuition. In *The Logic of Intuitive Decision-making,* Weston Agor refers to intuition as a highly rational decision-making skill, one in which the steps to process are hidden in the subconscious part of the mind. He argues that intuition is the product of both factual and feeling cues. Agor studied over 3000 individuals in leadership positions in a variety of organizations to determine the role intuition played in their decision-making process. Among his sample were 50 military personnel. Using a combination of the Myers Briggs Type Indicator and questions developed specifically for his study, he was able to provide a score for intuitive ability and a measure of how much an individual uses that ability.

Agor concluded that intuitive ability and usage of that ability varies by organizational level, and occupational specialty. Individuals with higher positions in an organization tended to have higher intuition scores. His study also indicated that women scored statistically higher on intuition than men in every occupational specialty. The military sample scores were about average when compared to the overall population with a mean score of 5.1 out of a possible twelve (Agor, 1986).

When the data were examined by experience level, a strong positive correlation was seen between experience and level of intuition in all of the occupational specialties including the military. This conclusion is further validated in Klein's work “Intuition depends on the use of experience to recognize key patterns that indicate the dynamics of the situation” (Klein, 1997).

d. External-Professional Factors

Training, education and experience combine to form a decision maker's level of expertise. In *The Psychology of Experts,* James Shateau identifies nine unique qualities that a high level of expertise brings to decision-making:

1. Experts have more highly developed perceptual and attention abilities. An expert can extract information that non-experts overlook.

2. Experts have a better ability to determine what information is relevant to the decision.

3. A high level of expertise increases the decision maker's ability to simplify complex problems.

4. An expert has the ability to communicate his or her expertise.

5. The expert has more developed skills for handling adversity.

6. While decision maker's at all levels of expertise have the ability to follow established strategies when the problem is straightforward, an expert has a greater ability to adapt to exceptions.

7. Experts have a strong level of self-confidence.

8. Experts know how to adapt their strategies to changing conditions.

9. Expertise tends to result in a higher level of certainty once the decision is made.

2. Factors determined at the time of Decision

a. Internal- Emotion

Over the past ten years, neuroscience and experimental psychology have demonstrated that emotions play a measurable role in the human decision-making process. Researchers have looked at both pre- and post-decision effects for various emotional states. Since the goal of this thesis is to model a single decision, only pre-decision effects will be considered here.

Isen argues that positive emotions increase creative problem solving and facilitate the integration of information (Isen, 1993). On the other extreme, negative emotion can produce a narrowing of attention and a failure to search for new alternatives (Fiedler, 1988). In addition, individuals in a negative mood make faster and less discriminate use of information.

The challenge with including emotion in a decision-making model is to determine an appropriate scale or series of scales to represent emotion. One proposal is a two-dimensional model of affect, based on pleasantness and arousal. Individuals in pleasant moods deliberate longer, use more information, and reexamine more information than others. Individuals in aroused states tend to take more risks (Lewinsohn and Mano, 1993). Those who are aroused and in unpleasant moods employ simpler decision strategies and form more polarized judgments. This two-factor approach provides adequate scope for the model proposed by this thesis.

b. External Stressors

Several situational factors have the potential to raise the decision maker's stress level. There is ample evidence that stress has a direct impact on decision-making ability. In 1980, D. F. Bordin studied combat infantry officers and non-commissioned officers to determine the impact stress has on performance. He concluded that stress may divert the leader's intellectual effort from the decision-making task, which in turn may affect his or her ability to communicate and process information (Fielder, et al, 1992). This lowered ability to process information decreases the decision maker’s ability to accurately perceive the situation. This leads directly to the conclusion that stress can erode a decision maker's ability to accurately perceive the risk inherent in a situation. In addition a decision maker's evaluation of how much risk is acceptable can also be affected. Concurrent thesis work at NPS by Captain Sakura Therrien examines environmental stressors in greater detail.

3. Risk

Risk plays a role in many decision-making theories and must be included in any model of combat decision-making. Traditionally, objective measures of risk are difficult to define and measure because in many cases, risk varies with the dangers and uncertainties of life. For example, between 1950 and 1970, coalmines became less risky in terms of deaths from accidents per ton of coal, but riskier in terms of accidents per employee (Wilson and Crouch, 1982). Was coal mining riskier in 1950 or 1970? Likewise, there is no single, objective definition of safety. For example, airline safety can be measured on many dimensions, including the percentage of flights ending in accidents relative to total number of flights and the percentage of traveler deaths relative to total number of travelers.

Further complicating the issue, rational choice models and descriptive models have explained risk in distinctly different ways. Rational choice theorists see the decision maker as balancing potential return with risk. In this case, risk is defined by a random variable with some known distribution. In the case of utility theory, the decision maker uses this distribution to compute the expected utility of each choice. Naturalistic Decision-making (NDM) theories, on the other hand, believe that a decision maker evaluates the risk in the situation through the filter of his or her motivations. The decision maker may not actually know the distribution of the possible outcomes, but will make choices based on his or her priorities. For instance, a commander who places a high value on avoiding casualties will select the course of action that does not expose his troops to enemy fire (Lopes, 1997).

A decision maker develops two assessments related to risk that will play a role in the final decision. The first is the decision maker's perception of the risk inherent in the situation, or simply risk perception. A decision maker's willingness to choose risky alternatives is his or her level of risk acceptance (Mellers, et al, 1998). These assessments occur in both rational choice and NDM theories. The differences between the two are in how the decision maker uses the assessments in the decision-making process.

Both risk perception and risk acceptance are internal processes of the decision maker. Therefore they have the potential to be affected by all of the factors discussed above. While there is no one single theory or explanation that models human decision-making, there is sufficient evidence of the effects of these various factors to develop a model of sufficient resolution for use in combat simulations.

III. MODELING CONSIDERATIONS

As discussed in the previous chapter, there are a variety of factors that go into decision-making. The challenge is to blend these factors into a comprehensive model that can be easily adapted for use in combat simulations. Like Posadas' model, the model developed by this thesis looks at a single operational decision made by a commander during combat operations. In addition to the factors discussed previously, the model must include reasonable inputs that would be available to a military commander in the situation. This chapter details the source of these inputs, discusses some limitations on scope of the model and proposes a Bayesian network/influence diagram as an appropriate graphical representation of the commander's decision-making process.

A. MILITARY INPUTS

The factors discussed in the previous chapter have the potential to impact how the commander processes information received to reach a final decision. Much of the information used to make a decision in modern combat will come from outside sources. In addition, the commander's goals will most likely be shaped by his or her perception of the intent of higher authority.

In Posadas' previous model these issues were addressed by using two nodes: information and command intent. The information node provided a status of the situation, while the command intent node provided information on the goals of higher authority. This model will deal with these issues in a similar fashion. A node that reflects the actual risk of the situation replaces the information node. A model currently under development in a thesis by CPT Therrien will provide a concise input for this node. The command intent node will be replaced by command risk acceptance, which will be discussed in greater detail in the next chapter.

B. LIMITS OF SCOPE

As mentioned earlier, this model considers only a single decision made by an individual commander during combat operations. These limitations are established in an attempt to balance conflicting requirements. On one side, sufficient detail is needed to accurately represent the human decision-making process. However, the model must deal with the challenges involved in representing this model as part of a much larger combat simulation. Where possible, an attempt was made to maintain generality, so that this model can be adapted to represent a variety of military communities.

C. BAYESIAN NETWORK

In order to capture the variety of conditional relationships between variables affecting decision-making, a Bayesian network is used as a modeling tool. By definition a Bayesian network consists of a set of variables and a set of directed edges between these variables that come together to form a directed acyclic graph. Since the graph is acyclic there is no directed path that creates a continuous cycle in the graph. For example, in the model proposed, it is possible to find a directed path from every factor to the decision, but it is not possible to find a directed path in the opposite direction (i.e., from the decision to each factor).

