A Study On Wartime Sealift Operation Using Simulation

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ABSTRACT

The ROK TRANSCOM is trying to establish a concrete wartime sealift operation plan. But there are many problems to be solved for setting up the plan. The most serious problem is to procure war materiel to be shipped in U.S.A and next one is to determine the number of sealift assets and to allocate them.

The process of sealift operation can be described as follows. Before the order of vessel mobilization, all vessels appointed for activation would be scattered in worldwide in the state of loaded or unloaded. After the order of vessel mobilization, vessels would go to SPOE(seaport of embarkation) to load war materiel. Some loaded ships should offload the commercial cargo to the near port as soon as they are activated, before they would go to SPOE. All vessels would load procured materiel in SPOE and then go to SPOD(seaport of debarkation). They would offload war materiel in SPOD and then go back to SPOE to load war materiel again.

We will simulate this process using ARENA[1], evaluate the sealift capability of ROK and find out problems of the sealift plan. This model ultimately evaluates the sealift capability and provides planners with critical information for establishing and correcting the plan. This study can also provide military planners with a flexible and accessible decision support tool to provide advance planning under a variety of conditions on the sealift capability.

The military planner is expected to make use of this model as a standard for establishing effective and concrete sealift operation in the near future. We can conclude how procurement capability significantly affects the result of sealift operation through this model. We could decide the appropriate level of sealift asset such as the number of vessels and the number of available berth. So we could allocate effectively the resources for completing the sealift operation within the TGT(Target) time.

1. INTRODUCTION

The ROK TRANSCOM is considering two ways for lifting wartime cargo from foreign countries. Airlift is effective for the small cargo to be lifted quickly, but is not appropriate for the large and heavy cargo. Sealift can deliver most of the supplies and equipments, even if cargo are over-sized or over-weighted. More than 85% of the cargo had lifted by vessels in the last Gulf war.

The purpose of this study is to estimate sealift capability of ROK in the future war. Any factors constraining the ability of sealift assets to deliver supplies and equipment in the desired time frame could impact wartime objectives significantly. Sealift operations should be clear and comprehensive to maximize the use of available assets, to allocate resources properly, and to ensure materiel flows from US to Korea.

This study focuses primarily on modeling the strategic sealift process from US to Korea. We define strategic sealift capacity as the amount of equipment and supplies capable of being moved from specific locations to specific destinations by means of ship within a specific period of time. We also define port congestion as the accumulation of ships in the port of area caused by either delays in the loading and offloading operations, or waiting for access to a pier or terminal. For this study, we do not consider cargo congestion in the port operation.

There is a critical constraint in this study. It is a lack of information about the amount of war materiel to procure in US, and the number of sealift assets such as available vessels for activation and available number of berths. Because the ROK TRANSCOM does not yet establish the wartime sealift operation plan, this information is based on the rough scenario proposed by the ROK TRANSCOM. In this simulation of strategic sealift process, we do not consider the following issues: (1) the clearing of material through a port; (2) environmental conditions such as natural meteorological phenomena and impact of weather; (3) the inaccessibility and unavailability of SPOEs and SPODs due to blockades, natural catastrophes, or guerrilla attack; (4) other US, ROK, or allied nation military or commercial sealift traffic in SPOE or on global shipping routes.

We will briefly explain the Desert Shield/Storm operation and US deployment plan on the Korean Peninsula to understand sealift operations in the section 2. We will make a simulation model of the sealift operation process on ARENA and estimate necessary parameters in the section 3. We will conduct simulations under several conditions and analyze the result in the section 4. We conclude in the section 5.

2. SEALIFT OPERATION

2.1 Desert Shield/ Desert Storm

The deployment of Desert Shield/Storm[2] is one of the largest operation in history. From 7 August 1990(C-Day, commencement) to 10 March 1991(R-Day, beginning of redeployment) US TRANSCOM moved nearly 504,000 passengers, 3.6 million tons of dry cargo, and 6.1 million tons of petroleum products, as shown in Table 1.

< Table 1 > Cargo and personnel lifted during war

Variable	Airlift	Sealift	Total (100%)
cargo	14.78 %	85.22 %	3,676,935 tons
POL	5.56 %	94.44 %	6,102,706 tons
personnel	99.45 %	0.55 %	503,478 tons

* US MSC SITREP

US MSC's sealift forces are as follows; Afloat Prepositioning Force, Fast Sealift Ships, Ready Reserve Force ships, and Chartered commercials. MSC had chartered 177 foreign vessels, including 41 RO/ROs, from 34 nations and 32 US flag commercials.

