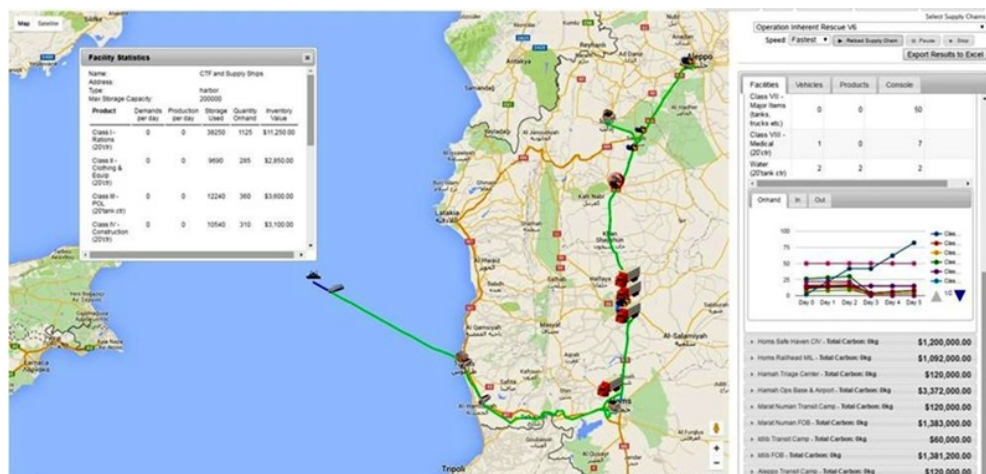# EXECUTIVE SUMMARY: Modeling and Simulating Humanitarian Supply Chains

In the near future it may be necessary for governmental, military and non-governmental organizations to work together to evacuate and relocate hundreds of thousands of Syrian civilians as part of a peace settlement. This paper describes a concise and accurate five-step planning and simulation process to explore options and design effective supply chains for such a mission. This process is called Mission and Operations Planning (M&OP). It is illustrated in the figure below, and further explained in this paper.

Mission and Operations Planning (M&OP) Process
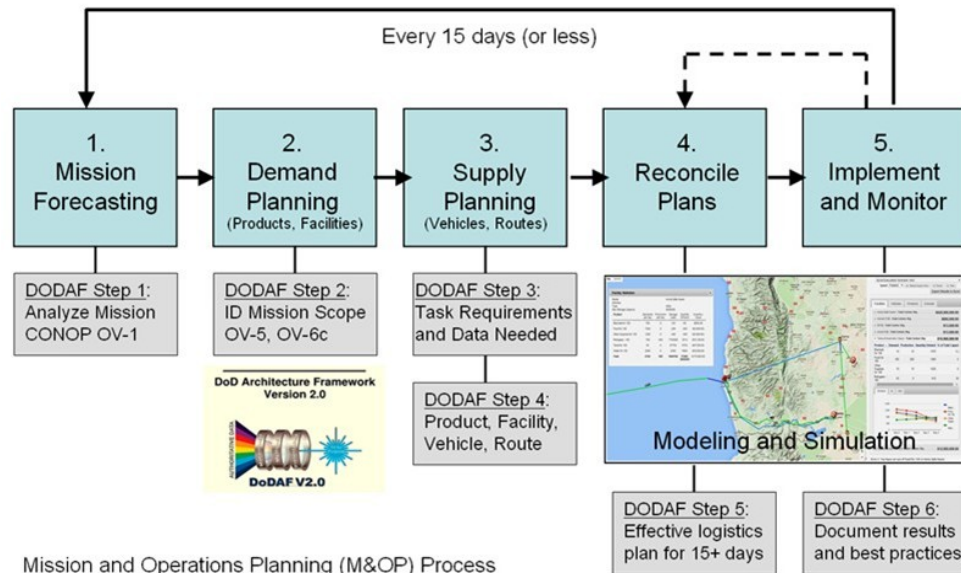
The M&OP process is based on the supply chain practice known as Sales & Operations Planning (S&OP), and modified by inclusion of Department of Defense Architecture Framework DoDAF V2.0 process steps and diagrams. Decisions are made on where personnel will be deployed, and what product demand will be created. Then plans are made to supply products to facilities to meet that demand. Simulations show how well different plans work. In the mission shown here, named "Operation Inherent Rescue", Syrian refugees are evacuated from cities in northern Syria and brought to a safe haven in the city of Homs.

