T.LOADS TREATMENT OF ASSIGNING AND FILLING ORDERS

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ABSTRACT

The Tactical Logistics Distribution System (T.LoaDS or TLoaDS) is a powerful and flexible simulation application for assessing current or future tactical distribution systems. It is a discrete event analytical model for assessing the pros and cons of new doctrine, distribution techniques, organizational structures, and equipment concepts. It can also be used for mission planning allocating available resources to sustain a military force in a wide variety of scenarios. This paper covers how TLoaDS models the order assigning and filling process. While order assigning is simple, the order filling process dynamically selects the combination of container, handler, and transporter appropriate for the current order, conditions and rule set. A scoring system with user adjustable weighting factors allows biasing the shipment plan towards more efficient use of transporters, or more responsive filling of orders.

1 INTRODUCTION TO T.LOADS

1.1 Need

New doctrine, procedures, techniques, organizations, and equipment impose challenges to Navy and Marine Corps expeditionary logistics. These subsystems interact and warrant a model that simulates these dependencies.

The military supply chain is substantially different from commercial supply chains, so commercial supply chain models are inadequate. Three of the key differences are: 1) tactical supply points move, whether ships, combat service support detachments, or combat trains, while warehouses, distribution centers and stores, rarely do; 2) tactical nodes can have chronic shortages of resources, while in the commercial world, more resources are usually acquired as needed; and 3) the tactical distribution system is subject to enemy attack; in the commercial world this is still too rare to model.

1.2 Description

At its core, TLoaDS is a supply chain throughput model. It simulates how distribution resources like pallets, forklifts and trucks work together to move supply commodities from supply points forward to where they are consumed. The core module is a stochastic discrete event simulation, like the commercial supply chain, warehousing and factory industries now turn to for critical problems. It uses a current commercially available supply chain modeling environment, with custom government owned TLoaDS code and user interface components. When it runs, the simulation engine keeps track of how all the individual commodities, orders, shipments, material handlers, and transporters interact with each other and their current environment according to the current process rules.

As TLoaDS runs, it generates a wide variety of time-based, quantified, and descriptive, text, plotted, and animated outputs that shed far more light into what is going on in the system, than spreadsheet, knowledge base, neural network, or linear programming models do.

Numerous non-core TLoaDS modules described in a previous WSC paper on the TLoaDS architecture (Hamber 2001) aid the analyst in managing and processing the vast amount of input and output data involved in a study. These include modules to 1) manage the different simulation levels involved in a study; 2) help prepare and advise the analyst in setting up the model inputs; 3) understand the detailed and overall performance of the distribution system. There is even on-line documentation in the familiar Microsoft Help environment. With animation on, the nominal run speed for a 50 node model without atrocious bottlenecks is 1 scenario-day per run-minute on a 1GHz PC with 512M of RAM. With animation off, it runs four to ten times faster.

For more information on TLoaDS, see our website: <http://www.nfesc.navy.mil/amphib/tload s/index.html>.

1.3 Terminology

Definition of a few terms is in order.

- Entities – We use this term in a broad sense consistent with both "a distinguishable person, place, unit, thing, event, or concept about which information is kept" (DMSO 1998) and "e.g. people or machines, that act and interact together toward the accomplishment of some logical end" (Section 1.2 of Law and Kelton 1991; Schmidt and Taylor 1970). This is in contrast to narrower definitions that distinguish "entities" from "resources" such as used in some modeling environments (Kelton, Sadowski, and Sadowski 1998), and in Section 3.3.3 of Law and Kelton 1991. Such a distinction is not wise in TLoaDS as many classes of entities can at the same moment or different moments be providing a service to an entity (i.e. a resource) and being serviced by another entity (narrow definition of entity). For example, while a truck is serving to distribute pallets of food and water, it can be served by a ferry transporting it across a river. Or a train can move a bunch of empty trucks from one node's pool to another to reallocate the truck resource.
- Containex – Our term for the class of entities that package a batch of material into a load for shipment. This includes boxes, cans, cases, pallets, drums, intermediate bulk containers, shipping containers, cargo nets, and slings. We coined this term rather than use "container" which in our user community has a strong connotation of 20 foot or longer intermodal shipping containers.
- Handler – Our term for the class of entities that load or unload containex from transporters, or move containex within nodes (distribution facilities). This includes not only forklifts, cranes, elevators, gantries, high lines, and conveyors, but men and pumps.
- Period – In order for TLoaDS to simulate a dynamic environment, the user divides a simulation run up into time periods of unequal length and sets the time for each to start. Each period has its own set of user input values for about thirty parameters. A few of these apply to the entire geographic area, like weather, seastate and time twilight starts and ends. Most of these parameters also vary by node. A few are node location, terrain, unit strength, ammo consumption tempo, threat condition, meal plan, air temperature, and accessibility by water. As the model runs and encounters the user scripted "start new period" event, it reads that period's set of input conditions, makes a bunch of computations and queries for use throughout the period, and then proceeds

