LOGISTICS MODELING AND PROJECT MANAGEMENT PRACTICES FOR CONTINGENCY BASING

by

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ABSTRACT

Contingency basing is a critical factor in mission success but requires significant logistical and commander support. Designing and constructing a camp that is safe, secure, and self-sustaining can be a difficult task for a Contingency Basing engineering manager. The infrastructure for basic needs such as electricity, fuel, water, food, and waste management is critical and needs to be flexible.

This research focuses on assisting the Contingency Basing engineering manager in designing and constructing a feasible base camp using project management and modeling tools. Measuring scalability and resiliency with in the contingency base was studied as well. The methodology concentrates on project management practices and logistics modeling as applied to contingency basing as well as measuring the scalability and resiliency of 40 functional contingency base blocks with 12 different coefficients. Project management tools will focus on retaining organizational knowledge by managing high turnover rate and extreme risk management. Modeling of several logistics systems with in the base camp will simulate real world problems. Strategic planning and clear metrics for resiliency and scalability will increase the effectiveness and efficiency of current basing standards.

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1. INTRODUCTION

1.1. MILITARY FORWARD OPERATING BASES

Forward operating bases (FOBs) or contingency bases, are used by the military for tactical support operations. "Most often, those tactical operations are associated with stability or civil support, but that is not always the case. Facilities may be established for either temporary or long‑term operations. A FOB provides [soldiers] with a secure area in which to rest, recuperate, repair and maintain equipment, plan and organize for upcoming operations. It may also be used to provide a secure environment for other agencies or units to function in specialty roles." (FM 3-21.20, 2006) FOBs can vary widely in sophistication, depending on size, support requirement, host-nation infrastructure, and duration.

United States military doctrine classifies contingency bases into three different categories based on the duration of usage: (1) Initial bases (less than 6 months), (2) Temporary bases (6 - 24 months), and (3) Semi-permanent bases (2 – 25 years) (Red Book, 2004). While a contingency base may start out as an initial camp for a battalion of soldiers, this can rapidly change into a temporary or semi-permanent base for an entire division. Simply put, a FOB is an evolving military facility that supports the military operations of a deployed unit and provides necessary support and services for sustained operations.

To the soldier, the contingency base is a 'home away from home'. They have become places where the stresses, frustrations, and discomforts of a combat soldier are alleviated. Contingencies bases are more than a refuge from danger, they offer a break from physical and mental stress of battle and a way to stay connected to home.

1.2. PROJECT MANAGEMENT

High turnover rates and extreme risk management can be everyday problems for the military. Turnover rates in combat zones are high for a number of reasons: geographical remoteness, combat stress, and being separated from friends and family, to name a few. While deployed, soldiers normally work 7 days per week frequently with 14 hours per day, in harsh climates and active combat zones. Extreme risk management often involves inexperienced personnel in disaster response situations. While the military has developed a risk mitigation plan, the process flow behind this plan can be difficult to understand. Reacting in the midst of a disaster also requires advancement planning to avoid confusion.

1.3. BASE CAMP MODELING

The U.S. Army does not currently have the capability to address base camp issues from a complete model based view. This results in poor design and operations, health and safety concerns, loss of operational flexibility, excessive capital and operating, and high resource demands. Consumable resources such as fuel, water, and materials require more soldiers, civilians, and contractors to escort, produce, and distribute said materials, requiring more resources in the process. FOBs often compete with their host nation for local resources causing tension with citizen which may have a detrimental impact on mission success.

To help with base camp planning, the Depart of Defense (DoD) must define common standards for base camp infrastructure. This will ensure that all “base camp planners and builders have similar expectations regardless of the service or organization supported.” The DoD should develop a reporting and design tool to track base camp infrastructure.

While using project management practices will add complexity to the system, a basing model needs to encompass people, tasks, structure, sustainability, and still conform to current infrastructure and transportation requirements set forth by the Department Of Defense.

2. LITERATURE REVIEW

2.1. PROJECT MANAGEMENT

2.1.1. High Turnover Rates. The military, like any civilian organization, must retain high quality, active employees in all situations. While this includes forced turnover caused by contractual limitations, organizational knowledge still needs to be preserved. Turnover, as defined by Heilmann, et al. (2009), is “the voluntary or involuntary act of leaving an organization and marked by the actual separation of the individual from the organization.” Figure 2.1 describes differences between voluntary and involuntary turnover.

Involuntary turnover is when the employee leaves the organization due to things outside the employee’s control. Box 1 is an employee leaving due to illness, continuing education, a relative moving, etc. They do not wish to leave and the organization has a positive view of them, but they leave anyway. Box 2 is an employee being fired. They do not wish to leave but the organization has a negative view of them and they are terminated.

Voluntary turnover is when the employee leaves of their own accord. Box 3 shows a positive evaluation of the employee but the employee wants to leave anyway. This is considered dysfunctional turnover as the organization must now find and train to replace the employee that left. It is a negative from the organization. Box 4 shows a negative evaluation of the employee and the employee wants to leave. This is functional turnover – the employee was going to be terminated anyway or the company is downsizing. It is a positive for the organization. This is not usually considered turnover.

		Organization's Evaluation of Employee	
		Positive	Negative
Employee's Evaluation of Organization	Wants to stay	1 Employee leaves	2 Employee is fired
	Wants to leave	3 Dysfunctional turnover Employee quits	4 Functional turnover Employee quits

Figure 2.1: Voluntary vs. Involuntary Turnover

Adapted from Dalton, et al. (1982)

Turnover in the military brings in another factor – constant vs. variable turnover rates. Variable turnover rates are what civilian and non-deployed military organizations are used to. Turnover is heavily employee dependent and not easily predicted. Murnieks, et al. (2011) states that constant turnover rates are the result of deployments being fixed periods of time, 6 or 12 months on average. "A typical [deployed military] project office turns over approximately 15% of its staff monthly. Given that the average turnover rate for corporations in the United States is 15% annually, the turnover rate experienced by [deployed] U.S. military […] is considered high." (Murnieks, et al., 2011, 483) Turnover is unavoidable due to the nature of the organization.

Due to regular rotation of military personnel, transfer of organizational knowledge and lessons-learned about challenges is infrequent or, in a disaster environment, possibly nonexistent.

2.1.2. Extreme Risk Management. Kaddoussi, et al. (2011) defines risk as the probability of an event occurring and its consequences, [or] uncertainty and its impact. Under normal circumstances, risks can be identified, analyzed, measured, and controlled, but contingency military situations are unique. Designed for mobility and quick response, military personnel are frequently among first responders to a disaster area. While "military units must be resilient and robust to deal with the uncertainties of combat" (Weeks, 2007, 482) they may have little to no actual disaster experience.

Deviations from expected outcomes may affect operations, processes, plans, goals or strategies. Top leaders must be accessible, break down communication barriers, and continually provide direction and support to personnel. Although "military and government organizations are well known for their tendency toward paperwork and bureaucracy" (Weeks, 2007, 487) sometimes effectiveness is greater than efficiency where paperwork is concerned.

The military makes a distinction between Tactical Risk and Accident Risk. Tactical risk is "concerned with hazards that exist because of the presence of either the enemy or an adversary." (FM 3-21.20, 2006) Tactical risk is mitigated by collecting intelligence about the environment, threats, population, local governments, and infrastructures. Accident risk is any operational risk other than tactical risk. This includes risk to civilians, friendly forces, and the impact of hazards on the operation. Accident risk is mitigated by continuous risk assessments and by using timely, efficient, and effective protective measures.

The Army field manual on Risk Management (FM 100-14, 1998) lists three commonly used principles to provide a framework for implementing a risk management process. The first principle is based heavily on Six Sigma's Define, Measure, Analyze, Improve, Control (DMAIC) process. Military leaders identify hazards and assess both accident and tactical risks. They incorporate control measures into estimates, operation plans, orders, and missions, and make sure all soldiers understand and properly execute risk controls. Leaders continuously assess variable hazards and implement risk controls. The second principle addresses the appropriate level in the chain of command to make risk decisions. Judgment is often needed in immediate situations with uncertainly and ambiguity. Guidance should be based on established military policies and in accordance with the higher commander's directions.

Accepting no unnecessary risk is the last principle. Risks are balanced against mission expectations. Risks are only accepted if the benefits outweigh the potential costs or losses.

2.2. SUPPLY CHAIN

2.2.1. Managing Military Supply Chains. Logistics, to the military, is the "science of planning and carrying out the movement and maintenance of forces. It includes those aspects of military operations that deal with the design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of materiel" as well as "acquisition or construction, maintenance, operation, and disposition of facilities" (Dictionary of Military and Assocaited Terms, 2010). It is a "complex process, involving collaboration and coordination among many organizational and informational entities, such as supply, transport and troops, which are geographically distributed and contain complex information" (Kaddoussi, et al., 2011).

The military supply chain plays an important role according to Jin et al.; while enhancing the peacetime and wartime military support benefit, it also reduces the military logistics operations cost. While the military has molded the supply chain into what they believe is efficient - a close linked chain structure, any problems that arise will influence the entire operation. The goal of military supply chains "is to meet the maximum army need [while] optimizing logistics support cost" (Jin, et al., 2010). Future supply networks must plan efficiency optimization under normal operating conditions as well as have resilience to unpredictable disruptive events as these are key in providing timely responses to support operations in theatre (Ghanmi, et al., 2009).

2.2.2. Scalability and Resiliency. Ensuring the scalability of a base of approximately 800 soldiers for less than 24 months to upwards of 20,000 soldiers for up to 25 years is an enormous task. The infrastructure for basic needs such as energy, fuel, water, food, and waste management is therefore critical and needs to be flexible.

