Operation Inherent Rescue:
A Humanitarian Supply Chain Simulation
for the Evacuation of Refugees from Aleppo, Syria

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Introduction

In the spring of 2016 the authors of this paper analyzed the situation in Syria and anticipated that in the very near future there may come a time that a government/military may be called upon to perform a safe evacuation of the thousands of civilians still left in Syria. Their analysis concentrated on the northwestern section of Syria, especially the cities of Aleppo, Idlib, Mahrat Neuman, Hammah and Homs where the fighting was most pronounced. They realized that for this military mission scenario to be successful careful planning similar to planning for any type of humanitarian supply chain, must take place.

This exodus became reality for the residents of Aleppo during the third weekend of December, 2016 when thousands of innocent city dwellers were evacuated by busses. Vehicles from the International Committee of the Red Cross (ICRC) and the Syrian Arab Red Crescent, followed by ambulances and green government buses evacuated civilians who were taken to Idlib located about 65 kilometers from Aleppo. [1]

Purpose of the Paper

The purpose of this paper is to describe and demonstrate a concise and repeatable five-step planning and simulation process for exploring supply chain options to support military and humanitarian missions such as the one involving the evacuation of refugees from Aleppo. The authors developed a fictional military mission scenario described below that assumes the United States was leading the humanitarian evacuation effort. However, the logistics and supply requirements that are identified in the scenario would be identical regardless of what country is leading the effort.

Initially the paper provides a brief overview of the basic entities of a supply chain because the humanitarian rescue described in the scenario must use a supply chain for transport of supplies and refugees. A short description of the simulation logic used by the software program is provided so the reader has an idea of how data will be manipulated/produced during a simulated supply chain operation.

This paper describes the process for developing a humanitarian mission plan. It begins with the initial planning considerations that must be addressed and the data that must be obtained prior to the execution of a mission. Then it describes how the data is entered in the commercial off-the-shelf, cloud-based simulation software and illustrates how the planning data, which represents all 10 classes of military material supply, would be used on a daily basis during the actual simulation. The paper points out that the simulation software allows the user to simulate different supply chain options in search for the optimal solution. However, nothing remains constant, so as the mission unfolds, the managers must refine their process as needed to keep supply chain plans up to date and be able to respond to changing conditions.

From a practical perspective, the simulation exercise illustrates how effective the planned mission would be prior to its actual implementation. What may have looked good on paper may not work in reality (simulated reality). From a training perspective, data from the simulation is made available to all involved parties for further discussion, analysis and "lessons learned" after the mission.

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[1] Evacuation of east Aleppo under way during ceasefire Syria News15 December 2016. Retrieved on March 1 from http://www.aljazeera.com/news/2016/12/east-aleppo-civilians-trapped-uncertain-ceasefire-161215034620364.html

Modeling and Simulation based on Four Supply Chain Entities

Although there are *numerous* permutations, the modeling and simulation of any supply chain whether humanitarian, military or business, can be accurately captured by the definition and combination of just four supply chain entities:

1) Products - items handled by a given supply chain
2) Facilities - places where products are made, stored, sold or consumed
3) Vehicles - means by which products are transported between facilities
4) Routes - paths and delivery schedules used by vehicles to deliver products

Inputs consist of the attributes and data values that define each of the four entities. This information about relevant products, facilities, vehicles and routes can be obtained from an Enterprise Resource Planning (ERP) program or supply chain management (SCM) system used by the companies participating in a given supply chain.

Outputs are the animated simulations showing how a supply chain operates and performs on a day by day basis over some period of time. There are on-screen, map-based displays showing movement of vehicles along routes, graphs showing on-hand inventory amounts, and numeric displays showing daily operating costs and related data. This data produced by the simulations can also be downloaded and/or loaded into spreadsheet reporting templates to produce financial and operating reports.

SIMULATION LOGIC

The simulation uses an agent-based, deterministic, non-linear mathematical model to define the interaction between the four supply chain entities. The simulation engine calculates the interactions between these entities on an hour-by-hour basis. At the start of each hourly iteration, checks occur to catch problems such as when on-hand amount of a product either does not meet demand or becomes so overstocked that storage capacity at a facility is exceeded. There are also checks for the number of products loaded onto vehicles to catch overloading where volume or weight limits are exceeded.

