Proceedings of the 2003 Winter Simulation Conference
S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds.

INITIALIZING A DISTRIBUTION SUPPLY CHAIN SIMULATION WITH LIVE DATA

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ABSTRACT

This paper describes VinLogic, a simulation of a supply chain network for the distribution of new automobiles. The model is implemented in Simulation Dynamic's Supply Chain Builder product. One of the key features of the model is its integration with a database containing the status of all vehicle shipments--VinVision. The information in the database is used to distribute vehicles and resources through the network at model start, and the model can then be used to project forward from the current situation. The model is thus able to have a "warm start," and does not require the warm-up period necessary in simulation models that start with the system empty and idle.

1 INTRODUCTION

Simulation models used to evaluate the performance of existing or new supply-chains tend to be non-terminating. Effects of transient conditions in the output data are commonly addressed by conducting long simulation runs, so that any initial conditions have only a miniscule effect on the long-run value of the performance measure.

An alternative way to deal with the effects of initial conditions is to prime the simulation by appropriately placing flow entities in the model at startup (Banks 1998). For a large supply-chain this can be a non-trivial matter.

2 BACKGROUND

Insight Network Logistics (INL), a subsidiary of Union Pacific Corporation, is a third–party logistics provider (3PL). DaimlerChrysler has assigned INL the task of tracking Chrysler Group (DCC) vehicle shipments from assembly plants to dealers across North America. The goal is to drastically reduce the order-to-delivery times of DCC vehicles by increasing network efficiencies across the automaker's distribution chain in the United States, Canada, and Mexico. INL makes extensive use of technology, including the VinVision vehicle shipment information system (Insight Network Logistics 2001) and the VinLogic simulation model to help achieve this goal.

2.1 The Distribution Network

The DCC distribution network consists of about 16 assembly plants, 18 rail loading facilities, 60+ rail unloading facilities, 10 ports, and approximately 3500 dealers (aggregated into about 60 dealer service areas). At the time the model was built, roughly 2.5 million vehicles moved through the network annually.

Vehicles are transported from the assembly plants to dealers using trucks or a combination of trucks and rail. The basic vehicle flow process is described below and shown in Figure 1. Vehicles roll off the assembly plant and are stored at or near the plant. Dealers within a couple of hundred miles are served by truck. Vehicles for other dealers are moved to rail loading-ramps, possibly on shuttle trucks. There they are combined into loads bound for the same destination and await a rail car. The vehicle's size determines which rail car they can fit on. The loaded railcars are then moved to a destination rail ramp. This journey may involve an interchange between more than one railroad. At the destination ramp the vehicles are unloaded from the railcars and parked in the ramp facility. Haulaway trucks then build loads for transport to dealers. Of course,

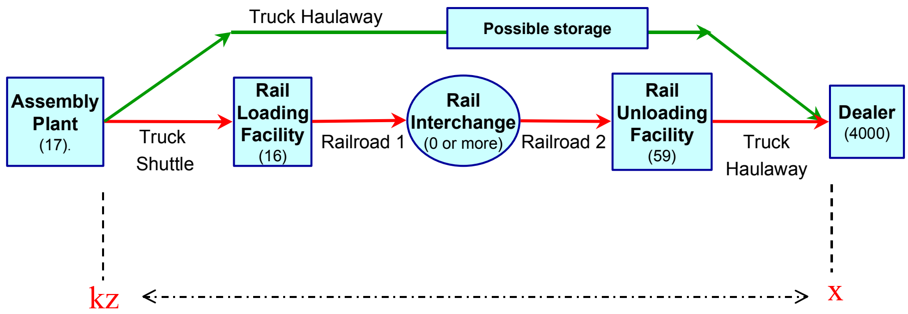

Figure 1: Vehicle Flow Process

several variations of these basic moves are possible (and do regularly happen!)

3 VINLOGIC SOFTWARE ARCHITECTURE

VinLogic is designed to predict future network performance and status. This includes transit times; railcar, truck and facility utilization; bottlenecks, etc. The model is used by INL's Network Design and Engineering team to make decisions on how to react to anomalous events by estimating their impact and corresponding management actions.

