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MODELING AND SIMULATION OF MULTINATIONAL INTRA-THEATRE LOGISTICS DISTRIBUTION

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ABSTRACT

Multinational logistics cooperation is essential for reducing the collective logistics footprint, optimizing resource usage and enhancing interoperability in military operations. In this paper, a Multinational Intra-Theatre Distribution (MN ITD) concept for alliance or coalition operations is examined. MN ITD considers the creation of a MN logistics distribution centre that combines elements of the nations' stovepipes into a single system to improve multinational logistics distribution in a theatre of operation. A discrete event simulation framework has been developed to assess the MN ITD time responsiveness. The MN ITD performance is assessed and compared against the current Canadian Forces distribution system. The study indicates that a MN ITD system would potentially reduce response times for intra-theatre distribution.

1 INTRODUCTION

This paper documents an analysis conducted on behalf of the Canadian Forces (CF) to examine some of the logistics distribution issues associated with multinational deployments. In the study, a Multinational Intra-Theatre Distribution (MN ITD) system for alliance or coalition operations is examined. A discrete event simulation (Banks *et al*., 2000) model has been developed to assess the system performance and to examine its driving parameters.

One of the biggest challenges facing the CF is to increase its global reach (i.e. ability to deploy and sustain forces overseas). The two key components of global reach are mobility and sustainability. Mobility is directly related to lift requirements whereas sustainability is tied to logistical support. To address the mobility requirement issues, the CF is acquiring a fleet of strategic and tactical airlift assets and is looking to procure a class of Joint Support Ship. To address sustainability issues, the CF is examining a hub-based support approach to improve its inter-theatre logistics distribution effectiveness and responsiveness. The approach relies on the establishment of a series of permanent and temporary operational support hubs at key locations around the globe (Boomer, 2006). The hubs will be used for cross-loading between modes of transportation as well as pre-positioning non-perishable items and will be replenished by sea to reduce transportation costs.

To improve the end-to-end logistics distribution effectiveness, the CF has also been examining future logistics concepts for intra-theatre distribution operations in a multinational context. One of these concepts being developed under the Multinational LOGWAR 08 Study Group (MLSG) considers the creation of a MN ITD system for alliance or coalition operations. MLSG is a UK-led force development analytical process to explore how to further multinational logistics approaches. It provides a forum where nations can develop a common understanding of the future logistics challenges, concepts, doctrine and processes within the multinational arena.

A key aspect of the MN ITD concept is the establishment of a Combined Joint Logistics Support Group (CJLSG) that integrates the nations' stovepipes into a single distribution system for common user materiel in a theatre of operations. MN ITD will have visibility of commodities, services, and resources, enable efficient use of constrained multinational distribution assets, and provide a reliable and responsive pipeline for sustainment execution in support of the overall operations.

In support of MLSG, a discrete event simulation framework has been developed to assess the MN ITD time responsiveness. The system performance is assessed and compared against a baseline scenario using independent national stovepipes. Sensitivity analysis is performed using Monte Carlo simulation to address the impact of key logistics parameters and underlying assumptions. An example application using CF logistics distribution model and data is presented and discussed to illustrate the methodology.

The paper is organized in four sections. The following section introduces the MN ITD vision and identifies key performance metrics of the system. The third section presents a simulation framework developed to assess the MN

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ITD time responsiveness. Concluding remarks and recommendations for future analysis are found in the fourth section.

2 MN ITD CONCEPT

2.1 Shaping the Vision

In current multinational deployments, each nation has its own distribution stovepipe which feeds its force logistical requirements within a theatre of operations. A MN ITD vision is being examined by MLSG to improve intra-theatre logistics distribution for multinational deployments. MN ITD considers the creation of a multinational warehouse and a centralized coordination centre to manage the materiel distribution flow in a theatre of operation.