During the simulation, an animated map displays movement of vehicles on supply chain routes. Onscreen graphs display 24-hour aggregate results of facility on-hand demand, production, imports and exports and show day by day interactions between the four entities. Patterns and trends emerge as each day's results are calculated and displayed. These can be analyzed to determine times and places where operational problems will occur unless changes are made to the supply chain model.

The simulation engine calculates daily usage, production and delivery of products at each facility. This updates on-hand amounts for each product at each facility each day, and shows how products flow through a supply chain. It reveals operating trends that develop over the period of the simulation. Simulations also provide daily supply chain operating data for items such as on-hand inventory levels and operating costs for different facilities and vehicles. This data can be downloaded for further analysis using spreadsheets or any other application that can import comma separated value files.

Mission and Operations Planning (M&OP) Process

The M&OP process shown in Figure 1 is based on two process models widely used in supply chains. The first process, from a business perspective, is the Sales and Operational Planning (S&OP) model illustrated by the blue boxes. This model operates under the premise that "...companies can align production with actual demand, through the merging of tactical and strategic planning methods across any number of organizational silos."[2]
The grey boxes represent similar steps for a military planning process based on the *U.S.Department of Defense Architecture Framework (DoDAF)*. DODAF is an organizing framework for DoD that provides an infrastructure for specific stakeholder's concerns through viewpoints organized by various views.[3]

[2] *Wikipedia, The Free Encyclopedia*, URL - https://en.wikipedia.org/wiki/Sales_and_operations_planning

