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INVENTORY MANAGEMENT SIMULATIONS AT CAT LOGISTICS

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ABSTRACT

Simulation is used extensively by Caterpillar Logistics Services, Inc. (Cat Logistics) to determine an appropriate strategy for achieving clients' inventory and customer service goals. Internally developed inventory management simulations, at the transaction and SKU level, help both to develop inventory / service strategies for potential clients and to determine the effect of a change in strategy for existing clients. Inventory management continues to be a significant contributor to the success of Cat Logistics. It is one service that distinguishes Cat Logistics from all other third party logistics providers; a distinction made possible, in large part, by Cat Logistics simulation technology.

1 INTRODUCTION

Cat Logistics employs a closed loop philosophy to ensure inventory and service targets are met. On an ongoing basis, inventory managers execute and monitor the strategy determined through simulation (Figure 1).

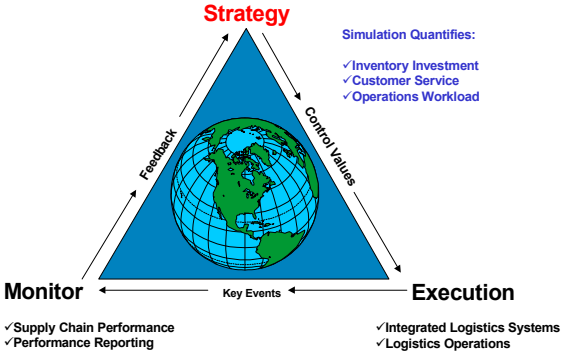

Figure 1: Cat Logistics Philosophy

1.1 Background

Caterpillar Logistics Services, Inc. <www.catlogistics.com> located near Peoria, Illinois, is a wholly owned subsidiary of Caterpillar Inc. <www.cat.com>, the world's foremost producer of earthmoving equipment and engines. Formed in 1987 to meet the global logistics needs of industry leading manufacturers and distributors, Cat Logistics is a natural outgrowth of Caterpillar's expertise in the international distribution of replacement parts. Since inception, Cat Logistics' sales have grown at an average annual rate of 31%. Its clients include DaimlerChrysler, Honeywell, Saab, Mitsubishi Caterpillar Forklift, Rover, Ericsson, and over 20 others.

As an integrated logistics provider, Cat Logistics distinguishes itself from traditional providers by offering a comprehensive package of services. These services include distribution, logistics information services, transportation, inventory, and supply chain management, and related consulting services (Figure 2). Diverse experience in these areas enables Cat Logistics to develop value-added, integrated solutions for clients. These services handle the entire logistics supply chain - from concept and strategy to daily operations.

Figure 2: Cat Logistics Services

1.2 Focus

The focus of this paper is the use of simulation in one service that distinguishes Cat Logistics from all other logistics providers and which has been a major contributor to Cat Logistics' success; this service is inventory management.

Cat Logistics' inventory management uses proven technology and techniques to help clients anticipate and prepare for future parts requirements. Caterpillar pioneered many of these techniques and refined them over thirty years through day-to-day operations in Caterpillar distribution centers and throughout its dealer network. Caterpillar's parts distribution network is recognized around the globe for exceptional customer service for replacement parts. Through its network of national and regional distribution centers and dealers, Caterpillar provides high service levels to customers worldwide.

Cat Logistics' inventory management experts have concurrently enhanced the Caterpillar technology to serve clients in diverse industries and have achieved significant improvements in inventory turnover and item availability. Utilizing Cat Logistics' inventory management services, clients are able to transcend the traditional inventory investment / item availability trade-off.

1.3 Traditional versus Cat Logistics Approach

Traditionally, providing high levels of item availability / service to customers means boosting inventory investments. To avoid expensive stock out situations, many firms keep a large bank of inventory on hand to fill customer orders.

The Cat Logistics approach allows companies to step beyond traditional inventory management. Upon implementation of the initial strategies developed through simulation, clients realize improved customer service in the form of increased service levels while inventory investment and other distribution costs decrease.

1.4 Demonstrated Performance

With inventory sized to support demand**,** Cat Logistics clients typically achieve inventory reductions of 15% to 40%. In many cases, Cat Logistics gains extraordinary improvements for clients by using improved technology to reduce inventory while increasing fill rates. Table 1 shows a few examples of the results Cat Logistics has achieved for existing clients.