As shown in Figure 2, VinLogic is implemented in a supply chain simulation software called Supply Chain Builder (SCB) (Phelps, Parsons, and Siprelle 2001) from Simulation Dynamics, Inc. (SDI). SCB is an extension of Extend, a general purpose simulation package (Krahl 2001). The VinLogic model, designed and developed by the INL/SDI team, provides an integrated tool suited to predicting vehicle distribution network behaviors.

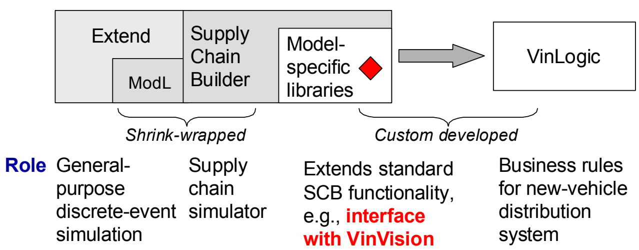

Figure 2: VinLogic Software Architecture

4 VINLOGIC MODEL OVERVIEW

The vehicle distribution model is a variation on the classic "Push" supply chain model. Vehicles are pushed from the plant through the model to dealer service areas based on plant production rates determined by the customer. The ordering of trucks and rail car resources to support the distribution is based on a "Pull" system driven from the demand created by the vehicle production and stock policies for resources.

4.1 Production Modeling

The VinLogic model utilizes weekly production plan from DCC as a basis for deriving daily production at each of the production plants. The plan specifies the number of vehicles to be produced each week. The model establishes the number of production days per week required to meet the schedule by comparing that with the daily production rates for each of the production lines.

4.2 Demand Modeling

Historical demand patterns and marketing assessments are the basis for these inputs. Demand at the dealer service areas is calculated by developing an average daily demand for each vehicle type at each dealer service area. The model applies a demand projection factor to this base demand to determine the demand for the vehicle type at any time during the model run. This demand projection factor is time-based and vehicle specific.

4.3 Loading Restrictions

The loading of railcars and trucks significantly affect the performance of the system. The model accurately reflects loading factors (vehicles per railcar or truck) and the loading rates for each conveyance (railcars or trucks per day). Load factors are derived by how many of each vehicle type fit on each conveyance. The model uses holiday calendars and shift schedules to limit when vehicles can be loaded.

The DCC network uses multiple railcar types with varying capacities. Since some sites handle multiple rail car types and some rail routes have vertical clearance issues, the model includes preferential rail car loading based upon the origin, destination, and shipment volumes. Vehicle height restrictions are enforced for loading railcars.

Trucks are classified as shuttle or haulaway. Shuttle trucks handle plant to rail loading facility moves and moves to remote storage lots. Haulaway trucks handle vehicles shipments from plants, destination rail ramps, and remote lots directly to the customer.

4.4 Resource Management

Resources, in the system and the model, place major constraints on the throughput of vehicles. Trucks, rail cars, vehicle parking spaces, and rail yard capacities are all restricted in the model to accurately reflect these real world factors. Shuttle trucks are maintained in pools assigned to the production plant. Haulaway trucks and rail cars are ordered from specific limited carrier pools whose size is determined by an annual industry-wide fleet sizing process (TTX/Reload). Production quantity and the empty return time drive the ordering of haulaway trucks and railcars.

The scarcity of vehicle parking spaces has a significant impact on vehicle movement through the system. The model constrains vehicle spaces at the production plants, rail loading facility and destination ramps. If vehicle spaces are running short at the plants or rail loading facilities, vehicles are shipped to storage at temporary remote parking lots. The model treats these lot sizes as unlimited since local logisticians can procure temporary parking to meet spikes in demand. Vehicles are routed to and from these remote lots by haulaway truck directly to dealer service areas or to rail loading facilities. At destination ramps, railcar unloading is halted if vehicle spaces are all full.