"Resilience is the key to developing a strategic plan that is sustainable and capable of producing results that are better than less resilient competitors" (Barroso, et al., 2010). It is more than the ability to recover; resiliency shows a level of flexibility and the ability to adapt to environmental influences. A resilient supply chain meets currents needs without compromising the capability to meet future needs. While individual components of a supply chain may be resilient, the system as a whole must take steps toward resiliency for a completely flexible and adaptable supply chain.

3. PROJECT MANAGEMENT PRACTICES

3.1. HIGH TURNOVER RATES

Turnover rates, whether constant or variable, are high in the military for a number of reasons. Increased stressed due to separation from friends and family members, hazardous combat zones, and a high level commitment and dedication from both the individual and loved ones to name a few. While there are numerous reasons personnel choose to leave (or stay), this research will focus on constant and variable turnover rates. Constant turnover in the military is comparable to that of professional consulting firms. “Workers in these organizations frequently rotate from one project or team to the next and must adjust to the nuances and culture of each new situation.” (Murnieks, et al., 2011) The more personnel turnover, the more performance is disrupted and organizational knowledge is lost. Top management must focus on reducing the effects of turnover, not wasting time and money on trying to reduce unavoidable turnover.

“Managers must develop strategies that will help them adapt to the difficult environment caused by an unstable workforce.” (Mowday, 1984, 366) When personnel leave, knowledge essential to the organization is lost. Organizational knowledge has two parts; the first, “pertinent factual data about the organization” and the second, “a mental model around which to structure that data meaningfully.” (Murnieks, et al., 2011, 483) Common mental models are first introduced during company training or boot camp. Training usually focuses on procedures, processes, and common software used throughout the organization. The military attempts to increase this shared knowledge by simplifying and standardizing software associated with project management, specifically electronic databases. Having all project information located in a single database makes it easy for managers and co-workers, to find needed information quickly. (Murnieks, et al., 2011)

The following (Table 3.1) explains several common organizational knowledge problems with simple recommendations to help minimize the effects of turnover.

Table 3.1: Common Organizational Knowledge Issues

Problem	Common Issues	Recommendation
Technology	• Steep learning curve • Low morale • Feelings of inadequacy	• Use common software programs (i.e., Microsoft Office) • Host training classes
Communication	• Lack of communication between new and current personnel or managers	• Encourage cross-training on projects • Encourage attendance for entire meeting to share knowledge
Culture	• Lack of cohesion • Limited organizational involvement	• Foster a trusting, supportive work environment • Leaders influence organizational culture
Role Clarity	• Inefficient • Unexpected results or behaviors • General confusion	• Clearly define roles and what is expected of personnel

Adapted from Murnieks, et al. (2011)

In the case of functional turnover, these unavoidable separations are of little consequence. It can be argued that it really does not matter why these individuals left;

they are not valued by the organization in any case. With dysfunctional turnover, however, the unavoidable category is of marked importance states Dalton, et al. (1981). Organizations that are overstaffed or facing monetary issues may find functional turnover a welcomed occurrence, eliminating the need for expensive and troublesome layoffs or terminations. Functional turnover is, of course, not without cost. Administrative paperwork, early retirement packages, and future training and recruitment still cost the organization time and money.

Dysfunctional turnover, as stated by Dalton, et al. (1982), can be further divided into controllable and unavoidable categories. Unavoidable situations consist of temporary or summer employment, returning to school, health or family concerns, and personnel commitments such as a spouse moving for a new job. This turnover is hard to plan for and can create uncertainty for managers. "In naturally occurring teams, the effects of voluntary turnover on [a] team's performance might be confounded with the effects of intentional replacements." (Solow, et al., 2002, 1061)

The controllable dysfunctional turnover category is where top management can "impact the level and perception of demands placed on individuals, the perceived control individuals experience to address those demands, the support perceived to be available to personnel, and the opportunities available to personnel to be involved in meaningful work." (Alarcon, et al., 2010, 302) This is where the organizational culture, work groups, and managers play a large role in whether an employee stays or quits, although military personnel may leave the organization for a different reason.

Military life is extremely demanding, requiring commitment from both the soldier and his family members. Dangerous assignments, frequent relocations, extended deployment, and possible death can cause stress and strain family relationships possibly leading to voluntary turnover of the soldier. Heilmann, et al. (2009) suggests that "family may play a much larger role than work experience in the formation of turnover intention" and "individuals who perceive higher levels of family satisfaction with military life reported lower levels of work-home conflict." In other words, a soldier considers family satisfaction with the military over their own work related attitudes. Managing voluntary turnover from the soldier's side may not be possible as families seem to have a greater impact on turnover. Additional research to determine how to increase family satisfaction with the military is required.

3.2. EXTREME RISK MANAGEMENT

"Planning for disasters involves two factors: (1) mitigation of damage through advance actions, and (2) planning for response to the event once the damage is done." (Weeks, 2007, 479) While military personnel are well trained, the uncertain and sporadic nature of disasters leaves most with little experience in responding to actual disasters.

3.2.1. Mitigation. Factor (1) can be addressed with a risk management assessment and follow through actions. The military uses the following five steps of risk management in the decision-making process:

Step 1: Identify hazards

Step 2: Assess hazards to determine risk

Step 3: Develop controls and make risk decisions

Step 4: Implement controls

Step 5: Supervise and evaluate

Steps one and two encompass the assessment by requiring individuals to identify hazards and the impact of each hazard on the operation. In steps 3-5, leaders balance risk against costs, eliminate unnecessary risks, continuously assess risks, and evaluate controls as follow-up actions to effectively manage risk. Figure 3.3 illustrates the continuous process that risk management entails while the following explores each step in more detail.

Step 1: Identify Hazards. A hazard, as defined by Dictionary of Military and Assocaited Terms (2010), is “a condition with the potential to cause injury, illness, or death of personnel; damage to or loss of equipment or property; or mission degradation.” The military uses six factors when assessing risk: Mission, Enemy, Terrain and weather, Troops and support available, Time available, and Civil considerations (METT-TC). Table 3.2 lists examples of potential hazards organized according to METT-TC factors. This is not intended to be a complete list of hazards.

Table 3.2: Examples of Potential Hazards by Risk Factor

Risk Factor	- Potential Hazards
Mission	- Duration of operation - Complexity or clarity of plan - Proximity and number of maneuvering units
Enemy	- Advantages provided to enemy by environment - Enemy capabilities - Availability of time and resources to collect intelligence

Adapted from FM 3-21.20 (2006)

Table 3.2: Examples of Potential Hazards by Risk Factor (cont.)

Terrain & Weather	- Visibility conditions (light, dust, fog, smoke) - Effects of climate, weather on troops, vehicles, equipment - Extreme heat or cold - Natural hazards (broken ground, steep incline, water)
Troops & Equipment	- Equipment status - Insufficient combat power - Poor communication - Soldier and leader proficiency - Impact of new leaders or crewmembers - Soldier and leader rest situation - Fatigue and dehydration - Lack of water, medical supplies, or evacuation capabilities
Time Available	- Insufficient time to plan, prepare, and execute operations
Civil Considerations	- Political attitudes and media contact - Interaction with friendly forces and local population - Civil support operations

Adapted from FM 3-21.20 (2006)

Step 2: Assess hazards to determine risk. This step determines which hazards can be eliminated or avoided altogether. Hazards that cannot be eliminated or avoided are assessed in terms of probability and severity and measured against a risk assessment matrix (Figure 3.1). Probability estimates for risk levels may be based on the specific mission being carried out or on previous missions and the events that occurred. Probabilities are divided into five categories:

- Frequent: Occurs very often; continuously experienced
- Likely: Occurs several times
- Occasional: Occurs sporadically
- Seldom: Remotely possible; could occur at some point
- Unlikely: Improbable, but not impossible

Severity is the result or outcome of a hazardous incident and expressed by the degree of injury or illness, loss of or damage to equipment or property, environmental damage, or other mission-impairing factors such as unfavorable publicity or loss of combat power. Severity, as defined by the military, has four degrees:

- Catastrophic: Mission failure, death or disability, mission-critical system or equipment damage, major property damage, severe environmental damage, mission-critical security failure, unacceptable collateral damage
- Critical: Severely Degraded mission capability, partial disability, extensive damage to equipment or systems, property, or the environment, security failure, significant collateral damage
- Marginal: Degraded mission capability, minor damage to equipment or systems, property, or the environment. Lost day due to injury or illness, minor damage to property or the environment

- Negligible: Little or no adverse impact on mission capability, first aid or minor medical treatment, slight equipment or system damage, but fully functional and serviceable, little or no property or environmental damage.

The estimated degree of severity and probability for each hazard is then compared to the Risk Assessment Matrix (Figure 3.1)

Risk Assessment Matrix

		Probability				
		Frequent	Likely	Occasional	Seldom	Unlikely
Severity	Catastrophic	**E**	**E**	**H**	**H**	**M**
	Critical	**E**	**H**	**H**	**M**	**L**
	Marginal	**H**	**M**	**M**	**L**	**L**
	Negligible	**M**	**L**	**L**	**L**	**L**

E - Extremely High Risk
H - High Risk
M - Moderate Risk
L - Low Risk

Figure 3.1: Risk Assessment Matrix

Step 3: Develop controls and make risk decisions. Step 3 consists of 2 substeps: develop controls and make risk decisions.

Controls are procedures and considerations a military unit uses to eliminate hazards or reduce their risk. After assessing each hazard, one or more controls that either eliminate the hazard or reduce the risk (probability, severity, or both) of a hazardous incident. It is important to consider the reason for the hazard, not just the hazard itself.

