Exploratory Analysis of the Supply Concept for the Standing Contingency Task Force

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ABSTRACT

The Canadian Forces (CF) is currently undergoing major changes guided by the Chief of Defence Staff's (CDS) vision. This vision requires both the refocusing and creation of CF capabilities. As part of this evolution the CDS envisions a Standing Contingency Task Force (SCTF) consisting of integrated maritime, aerospace and land forces that could be deployed on ten days notice to conduct an amphibious operation in an uncertain environment and have the land forces ashore supported for thirty days. This capability is relatively unknown to the CF and the concept of seabasing has yet to be analyzed using techniques available to the Canadian operations research community.

The purpose of this research is to provide insight into the parameters that impact on the ability of a seabase to re-supply a landing force. This will be accomplished using a three-step process. The first step will be to investigate the methodologies used by business and military organizations to solve similar problems. Second, to discover and/or develop a tool/tools that would enable the analysis of the deployed support requirements of the Canadian Forces new concept of a rapidly deployable, integrated, expeditionary amphibious force and third to use these tools to provide insights into the proposed option.

This paper focuses on the following areas of analysis: Given a distance from the seabase to the land units and a number of connectors, is the logistics system able to sustain operations? What is the maximum distance between the seabase and units ashore that is sustainable by surface connectors? How many connectors are required to support the sustainment at a given distance? These options are explored using discrete event simulation to examine their supportability from the sea as well as to determine the factors that most greatly influence the logistics support of the force ashore.

FOREWORD

The work conducted for this paper was started as the development of the Standing Contingency Task Force was in its early conceptual stages. The focus of the working groups at the National and component level was on the development of the operational concept. It was not until March 2006 that the SCTF Sustainment Working Group was put together and held its first meeting. The data and results contained in this study were presented at this working group and were used as part of the initial starting point for the development of the concepts for the supply and transport annexes for the SCTF sustainment concept of operations.

OVERVIEW

1.1 INTRODUCTION

This chapter presents the motivation behind the study as well as a description of the problem to be examined. An introduction to the Standing Contingency Task Force (SCTF) as well as the explanation of new sustainment concepts set the stage for the presentation of the issues to be analyzed.

The year 2005 marked a milestone for Canadian Foreign Policy and Defence. The Canadian Government published an International Policy Statement "A Role of Pride and Influence in the World"[1]. This set of documents covering Diplomacy [2], Defence [3], Development [4] and Commerce [5], articulate a vision for the role of Canada in the world. Each of these documents expresses the importance of a safe and secure world in order for Canada to prosper. Through this policy, the Government of Canada has committed to playing a role on the global stage.

In order to support Canada's international policy, the Department of National Defence conducted its first policy review in over ten years. This policy established a new vision for the Canadian Forces and stressed the following:

- The Forces will become more effective by better integrating maritime, land, air and Special Forces. The overall goal will be "focussed effects": the ability to deploy the right mix of forces to the right place, at the right time, producing the right result [6].

- The Forces will become more relevant, both at home and abroad. They will adapt their capabilities and force structure to deal, in particular, with threats that arise from the kind of instability that we have seen abroad, especially in failed states [6].

- The Forces will become more responsive by enhancing their ability to act quickly in the event of crises, whether in Canada or around the world. They will arrive on the scene faster, make a rapid transition to operations once there, move more effectively within theatre, and sustain deployments, in some cases for extended periods [6].

To support this vision the Minister of National Defence has tasked the Canadian Forces to develop the ability to deploy three kinds of joint formations: [6]

- A Special Operations Group (SOG) will be established to respond to terrorism and threats to Canadians and Canadian interests around the world.

- A Standing Contingency Task Force will be established to respond rapidly to emerging crises.

- Other Mission-Specific Task Forces (MSTF) will be deployed as required.

The SCTF is described as a force that will deploy within ten days notice, and provide an initial Canadian Forces presence to work with security partners to stabilize the situation or facilitate the deployment of larger, follow on forces should circumstances warrant [6].

In response to these tasks the Chief of Defence Staff (CDS) established teams and working groups to examine the issues of transforming the Canadian Forces in order to meet the

Governments requirements. In turn, the Chiefs of Land, Maritime and Air Staffs began to examine the impacts of transformation.

1.2 MOTIVATION

The CDS Action Teams (CATs) and other working groups established at the Canadian Forces and component levels have discussed issues regarding the initial force structure and employment of the SCTF.

The Chief of Land Staff (CLS) tasked the Directorate of Land Strategic Concepts (DLSC) to lead the development of options for the Land Component of the SCTF. The Chiefs of the Maritime and Air Staffs have also tasked like organizations to do the same. However, it has been understood that the capabilities and resource that the maritime and air components need to build within the SCTF are dependent on the size of the land force that is put ashore. DLSC and the SCTF Land Component Working Group proposed four options, based on a preliminary estimate, for SCTF Landing Force. These are:

- A basic light force option based upon a light infantry battalion, (LIB) consisting of two infantry companies, equipped with light patrol vehicles (LPV) and one company as a heliborne sub-unit. This battalion would be supported by a light combat support and combat service support elements;

- An enhanced light force option, based upon the same three infantry companies as described above, however, supported by a more robust combat support element;

- A basic hybrid option based upon two light infantry companies, equipped with LPV and a mechanized infantry company equipped with Light Armoured Vehicle Generation III (LAV III). The combat support element would be similar in capability to the basic light force with the combat service support element of adequate capability to support this force; and

- An enabled hybrid option with a similar organization to the basic hybrid with a more robust combat support element.

Of these options the basic hybrid option was chosen as the element upon which to base further study. It must be understood that this is not the final organization, but one that was accredited by the SCTF Land Force Working Group, for use as a starting point for analysis and discussion.

There has been a great deal of discussion at the National and Component working groups on the process to determine the number of helicopters and landing craft, as well as the size and capabilities of the amphibious ships. Through these discussions, numbers and types of ships, helicopters and capabilities of the landing force have been used to illustrate points or to give others general descriptions of capabilities. It has been acknowledged that these initial numbers were simply illustrations and that more rigorous analysis is required. It is to this end that the use of operational research (OR) procedures and tools are required to give a scientific rigueur to the analysis of the logistic support requirements of the land component of the Standing Contingency Task Force.

1.3 PURPOSE

The purpose of this research is to provide insight into the parameters that impact on the ability of a seabase to resupply a landing force. This will be accomplished using a three-step process. The first step will be to investigate the methodologies used by business and military organizations to solve similar problems. Secondly, to discover and/or develop a tool/tools that would enable the analysis of the deployed support requirements of the Canadian Forces new concept of a rapidly deployable, integrated, expeditionary amphibious force. Finally, these tools will be used to provide insights into the resupply of the basic hybrid option for the landing force.

1.4 SCOPE

The study of the sustainment system of a military operation is a very complex and detailed endeavour. The various options and levels of granularity in an operation, if addressed in a single study, can overwhelm the analyst. Some examples of the various areas of study with respect to the SCTF are shown in Figure 1.

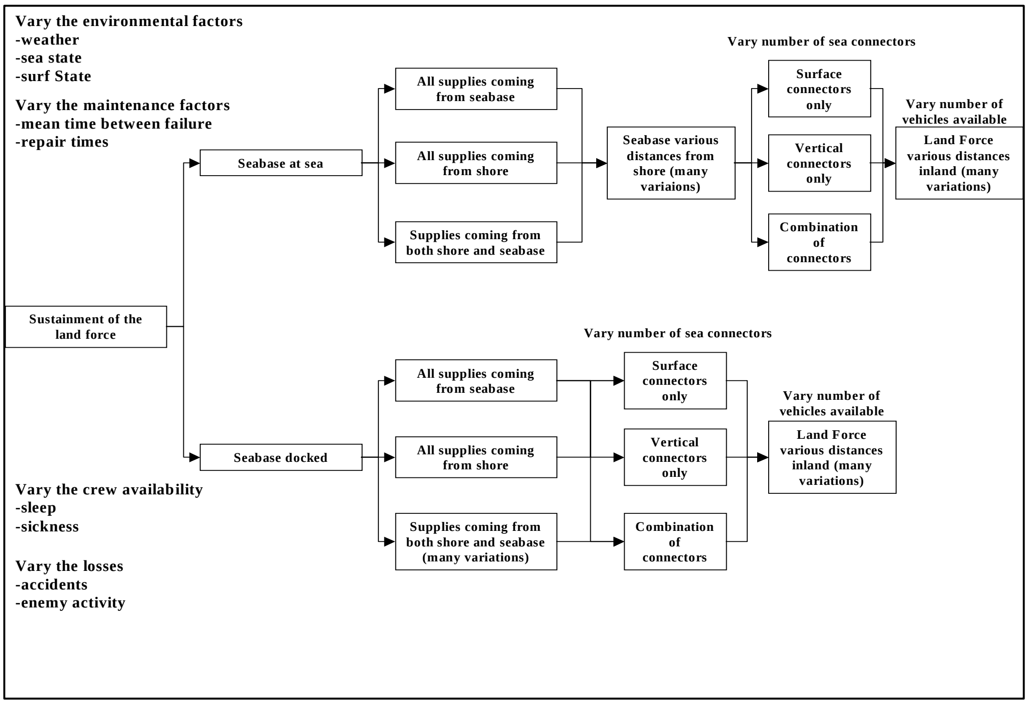


Figure 1 - Examples of potential areas of study

There are many paths and options requiring study. This study will examine only a few aspects of the overall requirements outlined in Figure 1. This paper will focus on sustainment of a landing force from a seabase. The detailed scenario is described in Chapter 3.

1.5 OUTLINE

The first chapter is introductory and provides background and justification for the purpose and reasons for this work. Chapter 2 contains a more detailed description of the SCTF as well as a description of a sustainment system that is being proposed by the Directorate of Army Doctrine (DAD). It then presents research into civilian (business) and military approaches to solve similar problems. Chapter 3 provides a description of the methodology and tools/processes chosen to provide insights into the problem. Verification, validation and accreditation processes with regards to the model chosen and data used are reported on in this chapter. Since the analysis of the SCTF sustainment system is conducted using simulation, it is crucial that the data used in the creation of this tool be presented to provide insight into the function and limitations of the analysis. To this end, Chapter 3 also presents the data that was either acquired or created in order to provide the inputs for the simulation. Chapter 4, reports the findings and analysis as a result of conducting the experiments, and finally Chapter 5 presents conclusions and areas for further study.

THE SCTF AND SUPPLY CHAIN MODELLING

2.1 INTRODUCTION

The SCTF is a capability unlike any the Canadian Forces has ever developed. The United States, the United Kingdom, Australia, France and the Netherlands all maintain forms of amphibious forces that have evolved to their current forms over a period of time. The Canadian concept of the SCTF is not unlike these countries in its approach to amphibious operations. The tasks that the SCTF is assigned and the ability of the Canadian forces to generate and sustain it make this a unique Canadian issue.

The purpose of this chapter is to better define the problem at hand, explore several potential methods of answering the questions posed, and lastly determine which methods have been put to use by others in solving similar problems.

2.2 WHAT IS THE SCTF?

In order to explore how others have examined issues, such as the concept of operation of the SCTF and its corresponding concept of support, must be understood. It must also be acknowledged that these concepts are only in the early stages of discussion and over time will be further developed.

As the SCTF is an integration of land, maritime and aerospace forces, each component was tasked to provide capabilities and resources as follows:

- The Canadian Forces will be able to sustain for up to six months the command element of the SCTF, either land based or sea based, capable of multinational lead-nation status in peace support operations [7].

- The Maritime Forces will be able to sustain for up to six months a task group of up to four combatant vessels with the capability for a national or multinational command component for operations abroad. This task group will be capable of precision fire and support to forces ashore and will be used as an integral element of the SCTF or in support of other national objectives [8].

- The Air Forces will be able to:

    - sustain indefinitely, the deployment overseas of two embarked maritime patrol helicopters (one on each coast) and one Aurora maritime patrol aircraft as the forward element of the SCTF anywhere in the world [8].

- provide for up to six months an Air Expeditionary Unit as an integral element of the SCTF. This unit will be comprised of:
  - up to two Aurora maritime patrol aircraft to support land-and sea based elements,
  - up to six maritime helicopters for deployment with the naval task group, and
  - up to six medium- to heavy-lift helicopters to support land operations [8].

- The Land Force will be able to provide the land component of the SCTF, capable of embarking and operating from a maritime platform [9].

The concept of operations of the SCTF, in very general terms, is that an integrated amphibious force will sail from CFB Halifax on ten days notice to move. It will deploy to an area of operations and be able to hover off the coast of the area of operations until the operation is complete or the land component is ordered to go ashore. The land component would be delivered by air and surface connectors to the shore and then would conduct operations. These operations could cover the full spectrum of operations, from war fighting, to peace support operations to, humanitarian assistance. Upon completion of their tasks, the land force is to be recovered to the ships and reconstitute in order for the SCTF to respond to a new mission. The corresponding concept of support must respond to this concept of operations.

2.3 CONCEPT OF SUPPORT

The SCTF must be capable of sustaining the land force ashore for thirty days [10] without being re-supplied. This means that the ships must have available all classes of supplies that the land force may consume while deployed. This period is over and above the supplies that are required to enable the SCTF to deploy to the area of operations. Fuel, food, water and ammunition and other supplies will be consumed by all components and must be available and deliverable to the forces ashore. Without this lifeline the forces ashore will eventually become operationally ineffective.

2.4 CANADIAN FORCE SUSTAINMENT CONCEPT

The SCTF is proposed to have a final operating capability by 2015. In this timeframe it is anticipated that the Canadian Forces will have adopted a sustainment system different then the doctrine outlined in B-GL-300-004/FP-001 Land Force Sustainment [11]. This new concept, described in the "The Force Employment Concept for the Army" [12], describes the use of a "push" system enabled by a flexible distribution system, including real-time asset visibility that would indicate combat usage. This new concept relies on the use of combat configured loads delivered by standard containers (i.e. sea containers), partial containers (i.e. quadcons) and palletized loading systems [12]. The introduction of the medium support vehicle system (MSVS) is a key piece in enabling the future Canadian Forces and the SCTF sustainment system.

2.5 SCTF SUSTAINMENT CONCEPT

The SCTF sustainment concept must follow as closely as possible the Canadian Forces Sustainment Concept, as it must work within the established doctrine. Therefore, the same terminology and concepts should apply. Figure 2, illustrates the generalized SCTF sustainment concept.