The simulations show that even though plans seem to work on paper, problems still occur. These problems can be found and fixed in simulations before they are encountered in the real world. An easy to learn and scalable off-the-shelf software application is used to model and simulate supply chain designs to explore options to support this humanitarian mission. Concepts and formulas used in this simulation are based on principles and practices taught in undergraduate and graduate level courses in logistics and supply chain management.

DESCRIPTION OF PROBLEM

In order to end the fighting, it may be necessary for governmental, military and non-governmental organizations to work together in a mission to evacuate and relocate hundreds of thousands of civilians as part of a Syrian peace settlement. Such a settlement may divide up the country by ethnic and religious groups similar to what happened to end the fighting in Bosnia.

The mission planning and simulation presented here begins with the following 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 NGO (Non-Governmental Organizations) 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*

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.

Approach to Problem Solution
This paper and accompanying video describe and demonstrate a concise and repeatable five step planning and simulation process for exploring supply chain options to support humanitarian missions such as the one described here.

A commercial off-the-shelf, cloud-based simulation application is used to model and simulate different supply chain options prior to their actual implementation. We demonstrate a concise 5-step process for teams to follow in using these simulations. The process and the simulations combine to create an easily learnable and scalable solution to enable logistics teams and mission commanders to explore different supply chain options and pick the most effective ones. And as the mission unfolds they repeat this process as needed to keep supply chain plans up to date and respond to changing conditions.

As supply chain plans are put in place, this same platform becomes a place where daily operations data can be collected and displayed for all involved parties to see. Based on this data and unfolding situations as the mission progresses, supply chain plans can be continually updated on a rolling 15 day basis or sooner as needed.

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: 999999) and establish secure air and land links between CTF vicinity Tartus (grid ref: 999999) 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.

Modeling and Simulation based on Four Supply Chain Entities

Although there are *numerous* permutations, the modeling and simulation of any supply chain whether humanitarian 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 ERP 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 day by day over some period of time. As shown in the screenshot in the executive summary, 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 loaded into spreadsheet reporting templates to produce financial and operating reports.

Modeling & Simulating Humanitarian Supply Chains

CONCEPTIAL MODEL

Every supply chain is composed of combinations of four types of entities: Products, Facilities, Vehicles and Routes. The model simulates a supply chain by combining these four entity types. By placing the entities on a map and simulating their interactions the user can see how the supply chain will work.