Controls fall into three basic categories: educational controls, physical controls, and avoidance. Educational controls are based on knowledge and skills through individual and collective training. Physical controls are signs to warn individuals and units that a hazard exists; barriers and guards are also used. Avoidance controls are when leaders take positive action to prevent interaction with an identified hazard. Controls also have criteria they must meet to be effective: Suitability - actually removing the hazard, feasibility, and acceptability (benefit gained must justify the cost).

Risk decisions are key elements in determining whether accepting the risk is justified or unnecessary. Risks must be balanced against mission expectations and compared with controls to determine residual risk levels.

Step 4: Implement Controls. Implementing controls involves coordination and communication with appropriate superior, adjacent, and subordinate units and with those executing the mission. This critical step ensures that controls are translated into clear, simple execution orders understood at all levels.

Step 5: Supervise and Evaluate. During mission execution, leaders must make certain their subordinates understand how to execute risk management controls. Leaders also continuously evaluate the unit's effectiveness in managing risks to determine improvement areas.

3.2.2. Response. Factor (2) is addressed below with four ways to help plan for disaster response in extreme risk management:

- Establishing a central information point can help filter the large amounts of data being received and provides a point of contact for weak communication channels.

A central point allows for personnel for different skills to be directed to where they are most needed.

- Reduce or eliminate normal approval processes that limit effectiveness. The current focus should be on responding quickly, not on the efficiency of a truck load.
- Using a common or well-known organizational structure, such as Figure 3.2, will reduce confusion and increase efficiency in personnel.
- Use an effective priority system. While most emergency supplies are important, a priority system must be created to distribute supplies when and where they are needed most.

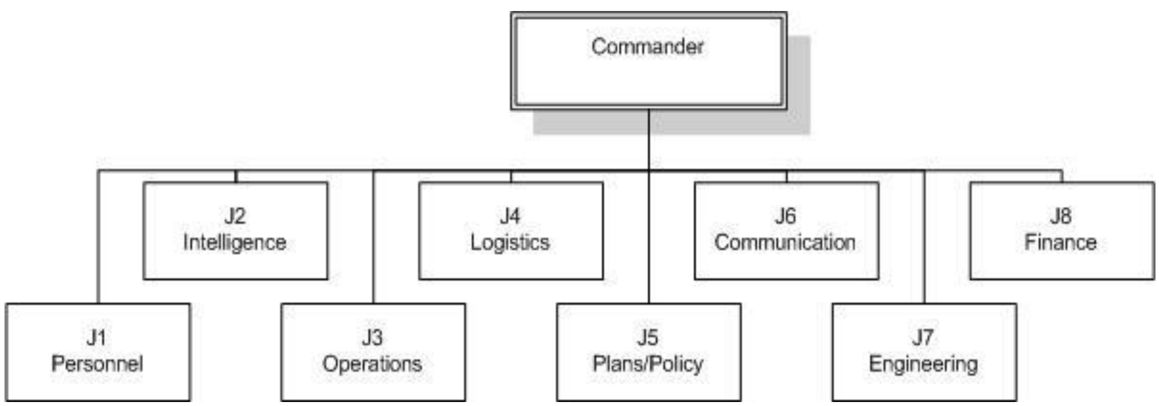

Figure 3.2: Military Organizational Structure

Adopted from ADRP 6-22 (2006)

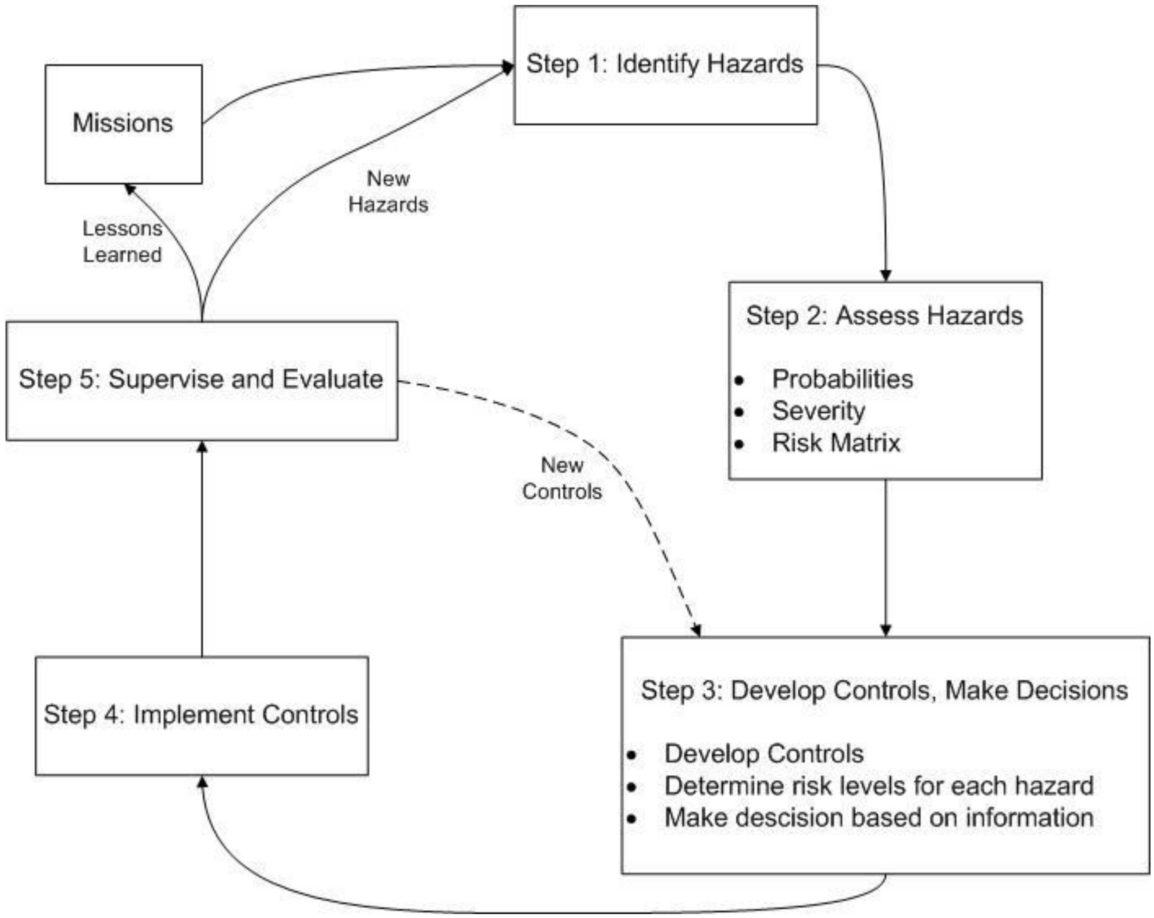

Figure 3.3: Risk Management Process

Adopted from FM 100-14 (1998)

4. KNOWLEDGE SHARING

4.1. RELATIONSHIP ANALYSIS TOOL

A drag and drop base camp planning tool is currently being developed. An estimator is brains behind the larger planning program. While the estimator was never intended to be released, it was given a user interface for ease of demonstration and validation. The knowledge sharing aspect of the estimator was an unintended consequence.

The knowledge sharing tool will help limit the effects of high turnover and decrease the stress of extreme risk. This knowledge sharing tool, also referred to as a Relationship Analysis tool, will help retain organizational knowledge of planning and layout data. The Relationship Analysis tool has been independently validated by subject matter experts and will be deployed with active duty personnel soon. Below, a brief overview of the tool is given followed by a study currently being conducted.

4.1.1. Overview of Relationship Analysis Tool. Figure 4.1 shows an overview of the user interface, while Figure 4.2 highlights the section describing the environment. In the first box, the user enters the number of operational soldiers; the tool is currently validated from 100 - 2000. The range that matches the number entered is also selected from the radial dials above. Moving to the right, mission type (offensive, defensive, recon, etc.) and climate (arid, temperate, etc.) are drop down list placeholders for future work. These are currently nonfunctional.