Figure 1 shows a simplified high level depiction of the MN ITD concept. Using this concept, the materiel requirements of each nation are sent through national strategic lift stovepipes to an Airport of Disembarkation (APOD) or Seaport of Disembarkation (SPOD). Materiel is then moved to a rear CJLSG, combined with supplies provided by Third Party Logistics Supply Services (TPLSS), and sent onward to a forward CJLSG. The rear CJLSG is responsible for processing nations' supplies and conducts break-bulk, cross docking, mixing, reconfiguration, and storage operations. The forward CJLSG is responsible for the day-to-day re-supply of the military units through the National Support Elements (NSEs). A Multinational Movement Coordination centre (MMC) is required to oversee the requisition, coordinate the replenishment, and manage the materiel flow between the different distribution centres.

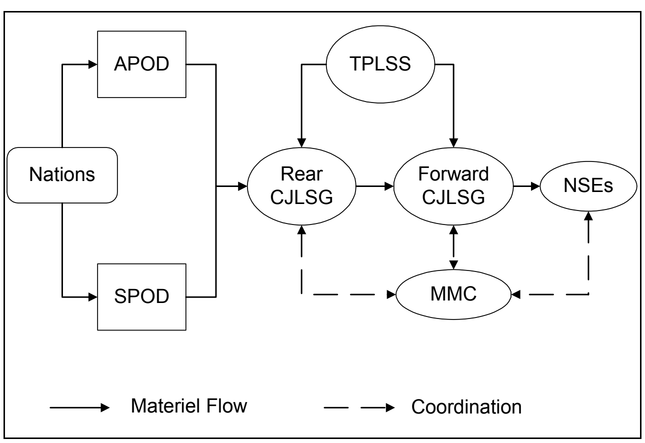

Figure 1: Simplified High Level Depiction of MN ITD.

The implementation of the MN ITD concept would optimize the collective logistics footprint, reduce infrastructure requirements, mitigate logistics distribution risks, and enhance military interoperability for multinational operations. Its success can be predicated on several essential elements including common language, visibility, centralized management, and transportation assets.

2.1.1 Common Language

Within the MN ITD vision, the multinational community will employ the same logistics terminology by developing techniques, procedures, and standard operating procedures that can be referenced when planning and executing sustainment operations. This would mitigate management risks that require the common understanding of all constraints and effects on intra-theatre distribution operations.

2.1.2 Visibility

The most critical aspect of end-to-end distribution is the visibility of resources (i.e. quantity and location of supplies throughout a distribution system). Indeed, multinational forces will continue to operate in an environment with special challenges where limited visibility of resources can have serious consequences in terms of cost avoidance or response time. Resource visibility is key for building a time definite delivery system in theatre. As such, MN ITD would improve the intra-theatre distribution visibility by providing access to logistical processes, resources, and requirements to make timely and effective decisions.

2.1.3 Centralized Management

A centralized management operation will allow for greater visibility of resources, increased distribution flexibility, and better control of materiel flow. The coordination of the MN ITD operations is accomplished through the CJLSG with the MMC providing overwatch. The MMC should be equipped with information technology that will allow for communications with major logistics command elements. The MMC intercedes when challenges arise that might cause the supply chain to fail or when a materiel-related operational priority so dictates.

2.1.4 Transportation Assets

Intra-theatre airlift support is usually the most expensive resource to operate. Using MN ITD, all air movements of materiel in theatre will be managed and coordinated through the CJLSG with oversight being provided by the MMC. This allows the movement of multinational supplies and equipment on national rotary and fixed winged assets. This economy of force and resource would maximize airlift availability, reduce operating costs, and provide greater flexibility for intra-theatre distribution operations.

2.2 MN ITD vs National Distribution Systems

MN ITD differs from national distribution systems in four key logistics areas.

