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Developing a Fuzzy Expert System to Examine Hazard Analysis in The United States Army

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DEVELOPING A FUZZY EXPERT SYSTEM TO EXAMINE HAZARD ANALYSIS IN THE UNITED STATES ARMY

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Contents

Abstract

The research conducted in this thesis is an attempt to determine if there are any biographical similarities between second lieutenants in the US Army who view risk in a similar manner and if so, which are the most significant. A study was conducted using in-group surveys of 72 second lieutenants receiving training in Infantry Basic Officer Leader Course (IBOLC). The participants were provided with two written surveys each presenting a scenario based on military activities. They were asked to evaluate the scenarios and fill out Risk Management (RM) worksheets based on the US Army's doctrinal process for conducting RM. The RM worksheets were then evaluated based on the hazards they identified for each hazard category. A fuzzy expert system was developed to evaluate the lieutenants' performance in assessing the different hazards. The output results were then evaluated using the two-step cluster process and one way ANOVA test in SPSS. The cluster results showed Platoon and Major as the two most significant predictors for cluster formation on the Foot March scenario. Of the two only Platoon demonstrated statistical significance on the ANOVA. Prior Service and Platoon were the two most significant predictors for cluster formation on the Maintenance scenario but neither showed statistical significance.

Table of Figures

List of Tables

Declaration

Some of the material contained in this thesis has appeared in the following published work:

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1. Introduction

Accidental and combat related death and injuries cause significant loss to US Army combat power every year. Additionally, losses of material and time run the dollar figures for such damages into the hundreds of millions. Risk Management (RM) is the process that the United States Army uses to identify and assess hazards, and to mitigate identified risks associated with military activities, both on and off duty.

RM decisions are often based on the experience, prior training, and intuitive assessments of leaders and their staffs [1]. This type of assessment leads to highly qualitative decision making that can be difficult to quantify into a structured process. The Army's RM process attempts to address this challenge by providing a format for leaders to follow that is not so restrictive as to limit initiative or creativity but structured enough to provide some uniformity to risk assessments.

In 1978, the Army changed the name of the US Army Agency for Aviation Safety to the US Army Safety Center and expanded its role to include responsibility for both aviation and ground safety. On January 31, 2005 the Safety Center was re-christened the US Army Combat Readiness Center (USACRC) and given "the expanded mission to become the center of gravity for all loss-related areas" [2]. The USACRC focuses on development of tactics, techniques and procedure (TTP) and process implementation to improve safety across the force.

The highly qualitative nature of the Army's RM process provides an opportunity to study how leaders assess hazards and determine risk. According to the literature reviewed for this research, a study of this type has not taken place. The proposed study should provide valuable feedback for the Army training community by identifying traits and commonalities in hazard identification and risk determination among leadership populations. These commonalities can be used to inform RM training processes for these populations to maximize its effectiveness.

1.2 The Risk Management (RM) Process

The multi-phase RM process consists of five steps:

Step 1 – Identify the Hazards – A hazard is defined as "a condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation" [1]. The goal of Step 1 is to identify all of the hazards that exist in an operation in order to be able to assess them.

Step 2- Assess the Hazards – This step focuses on quantifying the likelihood and severity of the hazards identified in Step 1. In this step the level of "initial risk" is determined for each hazard. FM 5-19 states that "Technical competency, operational experience, and lessons-learned weigh higher than any set of alpha-numeric codes. Mathematics and matrixes are not a substitute for sound judgment" [1].

This step in the process forms the basis for this research.

Step 3 – Develop Controls and Make Risk Decisions – The third step consists of developing a control for each identified hazard that includes information on what, when, where, why, and how the control measure will be implemented, and who will supervise it. Residual risk is the risk remaining for a hazard after the control measure are implemented. The overall level of risk for the operation is then determined. According to doctrine it must be determined to be at least as high as the highest remaining level of risk. Risk decisions are made at this point in the process. The level of decision making authority is based on the level of overall risk that is determined. The decision making authority may approve, disapprove, or return the document for further evaluation.

Step 4 – Implement Controls – The control measures identified in the previous steps are integrated into the plan for the operation and are implemented by the appropriate individual or group to ensure that they are effective and remain in place.

Step 5 – Supervise and Evaluate – During this step the controls are evaluated to determine their effectiveness at mitigating the hazards that were identified. This step also includes a feedback loop to input improvements and refinements to the process for further use.

The Military Decision Making Process (MDMP) is a multi-step process that is used when evaluating a situation or planning an operation. The process is designed to be implemented by an individual leader or a commander's staff. It allows them to provide a well-rounded and thoroughly thought out product for the commander's approval. There are other, more succinct versions of the MDMP that streamline some of the steps and are more efficient for use by lower level units or when time is a limiting factor.

The steps of the RM process are integrated into the planning cycle and MDMP in order to make determinations of risk level and, by accurately identifying hazards and risks, implement controls to mitigate them. The integration of RM into the MDMP takes place at all echelons of military planning. Hazard Analysis and Risk Determination are critical parts of the RM process because they determine the level of initial risk that the commanders or planners will assign to the operation. This research will focus on Step 2 – Assess hazards to determine risks.

The research was conducted as an in-group study based on the survey results collected from the participants. The participants consisted of second lieutenants attending the Infantry Basic Officer Leaders Course (IBOLC) at Ft. Benning, Georgia. The survey consisted of two military scenarios on which they conducted a risk assessment using the Army's doctrinal RM process. The hazards identified were evaluated with a rule based fuzzy expert system implemented in MATLAB and then evaluated for similarities and significance using the SPSS statistical analysis tool.

1.3 Organization

This thesis is organized as follows; the next chapter is the related works section covering RM as it relates to this study. Chapter 3 is research methodology and discusses how the research was initiated and conducted. The results of the research are covered in Chapter 4 and are analyzed in Chapter 5. The conclusion is Chapter 6 and contains the identified limitations of the study and recommendations for future work.

2. Related Works

The US Army has numerous Field Manuals (FM), Pamphlets (PAM), Army Regulations (AR), and Army Technical Publications (ATP) that address RM, but literature and study beyond these is very narrow in scope. Most published literature related to military operations falls into two categories, process description and analysis of individual events but not on Risk Management (RM) in the United States Army.

The United States Army Combat Readiness Center (USACRC) [2] publishes a monthly magazine called Knowledge. The magazine discusses many aspects of safety and often focuses on specific incidents as a means to discuss safety topics but they are focused on singular themes rather than generalizations across the force. Examples of topics from a recent issues include the dangers of drinking and driving, and the hazards associated with failure to properly chock a vehicle while it is in maintenance. The magazine generally focuses on the aftermath of accidents rather than on predictive analysis and trends in planning.

In [3] the author provides a description and overview of RM in the US Army but does little more than expand on the process described in ATP 5-19, Risk Management. The authors of [4] discuss a risk management process based on an amalgamation of techniques developed by the North Atlantic Treaty Organization (NATO), the United States, the United Kingdom and Sweden. They conduct an overview of the different methods and develop a framework of what they consider the essential elements of a quality RM process. Their evaluation of this framework is very narrowly focused on two aspects of military operations, intelligence and legal assessments. They do an effective review of the processes but they are process focused and do not conduct any evaluation of the individuals performing the assessments.

RM as a decision making tool is significant to the Army and military operations. The goal of RM in the Army is to use the process to structure an inherently unstructured domain. By integrating RM into the MDMP at each stage of the process it presents a much more structured and orderly system with the goal of producing repeatable results. This formalized structuring of the RM allows it to be used as an effective decision support tool by providing commanders and leaders with quantitative outputs that can be more easily evaluated. Research conducted in [5] discusses the significance of RM as a decision support tool for military leaders and the significance of modeling risk situations as a part of the tool. [6] discusses the use of quantitative risk assessments and their adoption by various military and government organizations. In [7] the author describes an outline of the risk decision making process. Within her model she develops the steps, and outlines the sub-processes used in each. Each of these works do a credible job of describing RM as a process and its importance in an operational setting but do not make an attempt to examine the individuals or groups that are working on the process.

Some interesting discussion on the planning aspects of risk management comes from civilian sectors. A study conducted on the German insurance sector found that: "While all firms allege to deal with operational risk consciously in general, only 60 per cent of them follow a structured and formally defined risk management process. Out of the remaining 40 per cent, most respondents indicated that operational risk is managed rather implicitly, i.e. without explicit formalization" [8]. Even though the type of risk in this study is different from the risk evaluated in most Army situations, the fact that so many firms in a risk centric sector (insurance) fail to utilize a formalized risk management process is surprising. Many accident reviews from military operations (another risk centric sector) identify failure in planning as the proximate cause to the accident.

The insurance sector has made attempts to integrate expert systems into the RM process. In [9], the authors use a neural network as a decision support tool to data mine company records to determine potentially fraudulent cases. The researchers point out a problem with some data mining tools is that they do not provide a tool that is easy for managers to understand or explain. The neural network used in this study has the limitation of low tolerance for missing data and during the study the researchers were forced to exclude records that were not complete. While this type of investigation could be useful to military RM practitioners for information gathering it still does not make an attempt to get in front of the problem by reviewing risk in a pre-event time period.