2 USE OF SIMULATION TECHNIQUES

To assist in achieving results such as those shown for clients in Table 1, inventory managers perform computer simulations based on actual demand histories (order lines and pieces) for each stock keeping unit (SKU).

2.1 Simulation Situations

Simulations are performed in two different situations. One of these situations is a consulting engagement or proposal development phase for potential clients (Figure 3). During this phase Cat Logistics acquires an understanding of the market and business goals from the client, and then designs the best network utilizing simulation / modeling tools.

Table 1: Proven Results

Client	Service [1] (Fill Rate)		Inventory Turns [2]	
	Before	After	Before	After
A	70%	93%	1.9	4.2
B	94%	98%	5.8	6.8
C	65%	95%	2.5	5.0
D	89%	94%	0.9	1.8
E	73%	93%	7.2	13.1

1 Service is the percentage of line items completely filled on the day the customer requests.

2 Inventory Turns is annual sales valued at cost divided by average working inventory valued at cost.

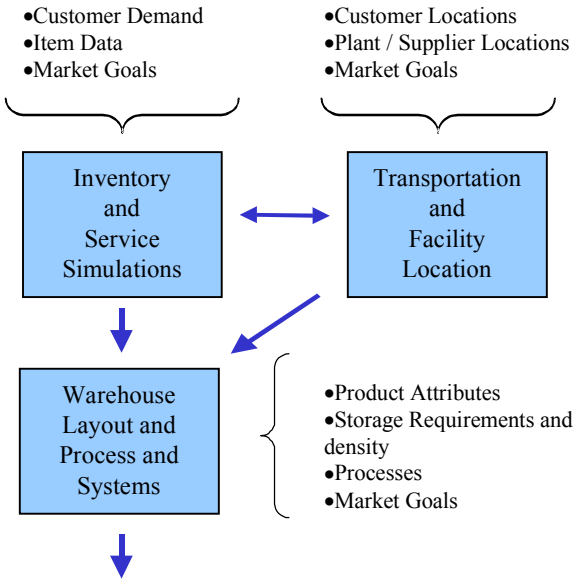

Figure 3: Network Planning \ Design

To achieve the "best" network solution, several iterations of inventory management simulations and facility size / site model studies may be necessary. During this phase Cat Logistics investigates such questions as how many warehouses should there be, what are the inventory / service tradeoffs, which stocking strategies should be employed and what will be their effect on inventory / service. In addition, simulations produce the maximum storage quantities for each item, which aid in facility sizing and planning. Finally, simulations will establish parameters necessary for Cat Logistics forecasting / inventory planning. This entire process of consulting or proposal development typically spans 3 to 6 months.

The second situation in which inventory simulations are performed is for ongoing client support. To ensure customer service and inventory objectives are being met, inventory managers support the client by monitoring performance in several ways, including:

- Using the online / real time backorder analysis Supply Chain Performance Management (SCPM) tool. SCPM identifies customer sales order lines not satisfied and determines specific reasons for the service losses, allowing inventory managers to take appropriate action on the areas of greatest concern.
- Reviewing key statistics regularly to determine if a change in the business environment has dictated a change in user parameters to achieve client goals.
- Reviewing operational reports that track inventory, purchase orders, demand forecasts and other statistics.

Through monitoring, inventory managers may propose strategy enhancements to the client. Additionally, the client may request changes to service strategies or may want to test the effects of proposed changes prior to installation. Examples of such changes include:

- Revising service targets
- Revising inventory targets
- Changing stocking policies
- Varying receipt volumes
- Introducing new products
- Increasing / decreasing the number or scope of warehouses
- Increasing / decreasing manufacturing / vendor lead times
- Changing minimum buy policies
- Changing costs.

Simulations allow inventory managers to evaluate results of these and other strategies prior to implementation, saving time and money. This ongoing support process typically spans 1 to 2 months and greatly reduces risks associated with change.