< Table 2 > The amount of sealifted by US and Foreign Flagged Vessel

Variable	US Flag Vessel	Foreign Flag Vessel	Total (100%)
dry cargo	2,402,217 (78.8%)	646,315 (21.2%)	3,048,532
unit cargo	1,785,554 (73.4%)	646,315 (26.6%)	2,431,869

* US MSC SITREP

US MSC estimated that chartered commercial had carried out 85% of the cargo during the Gulf War.

< Table 3 > The amount of sealifted by MSC's ships

Variable	FSS	PREPOS	MPS	RRF	US Flag commercial	Foreign Flag commercial	Total
STONs	321,941	206,836	257,444	691,048	308,285	646,315	2,431,869
Rate	13.24	8.51	10.59	28.42	12.68	26.58	100

* US MSC

2.2 Sealift deployment plan in the Korea

2.2.1 US military strategic sealift

In the early 1980s, US military planners recognized that a critical shortage in domestic sealift existed to meet the requirements of OPLAN for the defense of the ROK. With insufficient domestic sealift capacity, US sought to rely upon foreign flagged shipping to bridge the gap in capacity. On 25 March 1981, US signed a Memorandum of Agreement (MOA) with ROK that established the KFS Program. US and ROK officials designed the KFS Program to supplement the shortfall of US's mobility capability by identifying specific Korean-flagged vessels to be placed under the Operational Control (OPCON) of MSC in the event of war on the Korean Peninsula. Upon activation of the KFS Program and approval by the ROK Navy, MSC exercises OPCON over transferred vessels and exclusively coordinates the scheduling and movement of these vessels to CONUS or other specific locations. KFS vessels then load US military cargo for trans-oceanic movement to the Korean peninsula with US flagged ships. From operational data in the past Gulf war, we can estimate that SPOEs would be 6 ports in the west of US and 7 ports in the outside of US close to Korean Peninsula. Table 4 illustrate one part of MSC's TPFDD(Time Phased Force Deployment Data).

< Table 4 > Strategic deployment plan based on MSC's TPFDD

Ship Number	Ship Type	Trip Number	SPOE	SPOD	Load STON	Ship Capacity (DWT)	Ship Capacity (STON)	Ship Speed (Knots)
44	2	3	A	3	90.7	5956	5318	14.8
21	2	1	B	4	972.8	5981	5340	15.4
11	1	1	E	2	1292.8	5100	4554	12.4
~	~	~	~	~	~	~	~	~

* Peter J. Mahoney, 2000. Analysis of Port Congestion upon Sealift Operation Using Simulation. United States Naval Postgraduate School[3]

2.2.2 ROK's strategic sealift plan

We introduce briefly about ROK's strategic sealift plan due to its sensitivity on security. The ROK TRANSCOM is planning to transport about 90% of the cargo using sealift from US. This 90% is almost the same as those of US TPFDD. There is not yet a concrete plan about the amount of procurement in US, the number of vessels to activate, and the number of SPOEs and SPODs to use during a wartime. According to the rough draft for sealift made by the ROK TRANSCOM, 2 SPOEs, 4 SPODs and 00 KFSs would be used to transport war materiel from US[4]. Table 5, 6 show the composition of vessels to activate and war materiel to move.

< Table 5 > Vessels for activation

Variable	Container	Ro/Ro	Breakbulk	Total
Number	00	0	00	00
DWL (Ston)	20000	20000	20000	N/A

* DWL: Shipping load = 1 : 1

< Table 6 > Wartime materiel

CRDL	FMS	Commercial	Total
1.5%	92.1%	6.4%	100%

* CRDL : Critical Required Logistic

3. MODEL FORMULATION

Sealift operation involves the planned movement of the equipments and supplies from US via Korean Flag Ships from the designated SPOEs in US, to the designated SPODs in Korea. We derive our baseline model and simulation based on the ROK TRANSCOM's plan. We consider the following elements on our model:

- The identified amount of cargo provided by the ROK TRANSCOM
- 2 SPOEs, 4 SPODs
- A fleet of 00 Korean flagged ships
- Four initial locations of KFS prior to mobilization activation
- Nautical distances between SPOEs, SPODs, and the four initial locations are known

- 5 berths within SPOE-1, 3 berths within SPOE-2 and 2 berths within each SPOD

For our model, we consider 5 variables as stochastic factors: (1) the procurement rate of materiel in US; (2) the distribution of KFS on four initial position locations at the start of the activation; (3) ship's characteristics such as speed and capacity: Breakbulk ships may have different speed and capacities; (4) the number of berths available for use by KFS within SPOEs and SPODs during a wartime; (5) delay time of ships at the start of sealift operation and repair time when it is in breakdown.

For our model, we made some assumptions as shown in Table 7 and 8.

< Table 7 > The amounts of materiel to be moved and Procurement rate

Variable	Ammunition	Equipment		General		Total
SPOE	SPOE-1	SPOE-1	SPOE-2	SPOE-1	SPOE-2	2,123,600
Total (TON)	1,340,000	43,300	43,300	170,000	527,000	
Procurement rate (completion day)	3989(340)	138(320)	138(320)	575(300)	1781(300)	N/A

* Procurement rate : from M+5 to completion day of each type of materiel

We included 00 ships, separated into three categories as shown in Table 6

< Table 8 > Ship Categories Used in this Model

Ship Type	Description	Number	Speed(kts)	Capacity(ton)
1	Container	00	23	20,000
2	RO/RO	0	19	20,000
3	Breakbulk	00	15	20,000

We derived our 4 IPLs a port in Persian Gulf, a port in Japan, a port of Pusan, and a port in the East coast of the US- and the distribution of ships being located at these locations, from the analysis of commercial ship's activities and routes.

These four IPLs represent the largest probable locations for KFS. Table 9 presents these probabilities as used in our model to initialize the locations of each ship prior to the order of mobilization. We incorporated probabilistic delay times uniformly distributed between 0 to 11 days, based upon each ship type and assigned IPL.

< Table 9 > Probability(as a percentage) by Ship Type of KFS Being Located at IPLs at start of Sealift Operation

IPL	Ship Type		
	Containership	Ro/Ro	Breakbulk
Pacific Japan	33	25	52
PUSn	21	30	48
Persian	27	20	N/A
US East Coast	19	25	N/A

* Peter J. Mahoney, 2000. Analysis of Port Congestion upon Sealift Operation Using Simulation. United States Naval Postgraduate School

For this study, we consider especially probabilistic delay time of ships at the start of sealift operation. As shown in Table 10 we used data provided by an Hanjin Shipping Inc official. According to his remarks, the ship's availability rate of Hanjin is above 98%. All Hanjin ships have to be repaired every 2.5years, and the repair time is about 15 days.

< Table 10 > Mobilization delay time at the start of Sealift Operation

Variable	Rate	Relay time
Mobilization delay	2%	UNIF(1,15) day

* ROK Hanjin Shipping

We don't have any information about the capability of port and available berth within port. So we used assumptions related to port assets

< Table 11 > available berth and loading/offloading capacity

Variable	SPOE		SPOD			
	SPOE-1	SPOE-2	SPOD-1	SPOD-2	SPOD-3	SPOD-4
Available berth	5	3	4	2	2	2
capability	9000	9000	9000	9000	9000	3600
Cargo	Type-1,2,3	Type-2,3	Type-2,3	Type-1	Type-1	Type-1

* cargo(Type-1:ammunition, Type-2: equipment, Type-3:general)

Each type of cargo are designated for SPOE and SPOD, as shown in Table 11. With regard to nautical distances, we referred to distance table to be made by National Oceanographic Research Institute(NORI)[5].

We have to consider distance difference and total remaining amount of materiel in SPOE in this model. As you see in above Table 9, Breakbulk ships do not trip to Persian Gulf and East Coast of US under normal situations. So we need to distribute Breakbulk ships to go both SPOE-1 and SPOE-2. For this work, we use distance compensation factors in order to compensate distance differences from IPLs to both SPOE. When all ships leave for SPOE after unloading the materiel, they should be determined SPOE to go according to the amount of remaining materiel to be moved. Besides, we should consider distance difference between geographical positions for validation.