Forecasting risk is an integral part of many business operations and begins to take a proactive look at RM. In [10] a neural network is utilized to research risk management focused on sales forecasting. This study has many of the same limitations as [9] since the system is not tolerant of missing or incomplete data sets. The study does provide another reference point since it is proactively focused and uses correlations in existing data to predict future outcomes.

Work done in [11] provides a practical, proactive approach to RM by using a fuzzy expert system to forecast supply chain risk based on a number of factors within a company. Their method provides a feasible representation of the Army's RM process since it takes many different qualitative and quantitative factors into account. Their system uses fuzzy logic and the example is implemented using MATLAB. Their system is tolerant of missing records and allows the use of natural language instead of requiring all inputs as crisp numbers. Even though these sources focus on the prediction of risk, neither of them look at the human factors involved or take individual risk perception into account.

In [12] the researchers examine IT risk using a fuzzy-neural expert system. Their study is another example that closely represents the Army's process of RM. Their introduction has a number of statements that almost mirror the verbiage in ATP 5-19. Their description of risk and comment that "Risk calculation is never definite regardless of the method used", indicate that the research may have implication in the current study.

From a theoretical standpoint, game theory is often used when approaching RM modeling. Game theory is used in varying degrees to demonstrate risk in sectors as diverse as international business relations [13], and solid waste management [14]. As a theoretical model the research done in [13] and [14] provides an interesting structure to RM but it does not address the practical matter of individual input into the process.

Military RM falls more closely into the structures of Enterprise Risk Management (ERM) and Traditional Risk Management (TRM). In [15] ERM and TRM are discussed and differentiated based on their structure and characteristics. The author delineates between them by discussing TRM as reactive and ERM as proactive. Based on this description the Army has sought to incorporate an ERM style approach by viewing hazards and risk not just as individual incidents to be reviewed but as a continuous process with each phase as an input into the next. With this continuous process risks and hazards are sought out and addressed proactively in all parts of an operation, from planning to after action review.

In the field of ERM, it has been found that there is a positive association between objective setting and risk identification [16]. This means that for firms that set clear objectives and identified the risks associated with them it was "easier to create an inventory of risks and for individual business units to implement the tools to evaluate and monitor these risks." This concept is very similar to the Army's goal to achieve integration of RM into all levels of the MDMP [1]. By integrating RM into all levels of the decision making process commanders and their staffs optimally consider RM as it relates to each objective of the operation thus ensuring that the tools to evaluate risks and monitor them are in place.

Other ERM models are discussed in [17] where the author develops a four pillared approach to ERM based on a survey of Nordic companies and how they approach the process, [18] use of a system dynamics approach to ERM, and [19] using enterprise resource planning solutions. The wide range of research and model descriptions indicates the significance of RM across the spectrum of private and public organizations. RM discussion is mainly focused on the highest risk sectors that have the widest array of hazard inputs like credit, finance, and insurance. Military operations meet this definition also but are not routinely studied in scholarly works.

Individual risk perception is discussed in [20]. The researchers explored how individuals perceive new risks and the bias that they apply when comparing the hazard posed to themselves versus others or when the risk is not well defined. This research has some implications in the current study since it provides a look at risk perception from various individuals and how they view hazards. When completing a risk assessment for a military operation, if an individual feels that a hazard is not as significant simply because of a bias obtained by having heard about or being more aware of the hazard, they may incorrectly reduce the level of severity that they attribute to the hazard.

In [21] the researchers conducted a study to determine how risk can be perceived based on how the risk is framed. They determined that there is a difference between the level of risk that a person is likely to accept based on how the problem is framed, either positively or negatively. An older but informative study on the influence of risk in decision making is [22]. In this study the researchers discuss an isolation effect that caused study participants to make "inconsistent preferences when the same choice was presented in different forms" [22]. This research also has implications on military RM, especially when RM is being used as a decision support tool. This study indicates that how a hazard or risk is perceived or presented could have bearing on the level of risk out of proportion with the actual hazard or risk itself.

Considerable research has been conducted on individual risk propensity based on personality characteristics. One study of note is [23] where the authors discuss the significance of understanding the risk behavior of the members of an organization. They state "In organizational terms, a better understanding of risk behaviour could contribute significantly to risk management programmes" [23]. The authors also differentiate categories of risk takers between risk seeking and risk bearing. Risk seekers seek out situations that they perceive as hazardous for stimulation, either seeking challenge or fun. People in the risk bearing category are the goal achievers and risk adaptors. These groups do not seek out risk but are able to cope with it and manage risk in a way to achieve the desired results. This research will seek to identify linkages in the second category since most Army leaders should cluster in the risk bearing category for risk evaluation in their professional pursuits. Risk seekers may form as outliers to the overall group.

Personality influence on risk taking and acceptance is discussed in [24], and [25]. These studies evaluate a variety of biographical and experiential characteristics to determine which have the most significant impact on an individual's perception and risk tolerance. The research conducted in [25] is more focused on "risky" behavior like smoking and or occupational choice; this group might more closely resemble the risk takers from [23]. The results from [24] discuss risk bearing attitudes from the perspective that is more closely aligned with the risk bearing groups from [23]. Both of these studies are looking for associations between people who view or partake of risk in a similar fashion or at a similar level. These are similar directions to what this thesis is seeking.

Literature and research using expert systems in risk management is limited. The majority of the research in the field that uses expert systems focuses on data mining utilizing neural networks. Fuzzy systems are used in only a small number of research projects and none of this research has been conducted in the domain of military operations. The field of individual risk perception holds some implications for this research by providing some starting points for review when evaluating response clusters. Using a fuzzy expert system to view RM proactively as it relates to the human factors of Army leaders should provide useful information for the Army training system, and new research in the field.

3. Methodology

3.1 Research Goal

This study is being conducted in an attempt to answer the question "Are there similarities within populations of leaders in the United States Army in terms of how they evaluate hazards? If yes, which are the most significant". One challenge with military operations is that they contain so many situations that are difficult to quantify and must therefore be addressed by the experience and intuition of the leader assessing the situation [1]. Leaders in the Army are trained to assess threats and work on ways to mitigate them.

In the case of RM, the challenge of identifying hazards and mitigating them is exacerbated by the fact that most hazards cannot be engaged or destroyed but must be addressed or mitigated in order for an operation to continue. If similarities can be identified among leaders who assess hazards similarly, then these associations can be used to identify potential training opportunities for feedback to the training cycle in order to provide a greater commonality in hazard assessment throughout the studied population.

This research uses artificial intelligence (AI) techniques to determine how a population of leaders in the U.S. Army assesses hazards. The study was conducted by analyzing the results of RM worksheets collected from survey participants, analyzing them with a fuzzy expert system and then using clustering techniques to identify relationships between participants who identify hazards in a similar manner. A sample RM worksheet is shown in Figure 1.

A. Mission or Task:	B. Date/Time Group:	C. Date Prepared:
Conduct a deliberate attack	Begin: 010035R May XX End: 010600R May XX	28 April XX

D. Prepared By: (Rank, Last Name, Duty Position) CPT Smith, Cdr

E. Task	F. Identify Hazard	G. Assess Hazard	H. Develop Controls	I. Determine Residual Risk	J. Implement Controls (How To)
Conduct obstacle breaching operations	Obstacles	High (H)	Develop and use obstacle reduction plan	Low (L)	Unit TSOP, OPORD, training handbook
	Inexperienced soldiers	High (H)	Additional training and supervision	Moderate (M)	Rehearsals, additional training
	Operating under limited visibility	Moderate (M)	Use NVDs, use IR markers on vehicles	Low (L)	Unit TSOP, OPORD
	Steep cliffs	High (H)	Rehearse using climbing ropes	Moderate (M)	FM 3-97.6, Military Mountaineering
	Insufficient planning time	High (H)	Plan and prepare concurrently	Moderate (M)	OPORD, Troop-leading procedures

K. Determine overall mission/task risk level after controls are implemented (circle one)

LOW (L) MODERATE (M) HIGH (H) EXTREMELY HIGH (E)

Figure 1. Sample Army Risk Management Worksheet [26]

3.2 Scenario Selection

The scenarios designed for this research are based on discussion with the Maneuver Center of Excellence (MCoE) Safety Office on Ft. Benning, GA. The Safety Office staff identified planning and execution of tactical and non-tactical foot marches as one of the most casualty producing training events conducted on the installation. For this reason, a practical exercise that requires conducting RM on a Foot March scenario is the capstone event used for evaluation of students attending the Additional Duty Safety Officer (ADSO) course that is conducted quarterly by the MCoE Safety Office. The second scenario was developed with a maintenance and vehicle focus in a cold weather environment in order to differentiate the types of hazards that the respondents would have to react to. The scenarios were created based on the researcher's experience, conference with other US Army officers and Non Commissioned Officers and are based on Army doctrinal references including [1], [27], [28], and [29]. The scenarios used for this study are provided below.