Products – Facilities – Vehicles – Routes
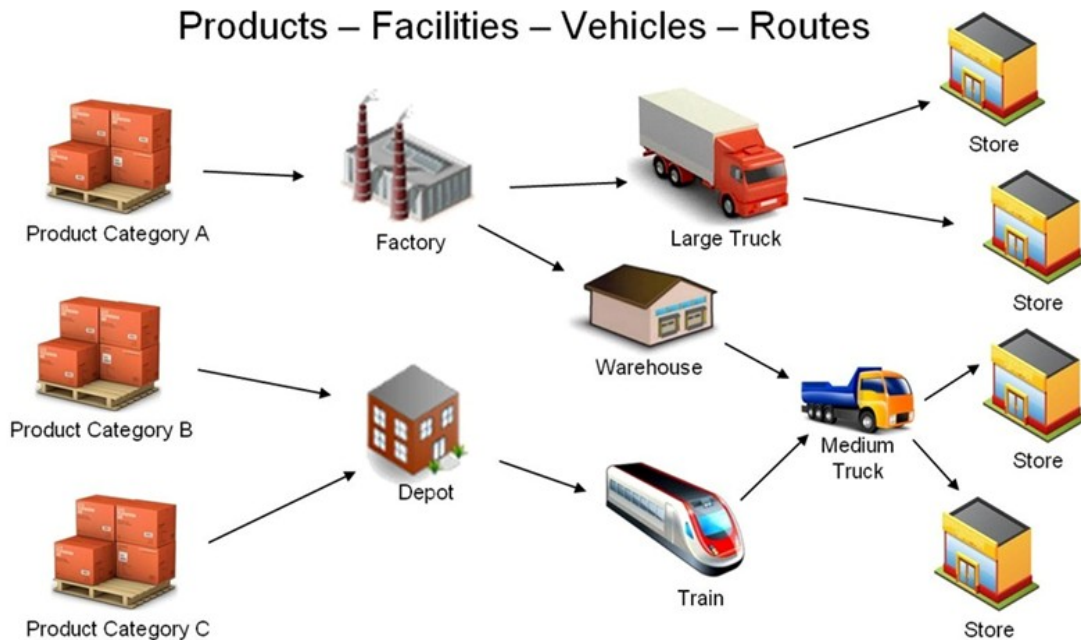
SIMULATION LOGIC

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 amount 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 operating problems will occur unless changes are made to the supply chain model.
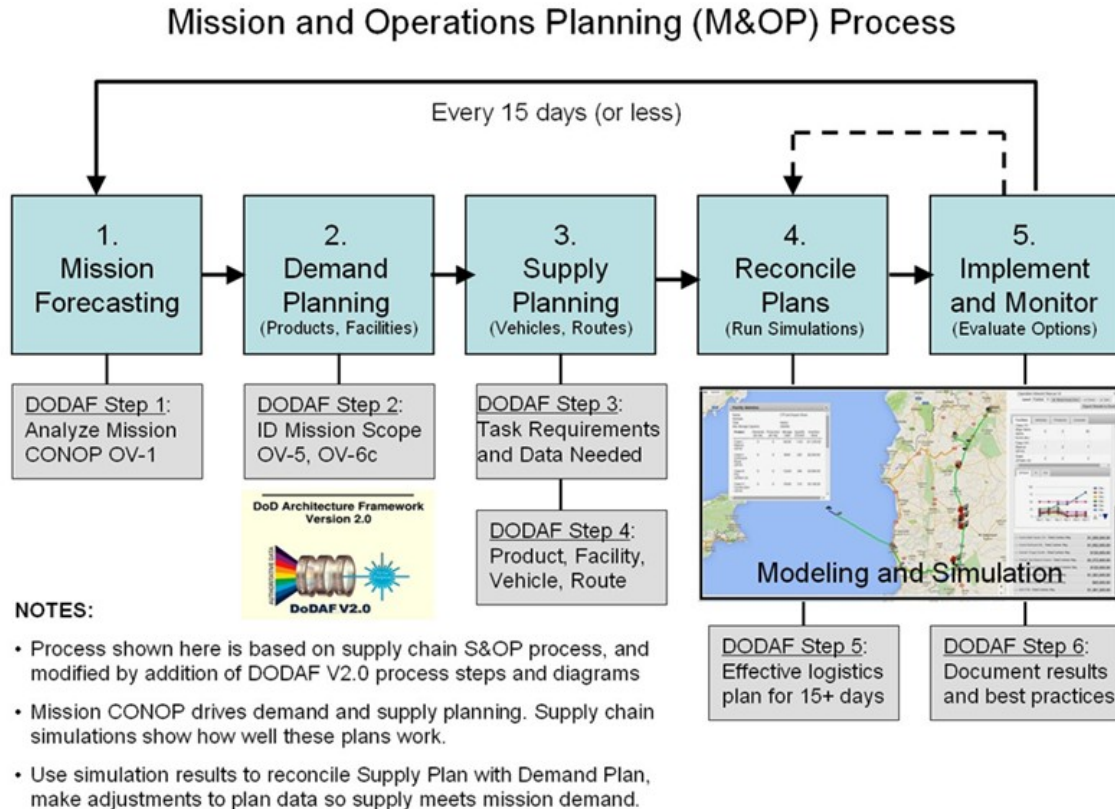
The simulation engine calculates daily usage, production and delivery of products at each facility. This updates on-hand amounts for each product at each facility each day, and shows how products flow through a supply chain. It reveals operating trends that develop over the period of the simulation. 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 is based on two process models widely used in supply chains (see diagram below). 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."[1]