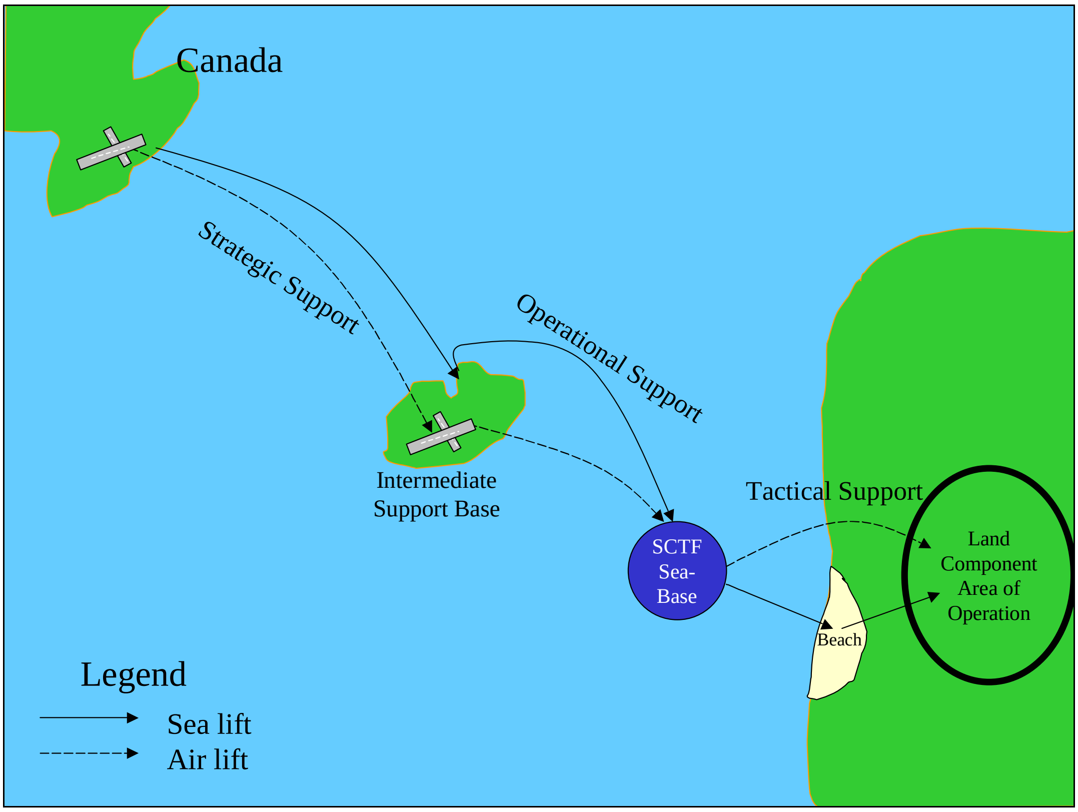


Figure 2 - Generalized SCTF Concept of Support

The strategic level of support is concerned with such activities as weapon and equipment design, construction of permanent bases and support facilities, the mobilisation and movement of forces and materiel from Canada to the port of disembarkation (POD) in theatre. In general, the SCTF will be based in Atlantic Canada (most likely CFB Halifax) [10]. The SCTF concept of operations (COO) does not preclude the establishment of an Intermediate Support Base (ISB) [10] to provide a more timely support to the SCTF. If the ISB is established, it would be considered an extension of capability from Canada and therefore, fall into the Strategic level of support.

The SCTF as a whole is considered an operational level capability. It is made up of tactical level capabilities from the naval, land and air components. The operational level of support to the SCTF is generalized as that support from either Canada or an ISB to the SCTF seabase.

SCTF tactical level of support is considered as that provided from the SCTF seabase to the Amphibious Task Group, including the air component and the landing force. Tactical support of the air component would include SCTF seabase support of; fixed and rotary wing aircraft of the SCTF, support of the ships of the naval task group including the amphibious ships, and support of the land force component.

Within the tactical level of support the SCTF would provide general support (GS) to all elements of the SCTF. Close support (CS) provided by the SCTF, will be established by component specific close support units (i.e. the Joint Support Ship for the naval component, the combat service support company for the land component, and the applicable air force close support organization). Lastly, each unit/sub-unit (naval, land and air component) must possess its own integral support (IS) to provide minute-to-minute support.

The scope of this study is to examine the sustainment of the SCTF Land component once ashore. This encompasses the tactical level of sustainment from the SCTF seabase to the deployed elements of the land component of the SCTF.

2.6 DEFINING THE PROBLEM

2.6.1 Background

As previously stated, the steps in this study include the investigation of the methodologies used by business and military organizations to solve similar problems. The discovery and/or development of a tool/tools that would enable the analysis of the deployed support requirements of the Canadian Forces new concept of a rapidly deployable, integrated, expeditionary amphibious force, and the use of these tools to provide insights into the proposed options.

In order to determine approaches to solve the issue, the problem must be better defined. Discussions surrounding the SCTF development have centered on questions such as:

- How long can the forces ashore be sustained, given a certain amount of supplies in the seabase?
- How many connectors (surface and air) are required to move the supplies ashore that are required by the deployed land force component? And
- How far inland can the land force operate and still be supported from the seabase?

2.6.2 Conceptual Model

In order to answer the above questions, a conceptual model must be created in order to better define the problem at hand. Figure 3 presents the conceptual model to be considered.

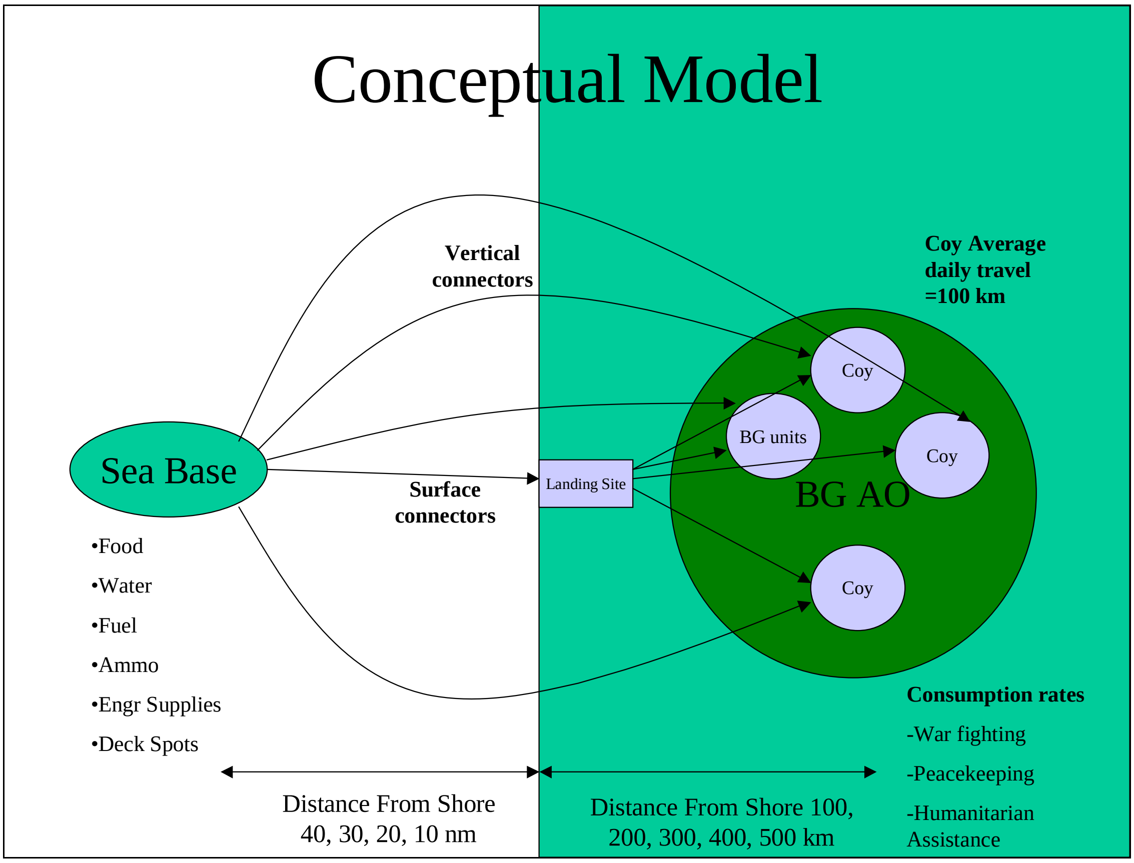


Figure 3 - Conceptual Model

This conceptual model consists of a warehouse of goods (classes of supplies) held in the seabase, connectors that move the supplies from the warehouse (seabase) to the consumers (units on shore) that consume supplies. The consumption of supplies by the units is dependant upon their operating environment that covers the spectrum of conflict from war fighting, to peace support operations, to humanitarian assistance.

The remainder of this chapter will cover possible methods of examining this problem.

2.7 MODELLING APPROACHES

The conceptual model described above is similar to a supply chain. A supply chain has been described as "a network of suppliers, manufacturers, and retailers who are collectively concerned with the conversion of raw materials into goods that can be delivered to the customer." [13] By their nature, supply chains, whether military or civilian, are complex with many tangible and intangible variables. Therefore, in order to conduct any analysis, models must be created. Models used to analyse such systems can be classified in a number of ways. Ram Ganeshan and Terry P. Harrison classified supply chain decisions into strategic and operational [14]. Strategic decisions are made over a long-term horizon and are closely linked to corporate strategy, whereas, operation decisions are short term and focussed on activities on a day-to day basis.

Strategic and operational decisions are further characterized by decisions relating to location, production, inventory and transportation [14]. Within the confines of this study, analysis will be conducted into assisting the decision process at an operational level concerning location, inventory and transportation. Ganeshan and Harrison divide supply chain modelling approaches into three areas: Network Design, "Rough Cut" methods, and simulation based methods. They suggest that simulation "is a method by which a comprehensive supply chain model can be analyzed, considering both strategic and operational elements" [14].

In his PhD dissertation Ming Dong describes five approaches to supply chain modelling: Supply Chain Network Design Method, Mixed-Integer Programming Optimization Modelling, Stochastic Programming and Robust Optimization Methods, Heuristic Methods and Simulation Based Methods [15]. Of all the methods described, he suggests that simulation based methods is a method by which an analysis of both strategic and operational elements of a supply chain model can be considered.

In most civilian cases, the supply chain analysis is focussed on the optimization of a means to maximize or minimize a value (i.e. profit and cost respectively). However, simulation allows supply chains to be analyzed with "what if?" scenarios, in order to measure the impact of changes in a system. Law and Kelton suggest a methodology for determining methods to study a system [16] as summarized in the figure below.

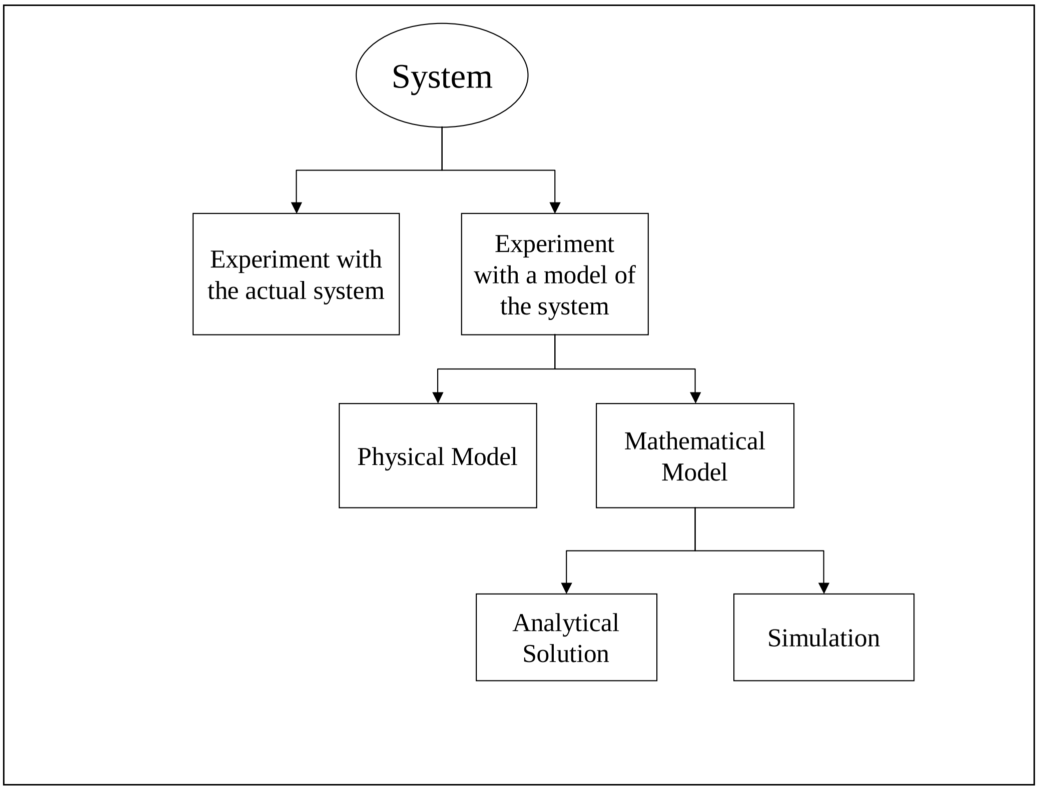


Figure 4 - Ways to Study a System

Following the flowchart in figure 4 we see that within the context of a supply chain system creating the actual system would be cost prohibitive, creating a physical model would not be productive and finding an analytical solution would by extremely difficult if not impossible. Therefore, using Law and Kelton's methodology, a simulation study is the recommended approach for such a complex model as a supply chain and more specifically, the supply system of the SCTF. The use of simulation to analyze supply chains has been successfully applied as described in a survey by Terzi and Cavalieri [17].

To this point, this examination of approaches has only considered studies and references concerning supply chains in a civilian/business context. However, approaches used to study the military sustainment system mirror those in the civilian world, and therefore, the same justifications for using simulation can be applied.

"Applied Operations Research, Examples from Defense Assessment" [18] describes a simple problem of an Army resupply system and suggests the use of constraint satisfaction. However, this approach would fail in providing indicators to all questions posed in this study. The example only covers two commodities (ammunition and fuel) with the requirement to run the model many times to get a multi-day assessment. Factors such as vehicle attrition, varying consumption rates due to operational tempo and the environment are not considered. If these and other factors were to be considered then the number of variables to be calculated would increase from the fifty described in the model, to an amount that would be incredibly difficult to debug and analyze and may even prohibit calculation.

The Joint Expeditionary Logistics (JELO) model was developed by Matthew Boensel and David Schrady and was developed as an expected value spreadsheet model that represented a number of closure alternatives, transfer, deployment and sustainment [19]. This model, while useful for conducting a first level analysis, does not consider the variation in the parameters, such as geographical distances, sea-state, and platform characteristics that would exist in a real world sea based logistics operation.

Simulation tools have been used by Kang and Gue [20], Bender et al.[21], Milton [22] and Bryan [23] in the conduct of analysis of sea based logistics. Simulations have enabled a full spectrum of analysis from providing insight into the operational problems of sea based logistics to conducting options analysis for future capability development. Several types of simulations have been employed from agent-based simulation to discrete event simulation.

Discrete event simulation tools have been used to simulate supply chains. It is this method that will be further pursued.

2.8 CONCLUSION

In this chapter, the Canadian Forces sustainment system was described and applied to the SCTF. From this description, a conceptual model was created that described the system to be analyzed. It was concluded that this system resembled that of a supply chain and research was conducted into methods of examining supply chains. It was determined by examining both civilian/business and military examples that simulation, more specifically, discrete event simulation would be the desired method to analyze the issues required to gain a better understanding of the tactical sustainment requirements of the SCTF's land force component.

BUILD THE MODEL

3.1 INTRODUCTION

At the 2003 Winter Simulation Conference, Averill M. Law presented a paper on "How to Conduct a Successful Simulation Study" [24]. In it, he prescribes seven steps to be taken. These steps consist of:

1. Formulating the problem;
2. Collecting information and constructing a conceptual model;
3. Validating the conceptual model;
4. Programming the model;
5. Validating the program, designing;
6. Conducting and analyzing experiments; and
7. Documenting and presenting the simulation results.