3.2.1 Foot March Scenario

Scenario: Conduct a Tactical Foot March for Training

SITUATION: Your BN is preparing to assume ready cycle for your BDE and your PLT has been telephonically alerted to report to work as part of an Emergency Deployment Readiness Exercise (EDRE) intended to validate your readiness to alert, assemble, and execute PLT Critical Tasks. While your PSG is preparing the PLT for movement and overseeing PCCs/PCIs, you report to the Company Commander and receive the following FRAGO:

MISSION: 1st Platoon, Company B, 1st BN, XX BDE conducts a tactical foot march no later than (NLT) 0300 16 MAR XX along ROUTE BLUE in order to validate their readiness in preparation for assuming alert cycle responsibilities.

METT-TC Analysis

MISSION: Conduct a tactical foot march.

ENEMY (Weather): The current temperature is 65 degrees Fahrenheit with low (20%) humidity. Conditions at your projected start time are 70 degrees with moderate to high (60%) humidity. At completion of the movement, temps will be in the low to mid 90's with high (80%) humidity. Cloud ceiling will be broken throughout the movement with a 0% chance of precipitation.

TERRAIN: ROUTE BLUE is 25 miles (40.2 KMs) in length. It begins at Start Point (SP)1 and ends at Finish Point (FP)1. It is comprised of a road network consisting of unimproved (varying from sandy to hard-packed clay) roads traversing rolling to hilly terrain. The roads are generally bordered by wooded terrain. Vehicular traffic is expected to be light, consisting mainly of tactical vehicles.

TROOPS: Squad Leader and above experience level is moderate within the PLT. Team Leader and below is moderate (see details below). All participants are healthy with no significant injuries. The PLT average on your last APFT was 260. Your PLT is only moderately rested as they were unaware of the upcoming EDRE and several chose to stay up late into the night. Their average amount of sleep is 5 hours.

TIME: You have 2 hours to complete all phases of planning and BPT depart from SP 1. You have 10 hours to move from SP1 to the FP1.

CIVILIANS: N/A

ADDITIONAL PLANNING CONSIDERATIONS:

- Your platoon represents an Airborne/Air Assault Modified Table of Organization & Equipment (MTOE) consisting of 3 x Rifle Squads, a Weapons Squad with 2 x machine guns teams, and a PLT HQ. The PLT HQ includes you, the PSG, a RATELO, and a Forward Observer.
- You PLT Medic is not present but you have 1 x current and qualified Combat Life Saver (CLS) on hand.
- You have 1 x 60 mm mortar team from the Co HQ attached to your PLT for the movement. You have not worked with this particular mortar team before.

- Your PSG is a SFC who has been in his position for 18 months.
- One of you three Rifle Squad Leaders is a SSG with over one year leading his SQD. Your 2nd and 3rd SLs are SGTs. One grew up in the SQD and has recently replaced the previous SL. The other is new to the PLT having recently arrived from another unit.
- Your Weapons SQD Leader is a former Rifle SQD Leader and the most experienced SSG in the PLT.
- Your Team Leaders all CPLs or SGTs and have at least 6 months, but less than 1 year of experience in their positions.
- You have four newly-assigned Privates spread throughout the PLT who have not taken an APFT or executed any foot marches with the PLT. Two suffered minor heat injuries during Initial Entry Training (IET).
- You will have organic FM radio contact with the CO CP who can relay any necessary MEDEVAC requests to the BN Aid Station, where a Front Line Ambulance (FLA) and the BN Physician's Assistant (PA) are located. Aero Medevac is available upon request.
- You have no external water resupply available.
- The first half of the foot march will take place during hours of visibility.
- The average total individual load within the PLT is 70 lbs.

3.2.2 Maintenance Scenario

Scenario: Conduct maintenance on your platoons M3 Bradleys

SITUATION: One hour ago your platoon was notified that you will be moving your vehicles to the installation rail load site in preparation for deployment to JRTC. This movement was planned for six days from now but a change in rail stock availability has forced the early movement. Your company completed gunnery on Friday (two days ago) and worked on recovery operations through Saturday but the poor weather slowed completion of recovery operations and they are not yet complete. The battalion had the day off on Sunday. The time is now 0900 Monday 17 January and your Soldiers have just reported for delayed work call. Your platoon must complete recovery operations, prepare vehicles for movement and move to the rail load site NLT 2000 for a 2100 rail load time.

METT-TC Analysis (Provided for your consideration)

MISSION: See above.

ENEMY: N/A.

TERRAIN and WEATHER: The battalion motor pool is a hard stand site located 3 miles from the company area. The current road conditions are fair with some wetness due to rain fall over the weekend. The road to the rail load site is paved and generally flat but the Crooked Creek crossing has a steep decent and ascent after the bridge. The rail load site is located 6 miles from the motor pool.

The current temperature is 26 degrees Fahrenheit with moderate (40%) humidity. The temperature is projected to fall throughout the day to a low of 5 degrees as a storm front moves into the area. The front is forecast to bring a wintery mix switching to snow by 1900.

Traffic and civilian movement on post can be expected to increase throughout the day as the weather deteriorates.

TROOPS: Squad Leader and above experience level is good within the PLT. Two squad leaders are very experienced but are new to the platoon within the last four months and have never served in a mechanized unit. The platoon sergeant has been called to a meeting by the battalion sergeant major and does not know when he will return. All participants are assumed healthy with no significant injuries. The PLT average on your last APFT was 225. Rest levels vary in the platoon depending on how the Soldiers spent their off hours after gunnery, TIME: You have 11 hours to complete recovery, move to the rail load site and stage. This must be accomplished NLT 2000 IOT meet the 2100 rail load appointment.

CIVILIANS: N/A

ADDITIONAL PLANNING CONSIDERATIONS:

- Your platoon represents a mechanized infantry platoon with four operational M3 Bradleys.
- Your company has a maintenance SOP but your platoon does not have a specific PLT level document.
- The rail load SOP is from battalion level and has not been updated since return from the last deployment.
- Your PSG is a SFC who has been in his position for 24 months.
- Two squad leaders are experienced NCO's but have never served in a heavy unit. They just completed their first gunnery. The other two are experienced in their positions and have deployed in a heavy unit.
- Your Team Leaders all CPLs or SGTs and have at least 6 months, but less than 1 year of experience in their positions.
- You have eight newly-assigned Privates spread throughout the PLT who have not taken an APFT.
- You have three identified prior cold weather injuries.

3.3 Recruitment Strategy

The RM worksheet data was collected from students attending IBOLC, the Army's initial training course for Infantry officers. The course teaches all of the tactical, technical, and legal information that officers need to perform their initial jobs in the Army. Prior to attending this course the officers have received training in many basic aspects of military operations at their commissioning source.

The officers in this study were commissioned as second lieutenants from one of three sources.

- **United States Military Academy (USMA)** – One of three service academies that the military uses to train junior officers. Students receive a four year college education and receive training in many basics of military art and science. Very few lieutenants commissioned through USMA have any prior service in the military.

- **Reserve Officers Training Corps (ROTC)** – ROTC training takes place at the college that the student is attending. The training they receive usually consists of one college course per semester and additional after school labs focused on teaching specific Army tasks. ROTC cadets are evaluated for potential during the summer between their junior and senior years at the Leader Development and Assessment Course (LDAC). Some lieutenants commissioned through ROTC may have prior service in the military.
- **Officer Candidate School (OCS)** – OCS is a means for enlisted Soldiers to transfer to the ranks of commissioned officers. The course is 12 weeks long and consists of a compressed training cycle of the officer centric skills that ROTC and USMA cadets received during their training. All lieutenants commissioned through OCS have some level of prior service in the military.

The backgrounds of the officers vary significantly based on prior service in the military, commissioning source, personal history, and other biographical categories. Each of them has been trained in the RM process at some point, either at a prior military school, or commissioning source prior to the training received at IBOLC. These variations provide additional points of reference for determination of similarities or differences in their evaluations. All data collection and survey results have been handled in compliance with IRB requirements.

Officers are assigned a course date at IBOLC based on graduation date from their commissioning source. Since USMA graduates are commissioned earlier than most other officers, the course of lieutenants participating in this study had a higher than average number of USMA graduates. On arrival at the school, the students are divided into one of three groups, or platoons. The platoon that the officer is placed in is randomly selected by the school and is not based on any biographical or experiential information. Each platoon is led and trained by a different cadre of instructors that is made of up both officers and NCO's. Even though the trainers are different for each platoon, each cadre follows the same Program of Instruction (POI) for the courses instructed.

The scenarios and all of the information required to complete them were provided to the participants along with a brief overview of the reasons for collecting their information. Each participant was told that participation was voluntary and a signed release was collected from each participant along with the completed RM worksheets. Participation from the students in the course was 73%. In total 72 correctly completed RM worksheets were collected and included in this research.