2.2 Simulation Models

For both simulation situations mentioned, 3 different inventory management computer-based simulation models are available. Each functions as a "what if " model rather than as an optimization model. All are written in FORTRAN with one model also in Access. The model used depends primarily on data available, fit of assumptions, and level of information / precision required.

2.2.1 Math Model

In the strictest sense, this model does not fully simulate the Cat Logistics system. It is used only if the client cannot provide transaction demand data, typically for a period of at least 12 months. This model requires only basic item information such as cost and vendor lead-time, plus a forecast for each item. The model generates estimates, based on theoretical mathematical calculations, for inventory, service and receipt levels for each item.

2.2.2 Single-Level Warehouse Simulator

This is an activity-based simulator for one warehouse that utilizes up to 24 months of warehouse demand transaction history for each item. The first 12 months of demand is used to determine initial forecast statistics (Figure 4). For the next 12 months, the simulator performs daily activities in response to each of the demand transactions. These activities include order filling / backordering, placing purchase orders, and receiving material. Forecasting and safety stock calculations are performed on a monthly basis for each of the 12 months. While this simulator is an obvious improvement over the Math Model, its ability to handle items with significantly variable order quantities was the main impetus behind its development. Significantly variable order quantities typically occur when there is both dealer and distributor demand at a warehouse. For example, for the same part, an order from a dealer may be for 4 pieces, while a distributor may order 2000 pieces. Output from this simulator includes inventory, service, receipts, schedules placed, backorders, and inventory turns for each month.

2.2.3 Multi-Level Network Simulator

This simulator is an activity-based network inventory simulator for multiple warehouses. Each month the model generates an appropriate forecast for each SKU based on the demand pattern detected that month (trend, seasonal, or random). Compound Poisson (a method considering two probability distributions, one for entries and one for pieces) and exponential smoothing forecasts are also available. This simulator includes all the features of the single warehouse simulator as well as network economic order quantity (EOQ) and safety stock, distribution requirements planning (DRP), push / pull deployment of material between warehouses, backorder search (referrals from other facilities) and stocking strategies. Output includes statistics for inventory, service, receipts, schedules placed, backorders, inventory turns, referrals, deployments, and stocking for each month, warehouse and in total.

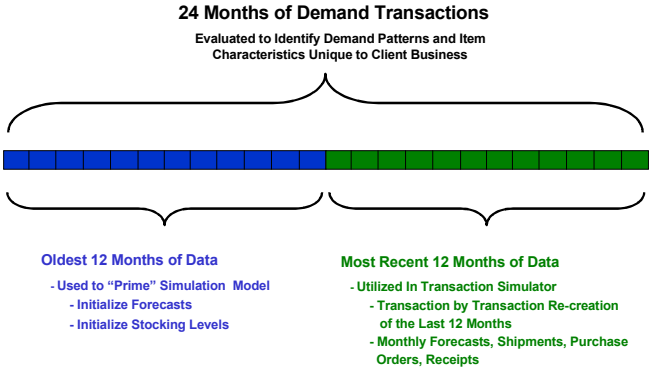

Figure 4: Transaction Timeline

2.3 Simulation Preparation

The first step in performing any simulation is to gather and purify client data, so that incomplete or inconsistent data is removed. Cat Logistics works with the client to ensure variables needed for input are understood and available. In many cases this is a time consuming, tedious process since clients often have difficulty providing information on all relevant SKUs. Demand history at the transaction level (order lines and pieces) for the full 24-36 months may be unavailable; costs or lead times may be missing for a significant number of SKUs. After receiving data, Cat Logistics generates a series of purification reports to summarize key aspects of the business. These reports show items excluded for lack of data and show entry / demand summaries by month, by forecasted entry categories, by forecast model, by lead-time categories, and by cost categories. Each report includes number of items, entries, demand and demand dollars. The purification step can consume a significant portion of the entire simulation process. Reports are always verified with the client to ensure purified data is representative of the business. Tables 2 and 3 are examples of purification reports.

The second step involves documenting simulation assumptions so that each assumption may be discussed and verified with the client. Examples are:

- Lead times are accurate and constant.
- Frequency of forecasting, replenishment and deployment are given.
- Length of the period required to expedite material is established.
- EOQ parameters (smallest and largest EOQ to consider) are agreed upon.
- Replenishment travel time between warehouses is determined.
- Search sequence for backorders is agreed upon.
- Warehouse deployment priorities are established.
- Service or fill calculations are based on complete lines filled (no partial fills).