to the next posted event. While some users like to make periods one day long, others script them to better fit the scenario.

1.4 TLoaDS Entity Flow Paths and Process Cycles

It is useful to examine the distribution process that happens between each customer and supplier pair involved in an order for supplies. Let's look at how three classes of entities move between the customer and supplier nodes. First, material entities move from suppliers to customers. But depending upon where a supplier and customer are in the supply chain, the supplier is likely to be receiving material entities from its supplier, and the customer may be a supplier to a customer further downstream. Second, these material entities are carried by transporter entities from the supplier to the customer. And usually, the material is dropped off and the transporter returns to the supplier it came from. Third, the order that typically came from the customer for the supplies, is an information entity that directly or indirectly gets to the supplier. The paths these entities take are shown in Figure 1.
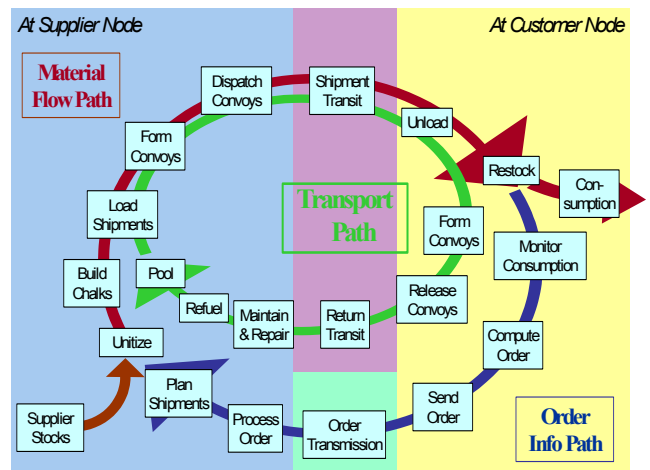

Figure 1: TLoaDS Basic Entity Path and Process Steps

The figure also shows the major steps in the process the entities take on their paths.

These sequences of steps can also be viewed as cycles. The transporter path already forms a cycle. A majority of the material flow path and the entire order info path together form a cycle. This second cycle is sometimes call the distribution cycle. (Figure 2).

The same major steps are shown – but note the Assign Order step is called Process Order, and Fill Order is called Plan Shipments. The former terms reflect those used in the commercial supply chain modeling software TLoaDS is based upon, while the latter retains the terminology used in a figure of an earlier paper proposing terminology for distribution techniques (Hamber 2000).
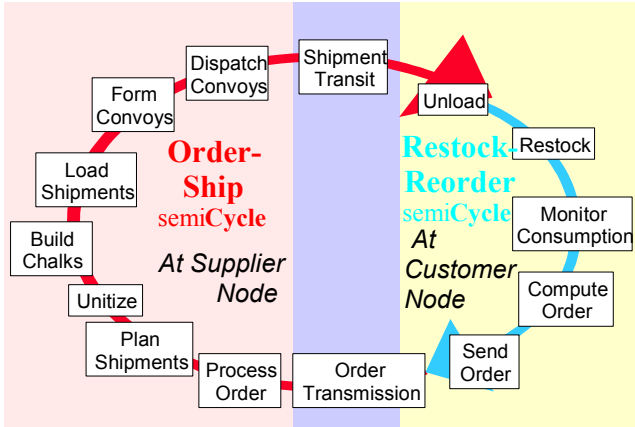
Figure 2: Distribution Cycle with Two Semi-Cycles

In Figure 2, the distribution cycle is shown as two semi-cycles. Here we clearly see what is commonly called the "order-ship cycle" is not really a complete process cycle. We call the remainder of the distribution cycle the "restock-reorder cycle."