4. SIMULATIONS

We analyze the expected average output values from six Critical Performance Indicators generated by simulations. The six CPIs are:(1) the overall average operations closure time;(2) the average closure time by ship type; (3) the average complete time to activate;(4) The average number of ship waiting for loading and offloading in SPOE, SPOD;(5) the average amount of loading by each ship type; (6) The average time between ship's arrivals in SPOE, Korea.

We conducted experiments for optimization of sealift assets with;(1) baseline model; (2) change in the number of each ship type and speed; (3) change in the available number of berth for use by KFS within SPOEs and SPODs.

We executed 40 iterations of each sealift operation to avoid abnormal results by inherent randomness. We will execute simulations with baseline wartime scenario and then analyze the results through sensitivity analysis in order to find out bottlenecks that impact on the closure time. We got the results as shown in Table 12 from simulations with a baseline scenario

< Table 12 > The simulation result of baseline model

Variable	Container	Ro/Ro	Breakbulk	The overall average value
The average closure time by ship type /	351.998 days	377.131 days	382.715 days	386.303 days
95% confidence level	0.17	4.27	1.70	2.43
The average amount of loading by each ship type	8038.4 ton (40.2%)	4557.9 ton (22.3%)	11152 ton (55.8%)	7916.09 ton (39.6%)
The average number of ship in queue awaiting access to SPOE-1/2	13.1 / 0	1.21 / 1.04	1.31 / 1.35	15.62 / 2.39
* The average completed time to activate : 52.9 days				

As you see the result in Table 12, the average closure time by Container ships is 352 days. But Ro/Ro and BB ships did not complete their mission to move war materiel within 365 days. Seeing the average number of ship in queue awaiting access to SPOE-1 and -2, we may think severe congestion in SPOEs. The reason that the ships are in queue is not the shortfall of the available number of berths, but the materiel to be stacked at stack area of berths. Some ships should await at outside of the harbor, if their materiel to load does not arrive at the berth.

We will execute simulations under a variety conditions on sealift assets from the baseline scenario.

< Table 13 > The sensitivity analysis

Variable(%)		Container	Ro/Ro	Breakbulk	The overall average value
Number of ship	1 Ro/Ro, 2 BB	352.1	361.6	371.7	372
	1 Ro/Ro, 3 BB	352	364.4	366.3	367.4
	1 Ro/Ro, 4 BB	351.9	364.5	362	364
Speed up	BB 2kts	-	-	370.1	-
	BB 4kts	-	-	360.3	-
	RR 2 kts	-	377	-	-
	BB 4, RR 2kts	-	383.4	360.9	-
The others		Experiments by hybrid conditions			

* No change by changing the available number of berth in SPOE,SPOD
* "-" : almost same

The number of ship and speed are very significant factors that might affect on the result of sealift operation. But the number of berth doesn't much on affect the performance of sealift operation. Actually, the number of berth to be used by ship during simulation is only 2. Besides, although the available numbers of berths are in range of 3 to 10, the results was almost the same as those of a baseline simulation. The delay time between ship's arrival during sealift operation is as shown in Table 14

<Table 14 > the time between ship's arrival

Variable	Korea			US	
	Container	Ro/Ro	Breakbulk	SPOE-1	SPOE-2
the average time between ship's arrival	1.97	18.5	5.7	1.6	8.2

* Column Korea : the time between 3 types of ship's arrival to Korea before divided into 4 SPOD

* Column US : the time between ship's arrival to SPOEs

The low utilization of berth is basically due to the low procurement rate of war materiel in this model. If the procurement rate is increased in short time, port congestion happens. Briefly speaking, Ro/Ro ship is sensitive to the change of the available number and speed of Ro/Ro, and Breakbulk is only sensitive to the change of the available number of BB. The optimum allocation of sealift assets is to add 1 Ro/Ro, 4 Breakbulk in this wartime scenario.

5. CONCLUSIONS

We didn't consider situations such as destruction of sealift assets by enemy or guerrilla's attack, ship's engine trouble during transporting cargoes and failures of port cranes. We also conducted simulations with only baseline wartime scenario, do not consider many other situation.

The purpose of this study is to provide the military planner with flexible and accessible decision support tool to provide advance planning information regarding the effects of congestion at any port upon sealift capacity, under a variety of conditions. So we expect that the military planner use this model as a standard for establishing effective and concrete sealift operation in the near future

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