In this chapter, through following steps 1 to 6 above the proposed model will be built. Although the first two steps have been touched upon in Chapters 1 and 2, they will be further detailed herein. Steps 6 and 7 will be left to Chapters 4 and 5 respectively.

3.2 FORMULATE THE PROBLEM

3.2.1 Introduction

This section will present the specific questions to be addressed, as well as the performance measures to be considered in the formulation of the problem. As described in Chapter 1 of this paper, the CLS' vision for the Canadian Forces included an amphibious expeditionary force to be known as the Standing Contingency Task Force (SCTF). The CMS was given the lead and organized a national SCTF working group consisting of representatives from the Land, Maritime and Air Forces. It was soon realized that the national working group could not address all issues they faced in the development of the SCTF and therefore, each component established its own SCTF working group. Through attending the National and Land Force SCTF working groups and through discussions with the Director of the Directorate of Land Strategic Concepts, it was determined that the sustainability of the Land Force Component once it had been deployed required study. Further discussions focussed on the overall objectives of the study, the specific questions to be addressed by the study, the performance measures used to evaluate the efficacy of the different options, the scope of the model and the options to be modelled.

3.2.2 Exploratory Analysis

This research will conduct an exploratory analysis of the logistic requirements for the land force options of the Standing Contingency Task Force. As the SCTF concept is in its infancy, analysis is of an exploratory nature to better define areas requiring detailed consideration and to provide insights into the concept of sustainment that is currently under development.

3.2.3 Specific Questions

The specific questions that this study will address were formulated after discussions held during various working groups and with individuals responsible for the development of the SCTF concepts: The specific questions are:

- Question 1: Given an unlimited amount of stocks in the seabase, a number and type of connectors, a number of deck spots, the number and type of forces ashore, and an accepted scenario, can the forces ashore be sustained for a period of 30 days?

- Question 2: Given an unlimited amount of stocks in the seabase, a number and type of connectors, a number of deck spots, the number and type of forces ashore, and an accepted scenario, at what distance inland can the forces ashore be sustained?

- Question 3: What other insights can be gained from this analysis?

As the size, number and type of ships that would make up the SCTF is yet to be determined, it would be difficult to fix the quantities of supplies in the seabase. Because of this, it is assumed that the combination of ships in the seabase will hold the required amount of supplies to sustain the land force ashore for thirty days. These supplies will either be resident in the seabase or the seabase will be re-supplied in a timely manner that, to the land component, will appear as an unlimited supply. This assumption also allows issues such as the sustainment requirements beyond that of combat supplies, and the storage space requirements for supplies consumed while the SCTF is in transit, hovering (waiting offshore before deployment of the land force), or those supplies consumed by the other elements of the SCTF to be ignored as this is beyond the scope of this paper.

The purpose of question one is to provide insights on whether a given number and type of connectors can sustain the force ashore within an approved scenario. Variation in the number of each type of connector will be compared for the land option ashore.

Question two is concerned with the distance inland a force can either be deployed or travel to and still be sustained from the seabase. This question will build upon the results of question one and extend the range from seabase to fighting echelon of those options that proved to be sustainable. It will provide insights into the breaking point of SCTF supply chain.

Question three allows for the capture of issues that are pertinent to questions one and two but have not been initially considered.

3.2.4 Scope of the Model

As previously described in Section 1.4, the scope of model is concerned with the sustainment of the SCTF Land component once ashore. This encompasses the tactical level of sustainment from the SCTF seabase to the deployed elements of the land component of the SCTF. The duration of the scenario modelled will be thirty days to reflect the maximum amount of time that the SCTF must support the forces ashore before being resupplied.

3.2.5 System Configuration to be Modelled

The general system configuration envisioned to be able to model the SCTF sustainment requirements consists of the following:

- The overall environment is perfect (assume perfect weather, 100% availability of equipment, 100% availability of crews, no losses). If the system does not function in this environment it will not function if these restrictions are tightened;
- The seabase is at sea and all supplies are coming from the seabase. If the land force cannot be supported from the sea then the baseline SCTF capability requirement has not been met;
- The distance from the seabase to the shore will be varied between 10, 20, 30 and 40 nautical miles. This is indicative of possible operating distances;
- Only surface connectors will be used (landing craft and ground vehicles). Given the fact that the vertical connectors (helicopters) are small in number and may not be dedicated to the task of sustainment, considering the surface connectors only will give worse case scenario. Adding other connectors will only make the scenario easier;
- The number of surface connectors will be varied to determine the impact;
- The distance between the shore and the land units will be varied between 100, 200, 300, 400 and 500 km. This is indicative of possible operating distances; and
- The number of logistics vehicles will be varied to determine the impact.

3.3 COLLECT INFORMATION AND CONSTRUCT A CONCEPTUAL MODEL

Chapter 2 described the Canadian Forces sustainment system and proposes how this system would be applied by the SCTF. Figure 3 of that chapter illustrates a conceptual model of how the SCTF sustainment system could be envisioned. This conceptual model is further modified to remove the air connectors (helicopters). This was done to enable the testing of the sustainment system in the scenario that that would push the sustainment system to a limit under an idealized situation. The Chair of the SCTF Land Force working group validated the conceptual model described by Figure 3 in Chapter 2 and approved the removal of the helicopters for the purpose of this study. This new conceptual model is pictured in Figure 5 below.

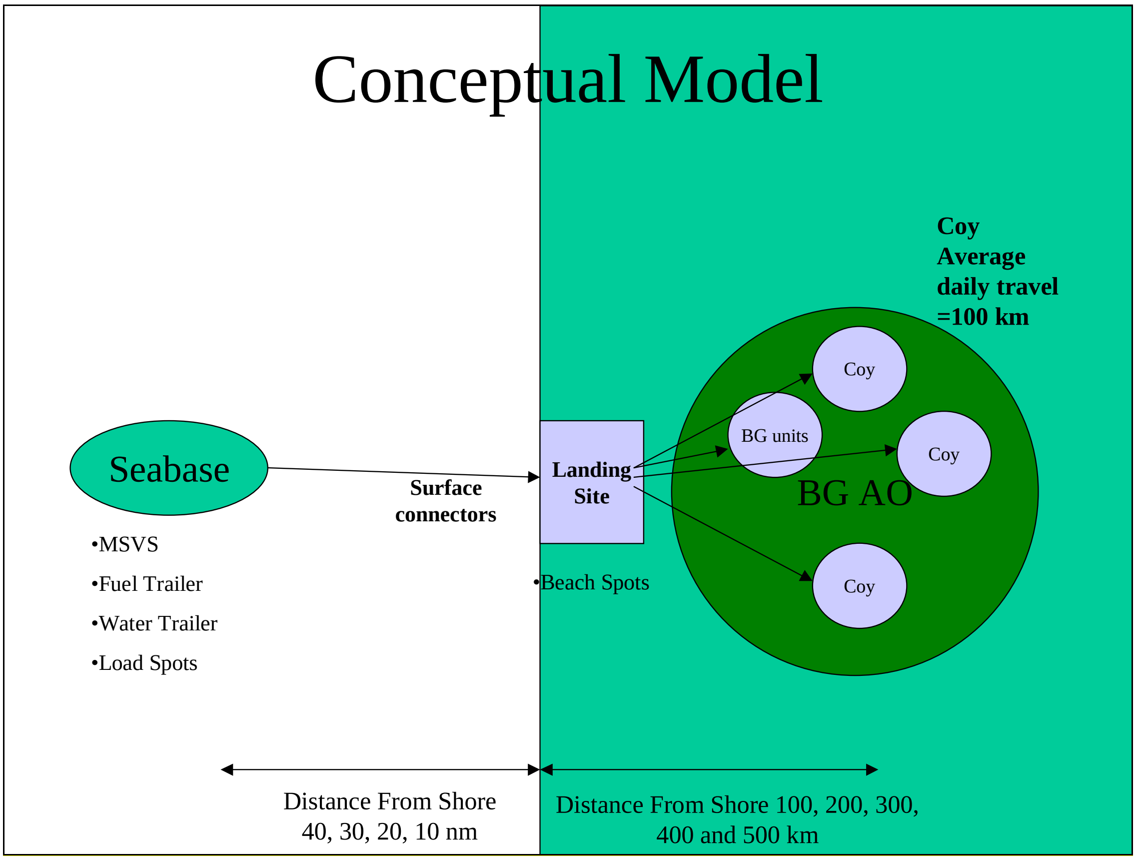


Figure 5 - Modified Conceptual Model

From this conceptual model, the data requirements concerning orders of battle, physical and performance characteristics of vehicles and sustainment requirements for the deployed land force were determined. The remainder of this section describes the data collected.

3.3.1 Orders of Battle

The first data requirement was to determine the order of battle that would be examined within the contents of this study. At the time of writing, there were still discussions about the capabilities considered as part of the options for the land force. The general Land Force option will consist of three infantry companies, a combat support company and a combat service support company. The infantry companies are equipped either with the Light Armoured Vehicle Generation Three (LAV III) or the Light Patrol Vehicle (LPV). The combat support company would consist of a reconnaissance element, an engineer element, and an indirect fire support element. It was determined through discussions with personnel from the Directorate of Land Strategic Concepts (DLSC) that a modified Basic Hybrid Battalion consisting of one infantry company equipped with the LAV III, two companies equipped with the LPV, a Combat Support element and Combat Service Support element.

In order to build the organization the Directorate of Army Doctrine was contacted to obtain approved sub-unit level organizations [25]. This directorate was conducting their own analysis of building blocks for Army sub-units. These sub-unit organizations were created to enable the creation of units that would operate in the traditional sense, i.e. within a land force formation. In order to create an order of battle for the SCTF land force the following steps were conducted:

- The approved sub-unit structures were obtained from the Directorate of Army Doctrine. [25]
- These structures were put together without modification into a battalion-sized organization reflective of the Basic Hybrid Battalion organization described above.
- Personnel from the Directorate of Army Doctrine were consulted to ensure that the most current data available was used and that there were no omissions or errors in entry and conducted a verification of this organization.
- The order of battle was then modified to better reflect the capabilities required of the SCTF land force.
- Personnel from the SCTF Land Component working group were consulted to ensure that the overall capabilities envisioned for the SCTF were resident within the proposed order of battle verified these modifications.
- The order of battle was validated and accredited for use by the Chairman of the SCTF Land Component working group. This organization, and the associated data, has been passed to outside agencies as the current authoritative data to be used in other studies and discussions.

The table below summarizes the number of personnel held by the Basic Hybrid Battalion.

	Officers		Non-Commissioned Members		Total		
	Deployed	On Ship	Deployed	On Ship	Deployed	On Ship	Combined
Headquarters	4	17	12	31	16	48	64
Signals Platoon	3	0	45	1	48	1	49
Reconnaissance Platoon	1	0	41	0	42	0	42
LPV Company	6	0	142	0	148	0	148
LAV Company	6	0	147	0	153	0	153
Engineer Element	5	0	56	0	61	0	61
Artillery Element	6	1	73	5	79	6	85

Table 1 - Personnel Summary for Basic Hybrid Battalion

In order to conduct the calculations required to determine consumption rates, detailed physical and performance data is required to act as inputs into the model. The required data and its collection are described below.

3.3.2 Data Sources

For many years, the Department of National Defence published a series of "Staff Manuals" which included a volume on Operational Staff Data. The purpose of this volume was "to provide data, characteristics, and planning factors for the equipment and weapons systems presently available in Canadian forces inventories, and the logistics requirements for Canadian formations during high intensity operations [26]." This Canadian forces publication (CFP) provided a central source of unclassified data to be used by staffs in conducting planning for operations.

However, the data contained within the manual is out of date and was created with open terrain, large-scale combat between corps and divisions in mind. Also, contrary to public belief, the Canadian Forces and especially the Land Force have undergone drastic changes in equipment and weapon systems over the last 20 years, which have not been included in updates to the manual.

The land force is currently developing a "digitization" program to provide automated command and control systems to commanders and their staffs. The "Operational Staff Data" manual is in the process of evolving into an automated toolkit. This toolkit was conceived as a series of spreadsheets that grew to the "Electronic Battle Box", and then to a system that is to be integrated into the Land Force Command and Control Information System. The Operational

Planning Environment and Reference Application (OPERA) does contain some updates to the underlying database regarding new vehicles but the methodologies for calculating the consumption rates is still based upon cold war high intensity combat between divisions and corps.

The Directorate of Land Service Support was contacted by email and several staff officers returned information on the various combat supplies. They indicated that either the staff tables or, if the mission had been ongoing for a period of years, historical data is used to estimate consumption rates. In the case of ammunition, some classified data was available but could not be used in this study. It was therefore determined that current available and unclassified operational staff data did not reflect the current concept of operation for the SCTF and therefore must be developed.

The SCTF consists of vehicles that are not included in the staff data handbook and must be capable of operating throughout the spectrum of conflict. Where possible the Data Summary of the Canadian Forces Technical Orders [27-40] for each vehicle was consulted to acquire physical and performance data on the vehicles within the SCTF. If the vehicle was not in the CF inventory, then the applicable Jane's Defence yearbook was accessed through the Defence Information Network and the data was retrieved.

3.3.3 Consumption Rates

The following sections outline the logic and methodology for calculating consumption rates used to determine the number of vehicles required to carry one day of supply (DOS). It must be remembered that the SCTF may operate in an environment where tasks could span the spectrum of operations (warfighting, peace support and humanitarian assistance). For the purpose of this analysis, war fighting consumption rates will be used to test the extreme of the system. It is acknowledge that the boundaries between each of these operations is not clear cut, and that a company could be engaged by hostile forces while delivering humanitarian assistance which, with regards to ammunition expenditure, could be considered war fighting. It is this approach that is used in the examination of certain combat supply consumption rates. The following sections detail the logic and methodologies behind the calculation of consumption rates used to determine vehicle requirements.