1.5 Consumption and Ordering Process

The details on how TLoaDS treats consumption and the first four steps of the order info path of Figure 1 is covered in and earlier conference presentation (Hamber 2002).

Currently, details on the treatment of unitizing through restocking and the rest of the Transporter path, are only covered in the TLoaDS user manuals.

2   ASSIGNING AND FILLING ORDERS

This paper covers the details of how TLoaDS models and simulates the Assign Order (Process Order) and Fill Order (Plan Shipment) steps of the distribution cycle.

While the availability and performance characteristics of containex, handlers, transporters, load spots, and the ways between nodes are considered in the fill order step, neither of these steps simulate any of these physical entities. These steps only simulate the interaction of information and decision making.

2.1 TLoaDS Order Assigning Process

This is the second to last step on the order info path of Figure 1 and the first step of the order-ship semi-cycle of Figure 2. The functions of this major step are to:

- Accounting -- perform the appropriate order management calculations
- Sourcing -- decide which supplier supplies each kind of material requested in a customer's order
- Issuing -- Send material orders to suppliers.

2.1.1   Accounting

There are three order management tasks in this step.

- Current Request Amount -- When the customer order is received, the Current Request amount is logged in the Node Supply Variables table.
- Current Unassigned Request -- When the request is processed, the requested amount is added to the Current Unassigned Requests table and the Current Request amount is reset to zero. If a request has not been processed at the time the next request is made, the newly requested amounts are added to the current request. When an order is issued, the amount in the Current Unassigned Requests table is reduced by the amount assigned.
- Current Unfilled Orders -- When orders are assigned to suppliers in the next step they are logged in the Current Unfilled Orders table.

2.1.2   Sourcing

If the customer order is for multiple materials, this step first disaggregates it into separate orders for each kind of material. Then TLoaDS looks up the primary supplier for each material for that customer in the Material Suppliers table.

While TLoaDS underlying COTS supply chain modeling software easily allows us to model more sophisticated sourcing methods, our users have not requested we make these methods easily accessible through our user friendly GUI.

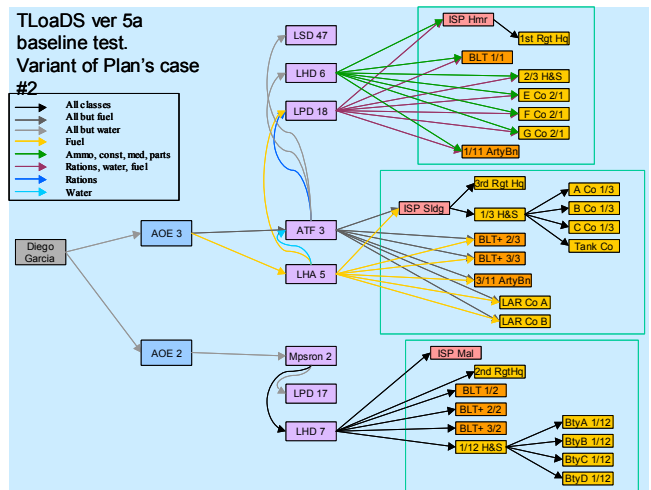The current flexibility of this method is suggested by the distribution network diagramed in Figure 3.

Figure 3: Representative Distribution Network

2.1.3   Issue Material Order

TLoaDS has a stochastic parameter to simulate the time delay for order transmission and processing. Where customers can order by network or radio, directly from their suppliers, and there is no wait for approval, this input should be zero. Where couriers are used, or orders are sent to some command node, or approvals or prioritizing is routine, this input should reflect the aggregate probability of delay. Where supplies are "pushed" to customers on a schedule, this parameter allows for periodically forwarding orders from command nodes to suppliers or from suppliers' command centers to their order filling centers.

2.2   TLoaDS Order Filling Process

This is the last step on the order info path of Figure 1 and the second step of the order-ship semi-cycle of Figure 2. The functions of this major step are to:

- Load Planning – break a material order down into a plan for n unit loads to be distributed by x transporter shipments
- Prioritizing – sorting the priority of unit loads and transporter shipments.
- Accounting -- perform the appropriate order management calculations.