- *Asset Sharing*: As discussed above, MN ITD would provide a greater airlift flexibility and availability by sharing multinational transportation assets for intra-theatre distribution.
- *Materiel Exchange*: Through multinational agreements, nations could exchange specific items (e.g. food, water, fuel, etc.) in theatre to reduce transportation cost and delivery time. The MN ITD system would facilitate materiel exchange in theatre.
- *Contracting*. MN ITD uses a centralized contracting process in theatre (similar to what is currently being done by the NATO Maintenance and Supply Agency), which would eliminate competition for resources between nations and avoid costs.
- *Command and Control*: MN ITD uses a centralized command and control system to coordinate the materiel flow in theatre. This approach might put an additional administrative burden on the distribution system that could affect its responsiveness.

2.3 Performance Metrics

Key performance indicators need to be established to determine if the multinational intra-theatre distribution infrastructure and operations meet the supported units' requirements. The primary measures of performance of a distribution system are reliability and responsiveness. Reliability is the requirement to deliver the correct item, to the correct place, at the correct time, in the correct quantity, with the correct documentation. Responsiveness is the speed at which the item moves through the supply chain system. This paper focuses on analyzing the time responsiveness aspect of MN ITD.

Response time can be is defined as the time required to deliver an item to its final destination, following the initial request by the supported units in theatre. It depends on several operational parameters such as item type (i.e. class of supplies), item availability, transportation assets, supply chain configuration, etc. Mathematically, the response time (R) can be formulated as follows:

$$R = T_F - T_0 \tag{1}$$

where T_F is the time at which the item is received by the unit and T_0 is the time at which the item is requested.

3 MN ITD MODELING AND ANALYSIS

A discrete event simulation framework is developed to analyze the MN ITD response time. In the framework, the distribution process flow is decomposed into discrete steps, where each step has a duration, delay, and may be further constrained by resource limitations. Both the MN ITD and the CF distribution system have been modeled and analyzed in order to assess the difference in response time between the two configurations for supply. The framework is implemented in Visual Basic for Applications.

3.1 Process Flow Description

3.1.1 MN ITD

Figure 2 depicts a detailed process flow of the MN ITD distribution system. The process starts with a combat unit of an individual nation requesting an item from its NSE. An item could be a piece of equipment or any common user supply item of a particular class. If the item is available in the NSE, then it will be issued directly to the unit, otherwise the request will be redirected to the multinational distribution system. Depending on whether the item is found in theatre or not, the request will be processed by the multinational system or by the individual nation. In theatre, the item could be in one of the CJLSG centres or could be provided by TPLSS.