3.3.3.1 Rations

The Land Force component of the SCTF is assumed to be on Individual Meal Packs (IMPs) for the 30-day operation. Each soldier would consume three IMPs/day and the total calculation for a DOS of rations for a given organization would be:

- $DOS_{IMP} = S \times 3$ meals per day
  - DOS_{IMP} – one day of supply of Individual Meal Packs per sub-unit
  - S – the number of personnel in the sub-unit

	# Pers on Shore	#IMPS/Day	DOS
LAV Coy	148	3	444
LPV Coy	148	3	444
HQ& Sigs	64	3	192
Recce	42	3	126
Engr	61	3	183
Arty	79	3	237
CSS Coy	41	3	123

Table 2 - Rations DOS per Sub-Unit

3.3.3.2 Water

There are various tables and rules that can be applied to the calculation of water consumption. Factors of heat, activity, Military Oriented Protective Posture (MOPP) level, hygiene and cooking are considered when calculating water consumption. The rates used in this model are given in the table below and the total DOS for water for a given organization would be:

- $DOS_{Water} = (S \times W_S) + (V \times W_V)$
  - DOS_{Water} – one day of supply of water per sub-unit
  - S – number of soldiers in the sub-unit;
  - W_S – number of litres of water used per soldier per day
  - V – number of vehicles in the sub-unit
  - W_V – number of litres of water used per vehicle per day

	# Pers on Shore	# Vehicles on Shore	L/pers	L/Veh	Water DOS (L)
LAV Coy	148	21	14	2	2114
LPV Coy	148	30	14	2	2132
HQ& Sigs	64	14	14	2	924
Recce	42	13	14	2	614
Engr	61	16	14	2	886
Arty	79	28	14	2	1162
CSS Coy	41	56	14	2	686

Table 3 - Water DOS per Sub-Unit

3.3.3.3 Fuel

The consumption of fuel is dependant upon the fuel economy of each vehicle and the distance travelled. It is impossible to determine exact distance travelled per vehicle in each company per day as some will patrol for the entire day covering potentially hundreds of kilometres while others may remain static. For the purpose of this model the calculation of fuel consumption is based upon a sub-unit travelling on 100 km/day on average. The consumption of the connectors (landing craft and vehicles) is not considered as it is assumed that they are refilled at the seabase prior to any trip and that the fuel available at the seabase is not an issue. Therefore the fuel consumption of the land force sub-units at 100 km/day is calculated by using

- DOS$_{\text{Fuel}}$ = $\sum_{AllVehTypes}(CR_{VehType} \times NV_{VehType}) \times 100$
    - DOS$_{\text{Fuel}}$ – one day of supply of fuel per sub-unit
    - $CR_{VehType}$ - consumption rate of fuel by vehicle type expressed in litres per kilometre
    - $NV_{VehType}$ - number of vehicles of a particular type

This results in the following given the organization of the Basic Hybrid Battalion:

	Total L/Km	Average Distance (km)	Fuel DOS (L)
LAV Coy	8.02	100	802
LPV Coy	4.98	100	498
HQ& Sigs	1.93	100	193
Recce	1.28	100	128
Engr	4.75	100	475
Arty	5.85	100	585
CSS Coy	18.48	100	1848

Table 4 - Average Fuel Consumption by Sub-unit per 100 km

3.3.3.4 Ammunition

The calculation of ammunition consumption is situational dependent and therefore impossible to classify using a single number or even a single distribution. It must be understood that no single unit expends ammunition at the rate described in the Operational Staff Data handbook for extended periods of time. Therefore for the purpose of this study a matrix of ammunition consumption tempos has been created. In sustainment doctrine each vehicle, soldier and weapon system is given a basic load of materials. This basic load is supposed to represent the amount of supplies normally held by a unit and calculated as the requirement to sustain that unit in operations for a specific period of time without replenishment. The normal holdings are a three-day basic load of combat supplies and 15 DOS of repair parts, general and technical stores [41]. Since ammunition supply is expressed in basic loads, to get 1 DOS the basic load is divided by three. The only ammunition data available is based upon a high rate of consumption in warfighting. However, a unit may incur a medium rate of consumption or a low rate of consumption based upon their current task. The following descriptions are used to clarify the terms:

- High rate of expenditure: A sub-unit is tasked to seek out and engage the enemy. The unit enters the task knowing that a high rate of expenditure of ammunition is possible. This is quantified as being 1 DOS as given in the staff tables [26] for each weapon type.

- Medium rate of expenditure: A sub-unit conducts a task that contact with the enemy is expected but not in all occasions. An example would be patrolling in a peace support operation. Contact with the enemy will not occur on every patrol but if it does, it consumes ammunition at higher rates. This is quantified as being 40% of the high rate of expenditure for each weapon type. This number was established through discussion and is as yet to be validated by the analysis of historical data. However the resultant numbers were examined by subject matter experts and deemed to be acceptable for use in this study.

- Low rate of expenditure: A sub-unit is not expected to contact the enemy at all, but training must continue. This is quantified as being 1% of the high rate of expenditure for each weapon type. This number was established through discussion and is as yet to be validated by the analysis of historical data. However the resultant numbers were examined by subject matter experts and deemed to be acceptable for use in this study.

By combining the above rates of expenditure with the spectrum of operations the following matrix is created. The percentages indicate possible amounts of time that in a given deployment the land force will be consuming ammunition at the given rates and is not indicative

			% of days at expenditure rate		
Expenditure of Supplies	Expenditure Factor	Description	Warfighting	Peace Support	Humanitarian
High	1	High expenditure of Ammunition	0.1	0.05	0.01
Med	0.4	Med expenditurte of Ammunition	0.5	0.3	0.1
Low	0.01	Low expenditure of Ammunition	0.4	0.65	0.899

of any scenario. These percentages must be adjusted for each scenario under consideration:

Table 5: Ammunition Consumption Rate Matrix

Therefore, the calculation of ammunition consumption in a given scenario (warfighting, peace support or humanitarian) will be:

- $DOS_{AmmoType} = (NW_{WpnType} \times CR_{WpnType}) \times (PT_H \times R_H + PT_M \times R_M + PT_L \times R_L)$
  - $DOS_{AmmoType}$ - one day of supply of ammunition of a particular type per sub-unit
  - $NW_{WpnType}$ - number of weapons in a sub-unit capable of firing a particular type of ammunition.
  - $CR_{WpnType}$ - consumption rate of a particular type of ammunition
  - PT_H - percentage of time anticipated to be in a high rate of ammunition expenditure

- PT_M - percentage of time anticipated to be in a medium rate of ammunition expenditure
- PT_L - percentage of time anticipated to be in a low rate of ammunition expenditure
- R_H - high rate expenditure factor
- R_M - medium rate expenditure factor
- R_L - low rate expenditure factor

Using the above calculation method and selecting the warfighting scenario the ammunition DOS for the LAV company is given in Table 6.

	Number of Weapons	Consumption Rate	% of Time at High Rate	High Rate	% of Time at Medium Rate	Medium Rate (% of High Rate)	% of Time at Low Rate	Low Rate (% of High Rate)	Total Rds/DOS per Sub-unit
25 mm HEI	15	250	0.1	1	0.5	0.4	0.4	0.01	1140
25 mm APDS	15	900	0.1	1	0.5	0.4	0.4	0.01	4104
7.62 4B1T Linked	2	1320	0.1	1	0.5	0.4	0.4	0.01	803
76 mm Smoke Grenade	19	16	0.1	1	0.5	0.4	0.4	0.01	92
9 mm	7	30	0.1	1	0.5	0.4	0.4	0.01	64
5.56 mm Ball	148	150	0.1	1	0.5	0.4	0.4	0.01	6749
5.56 4B1T Linked	0	600	0.1	1	0.5	0.4	0.4	0.01	0
M-72	0	1	0.1	1	0.5	0.4	0.4	0.01	0
Carl G HEAT	4	3	0.1	1	0.5	0.4	0.4	0.01	4
Eryx	9	2	0.1	1	0.5	0.4	0.4	0.01	5
ALAAWS Missile	4	4	0.1	1	0.5	0.4	0.4	0.01	5
40 mm Gren	2	30	0.1	1	0.5	0.4	0.4	0.01	18

Table 6 - Ammunition DOS for LAV Company

The logic and calculation methods explained above are incorporated into the methodology used to calculate the number of vehicles required to carry 1 DOS of each combat supply for each sub-unit.

3.3.4 Calculating Vehicle Requirements

The conceptual model presented at the beginning of Section 3.3 is not concerned with the consumption of individual supplies, but the turn-around time of the vehicles carrying those supplies. This section therefore presents the assumptions and calculations used to determine the number of vehicles required to carry one DOS for each deployed sub-unit.

The SCTF final operating capability (FOC) is envisaged to occur around 2015. By this time the army will have put the sustainment concept described in the Future Employment Concept [12] in to place. Therefore, the concept of “push” sustainment using containerization and the Medium Support Vehicle System (MSVS) with the load handling system (LHS) will be used for the transport of rations, ammunition and other general stores. For the transport of liquids (fuel and water), trailers will be used.

An MSVS LHS can transport items contained in ISO approved containers equivalent to a 20 ft sea container to a gross weight of 8000 kg [44]. These containers can either be full sea containers (Figure 6), quadcons (Figure 7) or flat racks (Figure 8).

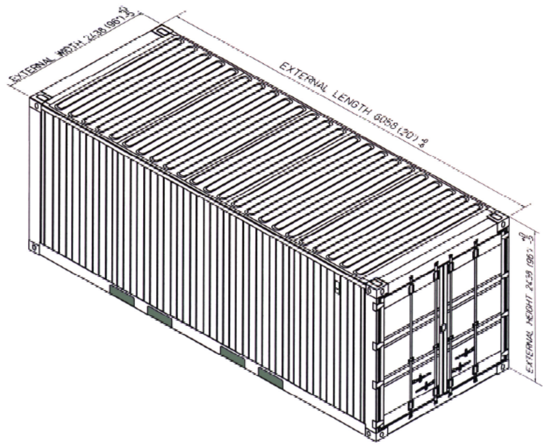


Figure 6 - 20 ft ISO Dry Cargo Container (www.seabox.com)

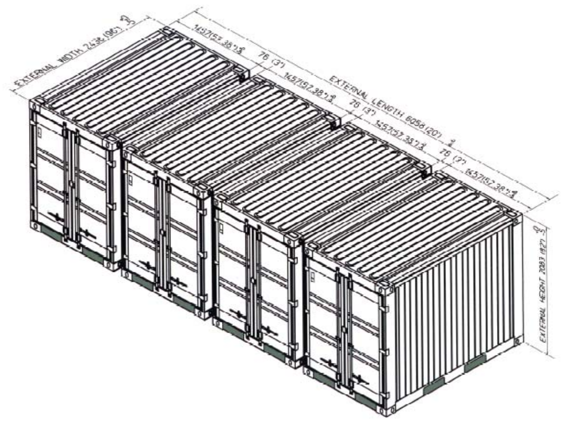


Figure 7 - 4 Quadcons Configured as Sea Container (www.seabox.com)

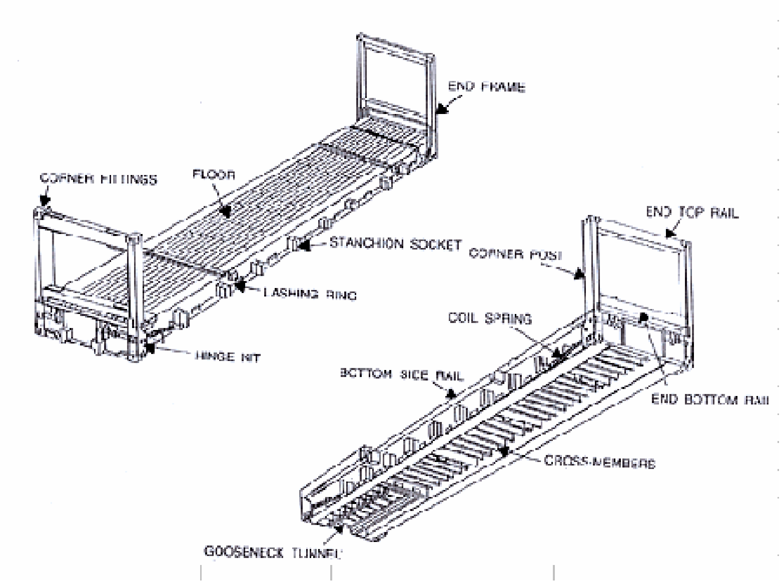


Figure 8 - Flat Rack Container (http://nn21.com/nn21Goods/Goods_05/goods_05_02.asp)

For the purpose of this paper these containers are described using the following data:

	Tare Weight (kg)	Payload Weight (kg)	Gross Weight (kg)	Volume (m^3)
20 ft Sea Container	2300	21700	24000	31.04
Quadcon	800	4200	5000	6.17
Flat Rack	2800	27200	30000	25.61

Table 7 – Dry Cargo Container Data

In order to transport liquid cargo (fuel and water), standard military fuel and water trailers will be considered. Both fuel and water trailers have a capacity of 2200 L and can be towed by the MSVS, even with a full load.

In order to determine the number of MSVS and trailers required the following calculations were completed.

3.3.4.1 Rations.

10 IMPs are packaged in cardboard boxes weighing 8.9 kg and having a volume of 0.028 m^3. The following table shows the number of containers required to carry each sub-units DOS of rations.

	DOS	Total Weight (kg)	Total Volume	# Sea Containers	# Quadcons	# Flat Racks
LAV Coy	444	395.16	1.24	0.07	0.33	0.08
LPV Coy	444	395.16	1.24	0.07	0.33	0.08
HQ& Sigs	192	170.88	0.54	0.03	0.14	0.03
Recce	126	112.14	0.35	0.02	0.09	0.02
Engr	183	162.87	0.51	0.03	0.14	0.03
Arty	237	210.93	0.66	0.04	0.18	0.04
CSS Coy	123	109.47	0.34	0.02	0.09	0.02

Table 8 - Number of Containers Required for Rations by Sub-Unit

3.3.4.2 Water

A standard military water trailer capacity is 2200 L. The following table shows the number of water trailers required to carry each sub-units DOS of water.

	Water DOS	# Water Trailers
LAV Coy	2114	0.96
LPV Coy	2132	0.97
HQ& Sigs	924	0.42
Recce	614	0.28
Engr	886	0.40
Arty	1162	0.53
CSS Coy	686	0.31

Table 9 - Number of Water Trailers Required by Sub-Unit

3.3.4.3 Fuel

A standard military fuel trailer capacity is 2200 L. The following table shows the number of fuel trailers required to carry each sub-units DOS of fuel.

	Fuel DOS (L)	# Fuel Trailers
LAV Coy	802	0.36
LPV Coy	498	0.23
HQ& Sigs	193	0.09
Recce	128	0.06
Engr	475	0.22
Arty	585	0.27
CSS Coy	1848	0.84

Table 10 - Number of Fuel Trailers Required by Sub-Unit

3.3.4.4 Ammunition

In order to calculate the container requirements for ammunition, the total weight and volume of the ammunition including its packaging must be considered. The baseline data for this was taken from the Canadian Forces Ammunition Technical Orders [45]. The following table presents a sample calculation for ammunition using the LAV company.

	Total Rounds	# Containers	Total Volume (m3)	Total Weight (kg)	
25 mm HEI	1140	38	0.684	915.8	
25 mm APDS	4104	137	2.466	3219.5	
7.62 4B1T Linked	803	4	0.028	36.06	
76 mm Smoke Grenade	92	4	0.236	168.8	
9 mm	64	1	0.008	8.4	
5.56 mm Ball	6749	8	0.104	126	
5.56 4B1T Linked	0	0	0	0	
M-72	0	0	0	0	
Carl G HEAT	4	2	0.06	22.66	
Eryx	5	5	0.835	110	
ALAAWS Missile	5	5	1	175	
40 mm Gren	18	1	0.039	25	
		Totals	**5.46**	**4807.22**	#MSVS
		#Sea Containers	0.26	0.84	1
		# QuadCons	0.88	4.01	2
		# FLAT Racks	0.22	0.92	1

Table 11 - Number of MSVS Required to Carry LAV Company Ammunition

The following table summarizes the MSVS requirements by sub-unit to carry one DOS of ammunition.