The variables in this model are either factors that influence the decision (inputs from outside the model) or conditional variables that are derived from these inputs. Each variable has a finite set of states, also referred to as the “state space”. A variable or node that only has arrows (directed edges) leaving the node is an example of a factor that is input from outside the model. Nodes directly relate to the factors discussed in Chapter Two. If a node has directed edges coming into the node, then that node is a conditional variable and the probability of a particular outcome is conditional on the outcome of the other nodes that feed into it. In other words if variable A has two directed edges coming into it from variables B and C, then variable A is conditional on B and C. ($P(A|B,C)$). In a Bayesian network, all variables have a probability table attached. In the case of variables conditional on other variables, a more complex conditional probability table is required.

While the use of a Bayesian network is an effective way to represent the interrelated nature of the conditional probabilities inherent in decision-making, the proposed model goes beyond a traditional Bayesian network to include a complex treatment of utility. The individual variables and their relationships will be discussed in greater detail in the next chapter. The model proposed in this thesis is a complete influence diagram that includes both a decision node and a utility node.

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IV. THE GENERAL MODEL

The influence diagram pictured in Figure 4-1 is a general representation of the proposed model. Nodes represent individual factors that have the potential to impact the decision-making process. As discussed in the previous chapter, the arrows represent a conditional relationship. The details of each node follow.

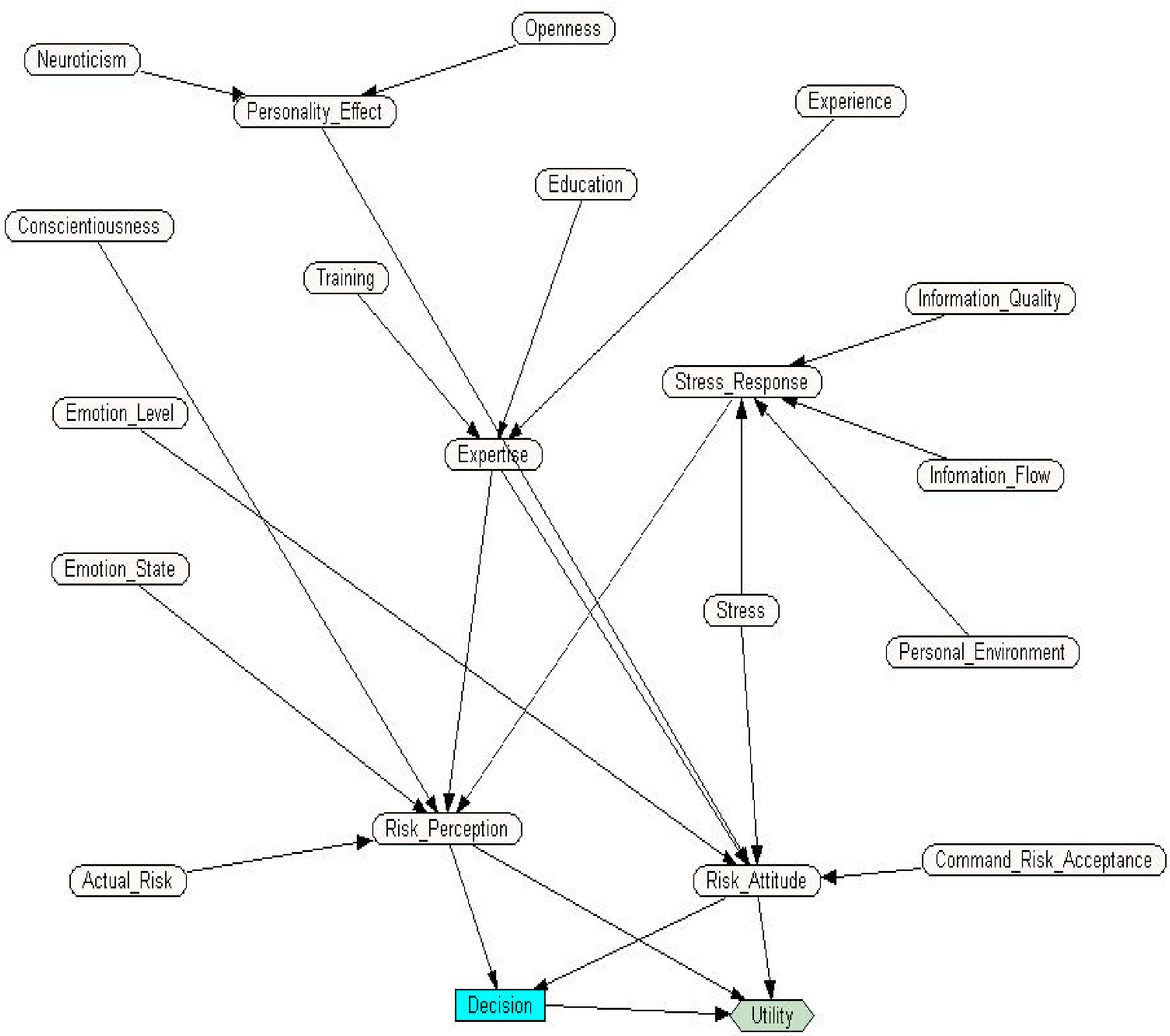


Figure 4-1 General Model of Commander's Decision-Making

A. FACTORS INHERENT TO THE DECISION MAKER

1. Internal Factors- Personality

Four nodes represent Personality Factors: Openness, Conscientiousness, Neuroticism and Personality Effect. Measurements for these nodes can be determined using any form of the NEO Personality Test.

Conscientiousness is a measure of the decision maker's ability to be organized, reliable, dedicated and self-disciplined. The state spaces for the Conscientiousness Node are high, medium and low. If the Neo Personality Test five-point scale is used, a score of one equates with a state space of low, two or three equates to medium and a score of four or five equates to high. Conscientiousness affects Risk Perception. A decision maker with a medium to high score in this factor is likely to correctly perceive risk. Having a low score makes a decision maker more likely to miss warning signs and therefore more likely to underestimate risk.

Neuroticism also affects risk acceptance. It is a measure of nervousness and worrying behavior. A high score on Neuroticism is associated with low self-confidence. A decision maker scoring high in Neuroticism tends to avoid risk, and a low scorer may seek out risk.

Like Neuroticism, Openness affects the Risk Assessment node. Openness is a measurement of curiosity, creativity and original thinking. An open decision maker is more willing to consider options he or she may not have used before, while a non-open decision maker will not accept risk or untried options. The Personality Effect node is dependent on Neuroticism and Openness and is used only to simplify the modeling process.

2. Professional Factors

The Expertise, Education, Training and Experience nodes address the professional background of the decision maker. The Expertise node is dependent on the Education, Training, and Experience nodes. Expertise affects both Risk Assessment and Risk Perception. The state spaces for Expertise are high, average, low, and none. A higher level of Expertise results in a higher level of Risk Acceptance and a better match between Risk Perception and Actual Risk.

The Education node measures the level of general academic accomplishment. State spaces are defined as High school, Bachelors degree, and Masters degree. Training is a measure of skill-specific training that prepares the decision maker for his or her specialty. The state spaces for this node will vary depending on the military occupation specialty (MOS) being modeled. Experience is simply a measurement of how much time a decision maker has spent working in the type of environment in which the decision is being made. State spaces for Experience are high, medium, and low, or the state spaces can be specifically defined by the group being modeled. For example when modeling infantry commanders, Experience may be expanded to include time in actual combat, as well as time in the service. These three nodes combine to define the Expertise score. By referring to the decision maker's service record one can easily capture the additional data needed for the model.