Railcar spaces (spot size) are limited at rail loading facilities and destination ramps. The rail networks will back up if the destination ramps become bottlenecks.

4.5 Vehicle Holds and Releases

In vehicle distribution networks, vehicle-shipping holds cause major perturbations. The holds are caused by a number of factors such as: marketing (new model year rollouts, new product rollouts and sales promotions), product quality (major quality issues or statistical quality diversions), or strategic (inventory build up preceding a planned shutdown). The model includes the ability to have planned holds that have a start date, end date, hold duration, and production hold quantity. The planned hold vehicles can be released en-mass or at a daily rate to prevent flooding the system with vehicles of one specific type. Another type of hold implemented in the model is the statistical quality hold which can be specified as affecting a certain percentage of production with a stochastic hold duration.

4.6 Routing Logic and Calendar Variation

The model uses routing information extracted from the VinVision system to establish supply chain routings between plants and dealer service areas. This raw data is translated into model routing using custom logic to filter extraneous information and report route file errors. It is crucial to note that since the route is defined in the model database, no changes to model structure are required when routes change. The model includes calendar-based variations in trip time along any rail leg in supply chain. Temporary or seasonal route segment replacements can also be scheduled should a rail leg be closed for maintenance or weather.

4.7 Model Outputs and Reporting

Custom reports built into the VinLogic model include these four focus points: bottleneck reports, throughput rates, transportation time, and transportation resource utilization.

During the model run, bottleneck reports are generated to identify choke-points as they emerge. Thresholds are defined to provide a filter mechanism, which differentiates between non-critical and critical network delivery issues that may require special effort to normalize.

The model also provides estimated daily throughput reports for all plant lots, rail loading facilities, and destination ramps. These figures are reported by shipment mode (rail route or truck route) and conveyance type (railcar type, truck, or vessel). This detail is crucial when evaluating different containment release strategies and supply chain design changes.

Transportation time between the plant and dealer service area is tracked on a daily basis along with canned reports that provide a segmental breakout of all routes in order to assess the feasibility of routing adjustments. The model also provides a daily snapshot of where the vehicles are in the pipeline to quickly identify inventory surges.

Lastly, VinLogic reports the number and location of each resource type throughout the simulated network.

5 MODES OF OPERATION

The model is used for planning with two distinct planning horizons: strategic and tactical. In this context, strategic planning deals with a three to twelve month window, and tactical planning refers to looking out one to four weeks.

Longer range planning involves predicting the effects of sales promotions, or of holding vehicles to build up inventory for a product launch. The impact of closing or relocating rail facilities can also be studied in terms of net impact to overall time in the network.

Planning for the near future includes answering questions of carriers and facility operators (such as "What's coming at me?" and "When will it get here?") by projecting future volumes and expected times of arrival.

The VinLogic model is designed to work in two modes, "cold-start" or "warm-start," corresponding to these planning horizons. For strategic planning, the traditional, or "cold-start", mode is used. The model begins with no production at plants, and no vehicles at facilities or in transit. All resources, e.g., trucks and parking bays—are idle and available. Vehicles may flow faster initially, as resources are readily available and there is no congestion. This is accounted for in the analysis by using a warm-up period during which performance metrics are not retained.

The cold-start method, appropriate for strategic planning, does not work as well for shorter-horizon tactical planning. In this case, it is better to initialize the model to the current system status and then project forward from the current situation. In the "warm-start" mode vehicles are at facilities or in transit on railcars and trucks at simulation start. As a result, the network starts at a "normal" pace. Warm-start allows a more accurate short-term analysis.

5.1 Warm-Start

This second mode presents additional requirements in model design as well as data. A mechanism is needed that will insert vehicles into inventories of facilities, or into railcar and truck loads at model start up.