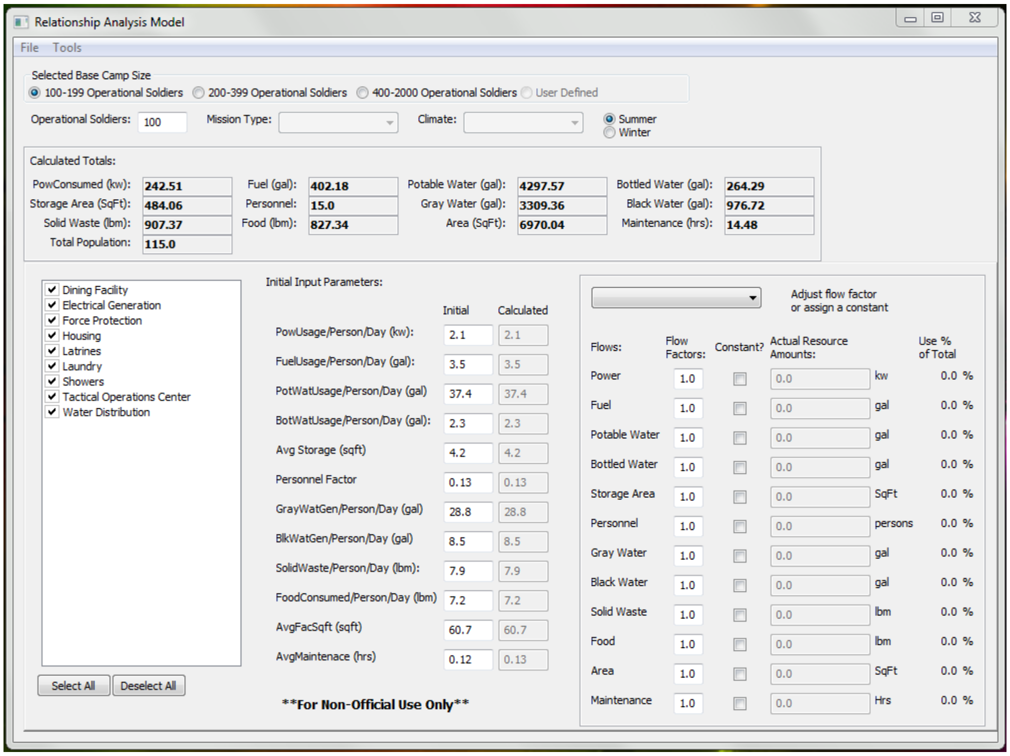

Figure 4.1: User Interface

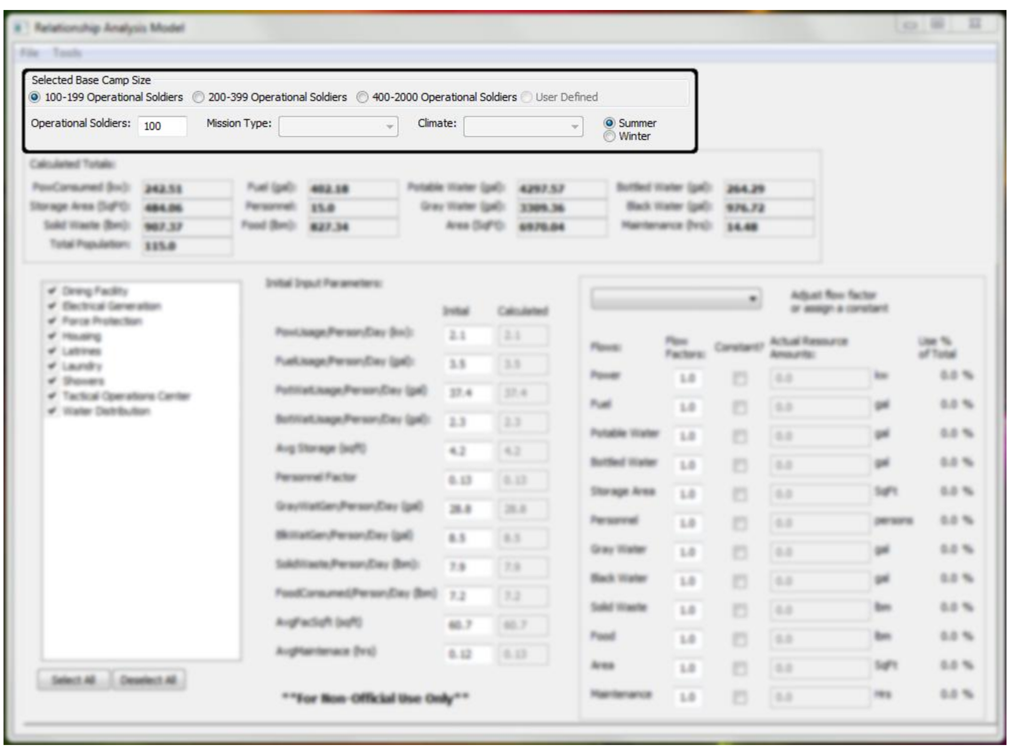

Figure 4.2: Environment

Figure 4.3 displays the calculated totals from the model. The totals will be zero when the program starts and until a facility is selected. The values represent consumed (water, power, fuel, etc.) or generated (waste, grey water, etc.) resources for the total base camp per day.

The next section, Figure 4.4, lists the available facilities based on the number of operational soldiers. The figure currently lists 9 facilities based on the input of 100 operational soldiers. There are currently over 40 facilities for up to 2000 operational soldiers and is still expanding (see Appendix A).

Figure 4.5 displays the initial resource usages. These values change based on the number of operational soldiers and are used to calculate the total resource usage seen in Figure 4.3. They can be adjusted to fit a particular base camp as needed.

Figure 4.6 includes details about each available facility. After selecting a facility from the drop down list, resources used per facility are displayed in the column 'Actual Resource Amounts'. The flow factor allows the user to add a factor of safety. If the actual resource amount of fuel for a dining facility is 75 gallons, a flow factor of 2 doubles the amount of fuel, i.e., 150 gallons. The resource value can also be set as a constant, i.e., 100 gallons of fuel. The percentage of total displays how much a facility is using of a resource, i.e., 75 gallons of fuel is 3.3% of the total fuel usage. Adjusting the flow factor or setting a constant for a particular facility only affects the calculated totals; it will not change the initial input parameters or affect any other facility's totals.