B. FACTORS DETERMINED AT THE TIME OF DECISION

1. Internal- Emotion

There are two Emotion nodes included in the model, Emotion State and Emotion Level. Emotion State refers to mood of the decision maker. The state spaces for this node include positive, neutral or negative. A decision maker in a positive state is more likely to accurately perceive risk. Emotion Level refers to the amount of emotion, either positive or negative, that the decision maker feels at the time of the decision. The state spaces for this node are high, normal, and low. A higher level of emotion results in a higher level of risk acceptance. Both emotion nodes can be measured by a subjective test after the decision is made.

2. External Stressors

Five nodes describe the external stressors that a decision maker experiences at the time of decision. These five nodes include Stress Response, Stress, Personal Environment, Information Flow, and Information Quality. Stress Response is dependent on the other four nodes, and has three state spaces (high, medium and low). A decision maker with a medium Stress Response will have better Risk Perception than one with a low or high Stress Response.

Stress affects both Stress Response and Risk Attitude. The model currently under development by CPT Therrien determines inputs for the Stress node. The higher the Stress rating, the higher the Stress Response level. A high level of stress will also result in a lower Risk

Acceptance. A low level of Stress may lead a decision maker to be more willing to accept risk.

Personal Environment refers to the physical effects of the environment on the decision maker. These effects can include extremes in temperature and difficult terrain. A positive Personal Environment results in low Stress Response while a negative Personal Environment increases Stress Response.

Information Flow measures the amount of information a decision maker receives. The five state spaces of this node are overload, high, medium, low, and none. Extremes on either end of this spectrum raise the Stress Response level. Information Quality refers to effectiveness of the information received. Information Quality can be high medium or low. The higher the quality of information received the lower the level of Stress Response.

C. SITUATION NODES

Several nodes deal with outside factors that the decision maker deals with at the time of the decision. These factors include Command Risk Acceptance, Threat, Time and Actual Risk. Command Risk Acceptance is the willingness of the higher chain of command to accept risk. A high level of Command Risk Acceptance increases the decision maker's willingness to accept risk. Threat is an optional node that stores the probability that a contact is a threat. Time describes any time constraints on the decision. Actual Risk is the real risk of the situation and impacts the Risk Perception node. The model under development by CPT Therrien models Actual Risk.

D. RISK

Two nodes describe the decision maker's relationship with risk. Risk Perception describes how much risk the decision maker believes is involved in the situation, and is dependent on Conscientiousness, Experience, Stress Response and Emotion State. Risk Acceptance describes the decision maker's willingness to tolerate risk. The state spaces for Risk Acceptance include risk seeking, neutral and risk averse. Risk Acceptance is dependent on Emotion Level, Stress, Personality Effect, Experience, and Command Risk Acceptance.

E. DECISION AND UTILITY

The Decision node is conditional on Risk Perception, Time, and Threat. The state spaces for the Decision node are the Courses of Action (COA) available to the decision maker. The Decision node affects the Utility node.

Risk Acceptance, Threat, Time and the Decision node affect the Utility node. The Utility node provides the value to the decision maker for each possible outcome. Using this information, the Decision node calculates the expected utility using the following equation:

$$E(U_{COA})=\sum_{rp} \sum_{ra} (P(RP)* P(RA)* U_{rp\ ra\ coa})$$

RP= Risk Perception Levels RA= Risk Acceptance Levels

$U_{rp\ ra\ coa}$= U(x) for the COA/RL/RA combination

The Decision is the COA that scores the highest or lowest expected value depending on how the individual decision is framed. Great care must be taken in defining the Utility node to avoid framing errors. An individual's

Risk Attitude can change depending on how a decision is posed. The problem is that a decision may be posed in several different ways. A change in Risk Attitude may change the outcome. This change in attitude results from the different points of reference used by the decision maker to frame the problem in different cases. Research has shown that decision makers tend to be risk averse in dealing with gains while in contrast, they tend to be risk seeking when dealing with losses. Great care must be taken when applying the model to avoid unintentionally skewing the decision (Clemen, 1996).

F. NODES NOT INCLUDED IN MODEL

Several possible variables were considered for inclusion but ultimately rejected from the model. This exclusion occurred because the node's impact was already incorporated through existing nodes or because there was no documented measurable impact on the decision. Because of the strong positive correlation between expertise and intuition, a separate node for intuition was left out. A variable dealing with cultural values was rejected due to lack of evidence that it affects the decision at the combat level modeled. If the model were on a different scale, such as a political decision, this node would need to be reconsidered. Similarly the variable of gender was also excluded. While an argument can be made that in the general population, gender plays a role in dealing with risk, the limited population from which combat commanders are drawn eliminates this difference. The personality traits of Extrovertism and Agreeableness were rejected because they do not play a role in combat decision-making.

The interactions between the factors in this model are demonstrated in the next chapter through three historical scenarios.

V. CASE STUDIES

In order to illustrate how the model represents the human decision-making process, several case studies are considered. In each of the cases below precise standardized personality test results were not available on the historical figures in question. Estimates on the appropriate state spaces were made based on available documentation.

A. CASE 1: TASK FORCE SMITH

Task Force Smith is widely recognized as the first American combat maneuver force to engage the enemy during the Korean War. In June of 1950, LTC Smith was commander of the 1st Battalion, 21st Infantry Regiment, 24th Division, stationed in Japan.

On June 25, the North Korean army had invaded South Korea by crossing the 38th Parallel. These forces were marching quickly through the capital, Seoul, on their way to the southern coast city of Pusan and total victory. In an attempt to buy time for other forces who were proceeding by boat, Smith took his task force by plane to Pusan. His orders were to fight a delaying action, break the enemy's momentum and allow more units to arrive in South Korea. Also, he was to send a clear message to the North Koreans that the United States was going to be part of the fight. In order to meet the enemy as far north as possible, TF Smith boarded trains and made it as far as Taejon before heading on by truck to a point about three miles north of Osan, where they deployed July 5th and waited for the enemy. There were 406 members of Task Force Smith waiting to face an enemy that would eventually number over 20,000 (Fehrenbach, 1994).

History has documented the tactics of the battle. The concern here is the ability of the proposed model to illustrate the human decision-making process. At the beginning of the battle LTC Smith made the decision to follow his orders and engage the oncoming Korean army. The influence diagram below shows the model applied to LTC Smith at the beginning of the operation.

