Integrating Manufacturing and Supply Chain Simulation

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Introduction

Simulation Tools

Simulation Dynamics, Inc. (SDI) developed a suite of simulation tools, SDI Industry, using the Extend simulation platform. The integration of two of these tools, SDI Manufacturing and SDI Supply Chain, provide a case study in multi-level modeling integration with significant problem solving potential.

SDI Supply Chain

SDI Supply Chain models the network of suppliers, warehouses, and shipping channels which provides materials to a production plant. It provides a tool for measuring supply chain performance under a variety of demand schedules and logistic parameters. Performance is measured in terms of total product cost, cash-in-system, time in system, and reliability.

SDI Manufacturing

SDI Manufacturing simulates the movement of materials through a production operation under the control of a production schedule. Material in the model may be represented as discrete items, as flow, or as a combination of the two. The model may incorporate a scheduler which converts a pattern of demand for finished productions into a detailed production schedule. Production models are built to study a wide range of production issues from schedule optimization, throughput improvement, to the impact of changes in in-process inventories.

SDI Data

Both SDI Supply Chain and SDI Manufacturing utilize the SDI data tool and its Excel interface. SDI Data is a fully functional relational database implemented in Extend. It allows the integration of data inputs and outputs, as well as communication between the two models.

Advisability of Vertical Model Integration

Although industrial processes can clearly be modeled at different levels of detail, from chemical reactions to global trade, vertically integrating models is often viewed as fools gold, with time management alone trapping the modeller at one scale or another. Certainly, to try to model activity uniformly at the manufacturing level and at the supply chain level could bring a model to its knees, we have found that integrating a single production plant with its supply chain can provide essential information about their interaction that modeling either system without the other cannot provide.

The Supply Chain simulator currently represents production at the plant by a production schedule generated by a separate production model. To study the impact on supply chain performance of alternative production parameters, the production model has to be re-run to produce a new schedule which would be fed into the Supply Chain simulator. This not a practical approach.

Likewise, the production model may be impacted by supply chain behavior. Some plants rely on zero out-of-product performance while others accommodate short supply delays by making schedule adjustments. Production models can only crudely model supply delays as random events.

Integrating supply chain and production models will allow events in each model to affect the other, with the chain of cause and effect rippling through both models.

Supply Chain Model

Materials

Specification of Materials

All materials in the model, from raw materials to finished goods, are specified in a materials table. For each material the units per pallet must be specified. Cost per pallet is used to give value to all inventories which begin a model run with a quantity greater than 0. During the model run, inventory values are calculated on the basis of the accumulated cost of the materials delivered to them.

Bill of Materials

The Bill of Materials table specifies the parts of materials assembled in the model.

For each material to be assembled, a formula is specified. The formulation is given in a separate table. The remaining fields specify the packaging components required for this material.

How Assembly is Handled in the Model

Formulations

The *Formulas* Table - Each unique formula must be named in the *Formulas* table. This provides a list of formula names which can be referred to by the *SKU BOM* and *Formulations* tables.

The *Formulations* Table - The *Formulations* table has one entry for each chemical contained in each formula. Each formula will, therefore, have a number of entries equal to the number of chemicals in it. The *Percent* field specifies the Kg of chemical per kg of SKU.

Warehouses

All locations where material can be stored are defined as warehouses. Movement of materials from one warehouse to another happens through "Links" (. The Warehouses table describes the properties of warehouses in the model. Each warehouse contains inventories of materials. These are specified in the inventories table. The costs of receiving, storing and shipping materials are specified in this table.

RECEIVING COST: Cost per pallet when material arrives.

PALLET CHARGE: Storage cost per pallet per day.

FIXED OVERHEAD: Daily charge divided among all pallets in storage that day.

SHIPPING COST: Cost to load each pallet. Does not include the transportation cost.

STORAGE COST: Sum of Pallet Charge and Fixed Overhead for each pallet. This is calculated each day by the model.

Links

The Links table describes the properties of the transportation links which move materials from one warehouse to another. Each record in the Links table specifies the "From" and "To" warehouses, and the pattern of pickups. The frequency of pickup and trip duration are specified form each link in days.