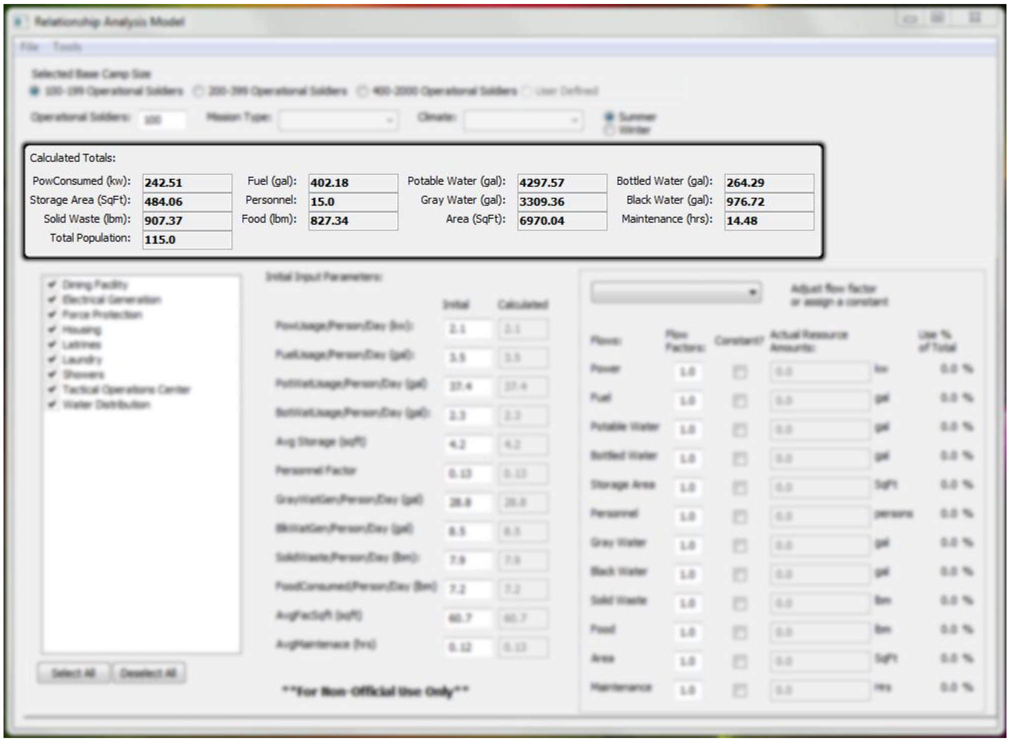

Figure 4.3: Calculated Totals

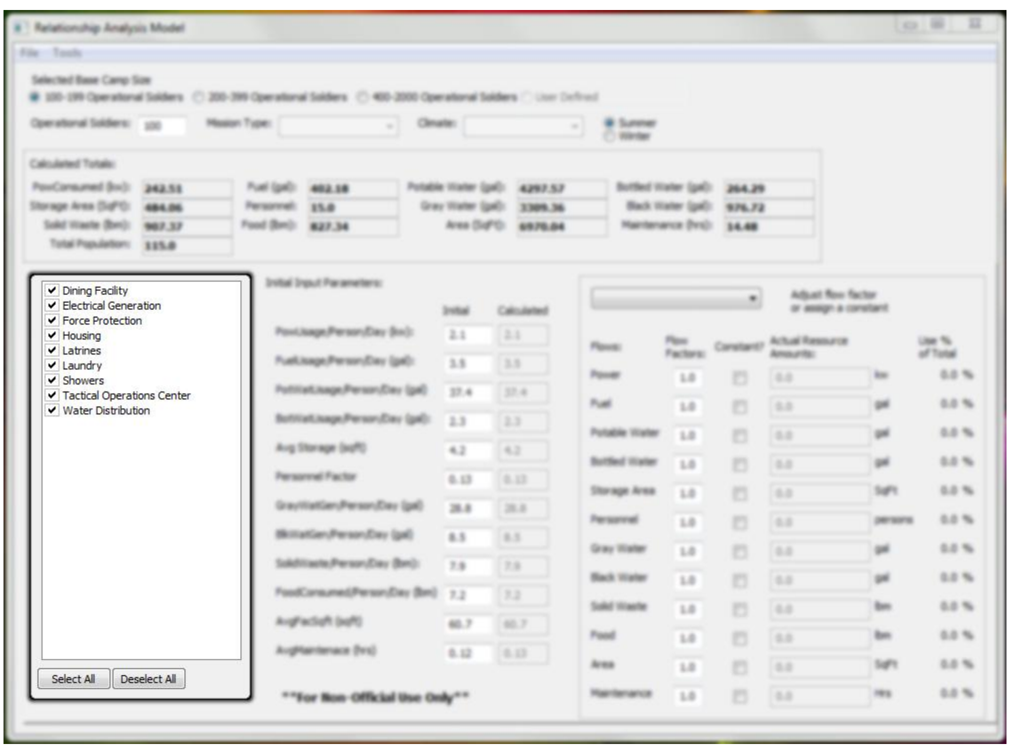

Figure 4.4: Facilities Selection List

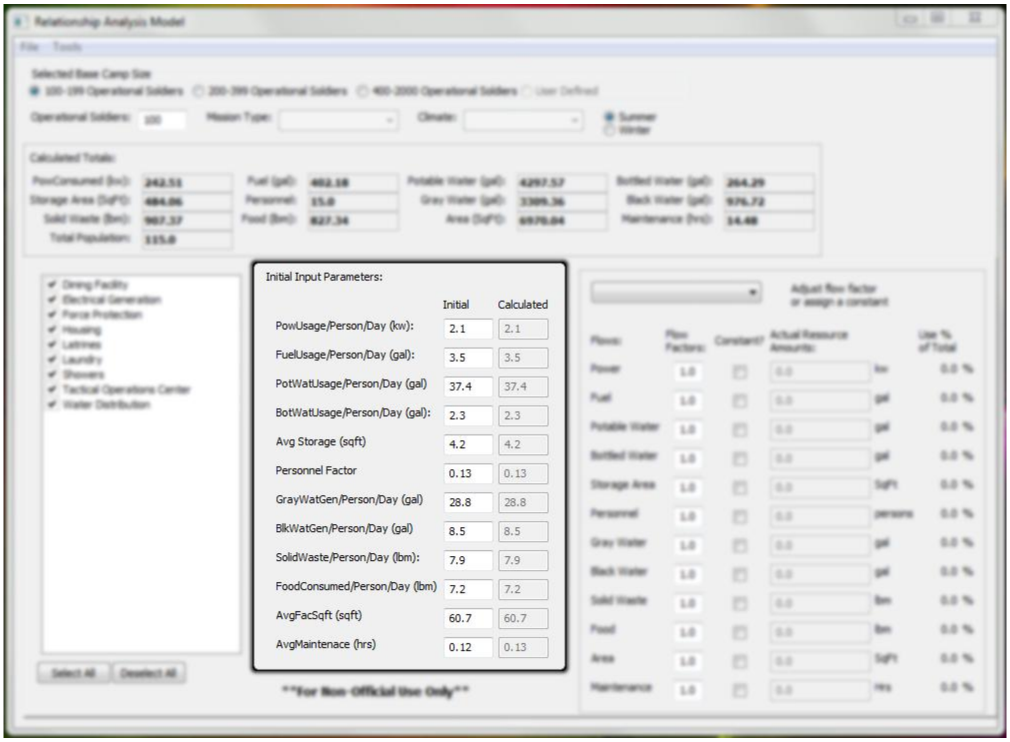

Figure 4.5: Initial Resource Usages

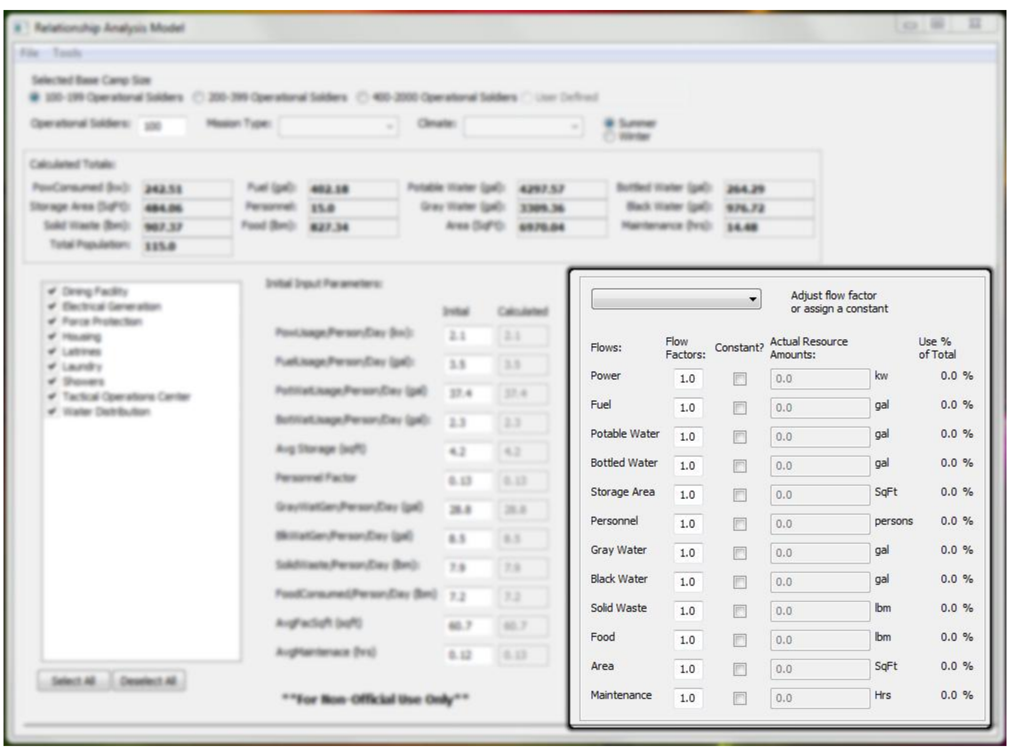

Figure 4.6: Individual Facility Adjustments

4.1.2. Usability Study of Relationship Analysis Tool. A usability study of the relationship analysis tool was created to provide feedback from the target audience. The target audience includes base camp or project managers, commanders, and those involved in the creation of a base camp.

The study is divided into 3 parts – demographic and background, accuracy, and functionality. Demographic and background information will classify the user by experience with base camp design and with base camps in general. The next section, accuracy, allows the user to determine if the calculated totals, facility list, and resource usage numbers are correct in the user's experience. The section consists of Yes/No questions and space to allow explanation of selected answer. The functionality questions assess the usability and layout of the tool and ability of the user to understand the data presented. The Likert scale is used for these questions with space to allow of explanation if needed. Questions asking what the user would add, change, or remove are also included here. The final question pertains to the tool itself and asks if the user was able to 'break' the program. 'Break', in this instance, refers to the program freezing, throwing an error message, or displaying negative numbers. The study hopes to improve the tool by incorporating user feedback into future versions. See Appendix B for selected questions from the study.

5. MATHEMATICAL MODEL SCALABILITY AND RESILIENCY

5.1. SCALABILITY

Ensuring the scalability of a base of approximately 800 soldiers for less than 24 months to upwards of 20,000 soldiers for up to 25 years is an enormous task. The infrastructure for basic needs such as energy, fuel, water, food, and waste management is therefore critical and needs to be flexible

5.1.1. Scalability Measures. This research objective concentrates on the scalability and resiliency of 40 functional contingency base blocks with 12 different coefficients. (See Appendix A) Two types of scalability are used – scaling out, which adds more infrastructure; and scaling up, which adds more resources to the contingency base design. Resiliency is measured by how the system reacts to rapid change, such as an interrupted supply chain network or a surge in soldiers.

The scalability metrics used examine two normally separate cases for when a system overloads. Scaling out, as defined before, creates additional infrastructure in the system. Infrastructure, in this case, includes buildings, roads, generation, and distribution. Scaling up, again adds more resources to the current system. Resources can be water, electricity, maintenance, footprint, and people. Usually a system can scale up or scale out to meet its changing needs. A contingency base requires both. Adding a building, scaling out, requires additional water, electricity, maintenance, etc. Scaling up, adding people or water to the system, requires an increase in buildings, roads, and distribution.

According to Winter (1999), scalability is the ability to grow your system smoothly and economically as your requirements increase. In this case, the system is a military base camp and the requirements include an increase or decrease in soldiers, contractors, or supplies. The current base camp system is in terms of 40 different function blocks. These are the most common facilities used by all branches of the military. They include buildings such as dining, laundry, housing, and medical. The blocks can also be used to describe functions such as electrical generation, water distribution, solid waste treatment, roads, and military police. The function blocks are mathematically described in terms of 12 coefficients like electricity (kW), potable water (gal), personnel, footprint (sqft), and maintenance (hrs/day).

The first equation that a scalability measure is applied to is the footprint of the building. The footprint is the square foot per person of the building multiplied by the total number of personnel. Square footage requirements are typically given in terms of 100 or 1000 personnel (i.e. 512 sqft per 100 users, 1624 sqft per 1000 users). Almost all of the other eleven equations used per block are described in terms of area. (See Equation (1), Table 5.1)

For example, potable water consumption per day per solider is 38 gallons. A dining facility has approximately 6.144 square feet per user and potable water usage is roughly 10% of the 38 gallons or 3.8 gallons per day per user per dining facility or 380 gallons per day per 1000 users per 6144 square feet. The scalability factor is then approximately 0.62 gallons per square feet. The scalability factor is then multiplied by the area of the building to determine the amount of potable water needed for a dining facility given a specified number of personnel.

$$\text{Amount needed} = \rho a s \qquad (1)$$

Where ρ is the scalability factor, a is the area in square feet per user (footprint), and s is the number of personnel. Obviously, the scalability factor changes by building (function) and may not be valid in all instances, i.e., water distribution, electricity generation, etc. as these are listed by personnel/demand not area.

The military has standards outlined in several different manuals that must be used (i.e., given). Comparing these equations to the data collected by the military and their contractors, scalability of a standard base camp can be determined.