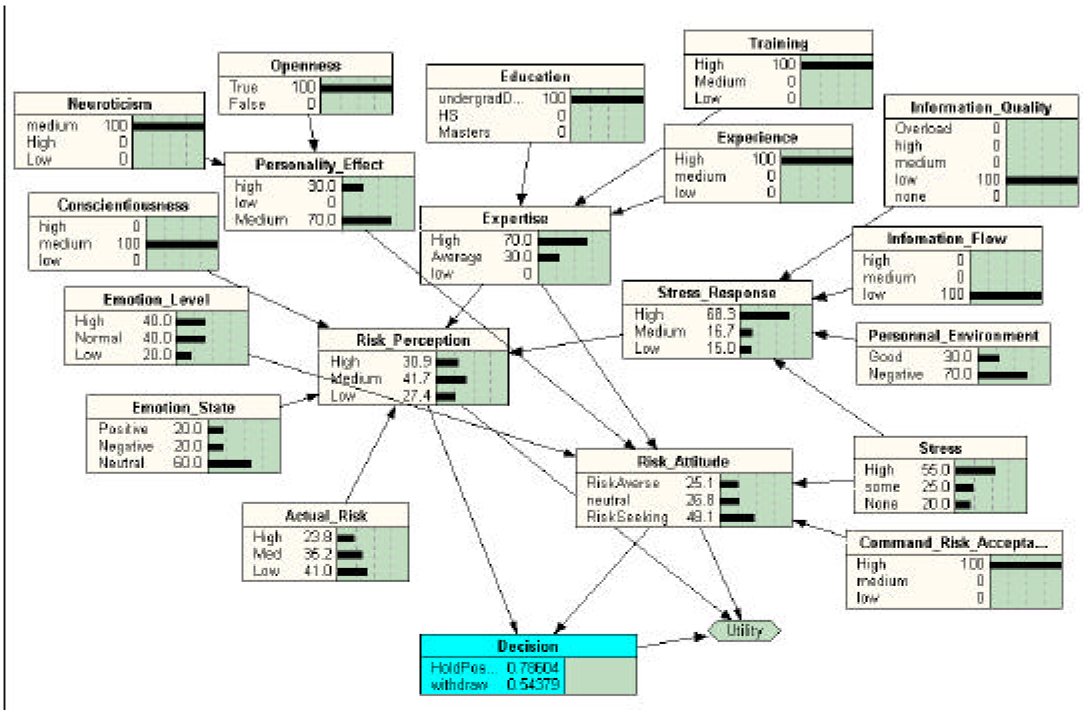


Figure 5-1 Task Force Smith At The Beginning Of The Operation

The model assumes that LTC Smith had medium scores in both Neuroticism and Conscientiousness. The Neuroticism score indicates he was a balanced individual with an average level of self-confidence. The fact that he was comfortable dealing with details with out being obsessed by them leads to the medium score in Conscientiousness. In addition, he had on an open personality, and was willing to consider other points of view. Since these scores are in the middle of the scale, his personality did not have a great effect on his risk perception or his risk acceptance.

A West Point graduate, LTC Smith's education was at the undergraduate level. Due to his participation in WWII his training and experience were high. These three traits combined for a relatively high expertise score, which resulted in a greater willingness to accept risk and a more accurate perception of risk.

There is little doubt that LTC Smith was going into a very stressful situation. His situational stress level as modeled by CPT Therrien's model was high. Information was a problem as both information flow and quality were low. LTC Smith's personal environment was poor but not as negative as it would be later in the operation. These factors combined for a stress response probability of 97 high.

The actual risk of the operation, as provided by CPT Therrien's models, was mixed. The command's willingness to accept risk due to strategic requirements was very high, which affected LTC Smith's risk acceptance. At the beginning of the operation his emotions were mixed, with his emotion state and level scores in the middle range. On one hand, LTC Smith was a combat veteran calmly facing the upcoming combat operations while on the other hand he knew that he was facing the initial battle of the Korean War which resulted in his experiencing relatively more intense emotions. The above factors combined for a slight tendency to be risk seeking. The Risk Perception node yielded a 41.7 percent probability that the risk was medium.

Utility values for the each option at each level of risk were calculated using the utility curve in Figure 5-2.

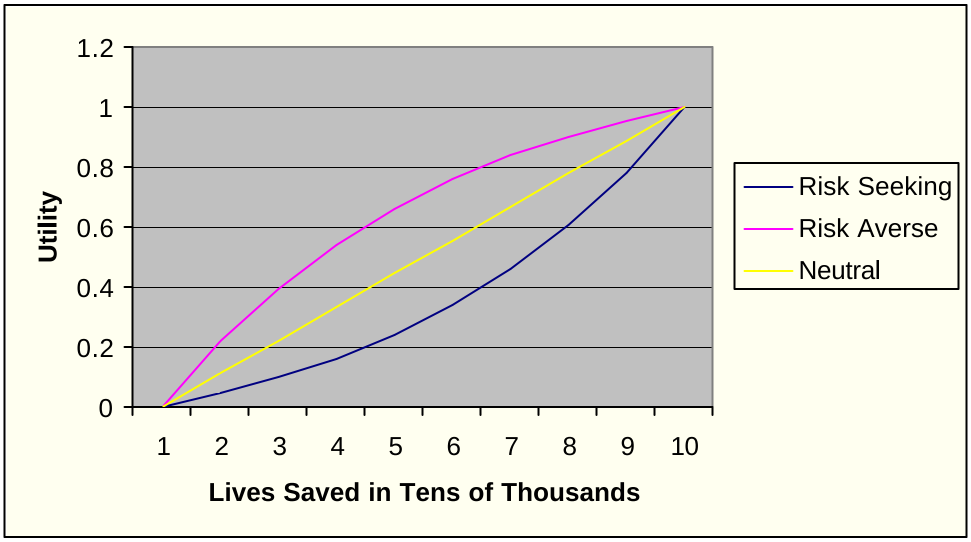


Figure 5-2 LTC Smith's Utility Curves

Note for each possible risk acceptance state space there is a separate curve. The utility curve for risk averse and risk seeking were computed using the following formula:

$$U(x)= \frac{1-\exp[-(x-low)/\rho]}{1-\exp[-(high-\ low)/\rho]}$$

The variable x represents changes in the number of lives saved. High and low are the high and low values of x. A subjective value ρ is used in both formulas to capture the nature of how the decision maker views potential utility. A negative value of ρ results in a Risk Seeking curve and a positive value of ρ indicates Risk Averse. In this case these values were set at -5 for Risk Seeking and 5 for Risk

Averse. For the risk neutral curve, the following formula was used:

$$U(x)=\frac{x-low}{high-low}$$

Both of the formulas above are designed for situations where utility is monotonic and increasing. Table 5-1 provides the resulting utility values for the six possible Risk Perception/Decision combinations for each Risk Attitude State Space.

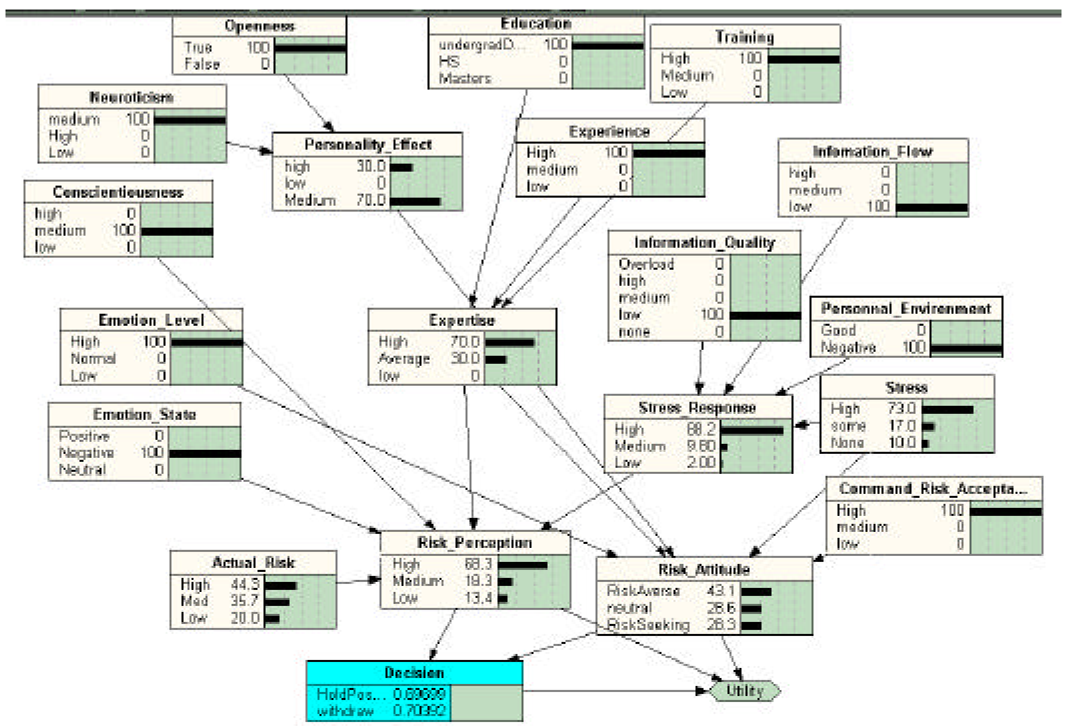
Risk Attitude	**Decision**	**Risk Perception**	**Utility Value U(x)**
Risk Averse	Hold Position	High	0.757302
Risk Averse	Hold Position	Medium	0.956155
Risk Averse	Hold Position	Low	1
Risk Averse	Withdraw	High	0.902602
Risk Averse	Withdraw	Medium	0.757302
Risk Averse	Withdraw	Low	0.659722
Neutral	Hold Position	High	0.555556
Neutral	Hold Position	Medium	0.888889
Neutral	Hold Position	Low	1
Neutral	Withdraw	High	0.777778
Neutral	Withdraw	Medium	0.555556
Neutral	Withdraw	Low	0.444444
Risk Seeking	Hold Position	High	0.340278
Risk Seeking	Hold Position	Medium	0.782833
Risk Seeking	Hold Position	Low	1
Risk Seeking	Withdraw	High	0.605032
Risk Seeking	Withdraw	Medium	0.340278
Risk Seeking	Withdraw	Low	0.242698