2.2.1   Load Planning

The overall result of this sub-step is to break down a material order into the necessary number of transporter shipments.

This first requires selecting what combination of containex, handlers and transporter to use to distribute the material order. We refer to a unique combination of a kind of containex, a kind of handler, and kind of transporter, used in combination to distribute a given kind of material from a given supplier, to a given customer, in a given period, as a material distribution combination (MDC). But prior to discussing the methods the analyst has available for simulating this selection process, one needs to understand what is required for a material distribution combination to be valid.

2.2.1.1   Identifying Valid Material Distribution Combinations

At the beginning of each simulation period, the loading combinations of containex, handler and transporter which are valid for each customer node, supplier node, and material in that period are determined and remembered until overwritten at the beginning of the next period. To be a valid MDC, it must meet the following seven tests:

- There is an record for the MDC in the Loading Rates Table specifying the loading and unloading time for that combination of containex, handler, and transporter.

- There is that kind of transporter assigned to the supplier.
- The transporter can travel to the customer during this period considering range, and terrain, route, day/night, and weather conditions.
- The transporter can be received by the customer this period considering the customer's location, and mission, posture, and threat conditions.
- There is that kind of handler available at the supplier.
- That kind of material is compatible with container.
- There is some kind of handler assigned to the customer which can unload the containex from that kind of transporter.

These constraints are diagramed in Figure 4.

Even with all these constraints, if many kinds of containex, handlers, and transporters are available at each node, and all the plausible MDCs are included in the Loading Rates Table, then there can easily be 100 valid MDCs for many combinations of node and material, and dozens at nodes where there are fewer kinds of handlers. If there are 50 nodes and 20 materials in the model, there are 50,000 valid MDCs to remember each period.

2.2.1.2   Selecting a Material Distribution Combination

The analyst has four methods available for controlling how the simulation selects an MDC for filling a given material order in a given period:

- Use first valid material distribution combination
- Use loading rules and scoring factors
- Use dictated combination or resource
- Avoid dictated combination or resource.

The third and fourth methods can be used in combination with either of the first two, but the first two are exclusive to each other. The choice of the first two is set by the Yes/No condition in the "Use Loading Rules" field of the Loading Rules table. "No" means to use the first valid material distribution combination, as explained in the next paragraph.

2.2.1.2.1   Use First Valid Material Distribution Combination

When this method is selected the valid MDCs for that period are first queried to exclude MDCs that don't meet any dictated combinations of resources.

Then the sim goes down the list of remaining MDCs looking for the first one that passes the validity tests of paragraph 2.2.1.1. That is the one that will be used.