3.4 Database Creation

Each respondent's information was captured via a biographical questionnaire that was returned to the researcher along with the RM worksheets. Data for each participant was collected and entered into biographical categories in the database. The categories that were evaluated were:

1. Platoon – The officers in the course were broken down into subgroups by platoon. Each officer was either in First, Second, or Third platoon.

2. Commissioning Source – Each officer received their commission in the army from one of three sources, Military Service Academy, Reserve Officers Training Corp (ROTC), or Officers Candidate School (OCS).

3. Prior Service – This category is based on whether the officer in question has ever served in the US Military in another capacity. Category is coded as Yes or No

4. Time in Service – categorized as less than 1 year, greater than 1 but less than 3 years, or greater than 3 years.

5. Component – This category is based on the component of service for the Soldier. Any officer that has no prior service is considered in the Active Duty category. Prior service officers can either be Active Duty, or Reserve Component based on which component they previously served in.

6. Major – This category was determined based on the collegiate major of the officer. Major was broken down into the five sub-categories listed in Table 1.

Table 1
Subcategories of biographical category Major

SUB-CATEGORY	INCLUDES MAJORS IN
Physical Science	Biology, Chemistry, Exercise Science, Geoscience
Social Science	Political Science, Psychology, Criminal Justice, Sociology, Languages, Law, Defense and Strategic Studies, Foreign Studies
Business	Business, Economics, Culinary Management
Math, Technology and Engineering	Engineering, Computer Science, Operational Research
History	History, Geography, Philosophy

7. Deployments – This category is the total number of deployments of the specified officer. From this respondent list the deployments range from 0 to 3.

Inputs from the survey respondents were coded into categories based on the Army standard evaluation areas of Mission, Enemy, Terrain, Troops, Time, and Civil Consideration (METT-TC). The categories Mission, Terrain, Troops, and Time were used in the evaluation of the collected data. These four categories were further broken down into the sub-categories listed in Table 2.

Table 2
Army evaluation criteria for METT-TC

Category	Sub-Category			
Mission	C2 Span of Control	SOP Dissemination		
Terrain	Temp/Weather	Route	Illumination	Traffic
Troops	Platoon Task Experience	Physical Condition of Soldiers and Equip	Leader Experience	Key Personnel Availability
Time	Planning Time	Time to Complete Mission		

3.5 Coding

The RM worksheets received from the participants were reviewed and the hazards identified in them were coded for inclusion into one of the 12 sub-categories. The specific wording of each identified hazard was evaluated and the most appropriate category was determined. Many of the hazards were identified by the participants in such a way that the definition of the sub-category was included. Hazards that included this wording were moved into that sub-category since they did not require any additional processing. Each sub-category is discussed in Tables 3-6 along with the definition for the category and any keywords that were coded into the category that were not included in the definition. Keyword columns that are blank did not have any hazards identified that did not include part of the definition in their identification.

Table 3
Sub-Categories, definitions, and keywords for Mission

Sub-Category	Definition	Keywords
C2 Span of Control	Difficulty related to controlling the overall mission related to the size and number of units or personnel	Lost Soldier / fallout
SOP Dissemination	Level of understanding and dissemination of standing operating procedures	

Table 4
Sub-Categories, definitions, and keywords for Terrain

Sub-Category	Definition	Keywords
Temperature / Weather	Environment that the mission is conducted in	Climate, Heat, Cold,
Route	Any hazards related to the route, or road trafficability	Surface traction, Ascent/Decent, Road width, Vehicle rollover, Eye injury, Snowy road, Collisions
Illumination	Visibility related to light level	Limited visibility
Traffic	Other traffic in the area, related to vehicles not involved in the mission	

Table 5
Sub-Categories, definitions, and keywords for Troops

Sub-Category	Definition	Keywords
Platoon Task Experience	Level of experience of either the individuals or collective unit on tasks involved in the mission	Inexperienced privates, Vehicle injuries (not traffic related), Soldiers run over by Bradley, Rail load equipment, Vehicle damage from loading, Motorpool mvt, Spills during fueling
Physical Condition of Soldiers and equipment	Any hazard or issue related to the physical abilities or condition of the Soldiers involved in the mission	Heat / Cold casualties, Dehydration, Blisters, Fatigue, Sleep deprivation, Previous heat injuries, Heavy load / equipment, Low APFT average
Leader Experience	Experience of leadership involved in planning or executing the mission	
Key personnel availability	Availability or absence of key personnel or leaders for the planning or execution of the mission	

Table 6
Sub-Categories, definitions, and keywords for Time

Sub-Category	Definition	Keywords
Planning Time Available	Time available for planning	
Time to Complete Mission	Time required to complete the mision	

3.6 Hazard Value Assignment

The RM worksheet correlates each hazard identified to a risk value (L, M, H, EH). The risk value of each identified hazard was taken from the RM worksheet and entered into the database. When multiple hazards were identified in the same category all of them were captured and added to the database. The values for input into the expert system were developed based on the Army Risk Assessment Matrix shown in Figure 2.

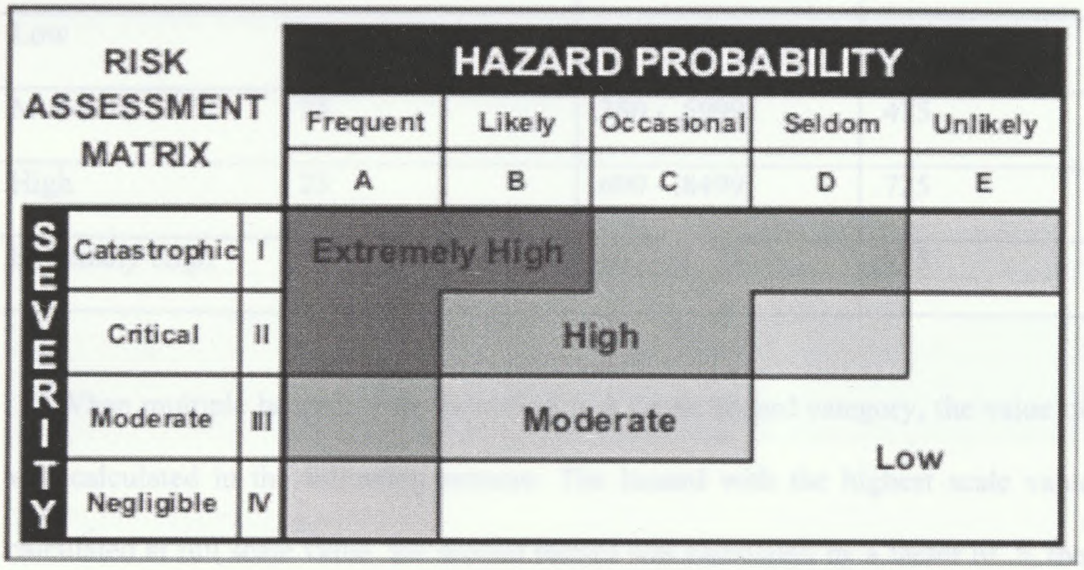

Figure 2. Army Risk Assessment Matrix [30]

Each risk value was calculated as a percentage of the total value represented in the matrix. For example, the risk value EH holds three of the total 20 positions in the matrix therefore its value is 15%. A ten position linear scale from 0 (lowest risk) to 1 (highest risk) was used and each risk value was calculated based on the percentage of the scale occupied by that risk value. The start and end point of the value was calculated and averaged to develop the scale value each level of risk. Since EH holds 15% of the scale its scale value was calculated at .925. Table 7 shows the values that were identified for each hazard scale value.

Table 7
Scale values calculation for identified hazards

Hazard Value	Percentage of Scale	Scale Range	Scale Value
Low	35	0 - .3499	.175
Moderate	25	.350 - .5999	.475
High	25	.600 - .8499	.725
Extremely High	15	.850 – 1	.925

When multiple hazards were identified in a single hazard category, the value of each was calculated in the following manner. The hazard with the highest scale value was calculated at full scale value, the second hazard was calculated by a factor of .5, the third value was calculated by a factor of .25, and the fourth was calculated at .125. These values were added together making the total cumulative for that subcategory cumulative. This decreasing valuation was implemented to ensure that each hazard in a unique subcategory was treated with more significance than multiple hazards in a single subcategory. The rational for this decision was that a leader who has identified one hazard in a subcategory is more likely to focus mitigation efforts on that category and identification of subsequent hazards for the same subcategory yielded a lower overall risk reduction than identification of a hazard in another category. Table 8 provides an example of this methodology.

Table 8
Coding example for multiple hazards

Hazards	Scale Values	Total Value
1M, 1M, 1L	.475, .238, .044	.757

Table 9 represents the data provided by one respondent for one scenario. The top shaded area shows the number and severity of hazards identified for each sub-section. Sub categories that are blank did not have a hazard identified by this respondent. The bottom shaded area shows the data after it has been converted to a numerical value based on the number and severity of the identified hazards.