Table 5-1 Utility values for Task Force Smith

The computed expected value for the decision options utilities was determined using the procedures discussed in Chapter 4 Paragraph E. This results in the choice "holding position" as the optimum choice with an expected utility of .748.

As the battle progressed factors that are determined at the time of the battle changed resulting in the following diagram.

Figure 5-3 Task Force Smith at the Time of the Withdrawal



Now the resulting optimal decision is to withdraw with an expected utility of .707. Note that while personality and expertise related nodes remained constant, emotion and stress response nodes have different state spaces from the initial model. This is due to the strain of the ongoing operation, which increased the stress and emotion levels. As the casualty count increased, LTC Smith's emotion state became more negative. This results in changes in both risk perception and risk acceptance, which changes the final outcome. This mirrors actual events as LTC Smith ordered a withdrawal late in the afternoon.

B. CASE 2: MIDWAY

The Battle of Midway, fought over and near the tiny U.S. mid-Pacific base at Midway atoll, represents the turning point of the war in the Pacific. Prior to this action, Japan maintained general naval superiority over the United States and could usually choose where and when to attack. After Midway, the two opposing fleets were essentially equals, and the United States was able to take the offensive.

RADM Raymond Spruance commanded Task Force 16, which over the course of 3 days was able to inflict critical damage on the Japanese fleet. The Japanese lost the four large carriers that had attacked Pearl Harbor, while the Americans lost only one carrier. More importantly, the Japanese lost over one hundred trained pilots, who could not be replaced due to their inefficient pilot selection and training procedures.

Figure 5-4 provides the influence diagram for RADM Spruance's decision to pursue the Japanese at the beginning of the battle.

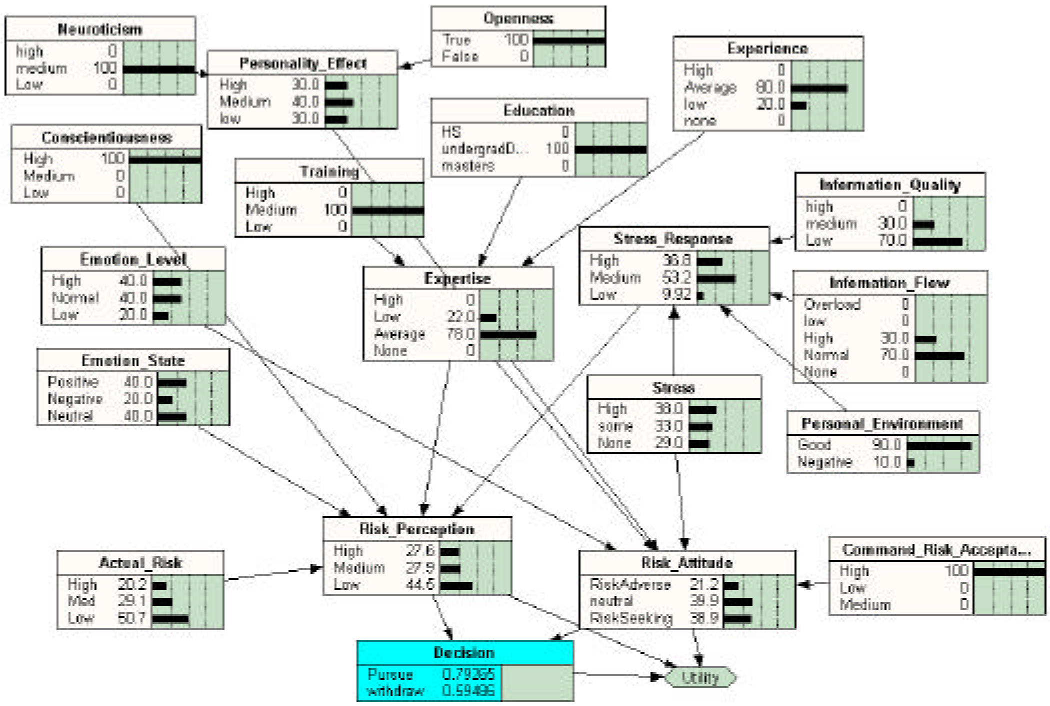


Figure 5-4 RADM Spruance's Decision at the Beginning of the Battle of Midway

The following excerpt from the official biography of RADM Spruance from the Navy historical archive provides some justification for many of the factors discussed in the model.

> RADM Raymond Ames Spruance graduated from the U.S. Naval Academy Graduation. Having served in battleships, destroyers and cruisers through his whole career, Spruance assumed command of a cruiser division at the time of the Japanese attack on Pearl Harbor in 1941. In this office, Spruance supported Admiral Halsey's carrier *Enterprise* during the early 1942 carrier raids, including shelling of Wotje, Maloejap, Wake and Marcus Islands. Later, he escorted the task force conducting the Doolittle Raid. As the battle of Midway approached, ADM Halsey became ill and, appointed Spruance as his replacement as Commander, Task Force 16, *Enterprise* and *Hornet* despite his lack of carrier experience. In the carrier staffs concern arose over the Admiral's battleship consciousness.

> Spruance, under the nominal command of Rear-Admiral Fletcher, led his carriers expertly with the help of Commander Browning, Halsey's Chief-of-Staff, and justly received a large part of the praise for the US Navy success in the battle.
> A quiet, shy and intelligent officer, Spruance was the ideal man to lead the Navy in the Central Pacific, despite the problems he sometimes had with naval aviation. He was always quite interested in the opinions of his staffs, and would stand to his decisions. Precise and calculating, he was even better a planner than a combat leader. With due respect to Halsey, it must be said that of the two, Spruance rated higher for Fleet Admiral promotion, for he was a better commander, an admirals' admiral, not a sailors' admiral as Halsey.

Based on his biography, the assumption is made that RADM Spruance had an average score in Neuroticism. While he was self-confident he was not overly egotistical. He was known for his openness to ideas presented by his staff, hence the model assigns a 100 percent probability that the Openness node state space is yes. This resulted in a medium Personality Effect, which affected the Risk Attitude node. In this case the medium range of the Personality Effect tends to pull the RADM's Risk Attitude toward the center for a neutral state space. Records also indicate that RADM Spruance was "precise and calculating," resulting in a Conscientiousness score of high. His high score in Conscientiousness impacted his Risk Perception. Like all individuals with a high Conscientiousness score, RADM Spruance’s insistence on understanding details ensured that his perception of the risk in the situation closely mirrors the actual risk involved.