Table 5.1: Equations by Coefficient

Coefficient	Equation Used
Electricity	Given as a percentage of electric usage (2% of 3kW) or equation (1) is used
Fuel	Given as a flat number (200 gal) or in terms of users (10000gal/1000users)
Potable Water	Equation (1)
Bottled Water	Equation (1)
Storage	Given in percentage (30% of total area)
Personnel	Given in terms of users (12 personnel/1000users)
Gray Waste Water	Equation (1)
Black Waste Water	Equation (1)
Solid Waste	Equation (1)
Food Consumption	Equation (1)
Footprint	Given as a flat number (1710 sqft) or in terms of users (512 sqft/100users)
Maintenance	Given in hours/day

5.1.2. Preliminary Results. The current mathematical models on scalability are only feasible up to approximately 3000 soldiers after which the model is no longer linear. These graphs show that while adding personnel, resources are not being added at the right time to support personnel or soldiers.

After 3000, potable water usage jumps (Figure 5.1), as does the total footprint. This indicates an estimation error in the mathematical equation as the total footprint should follow the number of soldiers per building as well as the number of buildings actually needed, not just square footage. Potable water should follow a more linear path. As the amount of soldiers increase, potable water per soldier will decrease to accommodate the increase in demand and to not overload the system. The increase in gray water (from showers, laundry, dishes, etc.) is considered normal.

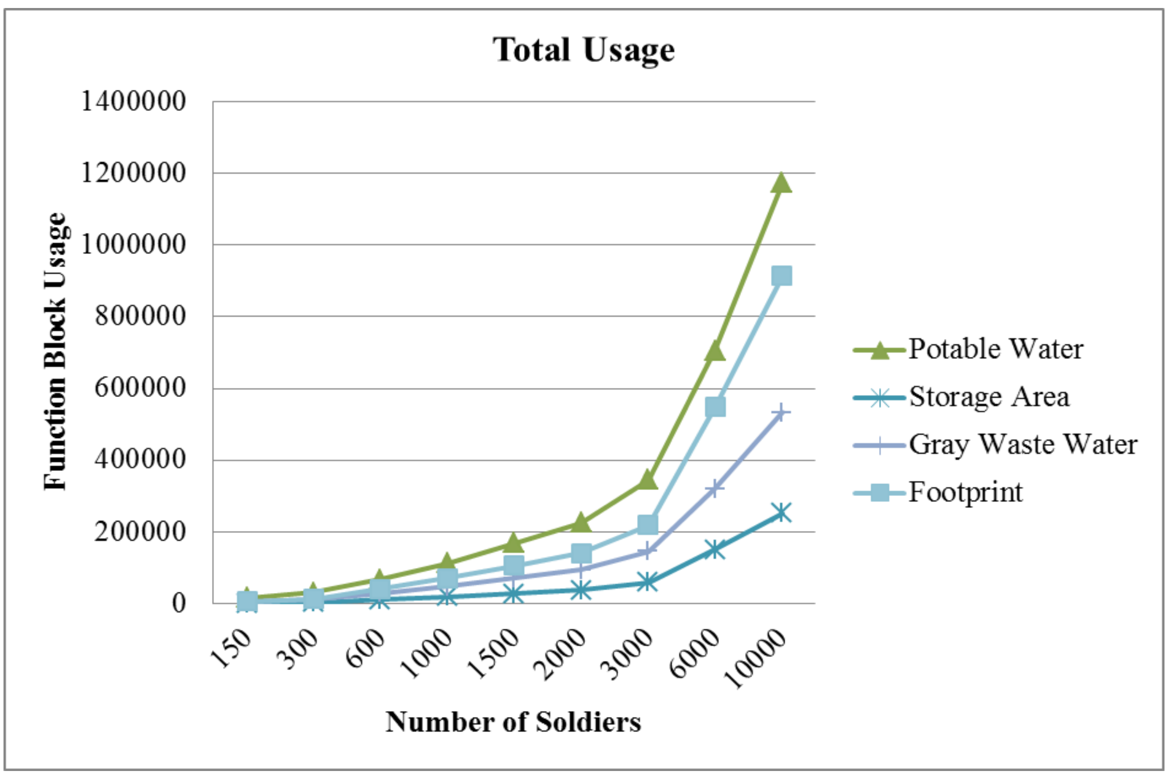

Figure 5.1: Total Function Block Usage A

Fuel usage (Figure 5.2) also shows a dramatic increase due to the inclusion of an airfield at 6000 soldiers. Additional research is needed to determine if fuel usages are correct. Although the personnel line in figure 2 appears to be flat, it is gradually increasing. Personnel numbers are less than 30 per 1000 soldiers, most under 12 per 1000 soldiers.

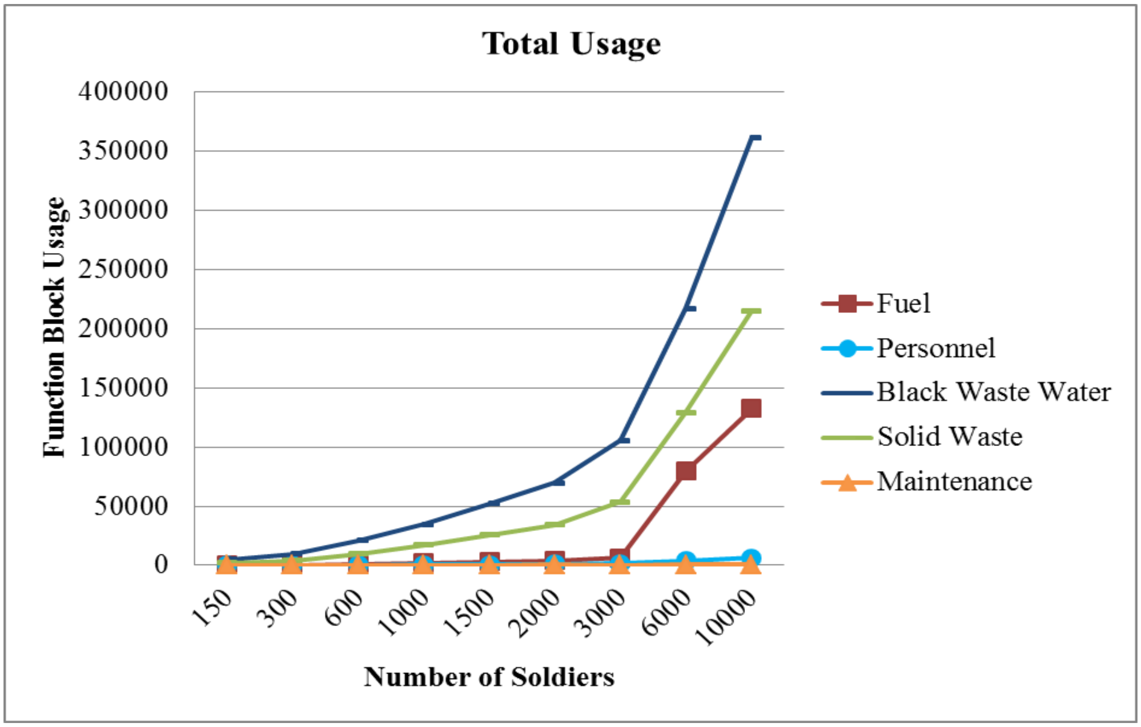

Figure 5.2: Total Function Block Usage B

Electricity usage (Figure 5.3 and Figure 5.4) shows a need for better planning as opposed to stacking generators when more electricity is needed. Stacking generators can lead to underutilization of the generators or an excessive load on the system. It should be noted that the assumed electricity usage per solder increases with the size of the contingency base.

A concerning observation is of the total maintenance hours. While Figure 5.2 shows a flat line, maintenance hours should linearly increase with the number of soldiers. This can be attributed to the set maintenance hours per function block. An equation is needed for maintenance to track the increase in personnel and subsequently the numbers of buildings (functions) on base.