	#MSVS for Ammunition
LAV Coy	2
LPV Coy	1
HQ& Sigs	0.5
Recce	0.5
Engr	2
Arty	2

Table 12 - Number of MSVS Required to Carry Ammunition

3.3.4.5 Miscellaneous Supplies

Besides the basic combat supplies, a unit requires other general and technical supplies to function. The Operational Staff Data Handbook [26] describes the daily quantity of general stores required per person. This data is used in the table below to calculate the total weight of general supplies required by each sub-unit.

		kg/person/day					
		Repair Parts	Technical Stores	Engr Stores	General Stores	Defensive Stores	
	#Pers	0.7	1.4	6.3	1.5	4.3	Total Weight
LAV Coy	148	103.6	207.2	932.4	222	636.4	2101.6
LPV Coy	148	103.6	207.2	932.4	222	636.4	2101.6
HQ& Sigs	64	44.8	89.6	403.2	96	275.2	908.8
Recce	42	29.4	58.8	264.6	63	180.6	596.4
Engr	61	42.7	85.4	384.3	91.5	262.3	866.2
Arty	79	55.3	110.6	497.7	118.5	339.7	1121.8
CSS Coy	41	28.7	57.4	258.3	61.5	176.3	582.2

Table 13 - Total Weight of General Supplies by Sub-Unit

Although the Operational Staff Data Handbbok does not give the volume taken up by each of the general stores, it can be assumed that, like ammunition, weight not volume is the driving factor behind the calculation of container and transport requirements. Table 15 summarizes the number of MSVS required to carry these general supplies.

	Total Weight	# Sea Containers	# Quadcons	# Flat Racks	# MSVS
LAV Coy	2960	0.52	2.47	0.57	<1
LPV Coy	2960	0.52	2.47	0.57	<1
HQ& Sigs	1280	0.22	1.07	0.25	<1
Recce	840	0.15	0.70	0.16	<1
Engr	1220	0.21	1.02	0.23	<1
Arty	1580	0.28	1.32	0.30	<1
CSS Coy	820	0.14	0.68	0.16	<1

Table 14 - Number of MSVS Required to Carry General Supplies by Sub-Unit

3.3.4.6 Summary of Vehicle Requirements

From the calculations in the previous sections and from discussions with the office responsible for the development of Land Force sustainment doctrine, it was determined that the use of quadcons would be the best choice for the supplies under consideration. From this the overall number of MSVS required can be determined using the fact that an MSVS must carry 4 Quadcons joined as a sea container and that each sea container can contain different types of supplies. Also the number of fuel and water trailers is summarized. Excess capacity in the MSVS is also allowed to factor in possible errors in the accuracy of calculations of the number of vehicles required. For the purposes of the study, the CSS sub-unit is not considered because it is not deployed and can be resupplied directly from the ship’s stores. Also, the smaller sub-units of the Headquarters, signals and recconnaissance will be grouped together as a miscellaneous sub-unit.

	# Ammo MSVS	# Food/Misc MSVS	# Fuel Trailer	# Water Trailer
LAV Coy	2	1	1	1
LPV Coy	1	1	1	1
LPV Coy	1	1	1	1
Arty	2	1	1	1
Engr	2	1	1	1
Misc	1	1	1	1

Table 15 - Number of MSVS and Trailers Required by Sub-Unit

3.4 VALIDATE THE CONCEPTUAL MODEL

3.4.1 Background

The Canadian Forces Synthetic Environment Coordination Office (SECO) defines verification, validation and accreditation (VV&A) as follows [46]:

- Verification is the process of determining that a model implementation accurately represents the developer's conceptual description and specifications. Verification answers the question "Was it built right?" Therefore, if a developer has described and specified the characteristics of a sonar acoustic response model, or an armoured vehicle visual model, or a dismounted section behaviour model, the verification process is conducted to ensure that the resulting model represents that original design input.

- Validation is the process of determining the degree to which a model is an accurate representation of the real world in relation to the intended use of the model. Validation answers the question "Was the right thing built?" Therefore, if a model has been created to simulate the visual view out of a dismounted soldiers sight for the purposes of small arms training, the validation process would be conducted to determine if the model accurately reflects the visual view of the real world for this purpose.

- Accreditation is the official certification that a model or simulation or federation (group of linked models in a simulation) is acceptable for use in relation to a specific purpose. Therefore, if a simulation was created to train armoured vehicle gunnery it might be accredited for that purpose, or perhaps for just part of that purpose, for example it may be accredited only as acceptable for static vehicle gunnery training but not for moving vehicle gunnery training because the simulation did not have any movement component.

3.4.2 Verification

Data is assumed to be verified as it was collected from Canadian Forces approved documents. In order to verify data that was produced using the baseline data, the data and calculations were presented to several personnel during individual sessions or as part of working group discussions. What are presented in Section 3.3 are the resultant data and calculations.

3.4.3 Validation

In order to validate the data and assumptions made to complete the calculations, subject matter experts from various fields and backgrounds were asked to conduct “face validation”.

Face validity is an informal validation technique. It is the process of determining whether the model or simulation seems reasonable to people who are knowledgeable about the system under study, based on performance. This process does not review the software code or logic, but rather reviews the inputs and outputs to ensure they appear realistic and representative [46].

These personnel were briefed on the origins of the data, the calculations conducted and their associated assumptions. With an understanding of the purpose of the data, the SMEs determined that the data and conceptual model were fit for the purpose of answering the questions outlined in section 3.2.3.

3.4.4 Accreditation

Based upon the validation of the data conducted by members of the Army SCTF Working group and the Sustainment Working Group, the Chairman of the Army SCTF accredited the data for use in this study. Use of the data for a purpose outside this study would require the re-evaluation of the VV&A process.

3.5 PROGRAM THE MODEL

3.5.1 Introduction

The purpose of the simulation is to provide an approximation of a real-life system in order to analyse the processes, over time, by manipulating various factors without expending the resources required to build and operate the system.

The simulation model developed for use in this analysis is based upon the seabasing and sustainment concepts discussed in Chapters 2 and 3. The purpose of this simulation is to create a virtual SCTF sustainment system and exercise it under various conditions in order to measure and assess its performance.

The simulation created for this analysis was created using the Extend® software package developed by Imagine That Inc. [47]. This section describes the programming tools/software used in the creation of the model as well as the logic behind the model and a detailed description of the model’s functions. This section is not intended to make the reader proficient in any software packages used but to instil an understanding of the model and how it was built in order to gain a better understanding of the results.

3.5.2 Model Overview

For ease of description the model is described as having three levels of detail. Level 1 is based upon the conceptual model and is translated into hierarchical blocks using the Extend® simulation software. Figure 9 provides a view of the Level 1 model. The model is broken down into six Level 1 areas; the seabase, travel between the seabase and the beach, the beach itself, a marshalling area, travel between the marshalling area and the sub-units and the sub-units themselves.

Level 2 is a further breakdown of the main areas of Level 1 and describes the sub-components, in hierarchical blocks of each of the main areas. Level 3 contains native Extend® blocks that run the simulation. The remainder of this section will be the description of the logic and data used in the creation of these six areas.

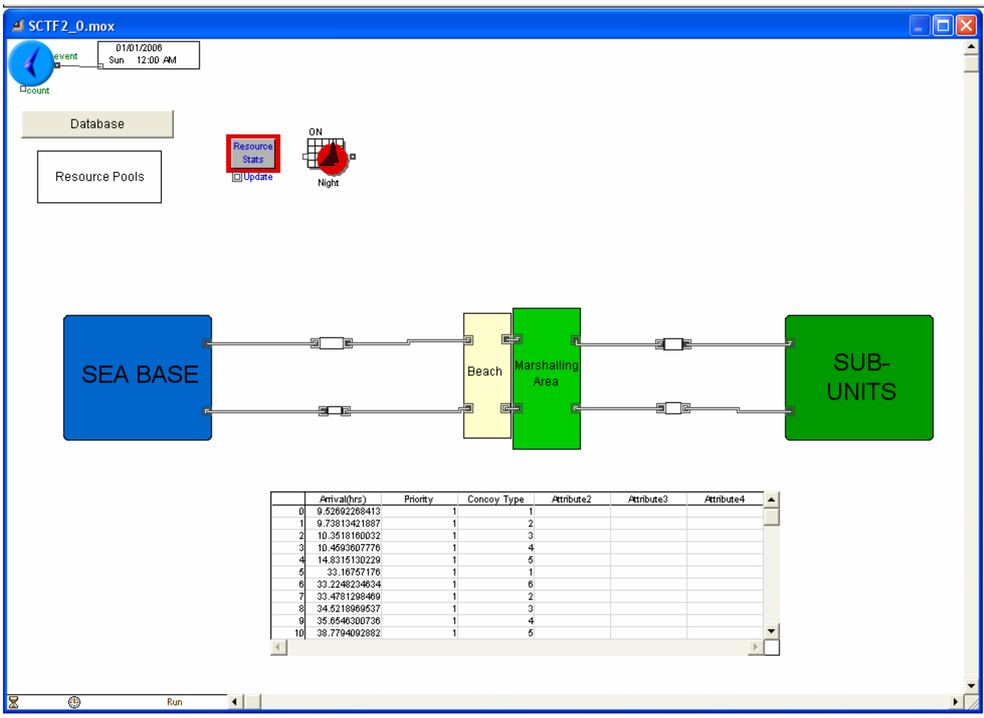


Figure 9 – Level 1 Overview of Seabase Simulation

3.5.3 Seabase

3.5.3.1 Loading

The seabase portion is divided into two main functions, the loading and dispatch of vehicles and landing craft, and the reception and unloading of vehicles and landing craft. The first step in this process is the creation of orders. This function simulates passage of cargo between the replenishment ship and an amphibious ship. In this model these ships are modelled as a single entity with the creation of orders used to simulate the passage of supplies from one ship to another. This approximation is used because the type of ships and their associated capacities and their means and times for transferring cargo were unknown at the time of writing.

The variation of this value allows for the establishment of a theoretical threshold for the time required to transfer cargo between ships.

In order to load an MSVS or trailer (fuel or water), a vehicle must be available along with its corresponding load spot. The number of load spots and initial number of vehicles is a design parameter for the SCTF and is defined through the “Initial Values” tab available through the Database button on Level 1 of the model. When a vehicle and load spot are available they are delayed, to simulate the loading of cargo. A triangular distribution is used in all cases for delay as the data available that describes these delays is stated as minimum, maximum and most likely times. The loaded vehicles are then loaded onto their associated landing craft.

For the purposes of this model, the landing crafts in use are the Landing Craft Utility Mark 10 (LCU Mk10) and the Landing Craft Vehicle and Personnel Mark 5 (LCVP Mk5). It has been assumed that three MSVS are able to be loaded onto the LCU and the LCVP can hold one each of the fuel and water trailer. If three MSVS are ready to load and an LCU and its load spot are available the loading of the craft begins. A similar process is used for the loading of the fuel and water trailers onto the LCVP. As this model uses delays to model the loading and unloading of landing craft it is not prescriptive as to the method of loading and unloading. Well decks, cranes and or ramps can be used to load the landing craft, one simply has to change the data found in the “Delays” tab of the Database to reflect the applicable loading times. The delays for the loading and unloading of landing craft are based upon data received from the Royal Navy [33]. Once the landing craft are loaded they are dispatched to the beach.

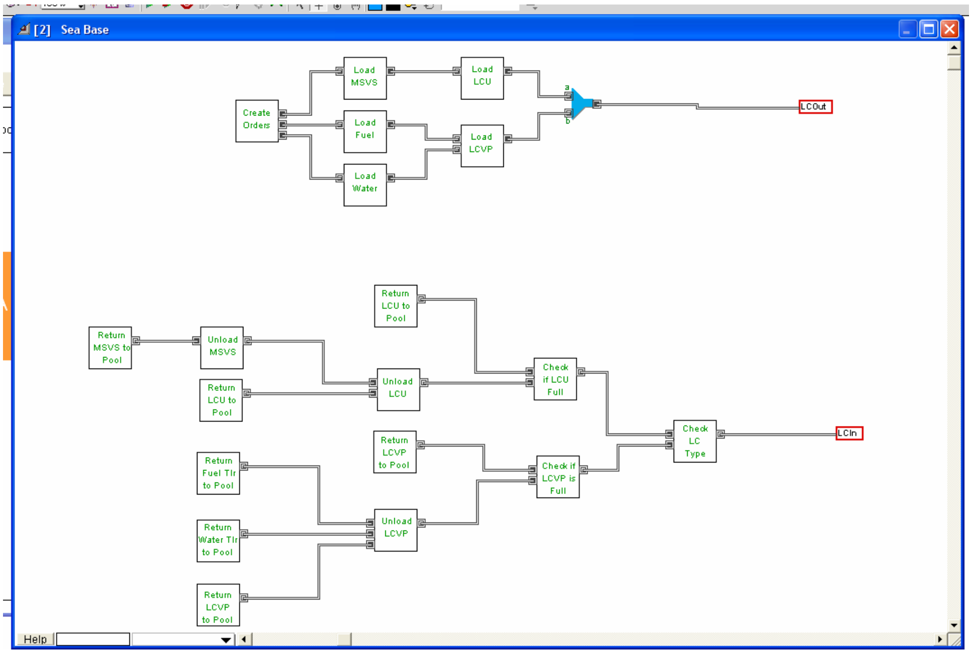


Figure 10 - Level 2 of Seabase Block

3.5.3.2 Unloading

When a landing craft arrives back at the seabase it is first checked if it is full or empty. Empty landing craft are returned immediately to the resource pool for re-use. Landing craft containing vehicles wait for their associated load spot and then are delayed the amount of time it would take to unload their vehicles before returning to the resource pool. MSVS have to be in turn unloaded of their containers before returning to the resource pool for re-use. It is assumed that any fuel or water carried in the returning trailers is still usable and will be "topped up" when the trailers are refilled. The trailers are available for re-use after unloading from the LCVP.

This model does not consider the break down of equipment nor the routine maintenance required on vehicles and landing craft. Running the simulation in better than perfect conditions indicates absolute instances when the system would fail and gives indications where further study is required if the system must function under these given conditions.

3.5.3.3 Level 3 Explanation

Although it is not the intent of this section to describe the entire model to the individual Extend® blocks detailed in Level 3 but the loading portion of the Seabase block will be explained in detail to further understanding of how the model works. Each of the blocks found in Level 2 (Figure 10) of the Seabase portion consist of native Extend® blocks that will be described hereafter.

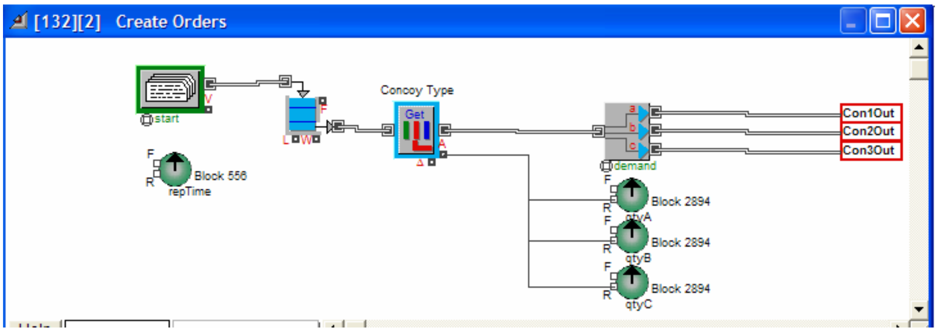


Figure 11 - Level 3 Create Orders Block

The first step in the model is to make available the shipments that are required by the subunits. A "Program" block is used to create items that have an associated attribute of "Convoy Type". This attribute is a number that signifies the destination of the shipment. Table 16 describes this attribute.