RADM Spruance graduated from the United States Naval Academy so his Education state space is undergraduate. His training and experience scores are mixed. On one hand RADM Spruance had an extensive background as a cruiser commander, which would normally result in high levels of Experience and Training. In the case of the battle of Midway, where aircraft carriers played a key role and were among RADM Spruance's responsibilities knowledge of Naval aviation becomes part of the nodes contributing to expertise. As the biography above indicates, he had little exposure to the carrier navy, which degrades both Experience and Training, and directly leads to 78 percent probability that RADM Spruance’s overall expertise is average. This average Expertise score lowers the accuracy of Risk Perception slightly and results in a more cautious level of Risk Attitude.

RADM Spruance was viewed as a calm, levelheaded leader, and accounts of the battle indicate that his Emotion Level and State avoided extremes (Prangue, 1983). This results in little effect by the two emotion nodes on the decision process, both at the beginning and end of the battle.

The nodes related to Stress Response can be drawn directly from accounts of the battle. His personal environment shipboard was fairly good and did not significantly add to his personal Stress Response. Through the various air patrols launched from the task force, Information Flow ranged from to high. However RADM Spruance was very aware that the quality of information he was receiving on the opposing fleet was low to medium quality at best which increased the level of Stress Response. The Stress node as defined by CPT Therrien's model was at high, which increased the level of Stress

Response and reduced the willingness to accept risk. The overall Stress Response level was medium to high which increased RADM Spruance's perception that the risk inherent in the situation was high.

Due to strategic concerns the higher chain of command was extremely willing to tolerate risk at this time. RADM Spruance hovered between a risk seeking and a risk neutral Risk Attitude.

The utility curves were plotted using the same method discussed in the Task Force Smith case.

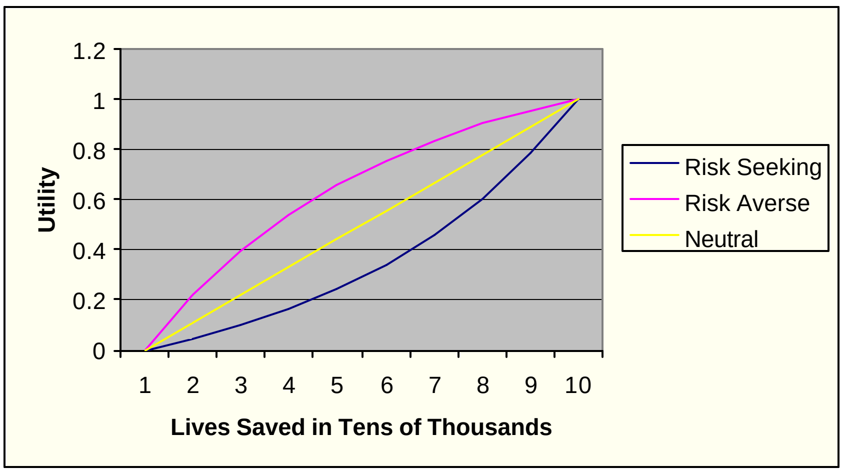


Figure 5-5 RADM Spruance's Utility Curves

Since there is no evidence that there was any extreme skew to how RADM Spruance perceived the possible utilities the subjective ρ is again defined as -5 for the risk seeking curve and +5 for the risk averse. The expected value of the options is defined as the expected American lives saved in the ten thousands and again ranges from 1 to 10. Table 5-2 provides the utility values for the six possible Risk Perception/Decision combinations for each Risk Attitude State Space.

Risk Attitude	Decision	Risk Perception	Utility Value U(X)
Risk Averse	Pursue	High	0.902602
Risk Averse	Pursue	Medium	0.956155
Risk Averse	Pursue	Low	1
Risk Averse	Withdraw	High	0.837193
Risk Averse	Withdraw	Medium	0.757302
Risk Averse	Withdraw	Low	0.659722
Neutral	Pursue	High	0.777778
Neutral	Pursue	Medium	0.888889
Neutral	Pursue	Low	1
Neutral	Withdraw	High	0.666667
Neutral	Withdraw	Medium	0.555556
Neutral	Withdraw	Low	0.444444
Risk Seeking	Pursue	High	0.605032
Risk Seeking	Pursue	Medium	0.782833
Risk Seeking	Pursue	Low	1
Risk Seeking	Withdraw	High	0.459461
Risk Seeking	Withdraw	Medium	0.340278
Risk Seeking	Withdraw	Low	0.242698

Table 5-2 Spruance's Utility Values at the Beginning of the Battle

In this case the optimal decision is to pursue with an expected utility of .793.

As the battle drew to a close in the afternoon of July 6th RADM Spruance knew that the U.S. had inflicted a great deal of damage on the Japanese fleet, but several ships were still in the area. While the U.S. held a clear advantage, continued pursuit would bring the U.S. Fleet into the range of enemy airplanes based at Wake Island. RADM Spruance had to decide if he should continue to pursue to retreating Japanese fleet or play it safe by calling off the pursuit and ordering Task Force 16 to return to Pearl Harbor. Figure 5-5 examines his decision at this time.

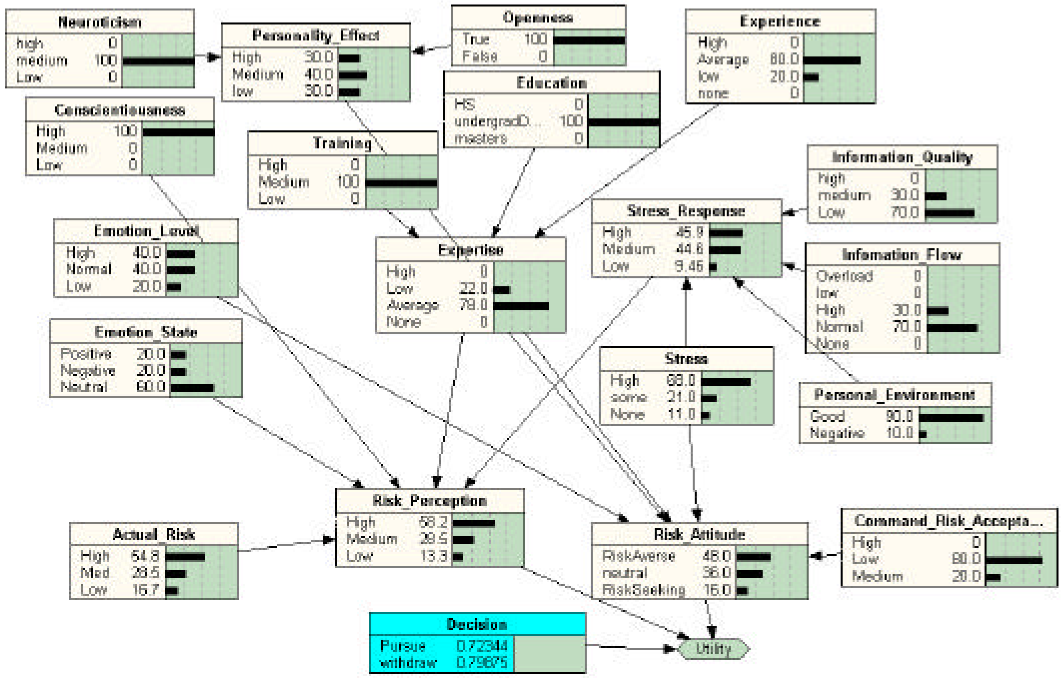


Figure 5-6 RADM Spruance's Decision at the End of the Battle of Midway

As in the earlier decision, the nodes related to Stress Response can be drawn directly from accounts of the battle. Personal Environment, Information Flow and Information Quality levels were constant throughout. The Stress node as defined by CPT Therrien's model was at high, which increased the level of Stress Response and reduced the willingness to accept risk. The overall Stress Response level was medium to high which increased RADM Spruance's perception that the risk inherent in the situation.