The grey boxes represent similar steps for a military planning process based on the the *Department of Defense Architecture Framework (DoDAF)*. DODAF is an organizing framework for the DoD that provides an infrastructure for specific stakeholders concerns through viewpoints organized by various views.[2]

Mission and Operations Planning (M&OP) Process

Every 15 days (or less)

| 1. Mission Forecasting | 2. Demand Planning (Products, Facilities) | 3. Supply Planning (Vehicles, Routes) | 4. Reconcile Plans (Run Simulations) | 5. Implement and Monitor (Evaluate Options) |

DODAF Step 1: Analyze Mission CONOP OV-1

DODAF Step 2: ID Mission Scope OV-5, OV-6c

DoD Architecture Framework Version 2.0
DoDAF V2.0

DODAF Step 3: Task Requirements and Data Needed

DODAF Step 4: Product, Facility, Vehicle, Route

Modeling and Simulation

NOTES:

- Process shown here is based on supply chain S&OP process, and modified by addition of DODAF V2.0 process steps and diagrams

- Mission CONOP drives demand and supply planning. Supply chain simulations show how well these plans work.

- Use simulation results to reconcile Supply Plan with Demand Plan, make adjustments to plan data so supply meets mission demand.

DODAF Step 5: Effective logistics plan for 15+ days

DODAF Step 6: Document results and best practices

SNAPSHOT OF THE MODEL

A description of the activities performed in each step of the M&OP process is presented here to show how data for the supply chain model is collected, and how the resulting simulations are used to explore options and make improvements to the model and the real-world supply chain being modeled.
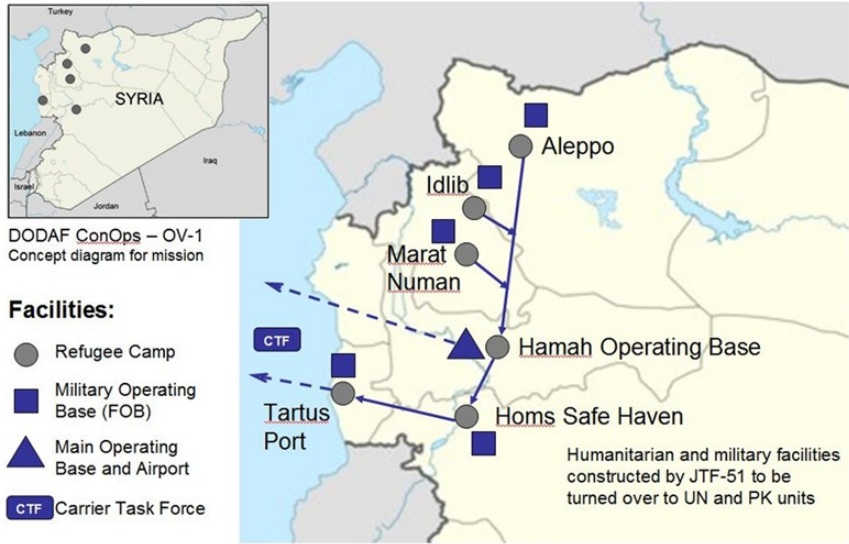
Step 1 - Mission Forecasting
This is where the mission commander decides how to achieve mission objectives. Facilities needed to support the mission are located on the map and personnel are assigned to those facilities as needed to carry out the activities that will occur at each facility. These decisions are shown in the concept of operations (ConOps) diagrams (simplified OV-1 diagram is shown below [3]).