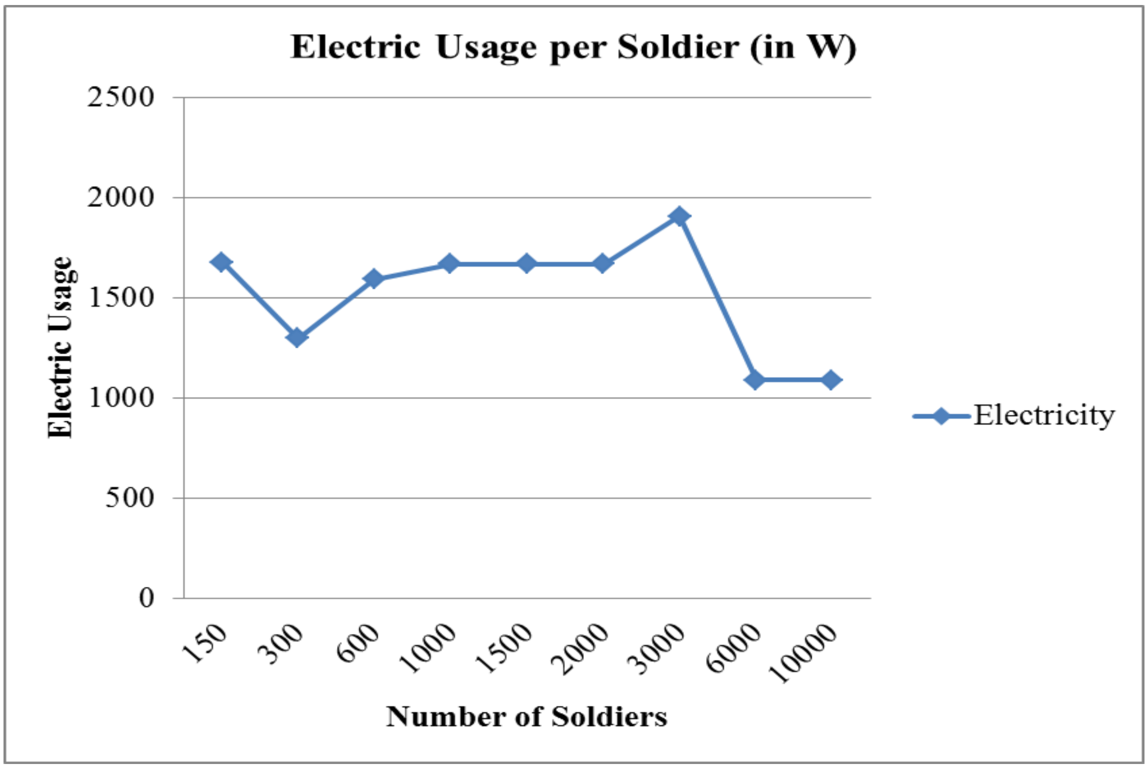

Figure 5.3: Electric Usage per Solider in Watts

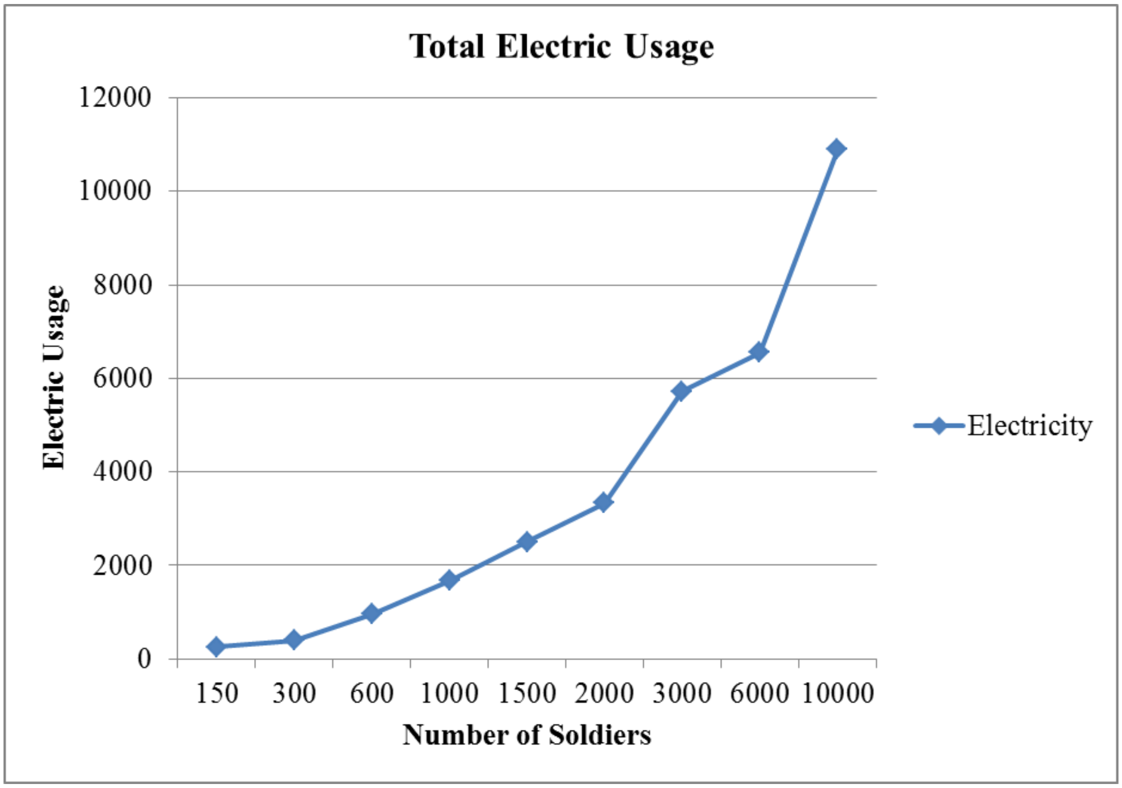

Figure 5.4: Total Electric Usage

5.2. RESILIENCY

The theory of resilience is multidimensional and multidisciplinary (Long, et al., Ponomarov, et al.). The army defines resiliency as "showing a tendency to recover quickly from setbacks, shock, injuries, adversity, and stress while maintaining a mission and organizational focus" (ADRP 6-22, 2006). Resilience can be achieved by redundancy in safety stock and multiple suppliers or by building in flexibility.

Redundancy is usually cited as being expensive with limited benefits but this applies to standard operations. Military supply chains cannot be considered "normal processes". Where an attack on a caravan or an improvised explosive device (IED) threat may be high impact, low probability for most civilian companies, for the military this would be considered high impact, high probability. The increased risk for these high events in theatre negates the extra expense of redundancy. Safety stock may be extra storage space on base. If space is limited, shorter reorder periods can increase stock quickly. If one supplier is cut off due to lack of transportation opportunities or on back order, multiple suppliers can limit disruption in theatre. Thorough documentation can control quality and cost concerns.

While redundancy is a "here and now" solution, flexibility is for the long term. A flexible supply chain is built into the overall system. It can "sense threats and respond to them quickly" (Sheffi, et al., 2005). Flexibility for resilience involves many aspects of the supply chain, from the ability to switch suppliers quickly to moving distribution channels, which allow a bounce back from disruption. Resiliency was not modeled due to the current lack of data.

6. LOGISTICS MODELING

6.1. BASIC LOGISTICS MODEL

The first logistics model was created from a basic water distribution problem. Using data obtained from the relationship analysis tool, a spreadsheet was created. A portion of the spreadsheet is shown in Table 6.1.

Travel time from the source to the facility was then computed. Using the usage of each facility in Table 6.1 and the truck capacity in Table 6.2, the total trips to refill each facility completely was computed.

The time loop from the source to a facility and back to source was then calculated using the variables found in Table 6.3 and formula (2). Table 6.4 shows the time calculated for each of the 3 facilities.

Using the X/Y positions from Table 6.1, a shortest path methodology was generated using a travelling salesman approach.

Table 6.1: Example of Data Spreadsheet

Facility	Dining, TEMPER XVIII, 96ft	Sanitation, TEMPER IV, 32 ft	TEMPER XVII, 64 ft
UID	463	488	495
Usage (gal/day)	500	2108	1000
Local Capacity (gal)	500	3000	3000
Position - X	752885.6	752865.4	752878.6
Position - Y	3505683	3505694	3505693
Distance From source (Ft)	59.03	34.66	51.69

Table 6.2: System Variables

System Variables	
Truck Capacity (gal)	500
Truck Efficiency (mpg)	12
Pump Speed (gpm)	125
Source Position - X	752846.3
Source Position - Y	3505681
Source Capacity	20000
Speed (ft per sec)	14.67
Time to dis/connect (sec)	20

$$\text{Time Loop} = Cx+Ls+DCx+Tsx+Cx+Lx+DCx+Txs \quad (2)$$

Table 6.3: Time Loop Variables

Time to connect hose (in sec)	Cx
Time to completely fill truck at source (in sec)	Ls
Time to completely fill facility (in sec)	Lx
Time to disconnect hose (in sec)	DCx
Time to travel from source to facility x	Tsx / Txs
Time to travel from facility x to facility y	Txy / Tyx

Table 6.4:Time Loop Totals

Facility	Dining, TEMPER XVIII, 96ft	Kitchen Sanitation, TEMPER IV, 32 ft	Kitchen, TEMPER XVII, 64 ft
Travel time (sec)	4.02	2.36	3.52
# of trucks to completely refill	1	4.216	2
Loop from Source->Fac->Source (sec)	568.05	564.73	567.05
To fill completely (sec)	568.05	2380.88	1134.10
To fill completely (min)	9.47	39.68	18.90

6.2. EXPANDED LOGISTICS MODEL

To allow the model to apply weighting to certain facilities, an expanded water logistics model was created. The expanded model allows the user to prioritize facilities that are deemed important, namely dining, water, and medical facilities.

The first step is determining whether the source (main water tank, fuel tank, etc) is 'critical.' For the expanded water model, critical is defined as the sum of the usage for all water tanks multiplied by a factor of safety (Equation 3). If the water left in the main source is less than the critical sum, the source is defined as critical. Figure 6.1 depicts the logic flow of the process.

$$C=(F1+F2+\ldots Fn)FS \qquad (3)$$

As seen below in Figure 6.1, if the source is not critical the logic defaults back to the basic model – a shortest path algorithm. If the source is critical, each facility is evaluated on a ratio of amount of water left to the usage per day. If the facility can survive a day without being filled, it is simply skipped for that day.

The facilities that cannot survive a day without filling are divided into two tiers. Tier 1 consists of high priority facilities crucial to base camp operations (i.e., dining, water, medical, etc.). The tier 1 facilities are then ranked by amount left and filled in least to most order. Each facility is filled until the usage per day of that facility is met up to fifty percentage of what is left in the source.