So the order the MDC records appear in the Loading Rates Table is very significant when this sim control is used.
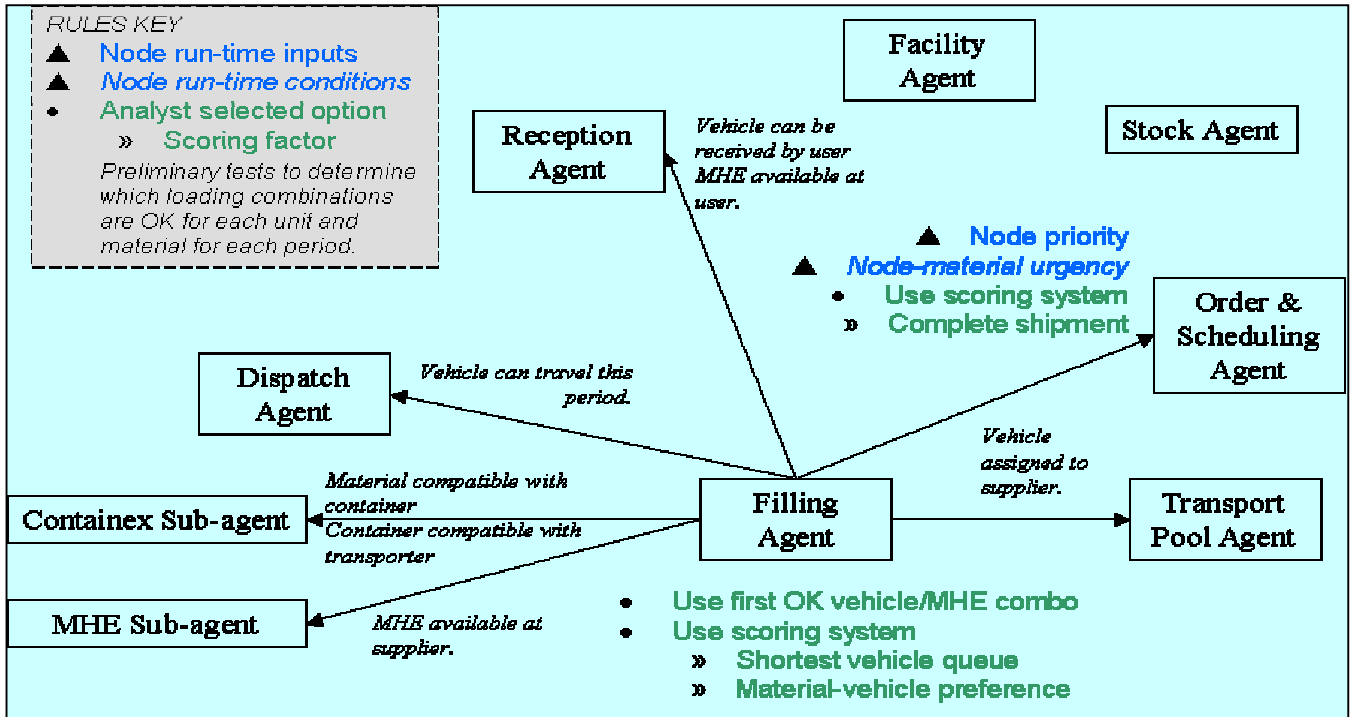
Figure 4: Filling Agent Constraints to Determine Valid Material Distribution Combinations

2.2.1.2.2 Use Loading Rules and Scoring Factors

Again, when this method is selected the valid MDCs for that period are first queried to exclude MDCs that don't meet any dictated combinations of resources.

The remaining ones are subject to a simple scoring formula (Equation 1).

$$S_{(MDC)} = P_{(CS)} - P_{(SQL)} \times F_{(SSQ)} + P_{(MVP)} \times F_{(MVP)} \quad (1)$$

The MDC with the greatest $S_{(MDC)}$ is used for the given material order. The process is repeated for each material order.

The variables are explained in the next three paragraphs. Their values are unbounded, and can be negative.

2.2.1.2.2.1 Complete Shipment

If there is a partially filled shipment going to the same unit, all else being equal, to promote an efficient distribution system, we would rather complete that shipment than start a new one. If this is the case, the specified points ($P_{(CS)}$) set in the Complete Shipment field of the Loading Rules table will be awarded to each MDC with that transporter.

2.2.1.2.2.2 Shortest Shipment Queue

All else being equal, to promote responsiveness in the distribution system, the analyst may want to assign materials to a shipment in the shortest queue of shipments waiting for a transporter. Points are subtracted from the MDC score for each shipment in the queue. $P_{(SQL)}$ equals the current state of the transporter's shipment queue length.

$F_{(SSQ)}$ is a weighting factor from the Shortest Queue field of the Loading Rules table.

There may be more than one partially filled shipment waiting for different transporters.

2.2.1.2.2.3 Material Vehicle Preference

If the analyst wants to favor or discourage the selection of one or more kinds of transporters for distributing a particular material, he can enter a value $P_{(MVP)}$ the appropriate cell(s) of the Material Vehicle Preference table. Positive values favor the transporter use, negative numbers discourage its use. Setting different values for different transporters, the analyst can address many issues including:

- The cargo loading efficiency favors one or many transporter over others.
- The relative speeds of transporters when responsiveness is important.
- The relative mobility of transporters where the terrain dictates.
- The relative survivability of transporters when the threat is significant.
- The relative covertness of transporters (e.g. when the customer doesn't want a big helicopter disclosing his location to the enemy).

$F_{(MVP)}$ is a weighting factor from the Material Vehicle Preference field of the Loading Rules table.