Unlike the beginning of the battle, at this point in time the higher command's willingness to accept risk was low. The primary objectives of the operation were met. The United States already had a decisive victory over the Japanese which would serve as a turning point in the war, and a fleet still recovering from the Pearl Harbor attack could not afford to risk assets (Prague, 1983). Combined with the factors previously discussed this indicates RADM Spruance's Risk Acceptance level was risk averse with a probability of .48.

In this case, CPT Therrien's model rates actual risk as high. This includes the threat of enemy reinforcement from Wake Island. This combined with the various factors above resulted in a Risk Perception probability of .582 high.

Once the Utilities are defined and the decision is evaluated, the optimum decision is to withdraw with an expected utility of .799.

C. CASE 3: HITLER AND THE BATTLE OF KURSK

Following their disastrous defeat at Stalingrad during the winter of 1942-43, the German armed forces launched a climactic offensive in the East known as Operation Citadel on July 4,1943. The climax of Operation Citadel, the Battle of Kursk, involved as many as 6,000 tanks, 4,000 aircraft and 2 million fighting men and is remembered as the greatest tank battle in history. To both sides, the salient around Kursk - 200 Km wide and 150 deep - was the single most obvious target for the Germans to attack in their, by 1943, traditional Summer offensive in the East. To the Germans it provided the perfect target to repeat the successes of 1941 and 1942, encircling vast Soviet armies and destroying them in the process.

In April of 1943 Hitler issued Operation order No. 6, which was the order for the Kursk offensive also known as

Operation Citadel. In the document he clearly stated the importance he placed on the offensive "The victory at Kursk must be a signal for the world" (Piekalkiewicz, 1987.) His chief of the General Staff urged that the assault be launched as quickly as possible to avoid giving the Soviets an opportunity to strengthen their forces. In the order, Hitler displays the same concern "For the success of the assault it is vital that the enemy does not succeed in forcing us to postpone Citadel," (Piekalkiewicz, 1987). Uncharacteristically Hitler hesitated. The loss at Stalingrad seemed to have taken the blind assurance for which he had been known away from him. He wanted to win this one. Facing the likelihood that Germany would face a two front war, he knew his armies had to win, or it would all be over. In addition, the losses suffered in and around Stalingrad had so weakened the offensive punch of the Wehrmacht that it would be some months into 1943 before anything like the earlier German offensives could be executed (Piekalkiewicz, 1987).

Figure 5-5 is the model applied to Hitler's decision in May of 1943 to delay the Kursk operation from May until June to allow for a period of preparation. The newest tank in the German inventory, the Mark V Panther was in production, but would enough of them be ready in time? The Inspector General of the Panzer Troops, Colonel General Guderian met with Hitler on May 10 1943 and encouraged him to give up the idea of the Kursk Operation. At the time Hitler indicated some reservations about the operation "The thought of this assault gives me a peculiar feeling in my stomach" (Piekalkiewicz, 1987).

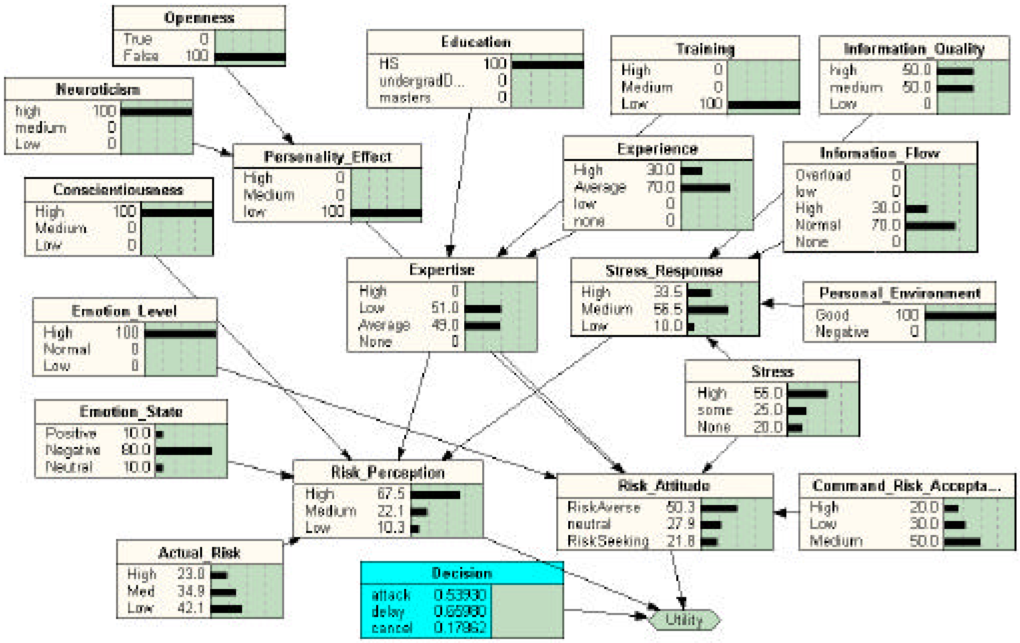


Figure 5-7 Hitler's Decision on Kursk

Since the personality nodes (Neuroticism, Conscientiousness and Openness) are inherent to the decision maker prior to the situation of the decision they are defined in this model based on histories account of Hitler's general personality, not any attitudes he showed directly in relation to the Kursk Operation. A dictator who was extremely sure of his own righteousness, Hitler displayed high Neuroticism and was not open to the ideas of others. This resulted in a low Personality Effect, which in turn resulted in a tendency to be more risk seeking. Hitler showed a high level of Conscientiousness, as was very aware of the details involved. If other factors had not intervened, this high level of Conscientiousness would indicate a more accurate assessment of risk.

Hitler's education was limited and his training for military command was low. However after several years of war throughout Europe, his experience in strategic planning was average to high. These factors combined for a level of Expertise between low to average, which results in a tendency to be more risk averse and degrades the accuracy of risk perception.

Germany's military organization results in Information Quality and Information flow in the medium to high ranges. Due to his position, his Personal Environment was good at all times. He shows some Stress as defined by CPT Therrien's model. These factors combine for a relatively medium Stress Response, which indicates that stress did not drastically affect either his Risk Perception or level of Risk Acceptance.

The two emotional nodes provide much of the explanation for his uncharacteristic behavior in this case. His comments to the Inspector General and his reaction to the German defeat at Stalingrad indicate that his Emotional Level was very high and his Emotion State was toward the negative end of the spectrum. This resulted in a tendency to be more risk averse and skewed Risk Perception to perceive risk higher than actual Risk.

Due to the nature of this example and the fact that Hitler was not accountable to a higher chain of command, the Command Risk Acceptance node is treated very differently in this case. The numbers provided represent his staff’s risk attitude, which was mixed. Less weight is given to this node than in the previous two cases, and the scores represent a negligible impact on Risk Acceptance.

Unlike the two previous cases Hitler's perception of the utilities is somewhat skewed. Figure 5-6 is his expected Utility curves, ρ is set for -3 for the risk seeking curve and 10 for the risk averse.