Table 9
Hazard value conversions for one data record

Mission		Terrain				Troops				Time	
C2	SOP Dis	Temp	Route	Illum	Traffic	PLT Exp	Phy Cond	Ldr Exp	Key Pax	Planning	Complete
1,M	1,M 1,M	1,M	1,H	1,H	1,M	1,M	1,M 1,M 1,M		1,M		
0.475	0.713	0.475	0.726	0.73	0.475	0.475	0.772		0.475		

3.7 Fuzzy Expert System

In [12] the authors conduct research with a fuzzy neural network that is similar in concept to the system developed for the purpose of this study but is used for a different purpose [12]. In their research they evaluate risk for specific IT systems based on natural language inputs from assessments made by the company. This research does not look at the human factors involved, but their system does inform the development of this system.

The architecture for the fuzzy expert system used in this study is represented in Figure 3. MATLAB version R2012a was used to implement this system and an overview of it is shown in Figure 4. Existing research in RM is primarily conducted via data mining utilizing a neural network. A neural network was determined not to be the most effective method to evaluate the data collected for this thesis since it cannot process records with significant missing data and is not tolerant of natural language.

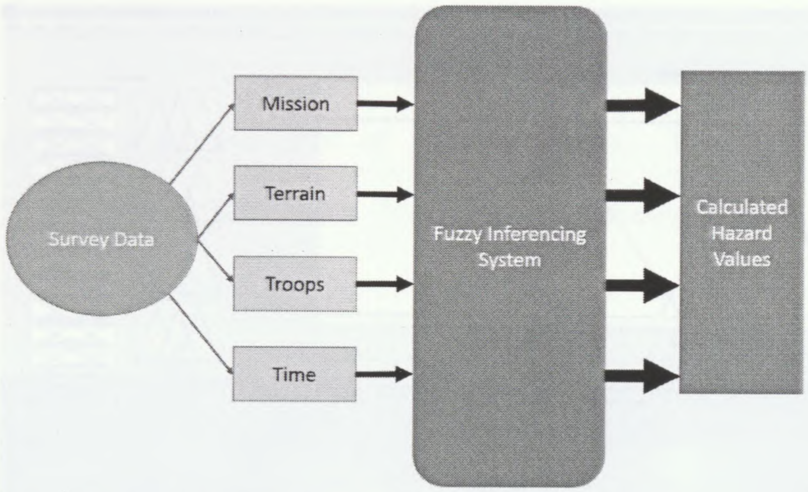

Figure 3. Fuzzy Expert System

The developed expert system uses trapezoidal membership functions, a Mamdani style fuzzy inferencing system (FIS) and a centroid defuzzification method to produce a crisp output as shown in Figure 4. Figure 5 displays the membership function for Span of Control within the Mission category of hazards. The Mamdani FIS evaluates each of the natural language inputs and determines its level within the membership function. Once each of the inputs has been evaluated within the membership functions, the rules (described below) are followed and the rule antecedent is applied. This results in a crisp numerical output for each hazard category.

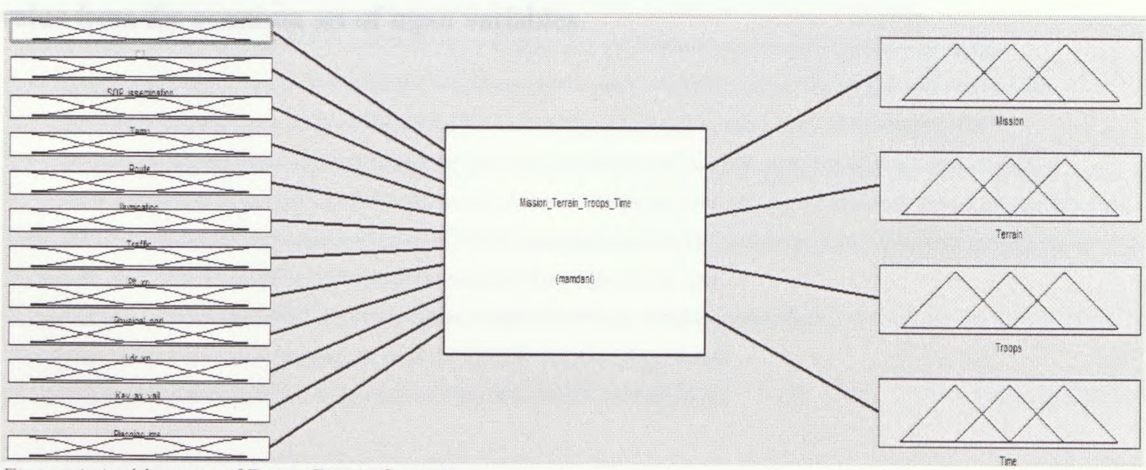

Figure 4. Architecture of Fuzzy Expert System

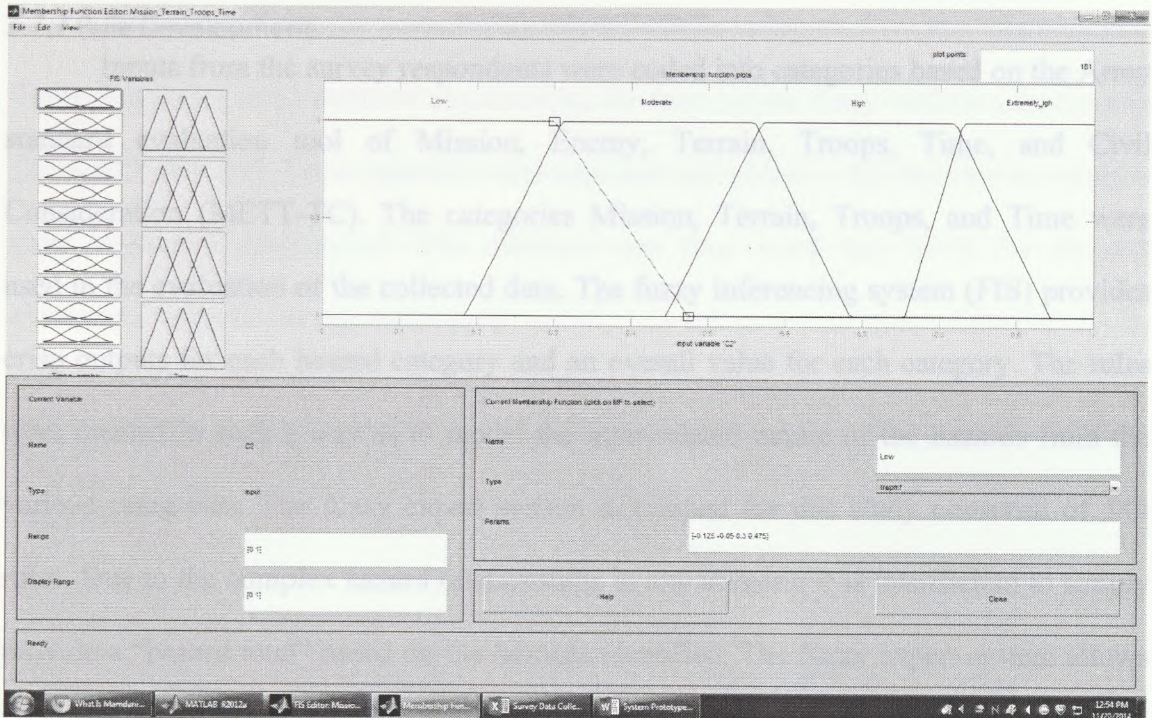

Figure 5. Span of Control membership function

MATLAB was selected for to build the fuzzy expert system since it allows for multiple output variables to be calculated from one set of input variables. The ability to combine what is essentially four separate fuzzy expert systems into one saved a significant amount of time in the creation of the fuzzy expert system. In this implementation each hazard category (Mission, Terrain, Troops, Time) receives its own value from the common set of input variables.

3.7.7 Rule Development

Inputs from the survey respondents were coded into categories based on the Army standard evaluation tool of Mission, Enemy, Terrain, Troops, Time, and Civil Consideration (METT-TC). The categories Mission, Terrain, Troops, and Time were used in the evaluation of the collected data. The fuzzy inferencing system (FIS) provides crisp outputs for each hazard category and an overall value for each category. The rules were created in such a way as to model the inter-related nature of the hazards from the various categories. The fuzzy expert system developed for this study consisted of 544 rules. Due to the complex hazard relationships in any scenario it is insufficient to simply provide a "hazard total" based on the hazards identified. The fuzzy expert system allows this system to be modeled and a crisp number to be achieved for each hazard category that can then be evaluated for relationships with other respondents samples. A sample of rules from the expert system are shown in Figure 6.