Convoy Destination	Convoy Type
LAV Company	1
LPV Company 1	2
LPV Company 2	3
Artillery	4
Engineer	5

Miscellaneous	6

Table 16 - Convoy Type Attribute

The program block also uses a "DB Inject" block to input the "Ship every x hours" value from the "Initial values" tab of the database. Each item generated passes into a First in First out (FIFO) queue. The item then passes through a "Get Attribute" block that reads the "Convoy Type" attribute. This attribute is passed to three "DB Inject" blocks that use the attribute to determine the number of containers that are associated with each sub-unit. This value is passed to an "Unbatch" block that turns the single item into the pre-requisite number of MSVS, water and fuel loads required. These items are passed to the "Load MSVS", "Load Fuel" and "Load Water" hierarchical blocks. Each of these blocks functions in a similar manner and therefore only the "Load MSVS" hierarchical block will be discussed.

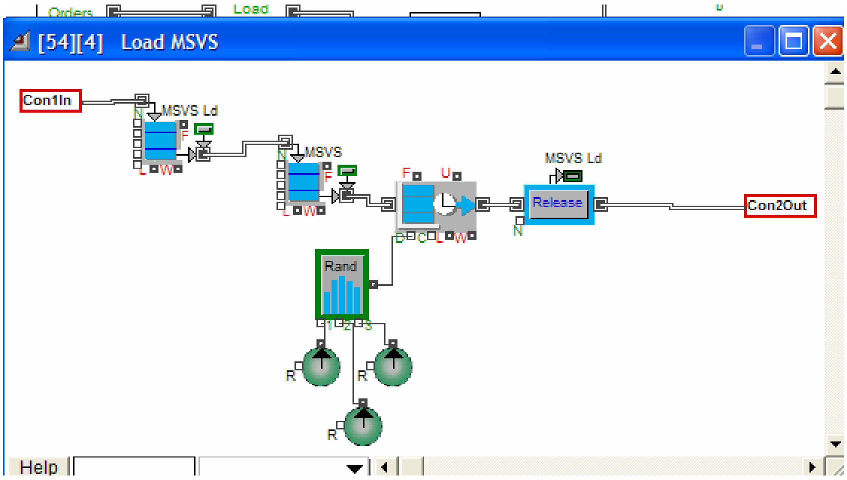


Figure 12 – Level 3 Load MSVS Block

The "Load MSVS" block (Figure 12) receives the number of containers to be shipped by MSVS. These items enter a "Queue, Resource Pool" block that acts similar to a FIFO queue but an item is only released if a resource is available, in this case a loading spot for the MSVS. If a loading spot is available, the item passes to another "Queue, Resource Pool" block to await the availability of an MSVS. When the MSVS is available the item is passed to an "Activity, Multiple" block where it is delayed in accordance with a randomly generated time created by the "Input Random Number" block. The random number is created through the use of a triangular distribution. This distribution was chosen as the data available for each delay was characterized by minimum, maximum and most likely times. These times are access by the "DB Lookup" blocks query of the "Load MSVS" entry in the "Delay" tab of the database. Once the item has been delayed the prescribed period it passes through a "Release Resource Pool" block that releases the MSVS loading spot back into the resource pool to be reused. The item is then passed to "Load LCU" hierarchical block.

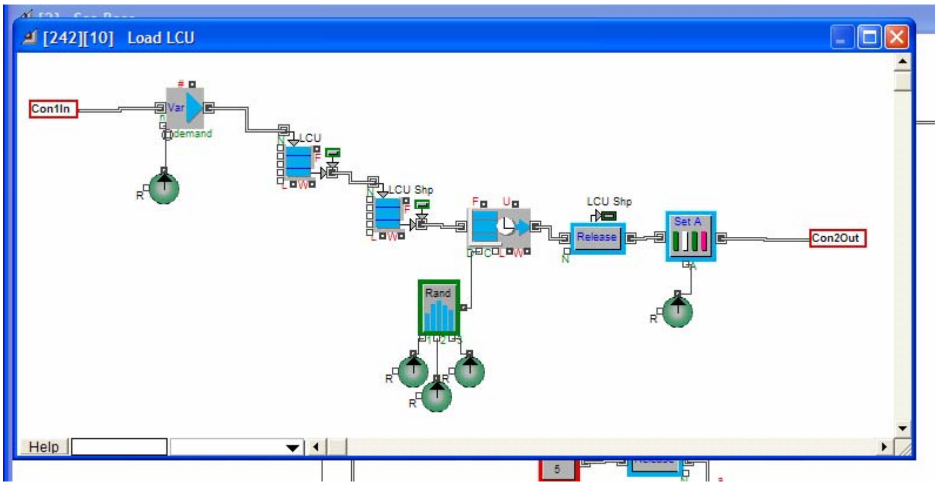


Figure 13 - Level 3 Load LCU Block

The items, now representing loaded MSVS, enter the “Load LCU” block (Figure 13) and enter a “Batch (Variable)” block. This block batches together a number of items as prescribed by the “# MSVS wo trailer” entry in the “LCU Description” tab of the database. This single item is then passed to a “Queue, Resource Pool” block to await the availability of an LCU. If an LCU is available the item moves to another “Queue, Resource Pool” block to await the availability of an LCU loading spot. Following this the item is passed to a “Activity, Multiple” block where it is delayed in accordance with the time indicated in the “Load LCU (Shp)” entry in the “Delays” tab of the database. When the time of loading has expired the item passes through a “Release Resource Pool” to return the LCU loading spot to be reused. A “Set Attribute” block is used to set attributes on the item. These attributes are LC Type (1 for LCU and 2 for LCVP) and #MSVS (set as 3). The item, now representing a loaded LCU is passed to the area of the model concerned with travel between the seabase and the shore.

3.5.3 Travel between Seabase and Shore

The travel between the seabase and the shore is modelled as a delay based upon the distance to travel divided by the speed of the landing craft. The distance between the seabase and the shore and the speeds of the various landing craft can be changed using the database. This model does not consider conditions, either environmental or man-made that would negatively impact on the time taken to get to shore. Continuing with the logic in Section 3.4.3.2, if the system doesn’t work under perfect conditions it would not work when conditions are worse.

3.5.4 Beach

The function of the beach is to receive and offload landing craft as well as load landing craft for return to the seabase. When a landing craft arrives it waits until a beach spot is available. Both LCUs and LCVPs use the same beach spots in this model. The number of beach spots is defined in the database. When a beach spot becomes available the landing craft is delayed until its cargo is unloaded. A check is then conducted if there are vehicles waiting to come ashore at the seabase or vehicles waiting to return to the seabase in order to route the landing craft. This simple set of rules represents a simplistic command and control system. If a more robust and dynamic command and control system were modelled the overall sustainment system could perform better. Command and control for the sustainment system is a large area open for further study and is beyond the reach of this study.

The vehicles that were unloaded from the landing craft are sent to the marshalling area. There is no delay in the transfer of vehicles from the beach to the marshalling as this transfer is theoretical and convoys could be put together on the beach. This may change as the concept of sustainment evolves.

Vehicles arriving from the marshalling area are loaded onto landing craft and depart for their return travel to the seabase.

3.5.5 Marshalling Area

The function of the marshalling area is to create and break up the various types of convoys required to deliver combat supplies to the various sub-units. It is assumed that the command and control mechanism in place tracks each vehicle and that the convoys are formed without error. As vehicles arrive from the beach, they are batched together into convoys based upon the calculations in Section 3.3 and summarized in Section 3.3.4.6. There is no delay associated with the creation or break up of the convoys. Once the convoy has been created it departs for the sub-units.

3.5.6 Travel between Sub-Units

As with the travel between the seabase and the shore in Section 3.5.3, travel between the marshalling area and the sub-units is modelled by a simple calculation of the distance to be travelled divided by the average speed of the convoy.

3.5.7 Sub-Units

Although the model depicts six different sub-units, they all operate at the same distance from the beach. When a convoy arrives at sub-unit it is delayed the time required to unload the containers from the MSVS, load the empty containers onto the same MSVS and exchange fuel and water trailers. The model can also be used to simulate the exchange of vehicles by making the delay at the sub-units a lesser time. It is in this block that data is collected on when each of the sub-units has been re-supplied. After this is complete the sub-unit should be back to its initial number of DOS.

Once the re-supply has been completed the convoy returns to the beach to be broken down and returned to the seabase via appropriate landing craft.

3.6 MODEL VALIDATION AND ACCREDITATION

Verification, “did I build the thing right”, is focussed on the actual programming of the model and the steps taken to ensure that the model functions in a manner that enables it to produce results relating to its initial purpose. To verify several runs with known outputs were conducted. Various modifications were completed until confidence was gained that the model was producing results that were not in error mathematically.

The validation of the programmed model, or “did I build the right thing”, was conducted through the use of a structured walk through of the model with subject matter experts (SMEs). At the Sustainment Working Group held in Halifax at the Maritime Warfare Centre from February 27th to March 3rd 2006, the model was briefed and critiqued by the members and deemed valid.

This validation was presented to the Chair of the Sustainment working group and it was agreed that the model was accredited for use.

3.7 SUMMARY

This chapter used the guidelines and methodology as presented by Averill M.Law [24] in order to construct a validated model to be used to provide insights into the SCTF supply concept. The data and the sources and the methodologies used to calculate the required information was also detailed. This information was then placed into a database that was accessible to the model. The three levels of the model were described in a general manner with a detailed explanation of a portion of Level 3 of the Seabase hierarchical block to provide understanding into the use of Extend. The model will now be used to conduct runs given certain scenarios in order to provide insights into the system under simulation.

DESIGN AND CONDUCT OF SIMULATION RUNS

4.1 INTRODUCTION

The purpose of this chapter is to define the scenarios that form the basis for each series of simulation runs, present the data gathered as a result of these runs and provide insights and analysis of these results. The purpose of the experiment is to provide insight into the parameters that impact on the ability of a seabase to provide basic support (in terms of numbers of convoys delivered per day) to its landing force. The parameters studied in this experiment were the distance from the seabase to shore, the distance from the shore to the landing force. Within each of these parameters a sensitivity analysis was conducted to provide insights into the impact of a decrease in the numbers of connectors and vehicles on the system.

4.2 EXPERIMENT DESIGN

4.2.1 Variables

The model described in Section 3.5 was used to run scenarios to provide insights into the operating distances between the seabase and the landing force. These distances are functions of many variables. These include:

1. The size of the landing force. As detailed in Section 3.3.1 and kept constant for all runs of the simulation.

2. The amount of supplies required ashore. As calculated in Chapter 3 and kept constant for all runs of the simulation.

3. The capability of the connectors (both sea and land). As described in Section 3.5.2 and held constant for all runs of the simulation.

4. The number of these connectors required. As calculated in Chapter 3.

5. The total number of connectors available. This number represents the total number of connectors (LCU, LCVP, MSVS, trailers) on the amphibious ship. An initial number of 4 LCU, 4 LCVP was taken from discussion on the most likely number of landing of that type that would be available. 40 MSVS and 20 each of fuel and water trailers were selected as an initial number based upon the original organization proposed for the CSS company.

6. The capacity and time required to store, load and unload at the ship and the shore. For the initial runs of the simulation it is assumed that a DOS is available for shipment ashore once every 24 hours. This assumption was made because the type of ships was unknown and therefore the storage capacity of the amphibious ship and the time taken to transfer supplies between the replenishment ship and the amphibious ship are unknown. Twenty-four hours represent the worse case scenario, longer and the landing force will not be re-supplied in time. A shorter time can be inserted which would provide indications on whether a build-up of supplies ashore could be undertaken.

Other variables exist, but are beyond human control. The environment, both natural and man-made, is assumed to be cooperative. The natural environment includes among other things, weather, sea-state and surf-state. The man-made environment includes loss of equipment, due to breakdown or enemy action and road conditions. These variables are all assumed to not adversely affect the system; therefore, if the system under simulation were to fail, it would only fail in a worse manner if the other variables inhibiting its function were included.

The following variables are included in the model and were held constant for each run:

- Number of load spots. Areas where vehicles were loaded or unloaded.
  - MSVS: 5;
  - Fuel Trailer: 2;
  - Water Trailer: 2;
  - LCU: 2; and
  - LCVP: 2,
- Number of Beach Spots: 2. Area where LCUs and LCVPs can land at the beach.

4.2.2 Number of Simulation Runs

The simulation runs were conducted with the seabase established at 40, 30, 20 and 10 nm from the shore. Each of these distances were run with the landing force operating at a driving distance of 100, 200, 300, 400 and 500 kms from the beach. A sensitivity analysis was conducted holding the seabase distance at 30 nm and the numbers of LCUs, LCVPs, MSVS and trailers were reduced until the system failed. Failure is defined when any sub-units of the landing force consumes all their integral supplies. Sensitivity to convoy speed was also conducted.

The number of scenarios anticipated had to be managed, and therefore, the following approach was developed. Each scenario was run 10 times, if a determination could not be made based upon these outcomes, another 10 runs were completed. Each run used a different random number seed. The same seed was used for each run number between scenarios. This is referred to as the common random number variance technique, and allows the same starting point on random number generators for more valid results during sensitivity analysis.

4.2.3 Measures of Performance

The questions, "how long can the forces ashore be sustained?" and "how far inland can the forces operate", are dependant on the number of days of supply (DOS) that the fighting echelon currently has on hand. Initially, the land force will deploy with integral sustainment support carrying a predetermined number of DOS of each combat supply. These combat supplies are containerized and require a number of trucks and trailers to carry them.

As an example, a sub-unit could deploy initially with three DOS of combat supplies. It is the sustainment system's responsibility to replenish this sub-unit with one DOS of combat supplies every 24 hours. As stated in the Army's Force employment concept, the sustainment system will move towards a push system relying on the introduction of the Medium Support Vehicle System (MSVS) and the concept of containerization. Therefore, the sustainment system will endeavour to deliver, at a minimum, one DOS of combat supplies to the sub-unit every 24 hours. If the sustainment system is capable of delivering more then one DOS every 24 hour period, then commanders have an option to create supply dumps to offset those times when weather or enemy action prevent the operation of the landing system.

The measures of performance are therefore:

- The number of days that the land force ashore has three DOS of combat supplies on hand as specified in the draft Concept of Operations for Sustainment [10]; and
- The utilization of the resources (MSVS, trailers, LCU and LCVP). The utilization represents the amount of time a resource is not sitting in the resource pool and therefore would be available to be maintained or allow for crew rest.

It is through the comparative analysis of these measures of performance in combination that will provide insight into the overall system performance. For example, a system that satisfies the first measure of performance but utilizes one or many of its resources to a critical level (considered as the utilization >0.8 for the purpose of this experiment) then it would be deemed as risky to accept the systems parameters.

4.3 RESULTS AND ANALYSIS

This section will present the results of each scenario and provide analysis and insights into the interpretation of the simulation runs.