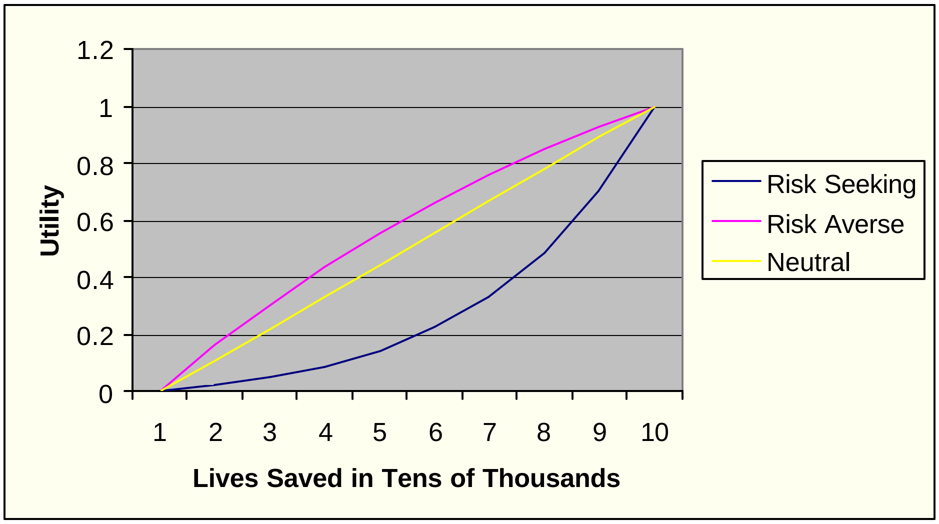


Figure 5-8 Hitler's Utility Curves

The risk averse curve is flatter which is due the fact that caution is less valuable in this case. Also affecting the outcome is the subjection ranking of nine risk/option combinations. Hitler saw almost no value in canceling the operation so the utilities for canceling in every case are ranked lower than the other options. Table 5-2 gives the expected utility for each risk/option combination for all three levels of Risk Acceptance.

Risk Attitude	**Decision**	**Risk Perception**	**Utility value U(X)**
Risk Seeking	Attack	High	0.146376175
Risk Seeking	Attack	Medium	0.334759044
Risk Seeking	Attack	Low	1
Risk Seeking	Delay	High	0.48792227
Risk Seeking	Delay	Medium	0.225012797
Risk Seeking	Delay	Low	0.090030573
Risk Seeking	Cancel	High	0.049657185
Risk Seeking	Cancel	Medium	0.020728389
Risk Seeking	Cancel	Low	0
Neutral	Attack	High	0.444444444
Neutral	Attack	Medium	0.666666667
Neutral	Attack	Low	1
Neutral	Delay	High	0.777777778
Neutral	Delay	Medium	0.555555556
Neutral	Delay	Low	0.333333333
Neutral	Cancel	High	0.222222222
Neutral	Cancel	Medium	0.111111111
Neutral	Cancel	Low	0
Risk Averse	Attack	High	0.555549542
Risk Averse	Attack	Medium	0.760305521
Risk Averse	Attack	Low	1
Risk Averse	Delay	High	0.84831304
Risk Averse	Delay	Medium	0.66304217
Risk Averse	Delay	Low	0.436751817
Risk Averse	Cancel	High	0.305460026
Risk Averse	Cancel	Medium	0.160360156
Risk Averse	Cancel	Low	0

TABLE 5-3 Hitler's Utility Values For Kursk

The result is an optimal decision of delaying operation with an expected utility of .61. This mirrors Hitler's decision to delay in early July.

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VI. CONCLUSIONS/RECOMMENDATIONS

This thesis proposed an influence diagram as a model to represent the impact of a variety of human factors on command decision-making in combat. Building on traditional utility theory, this model can easily be adapted for inclusion in various larger combat models.

The general model was evaluated using three case studies. The Task Force Smith example examines the models ability to represent how a decision maker's decision may be changed over time as the situation changes. The Battle of Midway example illustrates the effects of expertise on the decision maker's risk tolerance. Finally the Battle of Kursk example demonstrates how the model can be adapted to strategic level decisions as well as tactical or operational. In addition this example explores how factors determined at the time of the decision can override factors that are inherent to the decision maker.

The suggested model provides a framework that future thesis students can build upon by collecting data and validating the model for various warfare communities throughout the Department of Defense. Suggested future efforts should focus on specific groups to be modeled (e.g., army infantry officers at the company level). Appendix A provides a simple check list for gathering necessary data to model a particular group. Group data can then be converted into probabilities for incorporation into the model, and provide simulation data that more accurately represent the traits of the simulated population.

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APPENDIX A. DATA COLLECTION STRATEGIES

The model proposed by this thesis can be easily adapted to model decision makers in combat in a variety of military occupations and organizational levels. To apply the model to a specific group of decision makers, (e.g. Army Company Grade Infantry Officers) probabilities for the occurrence of each state space in each node are required. The first step is to identify a sample population of sufficient size to estimate the probabilities. Nodes that lack a parent node require some sort of external data collection. Once the needed factor probabilities are derived, sample scenarios can be used to collect decision and utility information to verify the accuracy of the model and intermediate nodes. The following provides a node-by-node methodology for gathering state space information for all parentless nodes.

A. INTERNAL FACTORS- PERSONALITY

The three personality related nodes (Openness, Conscientiousness, and Neuroticism) can be determined using any form of the NEO Personality Test. The Personality Effect node is derived from the Openness and Neuroticism nodes. Based on the Five-Factor Model of Personality, the NEO is rated on a 5-point scale. A score of one equates with a state space of low, two or three equates to medium and a score of four or five equates to high. This model does not use two of the five factors Extraversion and Agreeableness. The test is usually completed within 45 minutes. Information on administering the NEO can be found at http://www.rpp.on.ca/neopir.htm.

B. PROFESSIONAL FACTORS

The Education, Training and Experience nodes address the professional background of the decision maker, and information can be collected using the member's service record. The Training and Experience nodes should be carefully defined to reflect the expected profile of the population being modeled. For instance, the medium Training state space for Company grade infantry officer should be defined as the training expected of the average O3 infantry officer, the probably for that state space is the probability of that level of training among the sample population.

C. INTERNAL- EMOTION

The two emotion nodes, Emotion Level and Emotion State, can be defined using the Profile of Mood States (POMS) published by the Educational and Industrial Testing Service. Like the NEO the POMS extensive prior use and documentation helps ensure the validity of the measurement. The POMS can be ordered online at: http://www.edits.net/psych/poms.htm.

The POMS includes six scales. Four of the scales (Tension/Anxiety, Depression/Dejection, Anger/Hostility and Confusion/Bewilderment) can be summed to represent state spaces for the Emotion State node. Based on established norms the expected value of this combined scale for adult males is 36.5 with a standard deviation of 28.6. A combined score of 22.2 or less equates to a positive state space, 22.2 to 50.8 equals a neutral state and 50.8 or greater equals a negative state space.

The remaining two scales (Vigor/Activity and Fatigue/Inertia) can be combined to define the Emotion Level Node. Due to the way the scales are defined in the POMS, it is necessary to multiply the Fatigue/Inertia scale by negative one prior to adding the scales. The expected value of the combined scale is 9.3 and the standard deviation is 6.2. A score of 12.4 or higher indicates a state space rated low, 6.1 to 12.4 is a medium score and 6.1 or higher indicates a high level of emotion (McNair et tal, 1992).

These state spaces are based on established norms for the POMS, and may need to be adjusted at model developer's discretion for the specific population being modeled.

D. EXTERNAL STRESSORS

The four external stressor nodes that contribute to the Stress Response node are situationally dependent and probabilities for each state space are drawn from the scenario. The Stress node can be defined by CPT Therrien's model or can be subjectively rated by the model developer. Information Flow and Information Quality are also subjective ratings, but where possible service definitions should be incorporated. For instance, if the related intelligence community has a set standard of when information quality is considered good or bad, that standard should be used. The Personal Environment node is assumed to be good unless at least one of the following stressors present: fatigue, poor terrain issues, or unfavorable climate conditions.

E. SITUATION NODES

Several nodes deal with outside factors that the decision maker deals with at the time of the decision. These factors include Command Risk Acceptance, Threat, Time and Actual Risk. Again the scenario itself determines the probability for each state space and must be defined by the model developer. The model under development by CPT Therrien can be used to define the Actual Risk node.

F. DECISION AND UTILITY

In this model the model developer always defines the COAs for the decision. Utility values are developed using traditional utility theory methods. Utility curves can be developed using the equations provided in Chapter Five or others defined in utility theory literature.

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