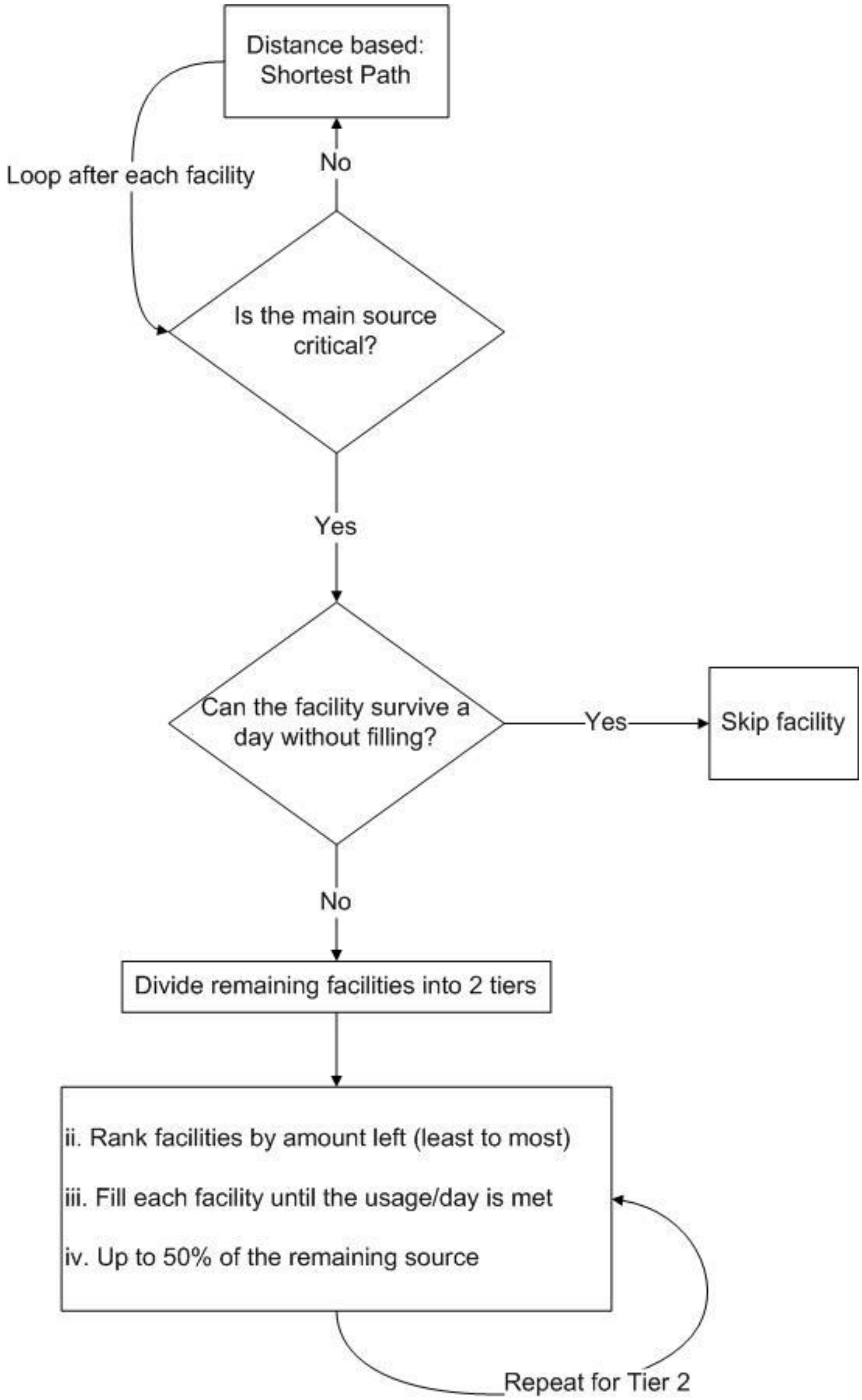

Figure 6.1: Expanded Logistics Model

If there is water left, tier two is filled based on tier one logic. Since there are more facilities in tier two, a shortest path algorithm is used. Figure 6.2 is a preliminary user interface for the expanded logistics model.

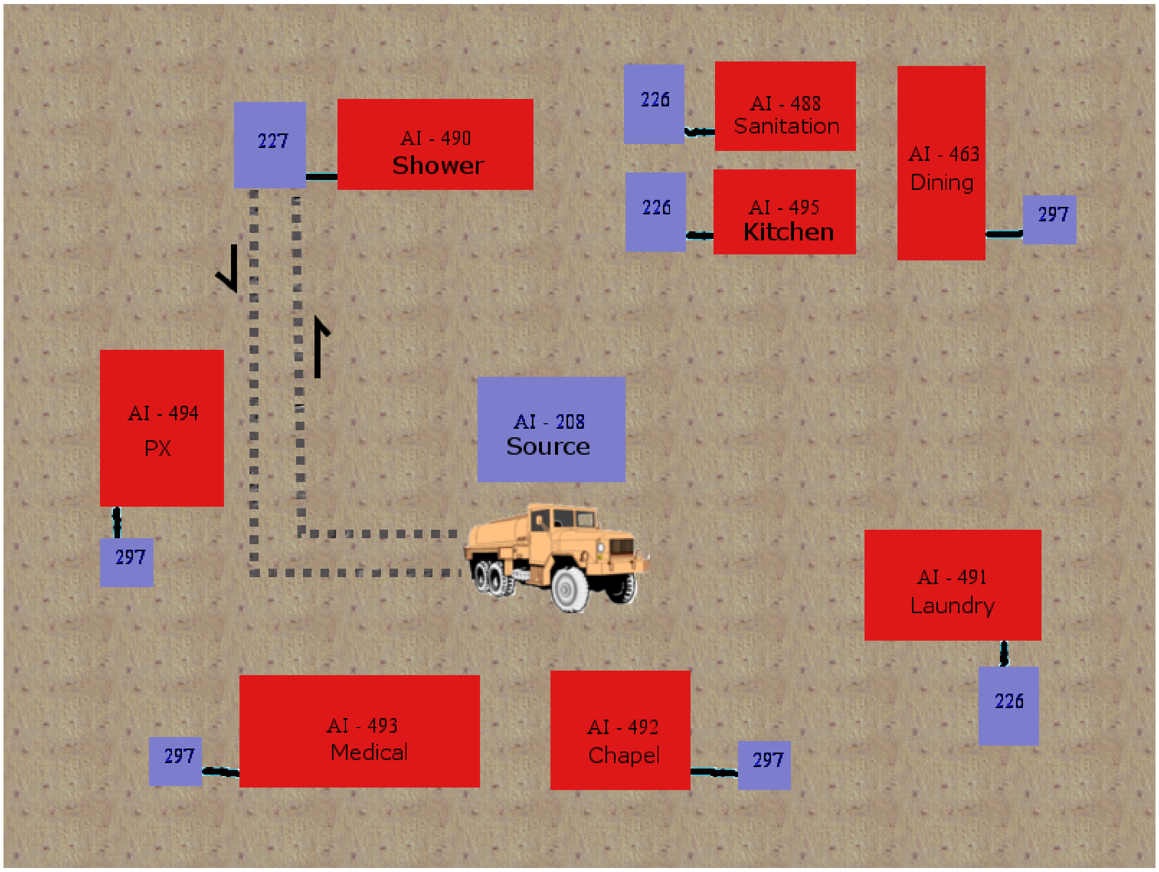

Figure 6.2: Preliminary User Interface for Expanded Logistics Model

6.3. FUTURE WORK

The expanded water logistics model can be adapted for other base camp systems. Reversing the expanded water logistics will allow the extraction of wastewater. Dry goods runs can be modeled by simplifying the water model and reversing the dry goods model will allow for the removal of solid waste.

APPENDIX A.

FACILITY AND RESOURCE LIST

Resources

1. Electricity (Watts): The total electricity that will be consumed/generated.
2. Fuel (Gallons): The total fuel required.
3. Potable Water (Gallons): Total potable water consumed across all facilities.
4. Bottled Water (Gallons): Total bottled water consumed across all facilities
5. Storage area (Sq. ft.): Storage space used across all facilities.
6. Personnel (Number): Number of support personnel required.
7. Gray Waste Water (Gallons): Waste water (Gray) generated from all the facilities.
8. Black Waste Water (Gallons): Waste water (Black) generated from all the facilities.
9. Solid Waste (lbs.): Total solid waste generated from all the facilities.
10. Food Service (lbs. of food/day): Food consumed per day.
11. Footprint (Sq. ft.): Total footprint area.
12. Maintenance (Hrs. per day): Total Maintenance hours for all the facilities.

Facilities

Dining Facilities	Laundry	Kennel	Latrines/Showers	Medical
Communication & Network	Housing	Ammunition Holding	Direct Support Maintenance	Fire Protection
Force Protection	Supply Warehouse	Postal Facility	Parking Lot	Motor Pool
Direct Exchange	Barber	Religious Services	Electrical Generation	Electrical Distribution
Water Purification	Water Storage	Water Distribution	Waste Water Treatment	Solid Waste Treatment
Security Checkpoint 1	Security Checkpoint 2	Tactical Operations Center	Administration	MWR
Education	Tailoring	Mortuary	Military Police	Bunkers
Airfield	Staging	Detention Area	Roads	Training Area

APPENDIX B

SELECTED QUESTIONS FROM USABILITY STUDY

Demographic and Background

- Years of service

- Rank

- Experience with base camp planning
  (None, Little, Some, Substantial)

- How often do you participate in base camp planning?
  (Never, Rarely, Sometimes, Often, All of the Time)

- Have you ever been stationed at a base camp of 2000PAX or less?

Accuracy

- Were the calculated totals what you expected? (Y/N)
  If no, were the results reasonable? (Y/N)

- Did you change any of the "initial input parameters"? (Y/N)
  If yes, Did you change the number because you felt it was wrong?

- Did you "adjust the flow factor or assign a constant"? (Y/N)
  If yes, did you change the number because you felt it was wrong?

Functionality

- Usability of program
  (Poor, Fair, Good, Very Good, Excellent)

- Layout of program
  (Poor, Fair, Good, Very Good, Excellent)

- Understanding of the calculated totals
  (Never, Seldom, Sometimes, Often, Almost Always)

- Are there features you would change or remove? If so, please explain.

- Are there features you would add? If so, please explain.

- Did you ever "break" the program? If so, please explain. ("break" includes: freezing of the program, an error message, negative numbers, etc.)

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