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

[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.
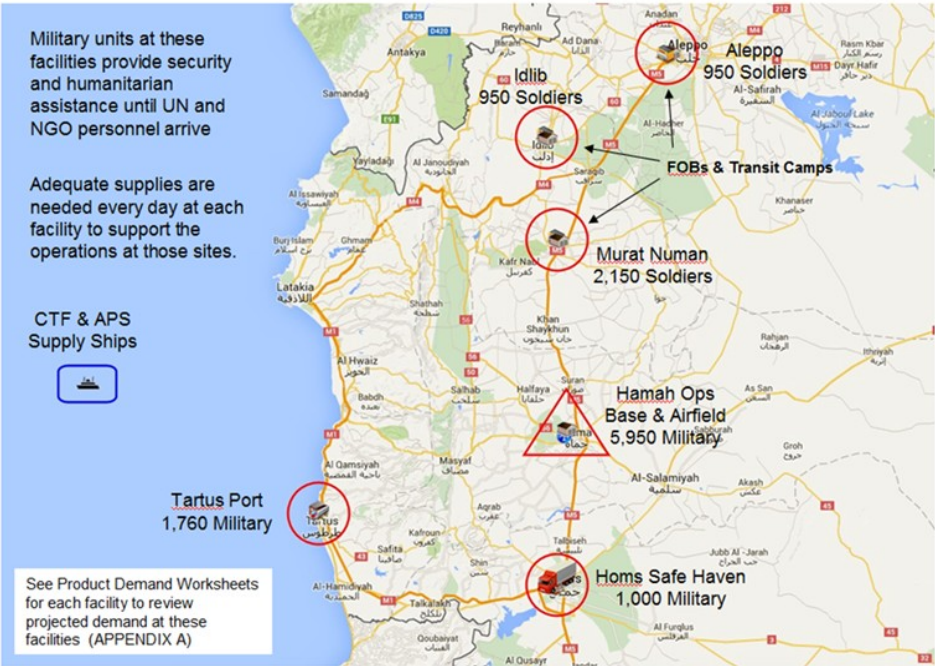
ConOps: Inherent Rescue

DODAF ConOps – OV-1
Concept diagram for mission

Facilities:
- ⬤ Refugee Camp
- ⬛ Military Operating Base (FOB)
- ▲ Main Operating Base and Airport
- CTF Carrier Task Force

Humanitarian and military facilities constructed by JTF-51 to be turned over to UN and PK units
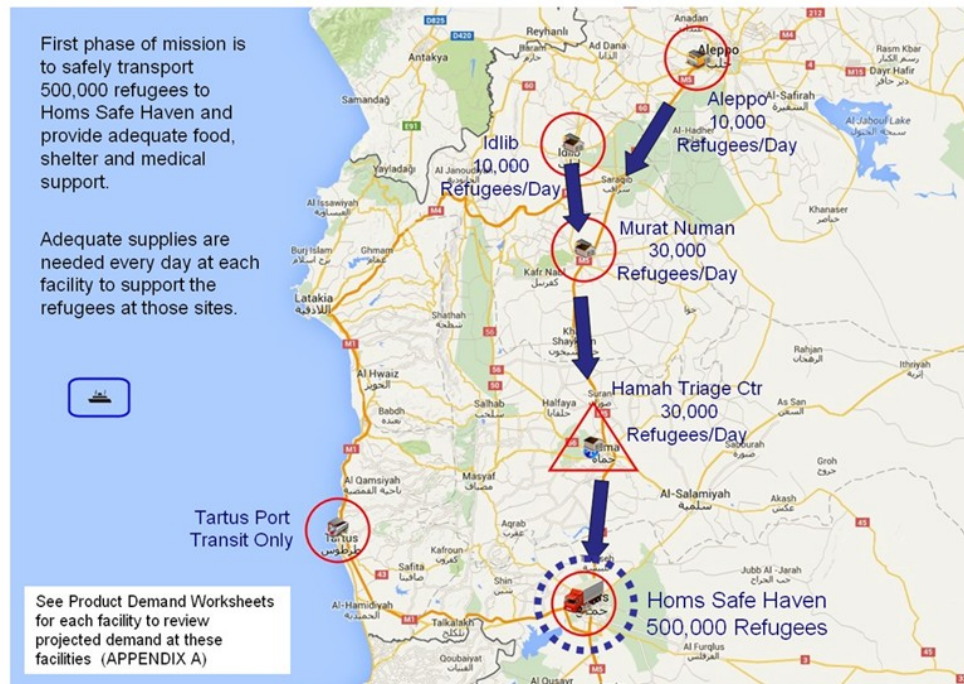
Step 2 - Demand Planning