2.2.1.2.3   Use Dictated Combination or Resource

By filling in the kinds of:
- Containex in the Transport Container Specification table
- Handler in the Transport MHE Specification table
- Transporter in the Transport Vehicle Specification table.

the analyst can force the given MDC to be used for specific customers. These tables have a cell for every node and every material. The nodes are representing customers being shipped to. The dictated combinations will only be used for those cells filled in.

Not all three tables need to be filled in for a given material and customer node; each table is a separate rule. For example, just filling in "jerry can" for all cells with "Infantry Co" at the node and with a kind of fuel or water as the material, will force all infantry companies to get their fuel and water by jerry cans, using any handler than can handle jerry cans (as specified by the containers per MHE table), and the first, or highest MDC scoring (depending on the Use Loading Rule field) transporter that can transport jerry cans (as specified in the containers per vehicle table), will be selected.

This method gives the analyst a lot of control in dictating the material distribution combinations used. But the challenge of using this method, is that the logical checks described in the next method are not done during the simulation to select a combination to use, but are still done to apply the operational constraints of the real system. As one applies more control in scenarios with more dynamic conditions that prevent certain combinations from being used by certain nodes in certain periods, the more care the analyst must take to insure the containex, handlers, and transporters are wisely allocated.

For example, when the simulation alerts the analyst that "There is no loading combination to get fuel from LAR Combat Train to LAR Co A in Period 4" it is because he wants the simulation to prevent fuel delivery to Co A in Period 4; say because he wants to sim the use of only large trucks for fuel delivery to Co A, and in Period 4 Co A crossed a river the large trucks can't ford, until the combat engineers finish bridging the river at the start of period 5. (For this to happen, the user also has to set A Co's "Ground-in" input for Period 4 to "No.")

2.2.1.2.4   Avoid Dictated
Combination or Resource

If the analyst wants to limit use of certain individual MDC for the entire distribution network for the entire run, he can just delete the corresponding record from the Loading Rates table. But if the limitation is for a specific material, or involves multiple MDC's with a common kind of containex or transporter, this is done more accurately or easily by leaving the appropriate cells blank in one of these tables:
- Materials Per Container
- Containers Per Vehicle (checks cube)
- Materials Per Vehicle (checks weight).

For example, to run an excursion where CH53 helicopters are not to be used for distributing water to any node, instead of eliminating all the loading rate records with CH35 and any containex that can load water (which would prevent the CH53 from using those containex to deliver anything), just blank out the cell in the Materials Per Vehicle table that shows how the maximum quantity of water a CH53 can carry by weight.

2.2.1.3   Calculate Transporter Payload

At this point in the order filling process the simulation now knows from the Selecting the MDC step:
- What type and kind of transporter will deliver it
- If there is a partial transporter shipment to accept all or the first part of the material order.

It also knows from resource characteristics, operating procedures, and scenario conditions:
- max payload weight for selected transporter as function of scenario factors such as terrain, temperature, sea state, runway length, wind vector, visibility, and flight range.

From the above information, TLoaDS computes the:
- maximum payload weight for empty transporters of the kind selected
- remaining payload weight available on partially filled transporters available

2.2.1.4   Develop Load Plan (Shipping Manifest)

At this point in the order filling process the simulation now knows from the Issuing step:
- The Current Unfilled Order quantity for the current material order

and from the Selecting the MDC step:
- How it is going to unitize the material (i.e. what containex will carry the material to the customer)

and from the Calculate Transporter Payload step:
- Maximum payload weight for empty transporters of the kind selected
- Remaining payload weight available on partially filled transporters available.

It also knows from resource characteristics, operating procedures, and scenario conditions:
- Units of ordered material per containex (by weight and cube)
- The tare weight of the selected containex

- Max number of selected containex per selected transporter (a check on cube)
- Max units of ordered material per selected transporter (a check on weight).

2.2.1.4.1 Load Planning Algorithm

From the above information, a load planning routine:
- Plans how full the first containex can be for the first, if any, partially loaded transporter (checking, weight, cube and unfilled order quantity)
- If no partially loaded transporter is waiting it plans how full the first containex can be for an empty transporter
- Computes remaining transporter payload and remaining unfilled order quantity
- Decides if another full or partial containex can fit on the same transporter (checking weight and cube)
- If so, it repeats this cycle with the same transporter
- If not, it repeats this cycle with the next, if any, partially loaded transporter
- If none, it repeats this cycle with another empty transporter.