Table 2: Data Purification - Data Exclusion Summary

Entries	# of Items	%	Entries (1,000s)	%	Sales ($M)	%
1	28,679	45.4	28.7	7.7	11.2	12.8
2	11,396	63.5	22.8	13.9	8.4	22.4
3	5,621	72.4	16.9	18.5	12.1	36.2
4 - 6	7,329	84.0	34.7	27.8	18.4	57.1
7 - 12	4,732	91.5	41.9	39.2	15.5	74.8
13 - 24	2,653	95.7	46.6	51.8	8.4	84.3
25 - 49	1,477	98.0	50.7	65.4	6.9	92.3
50 - 99	812	99.3	56.4	80.7	4.4	97.2
100 - 499	441	100.0	71.4	100.0	2.4	100.0
	63,140		370.1		87.7	

Items are slow moving, over 84% of items have 6 or fewer entries annually.

Table 3: Data Purification - Annual Entry Summary

	SKU's*	Lines	Pieces	Demand (COGS)*	On Hand
Beginning Total	714,784		88,409,600	$640,417,461	$60,304,805
Items without demand during last 36 months	456,954	0	0	$0	$12,393,373
Items with demand but no item master	28,370	45,030	1,064,906	$0	$0
Items with demand but no standard cost	1,027	22,006	487,722	$0	$0
Items with demand but no longer available for sale	22,799	204,743	2,746,361	$19,141,362	$107,732
Items shipped direct to dealers (oil)	125	6,982	16,621	$5,843,529	$42,702
Scrap and cycle count transactions	Not mutually exclusive	39,474	1,958,451	$3,232,920	Not mutually exclusive
Canadian replenishments	Not mutually exclusive	237,470	3,401,702	$23,497,831	Not mutually exclusive
U.S. replenishments	Not mutually exclusive	447,177	20,136,453	$116,034,878	Not mutually exclusive
Discount and taxes transactions	590	371,903	2,187,285	$0	$0
Publications and manuals	7,924	195,092	6,627,732	$2,026,319	$150,673
Input to Analysis (3 years)	191,336	10,976,639	49,782,367	$470,640,621	$47,269,705
Demand during months 13-36	0	7,269,252	33,315,407	$319,192,627	$0
Items without demand during last 12 months	39,568	0	0	0	$2,588,880
Input to Simulation (1 year)	151,768	3,707,387	16,466,960	$151,447,994	$44,680,825

The third step involves file preparation for simulation input. For the network simulator necessary files include a master, transaction, and forecast files.

2.4 Simulation Iterations

Once the above steps have been completed, simulation runs can begin. Due to the large volume of SKUs (sometimes 400K - 500K) and number of transactions in a year (sometimes 60 million or more), running the simulator may require significant computer resources. It is generally advisable to begin with a 15-20% sample of items, altering service parameters, inventory "dials", stocking decisions, etc. until desired service levels are reached. Once this is completed, the simulator is run for the entire network of items. If possible, a base case representing the current system is run using the client's past 12 monthly forecasts

and order policies. This depends on whether the client is able to provide forecast statistics for the last 12 months, ordering policies, etc. Examples of many different forecasting / ordering scenarios that might be simulated for a client using Cat Logistics technology include:

- Various distribution networks (3 independent warehouses versus 1 master and 2 satellites)
- Stocking strategies
- Client policies (emergency reserves, minimum buys)
- Vendor lead time changes
- Different forecast methods (Compound Poisson versus exponential smoothing)
- Search sequence changes
- Deployment changes
- DRP changes.

Inventory managers confer with the client ahead of time and reach agreement on which scenarios are most important to simulate. After presenting results to the client for review, other simulation scenarios may be investigated.