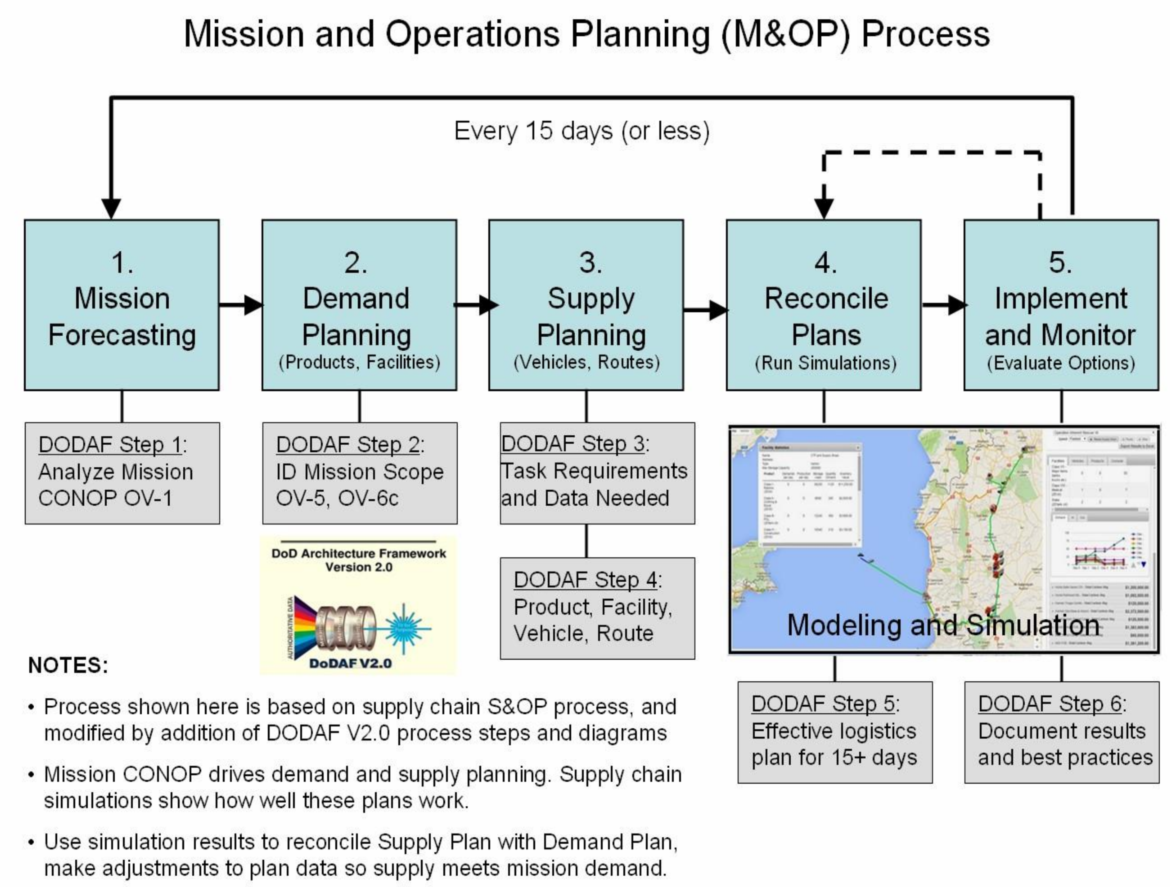

Figure 1

DESCRIPTION OF PROBLEM IN SYRIA

The United Nations (UN) has identified 13.5 million Syrians as requiring humanitarian assistance, with some 4.6 million Syrians being refugees outside of Syria. In order to end the fighting, it may be necessary for governmental, military and non-governmental organizations (NGO) to work together in a mission to evacuate and relocate hundreds of thousands of civilians as part of a Syrian peace settlement.
The mission planning and simulation presented here begins with the following situation report:

Situation Report

UN Security Council approves the "Munich Security Conference" *– previously endorsed by 17-nation International Syria Support Group. A Chapter VII "Peace Enforcement" mission is authorized with participant nations committing Peace Keeping (PK) forces as part of the approved Peace Support Operations (PSO).*

Since mobilization of aforementioned PK units will take 90-120 days from implementation, President of the United States (POTUS) has directed Secretary of Defense (SECDEF), in concert with Secretary of State (SECSTATE) to map out requirements to:

1) *begin de-escalation of combat operations within specified corridors of the contested areas within Syria to allow the safe migration of refugees;*
2) *allow for the safe passage and transit of NGOs and medical support as part of the Humanitarian efforts within the contested zones;*
3) *set up 'safe haven' areas for refugees to be housed, clothed, fed and medically supported in a secure environment*

4) *act as advance logistics support force for pending arrival of the UN Chapter VII PSO units*

*SECDEF ordered Commander, US Central Command (COMCENTCOM) to immediately begin planning and implementation of POTUS directive. Initial forces to be enroute to revised CENTCOM Area of Responsibility within 48 hours. Mission has been assigned code name **"Inherent Rescue"**.*

COMCENTCOM designated Joint Task Force 51 (JTF-51) as organizational entity responsible for this operation. All US CENTCOM organic assets will be available for Commander, JTF-51's disposal. US Navy Carrier Task Force (CTF) has been dispatched from 6th Fleet normal patrol duties in Mediterranean Sea to initially support Inherent Rescue.

CONOPS for Operation Inherent Rescue High Level Facilities and Units

Carrier Task Force (CTF) – plus supporting supply ships for Marines and Army

26th Marine Expeditionary Unit (26 MEU):
- **Tartus Port** – 1 BN+ (1000 Marines) plus 1 Logistics BN (600 Marines)
- **Homs Safe Haven** – 1 BN (-) (600 Marines); 1 Logistics BN(-) (100 Marines) plus HQ(-) augmentation (50)
- **Tartus Port** – Navy Special Warfare Platoon (SEALTeam 4 with assets from Special Boat Team 20 – 160 sailors)

Hamah Operating Base/Airport – Navy Construction Battalion (600 sailors)
Hamah Operating Base/Airport – USAF Para Rescue Team (35 personnel)
Hamah Operating Base/Airport – 7th Special Operations Wing (150 Aircrew & Maintenance Support) 3 C-130s
Hamah Operating Base/Airport – USMC ACE (Aviation Combat Element), (650 Marine/Crew/Maintenance) fixed & rotary – 12-28 aircraft
Hamah Operating Base/Airport – Heavy Lift Transport (fly in supplies, refuel, fly out evacuees, based elsewhere); C-17 transports – fuel requirements for this aircraft

82nd Airborne Division:
- **Hamah Operating Base/Airport** – 1st Brigade (BDE) plus Div (-) HQ, Aviation, and Support BNs (4500 soldiers)
- **Aleppo Transit Camp** – 1 BN+ (800 soldiers)
- **Idlib Transit Camp** – 1 BN+ (800 soldiers)
- **Marat Numan Transit Camp** – 1 BN plus HQ, Combat Engineer and Support BNs (2000 soldiers)

5th US Army Special Forces Group:
- **Aleppo SFOB** – 1st BN(-) (100 soldiers) plus Civil Affairs (150 soldiers)
- **Idlib SFOB** – 1st BN (-) (100 soldiers) plus Civil Affairs (150 soldiers)
- **Marat Numan SFOB** – 3rd BN(-) (100 soldiers) plus Civil Affairs (150 soldiers)
- **Homs SFOB** – 3rd BN(-) (100 soldiers) plus Civil Affairs (150 soldiers)