In this second step mission planners make decisions regarding the amount of supplies and frequency of deliveries to different facilities for the personnel at those facilities to carry out their mission activities. Final decisions are made for: type and amount of personnel involved in these activities; and activities that will occur at each facility. Then the supplies needed to support those activities are calculated. The figure below provides an overview of the facilities and the number of military personnel required at each facility for a successful evacuation mission.

Inherent Rescue Mission Facilities – Military

Military units at these facilities provide security and humanitarian assistance until UN and NGO personnel arrive

Adequate supplies are needed every day at each facility to support the operations at those sites.

CTF & APS Supply Ships

See Product Demand Worksheets for each facility to review projected demand at these facilities (APPENDIX A)

In this step the DODAF views that are most helpful are the OV-2, OV-5, and OV-6c. It is beyond the scope of this paper to describe the contents of these views. Appendices to this report provide high level listings of the daily supplies required by military and civilian personnel during this operation.
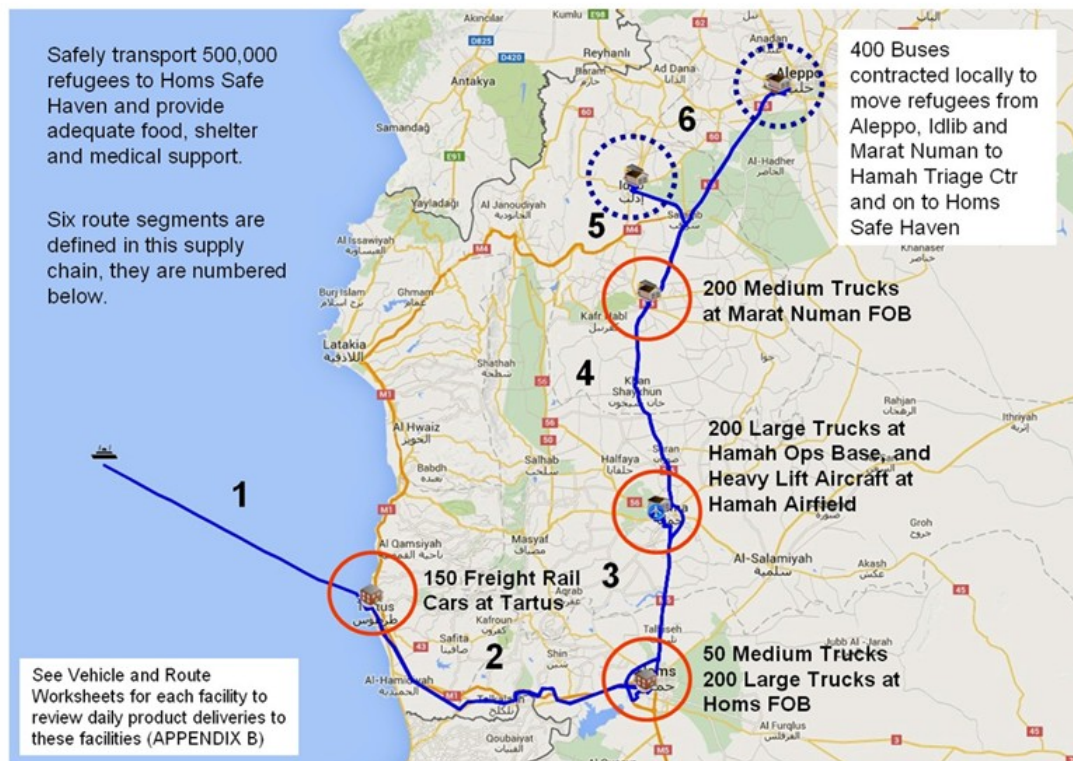
Modeling & Simulating Humanitarian Supply Chains