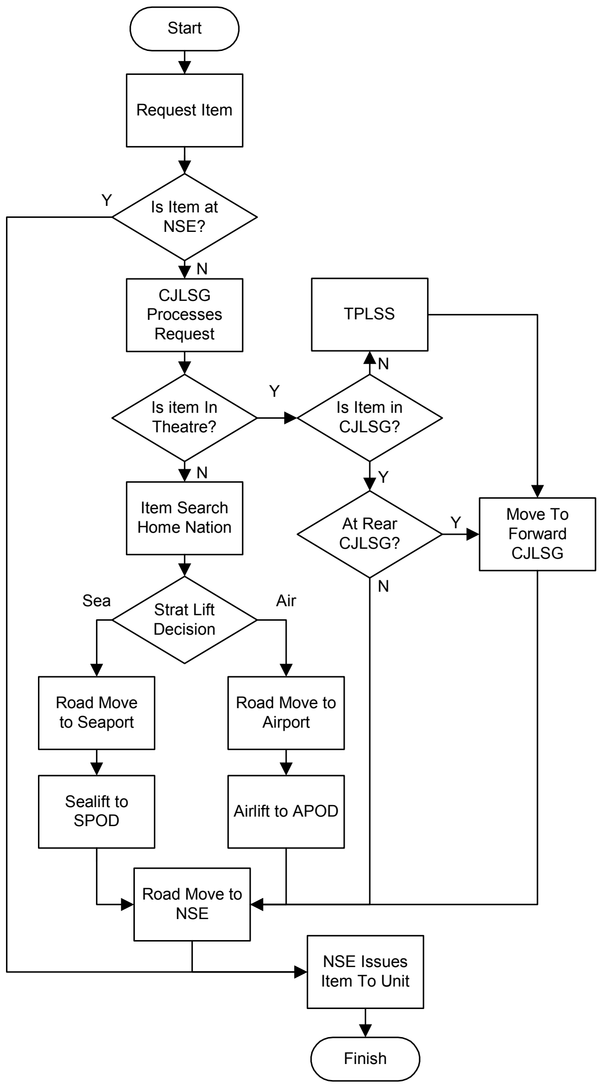

Figure 2: MN ITD Process Flow.

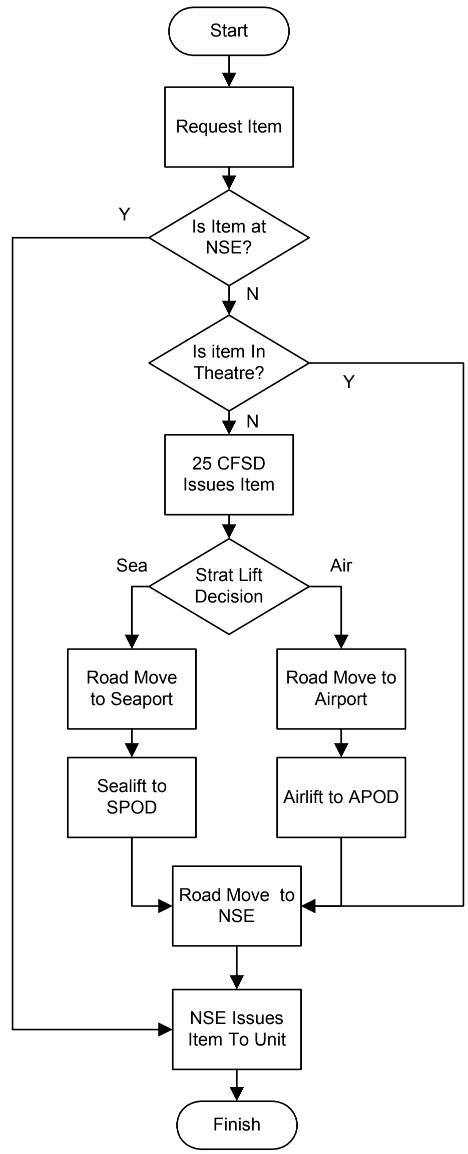

Figure 3: CF Distribution Process Flow.

3.1.2 CF Distribution System

To compare the MN ITD performance, the response time is also evaluated for the CF distribution system. Figure 3 depicts an overview of the CF materiel distribution process flow. Similar to the MN ITD, the CF process flow starts with a Canadian combat unit requisitioning an item from the Canadian NSE. If the NSE has the item, then it is immediately issued to the unit; if not, then the demand is sought from other sources within theatre. If the item is not found in-theatre, then the requisition is entered on the CF Supply System IT system and it is issued from the appropriate warehouse in Canada such as 25 CF Supply Depot (25 CFSD) in Montreal and transported to the NSE through the national stovepipe.

3.2 Model Development

To develop the MN ITD response time model, a notional scenario involving a coalition operation is created by MLSG. The scenario involves the deployment of a multinational task force to a generic nation for a 210 day period. Participating nations (Australia, Canada, Germany, United States, and the United Kingdom) have developed and provided their force packages, logistics requirements and transportation assets based on usage during historical missions (e.g. deployment to Afghanistan). Geographical locations are assigned to the rear CJLSG, forward CJLSG, and NSEs. A road transportation network that connects the APOD, SPOD, CJLSG centres, NSEs, and deployed units is established in theatre. In the scenario, it is assumed that the multinational task force has already been deployed and the MN ITD system is in its steady state condition. This means that the system has already been in place and the flow of materiel is continuous and stable. To avoid classification issues, detailed information about the scenario requirements and data will not be released in this paper.