Data, however, is the key to implementing the model initialization. We must know where each vehicle is located so that we can appropriately place it at the beginning of the model run. This is no simple task given the number of vehicles, plants, carriers, facility operators, and just the sheer geographical spread of the distribution network. Fortunately, such data is available and retrievable for use in the model through VinVision, INL's vehicle shipment information system, which maintains a vast database of vehicles from the time of planned production to dealer delivery. VinVision receives and processes EDI transaction messages from all parties handling vehicles and uses the information in the messages to update the location and status of individual vehicles.

In addition to being able to place initial vehicles in the network at the start of the model run, we must also provide vehicle data that compares to the data available on vehicles produced during the model run, e.g., time of manufacture.

6 PROCESS OF MODEL INITIALIZATION

Importing vehicle and railcar data from VinVision is a two-step process. First, raw vehicle and railcar data are extracted from the database to an appropriately formatted text file. Next, the vehicles and railcars are imported from the text file into the model.

A software utility was written to extract the data from VinVision for open vehicle records, i.e., those without a status of delivered. The extract process can run for as much as a half hour, depending on the volume of vehicle, railcar, and truck records active at that time. So, a feature was included in the utility that allows the user to specify a time when it will automatically run each day—typically, just before the start of the business day.

The process of importing the vehicle, railcar and truck records into the model is performed by a custom SCB database plug-in. The process must be initiated manually. Figure 3 is an example of a dialog box displayed at the end of the import process. It indicates the level of success in placing the vehicles in the network represented in the model.

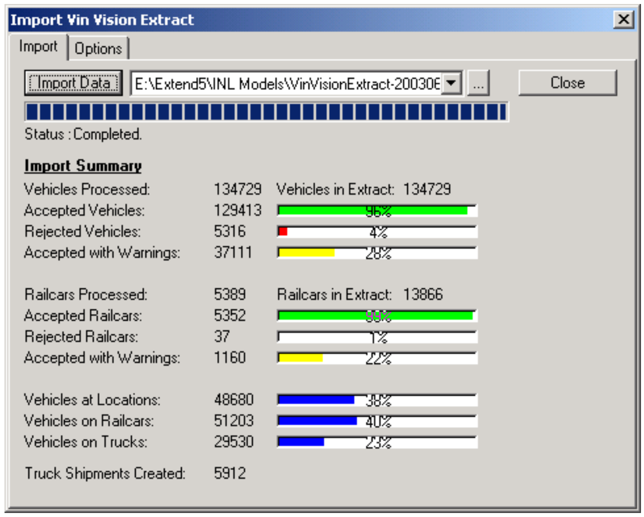

Figure 3: Importing Vehicle Records into Model

7 PROBLEMS OF MODEL INITIALIZATION

Several problems can arise during the importing phase of the initialization process. Usually they are because of incomplete, incorrect or inconsistent data in VinVision (arising from erroneous or tardy field reporting).

The simulation model needs to know, for the imported vehicles, what the next event is and when it is scheduled to occur. In order to predict the time of the next event for each vehicle in the network, three data points are imperative: the location of the vehicle, the next event, and the time of the last event.

The problems that arise, from not correctly knowing these pieces of data, may be classified as:

1. *Current state is not reasonable*, e.g., plant release timestamp was long ago but the vehicle is still not delivered. Another example is when a vehicle's stated current route segment does not match predefined vehicle routes (this can occur because the vehicle was forced to travel on a non-standard route due to a weather condition).
2. *Projected state is not reasonable*, e.g., the projected arrival time of a railcar at its next point is earlier than the time the extract was taken. This can be a consequence of untimely EDI reporting.
3. *Performance statistics are in doubt*. Sometimes the current location and state of the vehicle are known but the time of the last event is unknown. This can be because an event was not reported by a carrier or facility. It is important to know this time in order to calculate the duration in the last state, e.g., dwell, for end-of-run reporting as well as for possible use in dispatching decisions. In this case the last event time must be estimated from other information.

The heuristics within the model database import plug-in "groom" the VinVision data, providing both a solid set of initial shipment records and import record variance reports. The flexibility and robustness of this system is crucial, given the millions of data records it must process.