Inherent Rescue Mission Facilities – Civilian

First phase of mission is to safely transport 500,000 refugees to Homs Safe Haven and provide adequate food, shelter and medical support.

Adequate supplies are needed every day at each facility to support the refugees at those sites.

Aleppo 10,000 Refugees/Day

Idlib 10,000 Refugees/Day

Murat Numan 30,000 Refugees/Day

Hamah Triage Ctr 30,000 Refugees/Day

Tartus Port Transit Only

Homs Safe Haven 500,000 Refugees

See Product Demand Worksheets for each facility to review projected demand at these facilities (APPENDIX A)

Step 3 - Supply Plan

After determining the number of personnel and supplies needed at various facilities, the mission planning team decides on a plan (and contingency backup plans) for transporting products and refugees between facilities. An example of this plan is shown in the screenshot below.

Mission Route Map and Positioning of Vehicles

Safely transport 500,000 refugees to Homs Safe Haven and provide adequate food, shelter and medical support.

Six route segments are defined in this supply chain, they are numbered below.

400 Buses contracted locally to move refugees from Aleppo, Idlib and Marat Numan to Hamah Triage Ctr and on to Homs Safe Haven

200 Medium Trucks at Marat Numan FOB

200 Large Trucks at Hamah Ops Base, and Heavy Lift Aircraft at Hamah Airfield

150 Freight Rail Cars at Tartus

50 Medium Trucks 200 Large Trucks at Homs FOB

See Vehicle and Route Worksheets for each facility to review daily product deliveries to these facilities (APPENDIX B)

Step 4 - Reconcile Plans

When the data has been collected, and documented in the Supply and Demand Plans, it is used to build the supply chain model. The Demand Plan provides information about products, facilities and product demand at each facility. The Supply Plan provides information about vehicles, routes and delivery schedules and amounts.