2.5 Simulation Outputs

Each simulation output is shown by warehouse, by system, by month and in total. Reports include the number of items stocked, sales, lines processed, warehouse facing and warehouse search fill percent, referral lines filled, initial, average, and ending inventory, inventory turns, DRP schedule values, vendor receipts, and push / pull deployments. Although initial inventory, open purchase orders, and forecasts are set as accurately as possible at the beginning of simulation, it frequently takes the first six months for the simulation to achieve a steady-state environment regarding inventory and open purchase orders. As a result, in reviewing output, the last six months of the simulation period is often given greater consideration than the first six months. Another comment concerning simulation output is that exact simulation results are often adjusted to reflect the real world. Based upon client experience, a judgment will be made as to how well assumptions of the simulation fit the actual situation. If possible, a "base case" simulation is run using the client's current strategy to validate simulation results with reality. Then, simulation results are adjusted accordingly. A common adjustment is for poor vendor performance. The simulator assumes all shipments arrive within lead-time and there is no vendor delay. If, in fact, an average vendor delay is known, facing fill percentage at a warehouse will be adjusted to reflect the historical delay.

In addition to output reports, there is also an output file by SKU with all pertinent forecast statistics, ordering levels, peak on hand, number of total transactions, number filled by facing facility, and number filled by referrals. Cat Logistics' Planning group uses this output file to size new facilities or resize existing facilities.

2.6 Simulation Approval Process

All simulations undergo a formal simulation approval process before results are communicated to the client. The process involves an internal inventory management review, a commercial client manager review, and a simulation book (Tables 4 and 5 show sample results shared with the client). Simulation results and recommendations are shared with the client and results that best fit with the client's strategy are chosen. Occasionally, additional simulations are requested to evaluate further refined scenarios before a final decision is reached. Finally, Cat Logistics incorporates the simulation parameters into a production system.

Table 4: Simulation Results – Reduction in Number of Warehouses

Network Strategies

CURRENT	SKU's	ORDER LINES	AVERAGE INVENTORY	RECEIPTS	STOCK SERVICE	TURNS
Warehouse #1	85,663	1,478,194	$22.87M	351,961	96.34%	2.53
Warehouse #2	65,882	659,020	$5.21M	229,475	95.35%	4.95
Warehouse #3	53,304	413,332	$3.58M	169,395	93.12%	4.52
Warehouse #4	39,185	285,698	$2.64M	102,838	93.23%	4.23
Warehouse #5	41,300	289,545	$2.56M	127,948	94.24%	4.43
Warehouse #6	41,497	301,745	$2.45M	130,747	95.29%	4.82
TOTAL	326,831	3,427,534	$39.31M	1,112,364	95.23%	3.41
PROPOSED STRATEGY						
Warehouse #1	85,871	1,497,412	$23.01M	385,784	96.41%	2.55
Warehouse #2	42,122	537,927	$3.35M	142,659	94.97%	6.28
Warehouse #3	53,161	672,841	$3.91M	183,041	94.76%	6.73
Warehouse #4	52,011	719,354	$4.13M	198,733	95.02%	6.82
TOTAL	233,165	3,427,534	$34.40M	910,217	95.57%	3.90

Table 5: Simulation Results - Alternative Service Policies

Service Goal	System Fill (Lines)	Average Inventory ($ M)	Annual Receipts (Lines)	Inventory Turns	Net Inventory Impact
Today	89%	$82.6	N/A	N/A	---
Base Case	89.3%	$78.1	92,575	3.57	$4.5 M Savings
90%	90.2%	$80.1	81,268	3.49	$2.5 M Savings
92%	92.1%	$83.0	74,120	3.39	$0.4 M Increase
93%	93.1%	$85.4	74,309	3.31	$2.8 M Increase
95%	95.1%	$95.8	74,697	3.00	$13.2 M Increase

3 SUMMARY

Inventory management simulations allow Cat Logistics to understand the client's business - both before and after client implementation onto the system. The simulation process aids in understanding what is required to achieve a client's inventory and service goals. Knowing the client's business and utilizing simulation results, Cat Logistics can be confident the forecast and ordering technology will fit the client's business; and parameters, dials, and statistics have been properly established to initialize forecasting / replenishment systems. This allows Cat Logistics to have the confidence in providing service / inventory metrics with financial penalties. These metrics would not be possible without the simulation results used to predict system performance. No other leading third party provider of logistics services provides such metrics with financial penalties!

AUTHOR BIOGRAPHIES

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