Note the vehicles and the handlers that will do the loading don't have to be currently available -- this is just a planning step.

2.2.1.5 Issue Load Plan

The Load Plan and issue time stamp are saved to the appropriate fields of the following tables:
- Orders
- Shipments
- Shipment Containers
- Shipment Timing,

which the model's way of recording the requests for these tasks:
- Material from stocks to unitize
- Handler from pool to load spot to load
- Loading spot for loading
- Transporter from pool to loading spot to be loaded
- Shipment requests,

have been added to the appropriate queues.

This ends the Load Planning step whose task was to break a material order down into a plan for n unit loads to be distributed by x transporter shipments.

A unit load is a containex with material.

A transporter shipment is a transporter and all its unit loads.

2.2.2 Prioritizing

The relative priority of a material order is dependent upon both the priority of the customer, and the "request urgency" level of the material at the time of the most recent customer inventory status report (in military lingo -dump stat). In case of tie, the material orders will be prioritized in the order the material types are listed in the material types element list.

2.2.2.1 Sort Transporter Shipment Queues

After a material order's unit loads are completely assigned to transporter shipments, each queue of shipments waiting for a transporter is re-sorted in the order of the request urgency and unit priority of its shipments.

The transporter shipment queue(s) will also be re-sorted if:
- A customer's priority changes
- Get notice of a customer's urgency level change.

If the first shipment in the queue has had a vehicle assigned to it, it is locked into the first position.

2.2.2.2 Request Urgency

As stock levels go up and down, it is informative to have a classification scheme to communicate the general level of current stocks relative to a number of stock control thresholds. Our eight levels of request urgency have are:
- Level 8: Over max – stock > max stock capacity
- Level 7: Over stock – stock ≤ max stock capacity
- Level 6: Above reorder -- stock ≤ stock objective
- Level 5: on order -- stock ≤ reorder point
- Level 4: Urgent -- stock ≤ safety stock level
- Level 3: Very Urgent – stock ≤ half of safety level
- Level 2: Emergency – stock ≤ stock level = projected consumption during order-ship time. Note that this value can be greater than half the safety level.
- Level 1: Out of Stock – stock level = 0.

Levels 7 to 2 span from the threshold value shown, down to the threshold value of the next lower level.

The scheme is named after the fact that the lower the stock level is, the need for replenishment material becomes more urgent.

2.2.3 Order Transfer

The analyst has the option of defining secondary suppliers if there are indications the primary supplier may not be responsive. The order may be transferred to a secondary supplier because the primary supplier:
- Is out of stock (actual stock level)
- Inventory stock level (which takes into account material on order to be issued) is zero or less

- Transporter shipment queues are too long (due to high number of orders or relative shortage of transporters
- Becomes inactive or reduce capability (due to change in mission, threat or enemy action), or projected dispatch delays (due to mission, threat, or weather).

2.2.4 Accounting

Normally, there is one order management task in the order filling step.

2.2.4.1 Current Unfilled Orders

When orders are converted into shipment plans, the amounts in the Current Unfilled Orders table are reduced, to zero if the full order is met. If there is a residual order, either because vehicles were not available, or the supplier ran out of material, any new order amounts will be added to the residual amount.

If a material order is forwarded to a secondary supplier, then the amount in the Current Unfilled Orders table is transferred to the new supplier's accounting line.

3 SUMMARY

While there are many more techniques of assigning and filling of orders that can occur in tactical situations, TLoaDS models a good variety of methods for a simulation of the entire distribution cycle occurring for the entire tactical distribution network. Its ability to create shipment plans in response to a dynamic scenario with user allocated containex, handlers, transporters and load spots is rare or maybe unique for tactical logistics models. TLoaDS can evaluate many novel distribution tactics, techniques, and procedures that may better enable expeditionary maneuver warfare, Focused Logistics, and seabased logistics. Some algorithms could also apply to commercial supply chain modeling.

ACKNOWLEDGMENTS

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