Once the scenario is specified, a number of parameters, concepts and assumptions required for the model development and implementation need to be examined and discussed. Subject Matter Experts (SMEs) have been consulted to define and validate these parameters and assumptions:

- *Demand*. The demand for supplies depends on several variables such as the force size, type of mission, consumption rates, theatre environment, etc. Each nation has provided a realistic estimate of demand for its deployed task force using historical data. The demand is expressed in terms of quantity and class of supply. For simplicity, a standard airlift pallet can used as a unit of measure for supplies.
- *Classes of supply*: The classes of supplies are aggregated into two main categories: Common and National based items. The common items involve classes of supply that are common to all nations and which are conducive to sharing, including subsistence items (e.g. food and water), fuel (e.g. petroleum, oil and lubricants), and construction material. These items would be resourced through host nation contracts or via TPLSS. The national based items are usually unique to nations such as clothing, weapons, tools, spare parts, vehicles, ammunition, and medical supplies. These items should be sourced by individual nations and distributed through their own national stovepipes.
- *Transportation Assets*: As shown in Figure 1, strategic lift is a national responsibility. As such, nations send their materiel to an APOD or a SPOD using their own strategic lift assets. In theatre, the movement of common user materiel is conducted through the MN ITD system and nations provided a number of tactical lift assets for use by the multinational force. Typical transportation assets would include C-130 aircraft, CH-47 tactical lift helicopters, and heavy lift trucks.
- *Processing Time*. The time required to execute a given step in the process flow depends on the resource allocated to the step. For steps involving the movement of materiel between locations, (e.g. Road move to NSE), the processing time is calculated by simulating the transport process using strategic or tactical lift assets. In this case, the processing time depends on the speed, capacity, and number of assets assigned for the movement. For steps involving decision making or command and control tasks (e.g. CJLSG processes request), the processing time is implemented as a delay function. SMEs provided minimum, maximum, and most likely time estimates for each step using their expertise and experiential military judgments. In the majority of cases, a triangular probability function is used to represent the processing time distribution. To a lesser degree uniform and exponential distributions are also utilized.
- *In-theatre Probability*. The In-theatre Probability is the probability that the item is found in theatre either in the CJLSG's rear or forward centres or through the TPLSS. The In-theatre Probability also reflects the ratio of common items to national based items. It is expected that the MN ITD would increase the probability that an item is found in theatre as common items can be exchanged between nations thus increasing availability. Intuitively, an increased In-theatre Probability would improve the MN ITD time responsiveness. In the model, the In-theatre Probability is estimated by SMEs to be 0.9 for the MN ITD system and 0.7 for the CF distribution system.
- *Land Transport Ratio*. For tactical lift, the transport of materiel is usually conducted by road using heavy lift trucks or by air using tactical lift helicopters. The probability of using road move for tactical lift is called Land Transport Ratio. This ratio depends on travel distance, asset availability, and item priority and could have an impact on the materiel delivery time. In the model, a Land Transport Ratio of 0.9 is used for both the MN ITD and the CF distribution system.

3.3 Response Time Analysis

A large number of simulation runs (i.e. 10 000) was performed and statistical analysis was conducted to determine the average and standard deviation of response time for each nation. At each run, an item was randomly requested by an individual nation and processed through the multinational distribution system as described in Figure 2. The demand of each individual nation was used to build the probability distribution of the request arrival process. One transportation asset is usually assigned to each individual request in theatre. Requests could be processed immediately or delayed until transportation assets become available. For simplicity, requested items were assumed to have the same priority.

Figure 4 depicts the cumulative distribution of response times for both the MN ITD and the CF distribution systems. The response time for the CF distribution system is simulated with the Canadian demand and transportation assets using the process flow described in Figure 3. Preliminary results indicate that the MN ITD system would reduce the intra-theatre logistics distribution response time for the Canadian Forces. On average, the response time would be reduced from 4.8 days to less than two days. This reduction is mainly attributed to the use of multinational transportation assets and the increased availability of common user supplies in theatre through the MN ITD centralized contracting and materiel exchange processes.