4.3.1 Baseline Scenario

4.3.1.1 Introduction

With the seabase at 40, 30, 20, and 10 nautical miles, the simulation was run with the units at 100, 200, 300, 400 and 500 kms inland. The key distance between the seabase and the shore is 30 nm. This is the theoretical horizon from a point on shore at an elevation of 100 feet. Beyond this distance the seabase is considered relatively safe from threats on the shore. Also if the sustainment system can operate from this distance it is assumed that it could only operate more efficiently from closer distances.

4.3.1.2 Explanation of Sample Run

In order to understand the process and data collected, this section will present the methodology used to run the simulation and obtain the data and observations.

When the model is first opened it appears as in Figure 14. To access the data that is used to feed the model the "Database" button is pressed. This gives access to the database functionality available in the Industry module of Extend and is shown in Figure 15.

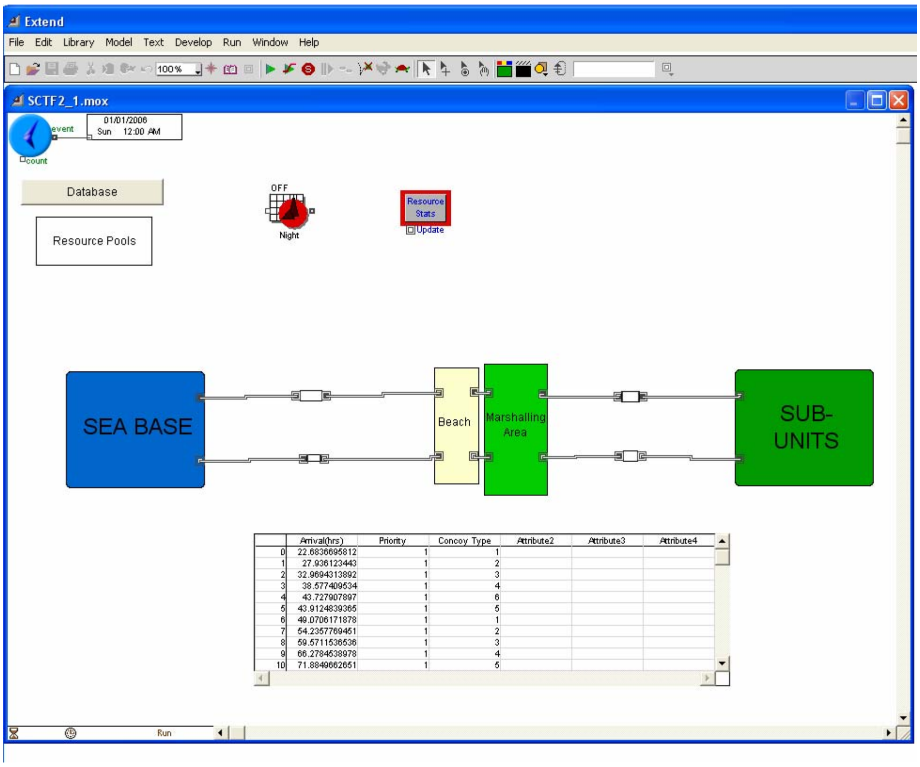


Figure 14 - SCTF Sustainment Model

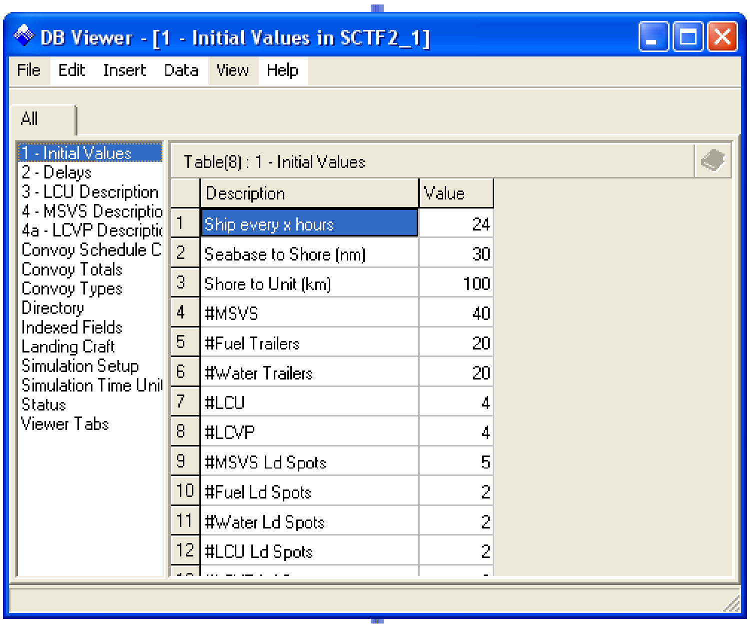
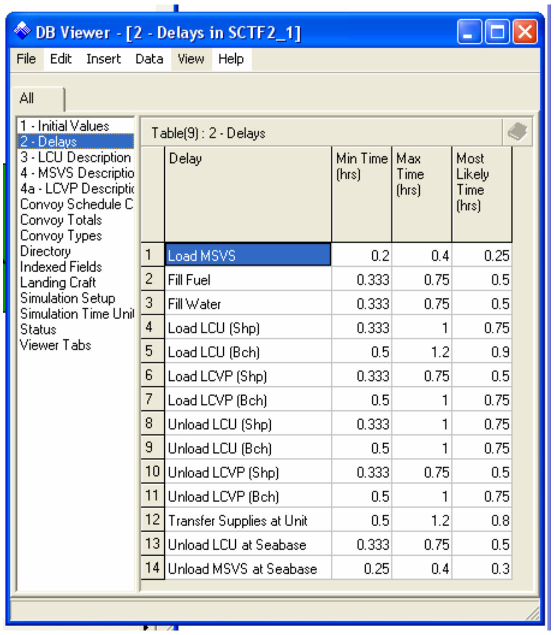


Figure 15 - SCTF Sustainment Model Database Initial Values

Figure 16 shows the minimum, maximum and most likely values used to feed the random number generators for the applicable actions in the model. The seeds for these random numbers are set through the database Simulation Setup tab (Figure 17). For each run of the scenario a specific seed is set (111 for run 1, 222 for run 2, 333 for run 3, 444 for run 4 … 1010 for run 10). These seeds are kept common for each series of runs of each scenario in order to compare results between runs for the purpose of sensitivity analysis. The Simulation Setup Tab is also the place where the duration of the scenario is set.

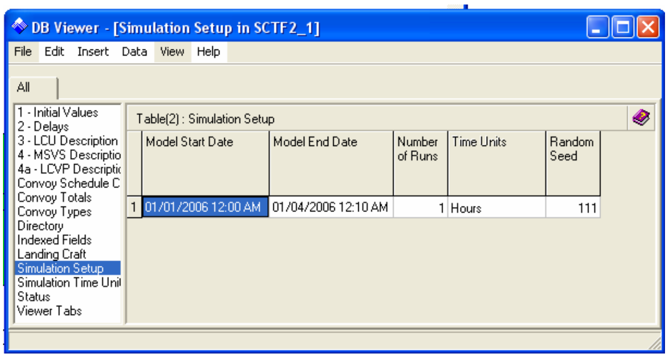


DB Viewer - [2 - Delays in SCTF2_1]

Table(9) : 2 - Delays

	Delay	Min Time (hrs)	Max Time (hrs)	Most Likely Time (hrs)
1	Load MSVS	0.2	0.4	0.25
2	Fill Fuel	0.333	0.75	0.5
3	Fill Water	0.333	0.75	0.5
4	Load LCU (Shp)	0.333	1	0.75
5	Load LCU (Bch)	0.5	1.2	0.9
6	Load LCVP (Shp)	0.333	0.75	0.5
7	Load LCVP (Bch)	0.5	1	0.75
8	Unload LCU (Shp)	0.333	1	0.75
9	Unload LCU (Bch)	0.5	1	0.75
10	Unload LCVP (Shp)	0.333	0.75	0.5
11	Unload LCVP (Bch)	0.5	1	0.75
12	Transfer Supplies at Unit	0.5	1.2	0.8
13	Unload LCU at Seabase	0.333	0.75	0.5
14	Unload MSVS at Seabase	0.25	0.4	0.3

Figure 16 - SCTF Sustainment Model Database Delays



DB Viewer - [Simulation Setup in SCTF2_1]

Table(2) : Simulation Setup

	Model Start Date	Model End Date	Number of Runs	Time Units	Random Seed
1	01/01/2006 12:00 AM	01/04/2006 12:10 AM	1	Hours	111

Figure 17 - SCTF Sustainment Model Database Simulation Setup

The seeds are used as the starting point for all "Input Random Number" blocks used in the simulation. These blocks receive their values by using "DB Lookup" blocks. An example of this is shown in Figure 15 and is taken from the "Load MSVS" portion of "Sea Base" Hierarchical block.

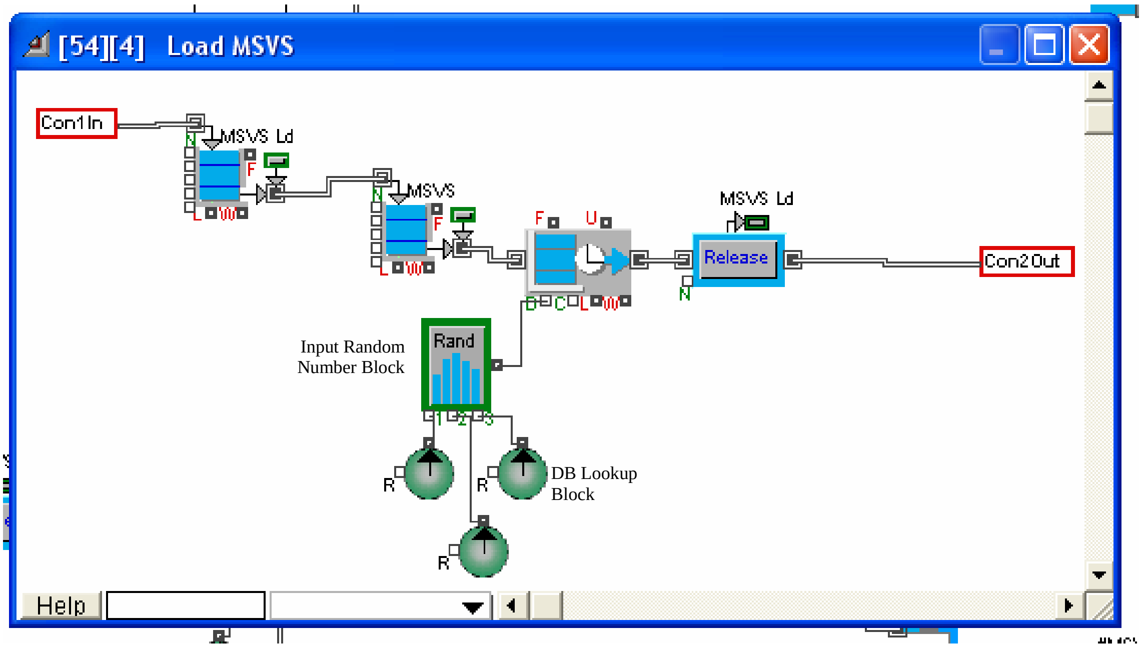


Figure 18 - Load MSVS

Once all the appropriate data has been inputted into the database the simulation is run. Animation can be enabled or disabled. Enabling the animation allows for the visual examination of the modelled system and is a good method for initial debugging or illustration of the model. Disabling the animation allows the model to run much faster. For this model the difference was 25 minutes per run with the animation enabled or five seconds per run with it disabled.

On the completion of the animation, the data collected by the "Information" block in the "Sub-Units" hierarchical block is then copied to an MS Excel spreadsheet. This data is available in the first level of the model by cloning it out of the "Information" block. It includes the time convoy passed through the sub unit and the convoy's type. The utilization of resources is captured by the "Resource Statistics" block and is also transferred to the spreadsheet.

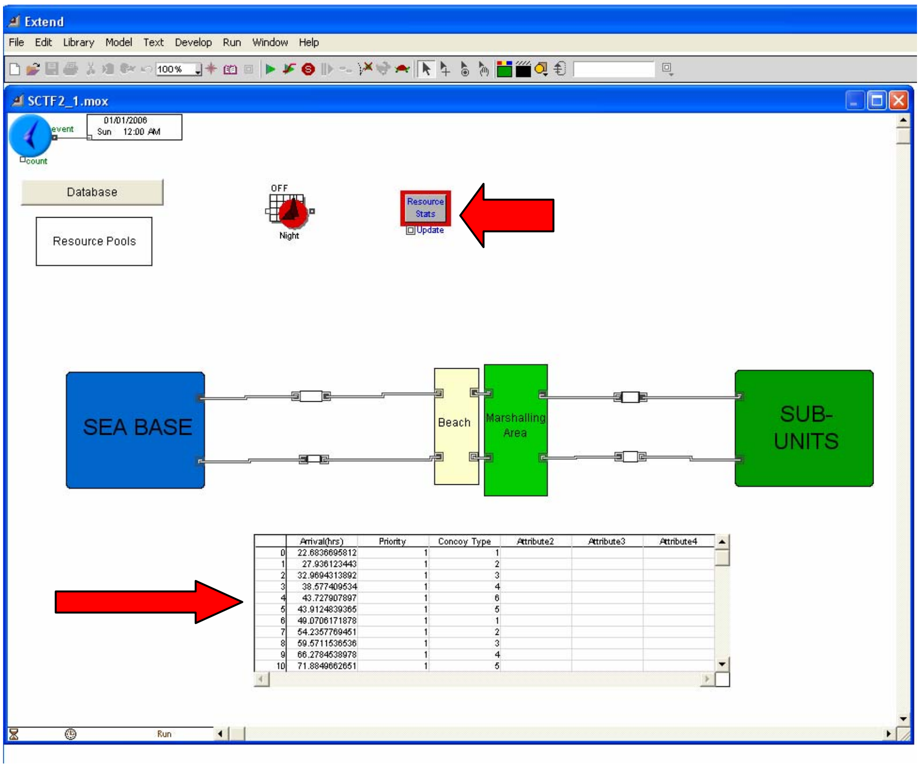


Figure 19 - Data captured by "Information" and “Resource Statistics” Blocks

The MS Excel spreadsheet is preformatted with a table that displays days of operation on the vertical axis with sub-unit type horizontally. Calculations are conducted to determine the number of deliveries per day to each sub unit. This value is added to the existing numbers of DOS on hand. The numbers of DOS for each sub-unit is decremented by 1 to simulate the consumption of supplies. This model has the sub-units consuming a full DOS every day (a worst case scenario). This table displays if any sub-units falls below the initial 3 DOS threshold. These results are reported using the following colour codes:

- Green – Indicates that the sustainment system under study was able to maintain three DOS at each sub-unit.
- Yellow – Indicates that the sustainment system under study was not able to maintain three DOS at each sub-unit however the sub-units did not deplete their integral supplies.
- Red – Indicates that the sustainment system under study was not able to maintain three DOS at each sub-unit and at least one of the sub-units integral supplies were depleted.

Further to the colour coding the utilization of resources is collected. These are averaged over the ten runs per scenario and are reported in a summary worksheet.

4.3.1.3 Run Results

In accordance with the draft Concept of Operations on Sustainment [48], each sub-unit is to be deployed with three days of integral support of combat supplies. It is this threshold of three DOS that must be maintained.

A baseline series of runs was conducted using the values outlined in Table 17.