8 COMPARISON OF OUTPUTS FROM TWO START-UP MODES

The graphs in Figures 4 and 5 show average transit time without and with model initialization respectively. The thicker line toward the top of the graph is the inventory of vehicles in the network (and is read on the Y axis to the left). The thin line near the bottom of the graph is the average transit—or kz-x—time (and is read on the Y-axis to the right). Notice that in Figure 4 the average transit time gradually increases over the first week or so. This is mostly as a result of easy availability of resources due to "cold-start".

In contrast, the average transit time in Figure 5 starts high, at about the normal or long term mean value. The start up effect is much shorter (3-5 days) for most performance measures. This is particularly impressive, given that in this model the first three days are used to populate the plant vehicle pipeline and no other model activity occurs. The model start date is set by starting with the VinVision extract date and backing it up three days to fill the plants' pipelines. Thus, the actual startup effect is on the order of 1-2 days for most performance measures.

Figure 4: Performance of Simulation Model Without Model Initialization

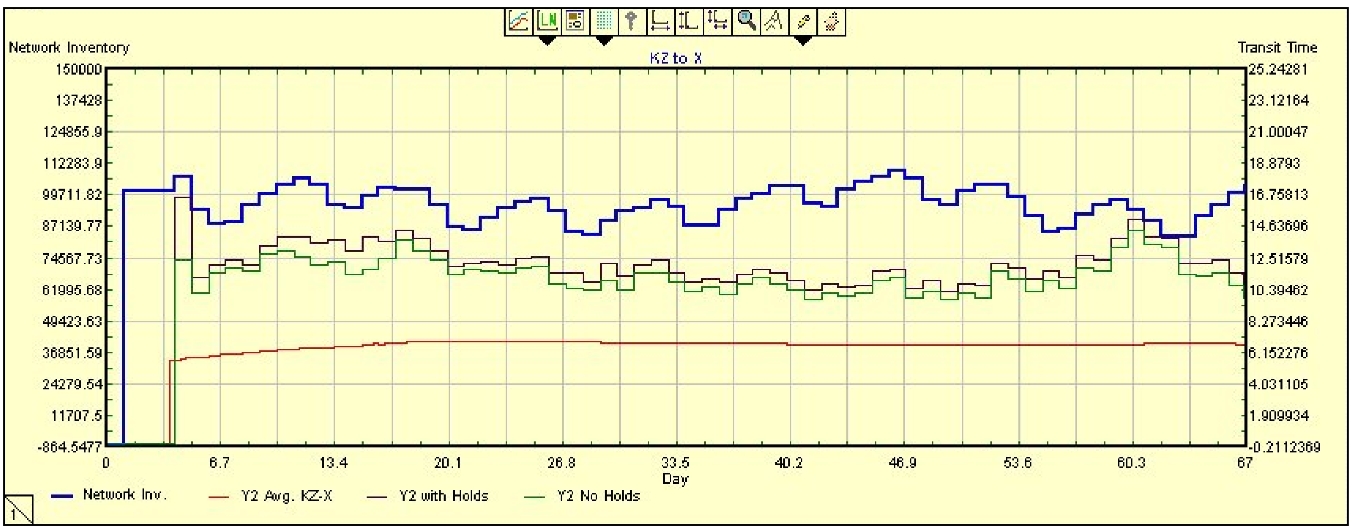

Figure 5: Performance of Simulation Model With Model Initialization

9 CONCLUSION

We provided an overview of a successful integration between a supply chain simulation model (VinLogic) and a vehicle shipment information system (VinVision). This integration allows the simulation model to be initialized with vehicle inventory in the network. Model initialization enables the model to be used not just for measuring performance over the length of the run, such as average transit time, but also to obtain a snapshot of the system as some time in the near future. Improvements in the timeliness of event reporting to VinVision will have a significant impact on the ability to make accurate projections.

ACKOWLEDGMENTS

The authors wish to acknowledge the contributions of the following members of the VinLogic development team: Larry Jensen, Scott Fee, Amber Clay, Dave Parsons, and Andy Siprelle.

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