ASSUMPTIONS, INPUTS & OUTPUTS
The mission scenario is further defined by mission orders that accompany the above situation report announcing the launch of Operation Inherent Rescue. The mission orders are:

Mission Orders:
JTF-51 will deploy to the designated Area of Responsibility (AOR) at Operating Base vicinity Hamah Military Airport (grid ref: 35.119 N, 36.715 E*) and establish secure air and land links between CTF vicinity Tartus (grid ref:* 34.895 N, 35.886 E*) and cities of Aleppo, Idlib, Marat Numan and Homs. Standard Rules of Engagement (ROE) apply and shall be published as an annex to this Mission Order.*

Requirements:
Provide secure support, humanitarian assistance and in-country relocation support for refugees migrating from Aleppo into Homs/Tartus areas.

- *Construct refugee centers to be part of the UN Chapter VII mission once those forces arrive in theater. Main refugee center to be Safe Haven in and around Homs.*
- *Provide identification, reunification of family, secure transport and orderly transition from Homs/Tartus to a destination outside of Syria – a TBD location.*
- *On order, be prepared to support PK Operations as those forces arrive in theater.*

Commander, JTF-51 will plan for a main support Operational Base (Hamah), a secondary Operational Base (Tartus) and Forward Operating Bases (FOBs) as required. Operational Base Hamah will double as an airfield entrance and egress point for the beginning and end of mission while Operating Base Tartus will double as a port based entrance and egress point.

As required, JTF-51 will identify, confirm, occupy and defend the land corridor, strong points and areas of vulnerability within the AOR such that population migration, vehicular traffic, medical support, logistical support and other assorted relief operations are not negatively impacted. Air corridors shall be coordinated with the Government of Syria, as well as with the Russian forces headquartered in Latakia.

SNAPSHOT OF THE PLANNING MODEL

A description of the activities performed in each step of the M&OP process is presented here to describe how data for the supply chain model is collected, and how the resulting simulations can be analyzed to determine optimal solutions for the real-world supply chain being modeled.

Step 1 - Mission Forecasting
One of the first activities is the development of an DODAF OV-1 which depicts the "high-level" Concept of Operations (CONOP) of the Syrian evacuation as shown in figure 2 [4]

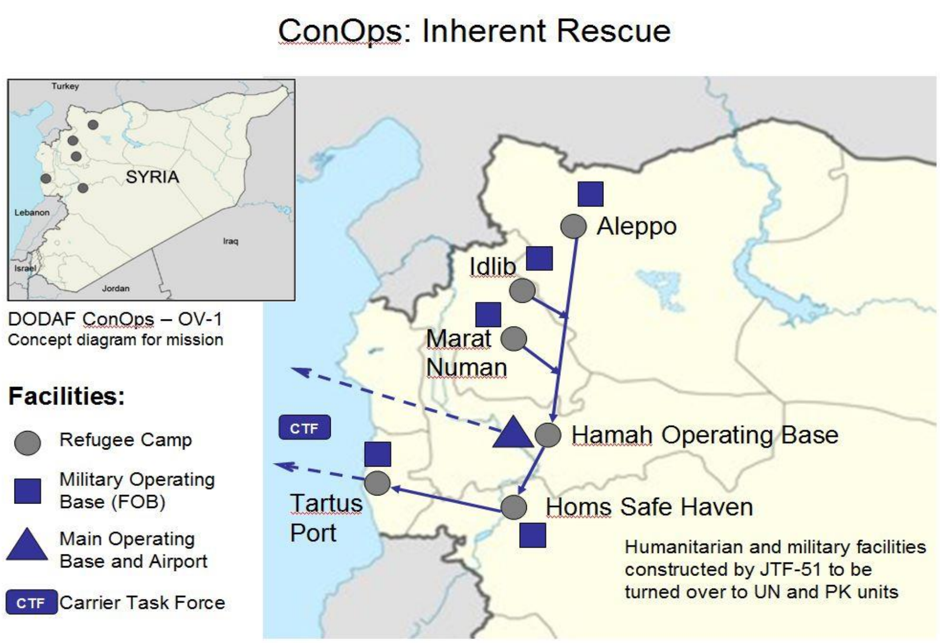

Figure 2

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[3] Note that this is only a representation of a CONOP (Concept of Operation) for this type of rescue. A true OV-1 would illustrate the interactions of all activities involved in the operation. This type of illustration/description is beyond the scope of this paper.