Shipments

Shipments between warehouses occur once per day. Pickups are at 4:00 pm and deliveries are at 8:00 am. All order processing within warehouses occurs at mid day.

Inventories

All material in the Supply Chain model is located in inventories. A single table in the database specifies all inventory parameters. This includes all information necessary for ordering, receiving, inventory management, production and filling orders.

PLACING ORDERS:

Orders are placed at an inventory when the inventory level goes below the specified buffer level.

SOURCE: Specifies the warehouse which will fill the order.

ON ORDER: Current unfilled order amount. This is reduced when materials are received.

MINIMUM ORDER: Orders are placed in increments of this amount.

BUFFER: When the inventory level goes below this amount, order is placed to bring it to or above this amount.

RECEIVING

REJECTION RATE: The probability that all or part of a delivery will be rejected.

REJECTION AMOUNT: The percent of a delivery which is rejected when there is a rejection.

INVENTORY MANAGEMENT

INVENTORY: The amount currently in inventory.

STARTING INVENTORY: User specified amount in inventory at the start of the simulation run.

PRODUCTION

ASSEMBLED: The user specifies a “1” in this column to indicate that this material is assembled at this warehouse. The model will change this number each run to the row in the BOM (Bill of Materials) table which is the first part assembled into this material.

FIXED COST: For assembled materials, this is a fixed charge amortized over all of THIS material assembled on each day. For other materials, this charge is amortized over all of

THIS material shipped on each day.

VARIABLE COST: This is a cost per pallet applied to assembled materials when they are assembled and other materials when they are shipped.

PROD. CYCLE: Materials which are scheduled in the Schedule table may be produced on a production cycle. When a value other than 0 appears in this field, say 7, the daily production specified in the first 7 days of the schedule for this material is repeated on a 7 day cycle.

PROD. DELAY: This is the time between the filling of an order and the availability of the material for shipping. During this period, the material is added to the IN PRODUCTION field.

FILLING ORDERS

STANDING ORDER: If a standing order amount is specified by the user, the Order to Fill amount is brought up to this level each day. This allows a warehouse to “push” material through without orders being placed from another warehouse.

ORDER TO FILL: This field receives order amounts from the ordering process of another warehouse which names this warehouse as its supplier. If orders are received in addition to a standing order, it is added to the standing order.

READY TO SHIP: When orders are filled, the material is moved to the Ready To Ship area. The amount is added tot he amount in this field. (See Prod. Delay above.)

DESTINATION: A destination can be specified for each inventory which will insure that that material will be shipped only to the specified destination. Otherwise, the material will be shipped through the next link which has a pickup.

PICKUPS: When a pickup occurs, all material ready to ship which does not have a different destination specified will be shipped. If there is not sufficient capacity in the link, a prorated amount of each material will be shipped.

Schedules

Current Approach

Consumption Tables

Schedules are currently imported into the model in Consumption tables. These are generated by the Skin Care production model. For each production day, the Plant, SKU, date and quantity in cases are specified. At the beginning of a run, all consumption tables are merged into the Schedule table and sorted by SKU and date.

Repeating Schedules

A production cycle can be specified by specifying a cycle period for any material in the Inventories table.

Randomness

The quantity field can now be specified as a random distribution using SDI's distribution specification format.

Potential Modifications

Cycles

The production cycle could be a field in a Demand (consumption) table in order to allow different cycles for different SKUs.

Seasonality

A seasonality field in the demand table would allow for the application of a seasonal demand factor from a specified seasonality table. This would be similar to the seasonality structure in the Skin Care production model .

Randomness

Specification of quantity as a random distribution would continue to be an option.

Schedule Generation

At the beginning of each simulation run, a firm schedule would be generated by the model, based on cycles, seasonal factors and randomness.

Custom Schedule Formats

Schedule formats, such as the schedule matrix used in the Paper model would require a translator if the schedule is to be read into the Supply Chain simulator. Several alternative schedule formats, such as the matrix, could be developed as standards within the Supply Chain.

Project Baseline

Schedule generator as described in A through D willt be developed. Custom formats will not be developed.