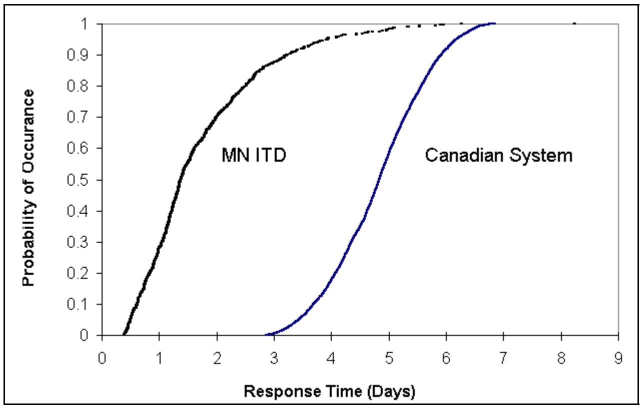

Figure 4: Cumulative Distribution of MN ITD and CF Distribution System Response Times.

3.4 Sensitivity Analysis

In this study, several parameters and assumptions are introduced in the simulation framework for simplicity and ease of calculation. Moreover, while use of historical settings offers a degree of realism to the scenario developed for the response time model, future multinational missions are likely to be subject to unique requirements that will require some deviation from the historical norm. Therefore, sensitivity analysis is conducted using Monte Carlo simulation to determine the impact of key logistics parameters and underlying assumptions. Monte Carlo simulation is a versatile method that uses random numbers and probability distributions to analyze the behaviour of a process involving uncertainty. The most commonly used distributions for sensitivity analysis are the Uniform, Normal and Triangular distributions (Law and Kelton, 2000). In this study, while there are many potential areas for detailed sensitivity analysis, we shall restrict our coverage to two logistics distribution parameters: In-theatre Probability and Land Transport Ratio. The Random Uniform distribution is used to represent each parameter variation as follows (Snedecor and Cochran, 1980):

$$\left| \frac{X - \overline{X}}{\overline{X}} \right| \leq \delta \qquad (2)$$

where X is the parameter, $\overline{X}$ is the average value of the parameter, and δ is a perturbation factor (e.g. $\delta = 20\%$).

4 CONCLUSION

The paper presents a study of intra-theatre logistics distribution within a multinational deployment context. The study is part of an ongoing force development effort by MLSG to examine future logistics concepts, doctrines and processes. An analytical framework has been developed using discrete event simulation to assess the MN ITD response time. Historical data is used to build a multinational deployment scenario required for the analysis. MN ITD is analyzed and compared against a baseline scenario using a CF distribution system.

Preliminary results indicate that the MN ITD system would reduce the intra-theatre logistics distribution response time by as much as 64% for common user items. This reduction is mainly attributed to the use of multinational transportation assets and the increased asset visibility and actual availability of supplies in theatre through the MN ITD centralized contracting and materiel exchange processes.

Following this analysis, a number of recommendations for the decision-makers appear to logically follow:

- Further analysis should be conducted to better quantify the effectiveness of the MN ITD concept. In particular, an analysis of MN ITD cost avoidance with respect to national distribution systems would be required to complement the response time study.
- Particular attention should be given to the host nation contracting and TPLSS during the MN ITD implementation as they provide additional capabilities to reduce response time.
- As the multinational stakeholders continue to develop the MN ITD concept, focus should be on distribution infrastructure, multinational forces coordination procedures, and consolidation of appropriate classes of supply and resources as they represent key elements in the concept development.
- Finally, further analysis should be conducted to address other issues associated with multinational deployments such as command & control and Reception, Staging and Onward Movement that could impact the intra-theatre logistics distribution.

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