Step 2 - Demand Planning
In the second step mission planners make decisions regarding component elements needed for effective performance of the CONOP. Among these decisions are: 1) the identification of key sites (locations) required to support the operational mission; 2) key tasks that must be performed at these locations; 3) facilities required to support effective performance of these tasks; 4) the type and amount of personnel required for effective operation at particular locations; and 5) the supplies required to effectively support the tasks. Since Operation Inherent Rescue involves evacuating civilian refugees from what is considered a hostile environment, calculations must be made for both military and civilian requirements.

The mission planner must consider activities that may occur if the evacuation supply chain is attacked by enemy forces, thus military personnel, weaponry, ammunition and armament used in armed conflict must be included in the supply chain.

Figure 3

Figure 3 above provides an overview of the facilities and the number of military personnel required at each site for a successful evacuation mission. Figure 4 on the next page illustrates the civilian demand requirements. Appendix A provides a sample of the in-depth supply requirements that must be identified for civilians and military at each facility location. Note that in this step the DODAF views that are most helpful are the OV-2, OV-5, and OV-6c. However, it is beyond the scope of this paper to describe the contents of these views.

Step 3 - Supply Plan
After determining the number of personnel and supplies needed at various facilities, the mission planning team must create a plan (and contingency backup plans) for transporting products and refugees. This is shown in Figure 4 below.

Step 4 - Reconcile Plans
When the data has been collected, and documented in the Supply and Demand Plans, it is used to build the simulated supply chain model. The Demand Plan provides information about products, facilities and

product demand at each facility. The Supply Plan provides information about vehicles and routes as shown in Figure 5 below.