Ship every	24	hours
MSVS Load Spots	5	spots
Fuel Load Spots	2	spots
Water Load Spots	2	spots
LCU Load Spots	2	spots
LCVP Load Spots	2	spots
Beach Spots	2	spots
Number of MSVS/LCU	3	MSVS
Number of Trailers/LCVP	2	Trailers
LCU Speed	8	knots
LCVP Speed	25	knots
MSVS Speed	30	km/hr

Table 17 - Data for Baseline Runs

When the runs were conducted the following was observed.

Ship to Shore	Shore to Unit				
	100 km	200 km	300 km	400 km	500 km
40 nm	**Green**	**Green**	**Yellow**	**Yellow**	**Yellow**
30 nm	**Green**	**Green**	**Green**	**Yellow**	**Yellow**
20 nm	**Green**	**Green**	**Green**	**Green**	**Yellow**
10 nm	**Green**	**Green**	**Green**	**Green**	**Yellow**

Table 18 - Results from Baseline Runs

These runs indicates that a landing force is only sustainable to 400 km inland when the seabase is operating at less then 20 nm from the shore. At the theoretical safe distance of 30 nm the landing force is sustainable at a 300 km driving distance.

At 30 nm each of the resources in the system is used at different rates. The following table shows the utilization of the resources in the system.

Resource	Utilization with Sea Base at 30 nm				
	100 km	200 km	300 km	400 km	500 km
MSVS Ld Spot	0.04	0.04	0.04	0.15	0.34
Fuel Ld Spot	0.07	0.07	0.07	0.07	0.07
Water Ld Spot	0.07	0.07	0.07	0.07	0.07
LCU Ld Spot	0.14	0.14	0.14	0.14	0.14
Beach Spot	0.37	0.37	0.37	0.36	0.36
LCVP Ld Spot	0.13	0.13	0.13	0.13	0.13
LCU	0.42	0.42	0.42	0.41	0.39
LCVP	0.32	0.32	0.32	0.32	0.30
MSVS	0.53	0.53	0.60	0.81	0.87
Fuel Tlr	0.38	0.38	0.48	0.68	0.67
Water Tlr	0.38	0.38	0.48	0.68	0.67

Table 19 - Utilization of Resources with Seabase at 30 nm

Only the MSVS at distances of 400 and 500 km exceeded the threshold of 0.8. This is a factor as it indicates that there is high demand for the use of MSVS and that there is a potential for failure if the number of MSVS were to be reduced either through enemy action or due to maintenance failures.

4.3.2 Sensitivity Analysis

A sensitivity analysis was conducted on various variables to determine the impact they have on the sustainment system modelled. This is important at this time in the development of SCTF concepts, as it provides guidance as to areas within the chosen sustainment concept that could drastically affect the systems capability to provide timely sustainment to the land force. Unless otherwise indicated only the variable under sensitivity analysis was changed. All others remained constant at the same value as that in the baseline runs.

4.3.2.1 Numbers of Landing Craft

The baseline model landing craft data is based upon the capability provided by the LCU mark 10. These types of landing craft are currently used by the British Navy and Royal Marines and are typically deployed in fours within amphibious ships. However, what would be the effect if the number of these landing craft available were reduced either by the acquisition of fewer numbers or through losses caused by enemy action or maintenance failures? The following table summarizes the results of the runs conducted in similar manner to those in Section 4.3.1.2 but sequentially reducing the number of LCU Mark 10s from 3 to 1.

#LCU	Sea Base at 30 nm				
	100 km	200 km	300 km	400 km	500 km
3	Green	Green	Green	Yellow	Yellow
2	Yellow	Yellow	Yellow	Yellow	Yellow
1	Red	Red	Red	Red	Red

Table 20 - Sensitivity of LCU Numbers

As can be seen from the resultant data, from 30 nm, the capability of the sustainment system under study is immediately affected by the loss of an LCU. The utilization of the LCUs had a mean of 0.52 when 3 LCUs were used. This increased to a mean of 0.72 when the numbers were reduced to 2. With a single LCU the system did not function and the utilization was not calculated for the entire run. A loss of a single platform still allows the system to function out to 300 km with confidence and farther if risk is assumed. However, if the system is reduced to two or less LCUs, the results indicate that the system is no longer robust enough to sustain operations without risk or at all.

The sustainment system also proposes the use of another type of landing craft. This is based upon the capability and performance of the Landing Craft Vehicle and Personnel Mark 5 (LCVP). It has a max speed of 24 knots and carries loads smaller then the MSVS. In this model the LCVP is used to transport one fuel and one water trailer with excess capacity left for other items. With all data remaining the same as in the baseline runs, the number of LCVPs was reduced from three to one.

	Sea Base at 30 nm				
#LCVP	100 km	200 km	300 km	400 km	500 km
3	Green	Green	Green	Yellow	Yellow
2	Green	Green	Yellow	Yellow	Yellow
1	Yellow	Yellow	Yellow	Yellow	Yellow

Table 21 - Sensitivity of LCVP Numbers

As indicated in Table 21 it can be seen that the sensitivity of the system to reductions in the number of LCVPs is less then that of LCUs. The number of LCVPs can be reduced to three and the results indicate that the system can function to 300 km. With two LCVPs the distance inland is reduced to 200 km. If only one LCVP is available within the system then although the system will function it is at risk. It is also important to note that with only one LCVP the utilization of this resource is at a mean of 0.98. Indicating that there would exist little down time for, among other things, maintenance and crew rest.

4.3.2.2 Numbers of Vehicles and Trailers

This section will test the sensitivity of the system under question to the reduction in number of MSVS fuel and water trailers. The number of each of these vehicles is important as it must be remembered that the SCTF is an amphibious force and in that the vehicles that it requires must be deployed within the hull of the ships of the amphibious task group and more likely in a single amphibious ship. The capacity of these ships is limited and the number of vehicles to be transported needs to be kept to the minimum number that will provide the capabilities required.

From the organization described by the Bsic Hybrid Battalion, which is based upon current vehicles and capabilities, the number of MSVS and trailers required was estimated. The baseline runs used 40 MSVS, and 20 each of fuel and water trailers.

	Sea Base at 30 nm				
km/h	100 km	200 km	300 km	400 km	500 km
90	Green	Green	Green	Green	Green
60	Green	Green	Green	Green	Green
30	Green	Green	Green	Yellow	Yellow
10	Yellow	Yellow	Red	Red	Red

Table 22 - Sensitivity of MSVS Numbers

As the number of MSVS were decreased, it can be seen that the capability of the system appears to be stable with the landing forced at a 200 km driving distance when the number of MSVS is either 35, 30 or 25 and a definite failure at 20 MSVS is observed. However there are differences in the system when the number of MSVS is at 35, 30 or 25 as described by the utilization of the MSVS as calculated at the seabase.

	Utilization	
#MSVS	100 km	200 km
35	0.6	0.6
30	0.7	0.7
25	0.81	0.81

Table 23 - Average Utilization of MSVS

As indicated in Table 23 as the number of MSVS is decreased the utilization of individual vehicles increases. This would provide less opportunity for crew rest and maintenance and a higher probability of system failure if some of the MSVS were unavailable for use.

The other type of vehicle in use in the system is a trailer. One of each type of trailer (fuel and water) is required to be delivered to each sub-unit. For this sensitivity analysis the total available trailers of each type is reduced to provide insights into the minimum number of trailers that could be deployed and still sustain the landing force.

	Sea Base at 30 nm				
#Trailers	100 km	200 km	300 km	400 km	500 km
15	**Green**	**Green**	**Yellow**	**Yellow**	**Yellow**
12	**Green**	**Green**	**Yellow**	**Red**	**Red**
9	**Green**	**Green**	**Yellow**	**Red**	**Red**
6	**Red**	**Red**	**Red**	**Red**	**Red**

Table 24 - Sensitivity of Trailer Numbers

In a similar manner as with the MSVS, the sustainment system showed the potential to operate with 15, 12 and 9 trailers out to a distance of 200 km. This must be mitigated by the utilization of this resource.

	Utilization	
#Trailers	100 km	200 km
15	0.51	0.51
12	0.64	0.64
9	0.81	0.81

Table 25 – Average Utilization of Trailers

The utilization of the resource of fuel and water trailers indicates that as the number of trailers is decreased their individual utilization is increased. This is not necessarily a factor with trailers, as their simple design and functionality decreases the requirement for maintenance.

4.3.2.3 Speed of Convoys

As experienced in many of the recent operations that Canada and our allies have conducted, the speed of the convoy will vary drastically with the terrain and conditions. At one end of the spectrum, convoys can routinely move at fastest possible speed (90-100 km/h) down modern highways while those deployed in less modern conditions may be forced to move at average speeds as slow as 10 km/h. The simulation runs conducted have been using an average of 30 km/h convoy speed. This section will conduct a sensitivity analysis of the impact of having the convoys travel at 10, 60 and 90 km per hour.

	Sea Base at 30 nm				
km/h	100 km	200 km	300 km	400 km	500 km
90	Green	Green	Green	Green	Green
60	Green	Green	Green	Green	Green
10	Yellow	Yellow	Red	Red	Red

Table 26 - Sensitivity of Convoy Speed

As logic would dictate, a faster convoy speed allows the system to support sub-units at greater distances from the shore. More importantly a 20 km/hr drop in average speed (from 30 km/hr used in the runs conducted in section 4.3.1.3) indicates that the success of the entire sustainment system at risk. This may cause the seabase to operate closer to the shore or to restrict the operating area for the landing force or cause the landing force to be equipped with appropriate engineering assets to improve the road conditions and allow faster convoy speeds.

4.4 SUMMARY

The SCTF operating envelope has been envisioned to be 100 nms (185 kms) from the seabase to the Landing Force. Given that the seabase may operate anywhere from 10 to 40 nm at sea, the Landing Force must therefore be sustainable while operating from 75 to 170 kms inland. It must however be acknowledge that the distance that the Landing Force is envisioned to operate inland does not equate to driving distance. Therefore, it is assumed that the system must be able to sustain the Landing Force to at least double (150 to 340 kms) the distance inland to compensate for winding roads and the unavailability of direct routes.

Using this rule of thumb, the sustainment system being modelled is able to support the Landing Force from closer then 30 nm. Beyond 30 nm the simulation indicates that the system is at risk of failing, in a near perfect environment and therefore, other options should be explored.

Through the sensitivity analysis, the simulation provided insights into areas that could impact on the system. The numbers of LCUs, LCVPs, MSVS and trailers were reduced individually, and the threshold at which the system was unable to function without risk given this reduction in resources was discovered. It was also determined that convoy speed has a large impact on the success or failure of the sustainment system. The relationship between seabase distance and land conditions, that determine convoy speed, must be examined for each specific operation.

It is acknowledged that the sensitivity to changes in these factors was only tested with the seabase at 30 nm and therefore, more analysis is required. However, as previously indicated the key distance for the seabase protection is 30 nm.

What was provided through this work is a tool that is able to test a specific scenario or sustainment concept with various variables taken into consideration. The tests conducted are not intended to cover all possible cases, but they do demonstrate the usefulness of this tool in the examination of SCTF sustainment concepts.

CONCLUSION

5.1 INTRODUCTION

The purpose of this paper was to provide insight into the parameters that impact on the ability of a seabase to provide basic support (in terms of numbers of convoys delivered per day) to its Landing Force. This was accomplished by developing an understanding of the problems facing the sustainment of an amphibious force, specifically, those envisioned for the SCTF working within the existing and future Canadian Forces sustainment concepts. With this understanding, a review of methods of examining supply chains was conducted. Given this review it was determined that the best manner in which to study this system that was still in conceptual development was to construct a simulation. Although there are many tools and methodologies for building and conducting simulation experiments, a discrete event simulation package was chosen to reduce the time required to build the model.

The building of the model was not the most time consuming issue. It was the gathering and validation of the data, from organizational structures to consumption data, which took the most time. In some cases the data was out of date or unavailable and educated assumptions were made. The simulation was then used to examine the issues of distance from the seabase to shore and the distance from the shore to the landing force. Within each of these parameters a sensitivity analysis was conducted to provide insights into the impact of a decrease in the numbers of connectors and vehicles on the system.

5.2 RECOMMENDATIONS

Based on the findings and the analysis conducted in Chapter 4 it is recommended that if the concepts for supply and transportation were to be as described in Chapter 3, then the following should be considered:

- The capability of the landing craft should be at least equivalent to that of the systems described in the model.
- The number of LCUs and LCVPs could not be allowed to drop below 3 each. At these points the system cannot operate without risk.
- The number of MSVS available for use could not be allowed to drop below 35 given a 30 km/hr convoy speed.
- The number of trailers could not be allowed to drop below 20 to maintain the system operating without risk.

These findings were presented at the Standing Contingency Task Force Sustainment Working Group that was held at the Maritime Warfare Centre in Halifax, Nova Scotia from 27 February to 3 March 2006. The data that was used to in the simulation and the concepts being modelled were validated by the members of the Transport and Supply sub-working groups that consisted of military subject matter experts in these domains. The working groups used the results presented in Chapter 4 to determine that a concept based upon moving vehicles to and from the beach was unworkable and by the end of the week a new concept had been developed. This concept consisted of leaving the MSVS on the beach and delivering the sea containers by LCU. This could allow for the continued delivery of supplies from the ship while the convoys deliver to the sub-units. It may reduce the number of vehicles required and will reduce the exposure of the vehicles to salt water as they will not be continuously exposed to the surf as they embark and disembark from the landing craft.

5.2 FUTURE WORK

As presented in Figure 1 in Section 1.4, there are many paths that require examination within the context of sustainment for the SCTF. This study provided insights into one of these paths. However, while conducting this work areas for future work were uncovered.

5.2.1 Consumption Rates

The biggest issue that was encountered in the development of the model was in the acquisition of accredited data for consumption rates of supplies. As described in Chapter 3, the Army once had the Operational Staff Data manual that could be used as a common reference for the capabilities of equipments used by the land force and the data could be used in determining the quantities of supplies used in operations. This data has not been updated, both in regards to the fleets of equipments used in the Canadian Forces, as well as the estimated consumption rates. The data contained in this manual is based upon that gathered during World War 2 and Korea and has not been updated to reflect the change in the operating concepts and effectiveness of weapons that exist in the Canadian Forces. It is recommended that the Canadian Forces and perhaps the Centre for Operational Research and Analysis (CORA), undertake a project to re-establish a common manual that contains updated data, which was once available in the Operational Staff Data manual.

5.2.2 New Sustainment Concept

The model used in this study should be further developed to model the new concepts that have been developed by the SCTF Sustainment working group. This model should include the potential use of vertical connectors (helicopters) as well as the required material handling equipment that will be required. It is unfortunate that this working group did not convene until late into this paper’s development, but it is the author’s intent to carry on with the support to the SCTF through the further development of this model.

5.2.3 Optimization

This study performed an exploratory analysis of the SCTF supply concept because definitive options for the type of vehicle to be purchase for the MSVS project, the specific type and capabilities of the landing craft and precise loading and unloading times were all unknown. The model produced allowed examination of “what if” scenarios regarding the supply concept under simulation. Once these items have been better defined as to their capabilities, further work should be conducted in order to optimize the numbers and performance of the specific vehicles and capabilities of the SCTF.

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