If (C2 is Low) and (SOP_Dissemination is Low) then (Mission is Low)

If (C2 is Moderate) and (SOP_Dissemination is Low) then (Mission is Moderate)

If (C2 is Moderate) and (SOP_Dissemination is Moderate) then (Mission is Moderate)

If (C2 is High) and (SOP_Dissemination is Low) then (Mission is High)

If (Temp is Moderate) and (Route is Low) and (Illumination is Low) and (Traffic is Low) then (Terrain is Moderate)

If (Temp is Low) and (Route is Moderate) and (Illumination is Low) and (Traffic is Low) then (Terrain is Moderate)

If (Temp is High) and (Route is Moderate) and (Illumination is Moderate) and (Traffic is Low) then (Terrain is Extremely High)

If (Temp is Extremely High) and (Route is Moderate) and (Illumination is Low) and (Traffic is Low) then (Terrain is Extremely High)

If (Plt_Exp is Low) and (Physical_Cond is Low) and (Ldr_Exp is Moderate) and (Key_Pax_Avail is Low) then (Troops is Low)

If (Plt_Exp is Moderate) and (Physical_Cond is Low) and (Ldr_Exp is Moderate) and (Key_Pax_Avail is Low) then (Troops is High)

If (Plt_Exp is High) and (Physical_Cond is Moderate) and (Ldr_Exp is Moderate) and (Key_Pax_Avail is Low) then (Troops is Extremely High)

If (Plt_Exp is High) and (Physical_Cond is High) and (Ldr_Exp is Moderate) and (Key_Pax_Avail is Low) then (Troops is Extremely High)

If (Planning_Time is Low) and (Time_To_Complete is Low) then (Time is Extremely Low)

If (Planning_Time is Moderate) and (Time_To_Complete is Low) then (Time is Extremely Moderate)

If (Planning_Time is Moderate) and (Time_To_Complete is Moderate) then (Time is High)

If (Planning_Time is High) and (Time_To_Complete is High) then (Time is Extremely High)

Figure 6. Sample rules from fuzzy expert system

The output from the fuzzy expert system shown in Figure 7 for the data records in Table 9 is set of crisp numbers representing the four output fuzzy variables in this case [.716,.895,.895,.18]. These numbers were captured and added to the database as values or their respective data record. The database was then input into SPSS for the data evaluation using clustering techniques.

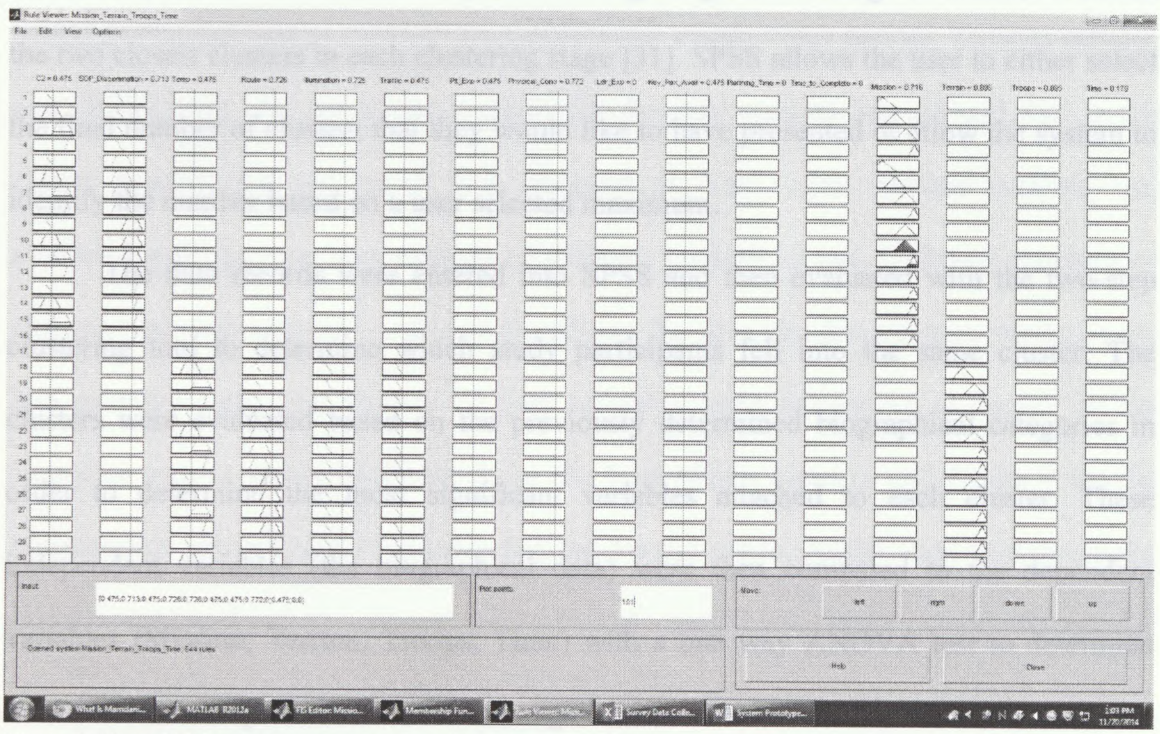

Figure 7. Hazard Value Output from MATLAB

3.8 Data Evaluation

Evaluation of the data collected from the fuzzy expert system was conducted in IBM SPSS Statistics version 21. SPSS is a powerful software package that allows users to conduct a wide variety of statistical analysis on data sets. The software permits data to be manipulated and then tested and reviewed for significance. The Two-Step clustering tool was used for this study.

The SPSS Two-Step clustering component is a cluster analysis tool designed to handle large databases [31]. The process involves pre-clustering and final clustering in one step and is designed to handle continuous and categorical variables. During the first step, SPSS calculates the Bayesian information criterion (BIC) for each number of clusters in a specified range to find the initial estimate for the number of clusters. In the second step it refines the estimate by determining the greatest change in distance between the two closest clusters in each clustering stage [31]. SPSS allows the user to either select the final number of clusters that they would like to have presented or allow the system to identify the number based on a user selected maximum.

The data records were entered into SPSS and then evaluated with the two-step clustering tool to determine which study participants fell into the same cluster. The clusters were evaluated based on the previously determined biographical categories in order to determine the most significant variables attached to each cluster. These independent variables (the biographical data) were then compared to the dependent variables (Mission, Terrain, Troops, Time) with a one way ANOVA test to determine which hazard categories held statistical significance. The results from the two scenarios were then compared to determine which biographical attributes provide the most significant impact on how the respondents identify hazards.

4. Results

The collected data has been analyzed using Two-Step clustering and ANOVA statistical tests in SPSS statistical software. The Two-Step clustering process was conducted with the dependent variables Mission, Terrain, Troops, and Time (hazard categories) to create the clusters. The clusters were then evaluated on the independent variables Platoon, Major, AC/RC, Commissioning source, Prior service, Time in service, and Deployment. An additional variable for the data records was created that is the cluster number that the record was assigned to. The cluster number variable was evaluated with the one way analysis of variance (ANOVA) test. Different numbers of clusters were experimented with and classifying the data into five clusters produced the best overall results. The clusters for both scenarios were categorized as "good" by the clustering tool as shown in Figure 8 for the Foot March scenario and Figure 9 for the Maintenance scenario. This indicates that the overall model quality used to produce the clusters was good and the clusters themselves are significant. Statistical significance for this study is determined as any significance factor of .05 or less.

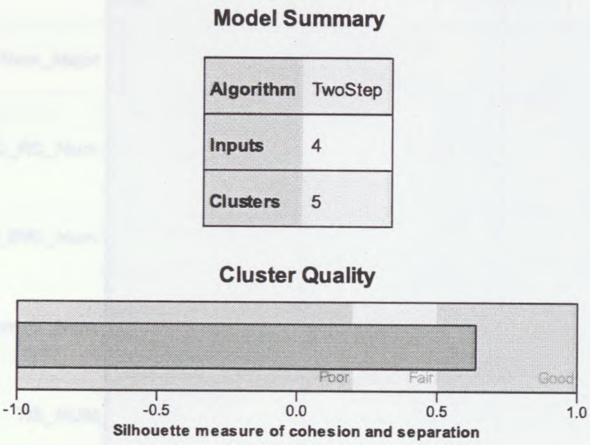

Figure 8. Model Summary for Foot March Scenario

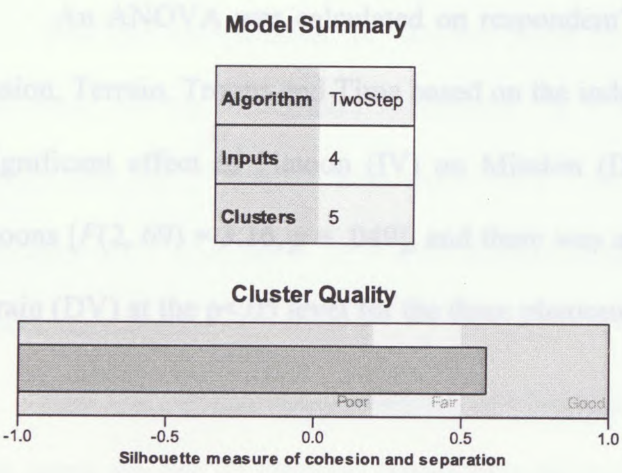

Figure 9. Model Summary for Maintenance Scenario

4.1 Foot March Scenario Results

For the Foot March scenario, Figure 10 shows the independent variables in order of significance as predictors of cluster membership. According to these clusters, Platoon is the most significant followed by Major and AC/RC.