Supply Chain Performance

Cost

All materials which begin a simulation run with inventories quantities (generally at supplier locations) have a cost specified in the materials table. As materials move through the model, they accumulate production, storage, handling and shipping costs. All of these costs have fixed and variation components. When materials are assembled into another material, the costs of the parts are added together. The cost of money is also calculated as a function of the time that a material is in the supply chain.

When the run is done, an overall average cost per case is calculated for finished goods.

Cash

Cash tied up in the supply chain is of vital interest to many manufacturers. The cash in the system is calculated continuously during each simulation run and an average is determined at the end of the run.

Time-In-System

The time-in-system is calculated for each material from the time it leaves the suppliers raw materials inventory to the time it arrives at the customer. Time-in-system for assembled materials is determined an average of the time-in-system of its parts, weighted by their cost contribution.

Reliability

There are several approaches to measuring reliability in the supply chain. The simplest is percent of orders filled on time. Alternatives include percent of time that buffers are at or above a specified minimum.

Manufacturing Models

Materials

Materials flowing through manufacturing models may be best represented by items, as with automobiles, with rates of flow, as with chemical processing, or with a combination of the two as with a product which is handled in batches at one stage and as continuous flow in another. SDI Manufacturing encompasses compatible tools for both of these approaches.

Time Management

All models built within SDI Manufacturing utilize the Extend discrete event clock. A variety of blocks within the model are able to post events which are managed by the clock.

Schedules

Schedules may be structured in a variety of ways, either utilizing standard schedule formats and schedule reader blocks, to custom schedule managers which interpret demand patterns and create detailed production and packaging schedules.

Integration

Schedule Integration

The Demand Schedule

Production models vary in the way that the production schedule is generated. At some level, there must be a schedule 'given' to the model as an independent variable. The demand schedule is, by definition, defined independent of the model. It can be the basis on which the more detailed schedules are derived which control production operations. The demand schedule can be as broad as annual demand for each SKU, or as specific as the actual production schedule which will control production at the plant.

Production Schedule/Demand Schedule Relationship

There are several ways in which the production schedule can be derived from the demand schedule.

Production Schedule = Demand Schedule

In the current Supply Chain model, the production schedule is brought into the model from the outside. It is actually generated by a separate plant model. This schedule specifies what is actually made on each day at the plant.

Demand Schedule Depletes Inventories

In the Lima HDL model, a demand schedule removes a specified amount of each brand from finished goods inventory each day. The production model creates a schedule at the beginning of each day based on the inventory levels at the end of the prior day. This could be implemented in the integrated model by having a demand schedule brought into the Supply Chain and having the Production model check finished goods inventory levels each day and create its production schedule. In this approach, it is not necessary for the production scheduler to access the demand schedule directly. It looks at inventory levels which are the consequence of product taken according to the demand schedule.

Forecasting

The production model may create its production schedule by looking beyond current inventory levels at future demand. Forecasting amounts to looking ahead in a demand schedule to determine the quantity of each SKU which will be required over some future time interval. This is currently done within production models, such as the Paper model, by inspecting a demand schedule.

To implement forecasting in an integrated model one of two approaches must be taken.

Demand Schedule in Supply Chain

If the demand schedule which enables the forecast is in the Supply Chain model, the production model must be able to inspect the demand schedule. This suggests that a set of functions be developed for this purpose. (See interface functions below.) Alternatively, code could be written in the production scheduler which itnspects the Demand Schedule directly.

Demand Schedule in the Production Model

The demand schedule could be retained in the production model. With this approach, the production model becomes the engine which drives the supply chain. The weakness of the approach is that the inventories being depleted by the demand schedule would have to be modeled inside the production model, not in the supply chain. This would undermine the goal of tracking cash, cost, reliability and time in system in the supply chain framework.

Interface Functions

Manufacturing models will communicate with their “Host” supply chain through a set of interface functions. These are built into several standard interface blocks and are available for use in custom blocks. These functions can check on inventory status, fill an order, return completed products to inventory, or report on wastage.

Conclusions

Simulation Dynamics, Inc., Maryville, Tennessee, February 1997. A case study in multi-level modelling: integrating SDI Manufacturing with SDI Supply Chain. Title supplied; the source document is untitled.