Once the supply chain model is built, simulations are run 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. An example of this is shown below.
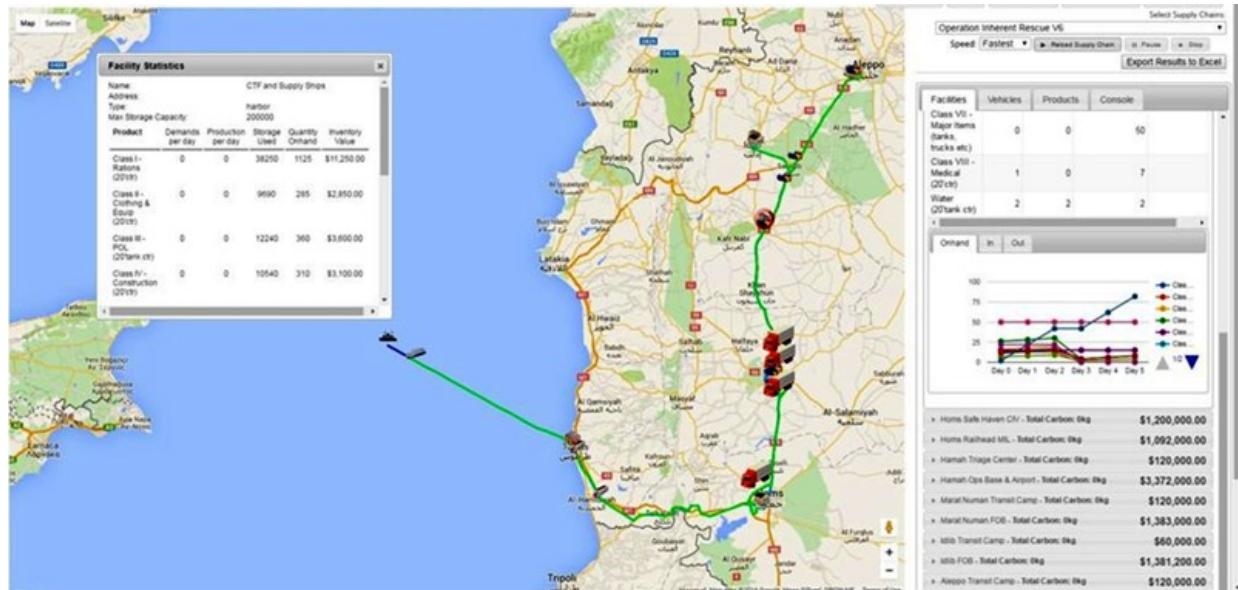
When simulations encounter a problem, they stop and present people with information and situational context needed to analyze and respond to the problem. The screenshot below is an example of a problem encountered and the information presented. In this screenshot the view is switched from map view to 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.

Modeling & Simulating Humanitarian Supply Chains

Step 5 - Implement and Monitor

The supply chain model that runs for 15+ days and delivers the best performance becomes the operating plan for the next 15 days or until the situation changes. Vehicle positioning and routes and product delivery amounts and schedules are implemented as shown in the supply chain model. Then the supply chain team monitors the situation and updates the model as events unfold. This is shown in the screenshot below. The map view and satellite views provide context in which to assess data from the field and gain a big picture understanding of the situation (situational awareness).

VERIFICATION AND ANALYSIS OF RESULTS

Simulation data can be downloaded to spreadsheet reporting templates for further analysis as shown in the screenshot below. Different templates can be created to analyze data in many useful ways.

Analysis of the simulation results verifies decisions for how 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 contains 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.

FURTHER EXPERIMENTATION

This modeling and simulation process has been used to explore and document the operations of other supply chains. These supply chains represent both real supply chains from existing companies, as well as historical and hypothetical supply chains. Examples are:
- The Java Furniture Company - modeling of the real supply chain of a company that makes furniture in Indonesia and exports to customers worldwide
- Unexpected Disruptions - exploration of possible responses to disruptions in the global supply chain of a consumer electronics manufacturer
- Burma Campaign - historical investigation of the supply chain that supported the Japanese Army's invasion of India from Burma in the spring of 1944

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. They also provide realistic training for a wide audience of people to learn from simulations and see for themselves the results of different actions. The process of building models and running simulations results in the development of situational awareness of real-world supply chains and their operating challenges. This awareness promotes situational awareness and facilitates group consensus building and effective decision making.

Military and Humanitarian Mission Applications
A planning and simulation platform that is easy to learn and can be used by different organizations participating in missions significantly improves mission planning and operations monitoring. The software and process shown here is easily adapted to support either commercial business operations or military and humanitarian decision making under conditions of stress and uncertainty.

It would be very productive for all parties involved in a humanitarian supply chain to participate in online sessions where everyone could see what was happening in the field and collaborate in real-time using simulations to explore possible responses to changing situations. All could see what works best and consensus would emerge quickly, making actions taken much more timely and effective.

Footnote
Data collection forms and product usage rates and formulas as they apply to Operation Inherent Rescue and other simulations mentioned in this report are further discussed in appendices that accompany this paper. These appendices are available on request (send email to info@scmglobe.com).

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