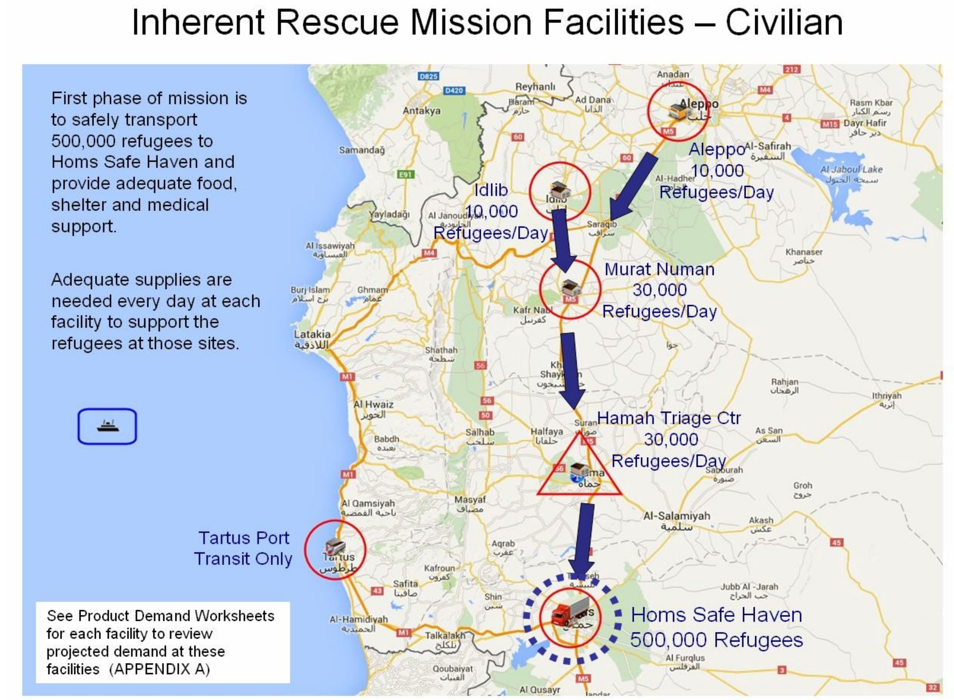

Figure 4

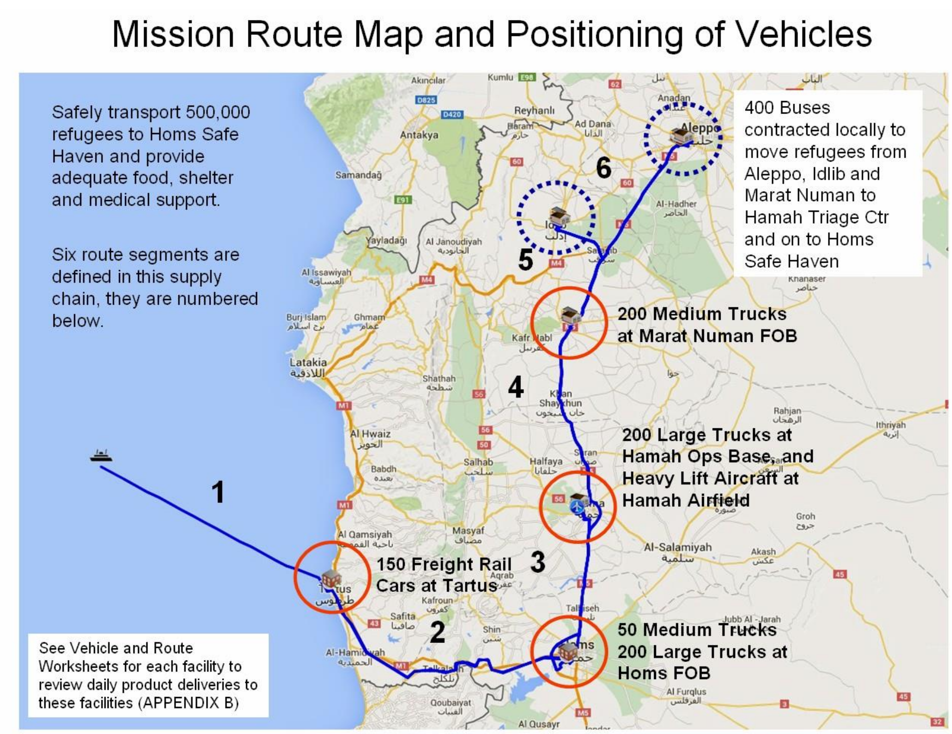

Figure 5

Once the supply chain model is built (populated with data), it can run simulations to see how well it performs. When the simulation determines points of failure in the model it will stop and display the problem such as where and when products run out at a facility or where too much inventory accumulates at a facility that does not have the capacity to hold the material, or when vehicles are overloaded with more inventory than they can carry.

When simulations encounter a problem, they stop and present decision makers with information and situational context needed to analyze and respond to the problem. The screenshot in Figure 6 is an example of a problem encountered and the information presented. In this screenshot the view is switched from map view to satellite view and it is zoomed in on the facility where the problem occurred; thus, enabling the user to better visualize why and how the problem occurred and what can be done to fix it.

Step 5 - Implement and Monitor

The supply chain model that runs for 15+ days and delivers the best performance becomes the plan for the supply chain for the next 15 days. The vehicles, routes, product delivery amounts and schedules are implemented to serve the facilities identified in the demand plan. The supply chain team can use the satellite and map views of the simulation to monitor the situation and as events unfold they can make necessary updates to the supply chain

Figure 6

VERIFICATION AND ANALYSIS OF RESULTS

Simulation data can be downloaded to spreadsheet reporting templates for further analysis as shown in Figure 7. Different templates can be created to analyze data from numerous perspectives.

Analysis of the simulation results verifies decisions for where to position vehicles and plan routes to deliver products to facilities and evacuate refugees. Simulation results show the vehicles, the route structure, and frequency of deliveries on those routes. This provides the flexibility needed to respond quickly to supply chain disruptions and prevents problems in one area of the supply chain from spreading to other areas (the “bullwhip effect”). Simulation results also provide good estimates of operating costs.

At the end of the five-step M&OP process, the model that results defines the specifications needed to create an actual supply chain that will perform well in the tactical situation described in this scenario. As the situation changes it is easy to update the model and use simulations to find effective responses