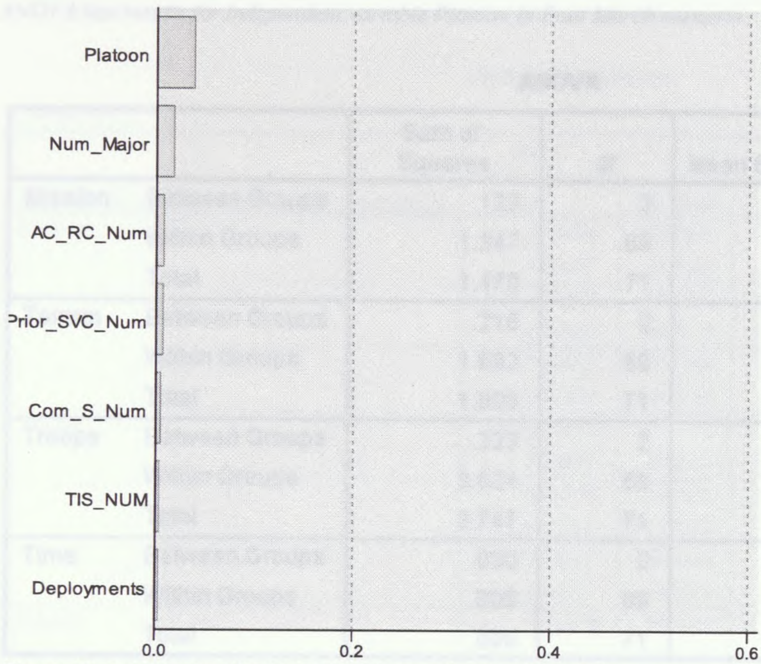

Figure 10. Independent Variable Significance for Foot March Scenario

An ANOVA was calculated on respondent's ratings of the dependent variables Mission, Terrain, Troops and Time based on the independent variable Platoon. There was a significant effect of Platoon (IV) on Mission (DV) at the $p<.05$ level for the three platoons [$F(2, 69) = 3.16$, $p = .049$], and there was a significant effect of Platoon (IV) on Terrain (DV) at the $p<.05$ level for the three platoons, [$F(2, 69) = 4.40$, $p = .016$].

Table 10
ANOVA test results for independent variable Platoon in Foot March scenario

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mission	Between Groups	.123	2	.062	3.156	.049
	Within Groups	1.347	69	.020		
	Total	1.470	71			
Terrain	Between Groups	.216	2	.108	4.406	.016
	Within Groups	1.692	69	.025		
	Total	1.908	71			
Troops	Between Groups	.223	2	.112	2.185	.120
	Within Groups	3.524	69	.051		
	Total	3.747	71			
Time	Between Groups	.000	2	.000	.000	1.000
	Within Groups	.000	69	.000		
	Total	.000	71			

Post hoc comparisons for Mission using the Tukey HSD test indicated that the mean score for the 1st Platoon lieutenants (M = .287, SD = .191) was significantly different than the 3rd Platoon lieutenants (M = .180, SD = 0). However, the 2nd Platoon lieutenants (M = .218, SD = .129) did not significantly differ from the 1st Platoon and 3rd Platoon lieutenants.

Post hoc comparisons using for Terrain the Tukey HSD test indicated that the mean score for the 3rd Platoon lieutenants (M = .655, SD = .217) was significantly different than the 1st Platoon lieutenants (M = .783, SD = .125), and 2nd Platoon lieutenants (M = .784, SD = .139). However results did not significantly differ from the 1st Platoon and 2nd Platoon lieutenants. The Tukey HSD test for Platoon is shown in Table 11.

Table 11
Tukey HSD test results for independent variable Platoon in Foot March scenario

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Platoon	(J) Platoon	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Mission	1	2	.068546	.037991	.176	-.02245	.15955
		3	.106417*	.044294	.049	.00032	.21252
	2	1	-.068546	.037991	.176	-.15955	.02245
		3	.037871	.042170	.643	-.06314	.13888
	3	1	-.106417*	.044294	.049	-.21252	-.00032
		2	-.037871	.042170	.643	-.13888	.06314
Terrain	1	2	-.000778	.042571	1.000	-.10275	.10119
		3	.128537*	.049634	.031	.00965	.24743
	2	1	.000778	.042571	1.000	-.10119	.10275
		3	.129315*	.047253	.021	.01613	.24250
	3	1	-.128537*	.049634	.031	-.24743	-.00965
		2	-.129315*	.047253	.021	-.24250	-.01613
Troops	1	2	.071636	.061447	.477	-.07555	.21882
		3	.149194	.071642	.101	-.02241	.32080
	2	1	-.071636	.061447	.477	-.21882	.07555
		3	.077558	.068205	.495	-.08582	.24093
	3	1	-.149194	.071642	.101	-.32080	.02241
		2	-.077558	.068205	.495	-.24093	.08582
Time	1	2	.000000*	.000000	.000	.00000	.00000
		3	.000000*	.000000	.023	.00000	.00000
	2	1	.000000*	.000000	.000	.00000	.00000
		3	.000000*	.000000	.000	.00000	.00000
	3	1	.000000*	.000000	.023	.00000	.00000
		2	.000000*	.000000	.000	.00000	.00000

*. The mean difference is significant at the 0.05 level.

The independent variables Major and AC/RC are listed as the second and third most significant indicators of cluster membership. Neither of these variables approached statistical significance when compared against any of the dependent variables with the ANOVA test as shown in Tables 12 and 13. These results indicate that while the two variables did contribute to the cluster formation they did so at a low enough level that they are not significant to this study.

Table 12
ANOVA test results for independent variable Major in Foot March scenario

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mission	Between Groups	.134	4	.033	1.678	.165
	Within Groups	1.336	67	.020		
	Total	1.470	71			
Terrain	Between Groups	.031	4	.008	.277	.892
	Within Groups	1.876	67	.028		
	Total	1.908	71			
Troops	Between Groups	.079	4	.020	.359	.837
	Within Groups	3.669	67	.055		
	Total	3.747	71			
Time	Between Groups	.000	4	.000	.000	1.000
	Within Groups	.000	67	.000		
	Total	.000	71			

Table 13
ANOVA test results for independent variable AC/RC in Foot March scenario

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mission	Between Groups	.006	1	.006	.276	.601
	Within Groups	1.465	70	.021		
	Total	1.470	71			
Terrain	Between Groups	.002	1	.002	.084	.773
	Within Groups	1.905	70	.027		
	Total	1.908	71			
Troops	Between Groups	.128	1	.128	2.477	.120
	Within Groups	3.619	70	.052		
	Total	3.747	71			
Time	Between Groups	.000	1	.000	.000	1.000
	Within Groups	.000	70	.000		
	Total	.000	71			

No other independent variables showed statistically significant results when compared to the dependent variables. None of the respondents found any hazards associated with the variable Time in the Foot March scenario. The manner in which the scenario was presented did not stress time as a significant factor. This resulted in each officer having an identical hazard value for the category so there was no statistics data available for this variable from the Foot March scenario.

4.2 Maintenance Scenario Results

For the Maintenance scenario Prior Service is the most important predictor of cluster membership followed by Platoon and Time in Service as shown in Figure 11.

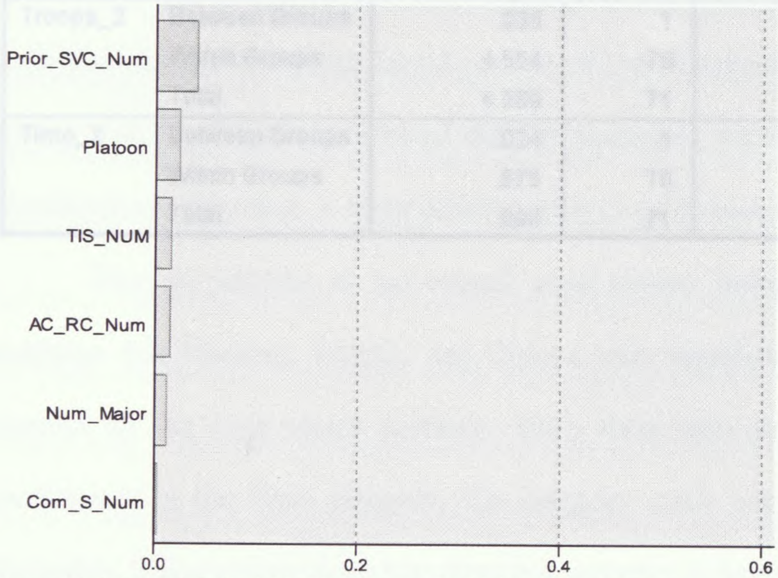

Figure 11. Independent Variable Significance for Maintenance Scenario

There were no statistically significant independent variables for the Maintenance scenario. Table 14 shows that even though Prior Service was identified as the most significant predictor of cluster membership it failed to reach the level of statistical significance in any hazard category.