Inherent Rescue Fixed and Variable Cost Report with Supply Chain KPIs - MILITARY OPERATIONS - 15 Days - Scenario 1									
FIXED COST	**Total**		**Tartus Port**	**Homs**	**Hamah**	**Marat Numan**	**Idlib**	**Alleppo**	
Rent - CIV	$4,770,000		120,000	3,000,000	600,000	600,000	150,000	300,000	
Rent - MIL	$1,219,500		216,000	360,000	387,000	136,500	60,000	60,000	
TOTALS	$5,989,500.00		$336,000.00	$3,360,000.00	$987,000.00	$736,500.00	$210,000.00	$360,000.00	
VARIABLE COST		**Class I - Rations**	**Class II - Clothing & Eqp**	**Class III - Petrol, Oil. Lub**	**Class IV - Construct Mat'l**	**Class V - Ammunition**	**Class VI - Personal**	**Class VII - Major Items**	**Class VIII - Medical**
Product Prices:		$38,400	$24,000	$14,000	$34,000	$65,000	$18,000	$250,000	$65,000
Tartus Port									
Beginning Inventory - Shipped In	2016	216	192	288	384	0	192	0	168
Ending Inventory On-Hand	485	74	22	79	76	0	48	0	50
Percent Change	-75.94%	-65.74%	-88.54%	-72.57%	-80.21%	NA	-75.00%	NA	-70.24%
Avg On-Hand Inventory Amount	27	57	14	44	46	0	27	0	28
Avg On-Hand Inventory Value	$10,758,747	$2,170,880	$339,200	$622,533	$1,577,600	$0	$492,000	$0	$1,820,000
Product Weekly Shipments	1,008	108	96	144	192	0	96	0	84
Inventory Weeks of Supply	0.52	0.52	0.15	0.31	0.24	NA	0.28	NA	0.33
Homs Railhead									
Beginning Inventory Shipped In	1265	132	132	165	264	0	110	0	88
Ending Inventory On-Hand	486	25	51	90	116	0	14	0	16
Percent Change	-61.58%	-81.06%	-61.36%	-45.45%	-56.06%	NA	-87.27%	NA	-81.82%
Avg On-Hand Inventory Amount	32	27	39	59	77	0	14	0	15
Avg On-Hand Inventory Value	$11,477,253	$1,054,720	$940,800	$826,000	$2,629,333	$0	$256,800	$0	$970,667
Product Weekly Shipments	633	66	66	83	132	0	55	0	44
Inventory Weeks of Supply	0.42	0.42	0.59	0.72	0.59	NA	0.26	NA	0.34
Hamah Operating Base									
Beginning Inventory Shipped In	840	120	96	84	132	0	96	0	72
Ending Inventory On-Hand	266	31	30	35	23	0	30	0	20
Percent Change	-68.33%	-74.17%	-68.75%	-58.33%	-82.58%	NA	-68.75%	NA	-72.22%
Avg On-Hand Inventory Amount	16	17	16	21	17	0	16	0	13
Avg On-Hand Inventory Value	$5,764,160	$655,360	$384,000	$298,667	$562,133	$0	$288,000	$0	$866,667
Product Weekly Shipments	633	66	66	82.5	132	0	55	0	44
Inventory Weeks of Supply	0.26	0.26	0.24	0.26	0.13	NA	0.29	NA	0.30
Marat Numan FOB									
Beginning Inventory Shipped In	288	60	48	36	0	0	48	0	48
Ending Inventory On-Hand	114	23	18	3	0	0	17	0	33
Percent Change	-60.42%	-61.67%	-62.50%	-91.67%	NA	NA	-64.58%	NA	-31.25%
Avg On-Hand Inventory Amount	7	17	11	3	0	0	10	0	19
Avg On-Hand Inventory Value	$2,826,880	$634,880	$268,800	$44,800	$0	$0	$182,400	$0	$1,248,000
Product Weekly Shipments	144	30	24	18	0	0	24	0	24
Inventory Weeks of Supply	0.55	0.55	0.47	0.18	NA	NA	0.42	NA	0.80

Figure 7

FURTHER EXPERIMENTATION

This modeling and simulation process has been used to explore and document the operations of numerous other supply chains. These supply chains represent both real supply chains from existing companies, as well as historical and hypothetical supply chains. Examples are:

- Battle of Smolensk – illustrates how the path taken by the German Army in its advance on Moscow in the opening phases of World War II was largely dictated by logistics requirements.
- Burma Campaign - historical investigation of the supply chain that supported the Japanese Army's invasion of India from Burma in the spring of 1944.
- Unexpected Disruptions - exploration of possible responses to disruptions in the global supply chain of a consumer electronics manufacturer.