Table 14
ANOVA test results for independent variable Prior Service in Maintenance

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Mission_2	Between Groups	.011	1	.011	.622	.433
	Within Groups	1.183	70	.017		
	Total	1.194	71			
Terrain_2	Between Groups	.017	1	.017	.464	.498
	Within Groups	2.613	70	.037		
	Total	2.630	71			
Troops_2	Between Groups	.035	1	.035	.545	.463
	Within Groups	4.554	70	.065		
	Total	4.589	71			
Time_2	Between Groups	.024	1	.024	1.899	.173
	Within Groups	.875	70	.012		
	Total	.898	71			

5. Analysis

The statistical tests conducted for this study showed mixed results. There were no clear statistically significant results in the overall hazard categories based on the seven independent variables (biographical information). The two-step clustering process did show that there were independent variables that were predictors of cluster membership. The ANOVA test demonstrated that there were statistically significant results for individual hazard categories based on one of the independent variables, and post hoc testing with the Tukey test showed that the categories within the variable Platoon were significant to each other. A more detailed analysis of these results is provided below.

This, in addition to the overall good quality rating of the clusters in SPSS, indicates that Mission, Terrain, and Troops were significant in the formation of the clusters for the Foot March scenario. Since there were no hazards identified by the participants in the Time category, this category made not contribution to the cluster formation. These values show that there is a variation in how the hazards in the first three categories were identified by respondents assigned to different clusters and indicate further examination based on the other independent variables.

The cluster results from the Foot March scenario indicated that Platoon was the most significant indicator of which cluster the respondents data record would be assigned to. Platoon demonstrated statistical significance for the dependent variables Mission ($p=.049$) and strong statistical significance for the dependent variable Terrain ($p=.016$). These results indicate that there may be a correlation between the instruction provided to the officers in the three different groups and the level of severity that they identified for hazards in the scenario. This is plausible since even though the same instruction materials are used for the RM training blocks, each student is instructed by the cadre for their assigned platoon. Due to the nature of the subject matter, each instructor would likely draw on their background and experience and likely place greater emphasis on different parts of the instruction.

The independent variable Prior Service showed no statistical significance in the Foot March scenario. This result is surprising since officers who had prior service experience should have viewed the hazards associated with the scenarios through a significantly different experiential lens than those who did not. The lack of a correlation between prior service and assignment of hazard severity may have been a result of the population of prior service officers in the data sample. 17 of the 72, or 24%, officers in the data sample were prior service and they were distributed across the three platoons. At 24% the sample size should have been large enough to show up as statistically significant unless there were other factors such as a masking effect from the variable Platoon.

The variable Deployments also showed no level of statistical significance for the dependent variables. Due to the very small sample size, generalizations cannot be made from this result. Out of the sample 72 records, only five, or 7%, had prior deployments. A much larger sample of leaders with deployment experience would be required to determine any statistical significance to this relationship.

In the Maintenance scenario, cluster quality was also rated as good indicating that the four dependent variables Mission, Terrain, Troops, and Time were significant in the cluster formation. Time was identified as a factor in this scenario and hazards were identified by many of the respondents. Prior Service, Platoon, and Time in Service were the three most significant predictors of cluster membership but none of them demonstrated statistical significance in relation to any of the independent variables.

The fact that Prior Service was the most significant indicator of cluster membership was expected but the fact that it was not significant for any of the dependent variables was surprising. Since scenario two was vehicle based and included tasks directly related to vehicle training operations, Prior Service, AC/RC, and other experiential based independent variables were expected to show significant. Many of the tasks included in the Maintenance scenario would not be common to the experience of an officer that has not served in the military prior to commissioning. This could indicate that the hazards presented in the scenario were not unique enough to prior service officers or that the much higher percentage of non-prior service officers in the study created a swamping effect for the variable.

The lack of results based on Commissioning Source was also surprising. The training received between the three commissioning sources varies significantly and in both scenarios Commissioning Source was one of the least significant variables for cluster membership prediction. The lack of significance based on commissioning source may be a positive for the Army. The fact that Commissioning Source showed no significance for cluster membership could mean that the training received at each commissioning source is similar enough in value that it produces a common view on hazards and risk. This result should be explored for validation with further research.

It is not possible to draw definitive conclusions for the results of the two scenarios due to the lack of commonality of statistically significant results between them. The most evident correlation is that the hazard categories Mission, Terrain and Troops were significant in cluster formation for both scenarios. This provides an indication that the respondent's background has a more significant impact on the hazards they assessed in these categories but the lack of broader statistically significant results prevents drawing this as a definitive conclusion.

The variable Platoon did show a correlation among the two scenarios being the most significant predictor of cluster membership in the Foot March scenario and the second most significant predictor in the Maintenance scenario. The fact that it was only statistically significant in relation to two dependent variables in the Foot March scenario and not statistically significant in the Maintenance scenario prevents generalization regarding the significance of the training received by the respondents and its impact on their hazard assessments. The correlation of Platoon among the two scenarios does point to training as an area worthy of further study.

6. Conclusion

Research in the field of RM is extensive and covers a wide breadth and depth of aspects of the topic but the evaluation of RM in the US Army is limited. Works like [3] and [4] discuss the process of Army RM but did not look at the individuals making inputs into the process, only the process itself. Works by [5], [6], and [7] explore RM as a decision making tool and the value it provides to leader. RM use in the civilian sector is discussed in [8] and [9], particularly how it relates to forecasting in insurance. The authors of [10], [11], and [12] use expert systems or neural networks to evaluate RM in sectors like logistics and IT. [15], and [16] discuss ERM and from these works the similarities between ERM and military RM are described. [20], [21], [22], [23], [24], and [25], discuss risk from the perspective of the individual and the impact that personality factors may have on an individual's view of risk.

The work done in this thesis extends the application of fuzzy expert systems to the domain of RM in the US Army. The two-step clustering technique was used to identify clusters of similar behavior which were then analyzed using One-Way Anova statistical test. The results of this study did not show clear, statistically significant correlations between how various individuals view risk, however they did provide some insight into certain training and background characteristics that may be influential to an individual's hazard assessments. For example, having Platoon as a significant predictor in the clusters formation may indicate that the most recent training received applies in a more significant manner than previous training (Commissioning Source) or experience (Prior Service). The study also demonstrated that the tools and techniques used for processing and evaluating data seem to be valid for use in this domain.

6.1 Limitations

One of the limitations to the study that prevents generalization is the relatively homogeneous nature of the data sample. The survey respondents for this study came from a single class of second lieutenants at a single point during their training. 48 of the 72, or 66%, of the officers surveyed were commissioned from US Military Academies. This is a significantly higher percentage than the total number of lieutenants commissioned into the Army by USMA which was 17.8% in 2005 [32]. Another side effect of the high percentage of USMA officers in the study is that it reduces the number of prior service officers in the study below normal levels since very few USMA cadets have prior service in the military. The smaller population of prior service officers also reduces the number of previously deployed officers in the study, only five respondents in the study have served an operational deployment. This small number removes Deployments as a valid variable even though it would be considered a major background indicator of hazard assessment.

Another limitation in this study is that as a commissioning source, OCS was underrepresented in the study. Nine of the 72 respondents, or 12.5%, listed OCS as their commissioning source, in 2005 OCS provided 25% of commissioned lieutenants not entering a specialty branch as a direct commission [32]. As a commissioning source it would be expected to provide a significant number of previously deployed officers since all of the lieutenants commissioned through OCS have prior service. In this study three of the five officers with operational deployments came from OCS.

6.2 Recommendations for Future Work

While these limitations do prevent generalization from this study they do provide clarification for the direction of future work. Future work in the field could follow three paths. One is expanding the current research to include a larger pool of officers of different ranks and backgrounds. Since the officers in this study were all from the infantry branch it is not possible to generalize to lieutenants of different branches. Future work should be expanded both vertically, to include officers of higher ranks, and horizontally to include lieutenants with different branches. Research can also be expanded to include enlisted ranks since there are approximately 4.5 enlisted Soldiers per officer in the Army [33] this study would vastly increase the population available for study. Studies expanded in this manner would allow generalization across the force and could lead to more significant assessments on which experiences have the greatest influence on hazard assessment. Previous work in [34] indicates that rank and time in service are indicators of risk perception.

The second method of research expansion would be pre and post testing of IBOLC lieutenants. Respondents could be surveyed at their initial arrival to IBOLC and then again at the end of the course and have their results compared. This research study would test the effect of the variables Platoon, which is tied to instruction received in the IBOLC coursework, and Commissioning source, which would be tied to training received prior to commissioning.

The third possible path of study is to conduct the study on a similar population of IBOLC officers again to confirm results. If similar results are achieved then the study could be expanded to basic officer courses in other branches to see if the results can be generalized to second lieutenants. The results from several branches could be tested against each other for statistical significance to determine if there are similarities or differences between the risk perceptions of the officers.

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