CONCLUSIONS AND RECOMMENDATIONS

Models and simulations can be used to present the supply chain and explain its operations to a wide audience of people from managers on the scene to senior commanders, government officials and politicians. The software and process described in this paper can be easily adapted to support either commercial business operations or military and humanitarian decision-making under conditions of stress and uncertainty. The process of building models and running simulations result in the development of situational awareness of the real-world supply chain and its operating challenges. This awareness facilitates greater group consensus and enhances effective decision-making. Conversely, the real-time simulation also allows for 'on the fly' data input that will give planners feedback on options should they encounter an unexpected disruption to the operation (example: if the main route bridge is interdicted and destroyed once movement begins – what options are available?)

From a professional training perspective, a simulation exercise could be used to train personnel who would be called upon in a disaster situation. It would be very productive for all parties responsible for decision making to participate in single online sessions where everyone could simultaneously witness what was happening in the field and collaborate in real-time model building and simulations to respond to frequently changing situations. This modeling and simulation application has been used over the last four years in both graduate and undergraduate supply chain and logistics courses. The results have been that students are able to obtain a deeper understanding and appreciation for how the basic components and formulas related to supply chains that are explained in textbooks apply to real life situations.

APPENDIX A
Sample of Daily Supplies Required by Military and Civilian Personnel

Products Needed for CIVILIANS

Product	Price	Weight	Size	Comments
Food Mix (for 4,000 people/day)	$22,500	10,500 kg (container wt is 2,200 kg)	34 m3	For a 20 ft. FLC – fully loaded container
Blankets and Mats (for 5,000 refugees)	$14,400	7,600 kg	34 m3	Blended avg cost for mix of blankets and mats
Medical Supplies (for 5,000 refugees)	$65,000	14,200 kg	34 m3	Avg for 20' FLC
Tents and Shelters (for 1,000 refugees)	$36,000	10,200 kg	34 m3	20' FLC with mix of tents (UNHCR data)
Fuel – Diesel (same as Class III)	$14,000	22,600 kg	34 m3 (24 m3 storage capacity)	20' tank ctr - Purchase locally
Other Supplies (5,000 refugees)	$35,000	11,500 kg	34 m3	Avg for 20' FLC - purchase locally
Water	Carrier produces 100k gallons or 370 m3 daily	23,200 kg (container wt is 2,200 kg)	34 m3 (24 m3 storage capacity)	Transport in 20 ft. tank ctr – 5,000 people per day
Refugee	--	80 kg	2 m3	Weight and space requirements per person

Products Needed for MILITARY

Product	Price	Weight	Size	Comments
Class I - Rations	$38,400	9,500 kg / 7,300 kg cargo (container wt is 2,200 kg)	34 m3	20 ft. fully loaded container = 3,000 MREs
Class II - Clothing And Equipment	$24,000	10,500 kg / 8,300 kg (container wt is 2,200 kg)	34 m3	Avg for 20 ft fully loaded container (FLC)
Class III - Petroleum, Oil and Lubricants (POL)	$14,000	22,600 kg / 20,400 kg	34 m3	Transport in 20 ft. tank ctr - avg cost
Class IV - Construction materials	$34,000	18,500 kg / 16,300 kg	34 m3	Avg for 20' FLC
Class V - Ammunition of all types	$65,000	20,200 kg / 18,000 kg	34 m3	Avg for 20' FLC
Class VI - Personal demand items	$18,000	10,500 kg / 8,300 kg	34 m3	Avg for 20' FLC
Class VII - Major end items (tanks, vehicles)	$250,000	(need avg weight)	(need avg size)	Prod becomes a vehicle (see Vehicles data)
Class VIII - Medical material	$65,000	18,000 kg / 15,800 kg	34 m3	Avg for 20' FLC
Class IX - Repair parts	$60,000	20,000 kg / 17,800 kg	34 m3	Avg for 20' FLC
Class X - Material to support nonmilitary	$35,000	11,500 kg / 9,300 kg	34 m3	Avg for 20' FLC
Water	Carrier makes fresh water - 100k gallons or 370 m3 daily	23,200 kg / 21,000 kg (container wt is 2,200 kg)	34 m3 (24 m3 storage capacity)	Transport in 20 ft. tank ctr – both water and av fuel
Aviation Fuel	$15,000	22,200 kg / 20,000 kg (container wt is 2,200 kg)	34 m3	Avg for 20' FLC

Note that this is only a sample of the data requirements. Similar in-depth charts must be completed for each facility location in the mission scenario. This forces the mission planner to critically analyze the specific material and personnel requirements that are needed at each site. This information is then input into the simulation software. When the mission planner runs the simulation, it will inform him/her if there are any problems with the data. Changes can then be made in order to optimize the supply chain.