

Enabling Strategic Fulfillment: A Decision Support Tool for Fulfillment Network Optimization

by

Bryan Drake

B.S. Electrical Engineering and Computer Science, Case Western Reserve University, 2006

Submitted to the MIT Sloan School of Management and the Electrical Engineering and Computer Science
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Master of Business Administration

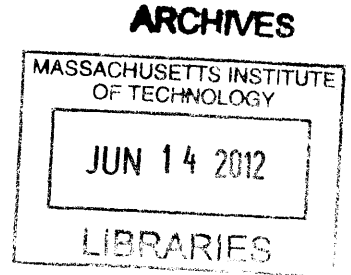
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Signature of Author _____
Electrical Engineering and Computer Science, MIT Sloan School of Management
May 11, 2012

Certified by _____
David Simchi-Levi, Thesis Supervisor
Professor of Civil and Environmental Engineering and Engineering Systems

Certified by _____
Stephen Graves, Thesis Supervisor
Professor, School of Management and Engineering Systems

Accepted by _____
Leslie Kolodziejcki, Professor of Electrical Engineering and Computer Science
Chair, EECS Committee on Graduate Students

Accepted by _____
Maura Herson, Director, MBA Program
MIT Sloan School of Management

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Strategic Fulfillment: A Decision Support Tool for Determining Vendor and Distributor Relationships

by

Bryan Drake

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Abstract

Dell's Third-Party (3P) Product network uses several different order fulfillment methods, though the determination of which products are fulfilled under which method is not clearly delineated. We have developed a tool to assist in the decision making process for Dell's 3P distribution network. This tool transparently presents the results of cost modeling and forecast variance simulation while maintaining usability to achieve broad adoption and exert influence on product fulfillment method decisions. The cost model created takes into account product, overhead, logistics, and capital costs and has the capability to deal with volume uncertainties through simulation. This tool solidifies the discussion around choosing the correct fulfillment method decision process and is the first step towards quantifying the fulfillment method decision.

Thesis Supervisor: David Simchi-Levi

Title: Professor of Civil and Environmental Engineering and Engineering Systems

Thesis Supervisor: Stephen Graves

Title: Professor, School of Management and Engineering Systems

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1 Overview and Background

The research presented here stems from work done during the latter half of 2011 between Dell and MIT. We focus on a model designed to optimize Dell's choice of fulfillment method for their Software & Peripherals (S&P) business. On top of this model we create an implementation tool that enables users of our tool to make these discrete fulfillment method decisions based on projected total costs and service levels. We move product purchasers from asking the qualitative, "Which fulfillment method is best?" to choosing the fulfillment method(s) presenting an appropriate set of customer service and financial tradeoffs.

1.1 Dell Computer Corporation Background

Dell was founded in 1984 and has evolved to become a provider of information technology (IT) hardware and services. Leveraging its network of distributors, original equipment manufacturers (OEMs), third party logistics providers (3PLs) and Dell's own facilities has allowed them to become a major player in the IT industry.

To protect the confidentiality of Dell's proprietary information we do not disclose actual data in this paper. Mocked or masked data is used in our figures, tables, and text that attempts to preserve the analysis and conclusions derived from actual data.

1.2 Software and Peripherals at Dell

Recent growth in Dell's S&P group has generated attention. Dell's S&P group accounts for ~\$16B in revenues for FY2011 and has recently been restructured as a single division; previously S&P had been split amongst the divisions Public\Large Enterprise (PLE) and Small & Medium Business (SMB) organizations. The S&P group is responsible for all product outside of desktop, laptop, server and mobile computers. In addition to Dell-branded accessories, non-Dell branded products are also sold by Dell. Examples of non-branded product include, but are not limited to, televisions, speakers, mice, server room equipment such as power and cooling systems, and software, among others. These non-branded, third-party devices are the focus of the fulfillment cost model.

The S&P group is split into three geographic regions: Americas; Europe, Middle East and Africa (EMEA); and Asia. Although the S&P group is global, each region still holds many processes, tools and

methods of business that suit local needs. Although the scope of data analyzed in this model is for the Americas region; the models, processes and methods are applicable and extensible to other regions.

1.3 Fulfillment Methods

Within the S&P network there are three different modes of fulfillment: in-network, distributor, or direct from vendor. There is also a difference in sources for products that carry a Dell logo versus those procured from third-party sources. To capture these differences we will refer to Figure 1.

It is likely that, in an optimal supply chain configuration, product would exist in each of these boxes. For example, box “A” denotes product branded by Dell and then warehoused and distributed to a customer by a third-party distributor. Box “B” denotes product produced by a third-party OEM, then stocked and distributed to the final customer by that OEM as well. Dell does not manufacture any significant portion of its S&P products.

		Product Type	
		Dell Branded	Third Party
Fulfillment Method	In-Network		
	Distributor	A	
	Drop Ship		B

Figure 1. Product Mix by Fulfillment Method

Each fulfillment method can be compared relative to others according to Figure 2. A ‘+’ symbol indicates an advantage for that particular fulfillment method.

		Product Type					
		Economies of Scale	Relationship Management	Information Communications	Inventory Costs	Variable Markup	Delivery Time
Fulfillment Method	In-Network	+	-	+	-	+	+
	Distributor	+	+	+	+	-	+
	Drop Ship	-	-	-	+	+	-

Figure 2. Fulfillment Method Comparison Table

In-Network assumes the most inventory risk, but removes external markups and gives Dell direct control of the service quality. Using a distributor removes inventory risks, but carries additional fees and

potentially causes loss of control; however, the large volume of business Dell does with distributors has enabled strong communications channels and created an environment where Dell can leverage its size to monitor and influence service quality. Drop ship assumes zero inventory risk and has no markup cost, but relinquishes all control of service quality to the product supplier and has high costs for communications between the two parties.

1.3.1 Distributors

Using a distributor outsources the handling of physical product and the management of suppliers. Distributors are the default method of fulfillment for Dell in the US.

Costs

Distributors charge a fixed % of revenues for their services. This is highly desired for a low-risk supply chain. There are overhead costs associated with managing a supplier but these are relatively small. The main concern with a distributor is the loss of control over service quality and giving up a piece of margin that could be conserved. Distributors may be able to do the fulfillment at a lower cost but distribution is a low margin business and distributors themselves exist to show a profit.

Advantages

Distributors often have lower cost structures due to economies of scale. They are also able to aggregate demand from amongst several sales networks (companies selling the same product) increasing the aggregate demand served from one location and lowering the necessary safety stock and associated carrying costs. Safety stock is lowered intuitively because as demand varies, product that would have been destined for one demand market can easily be reallocated to another when aggregated, but technically lowers because of the lower variance in demand that occurs at an aggregate level.

Relationship Management

When managing distributors it is important to leverage buying position and global scale. Dell is in an exceptional position with Distributors due to its large sales volume and global reach.

Distributors assume the risk of unsold inventory; consequently Dell does not have control over inventory levels at a distributor facility. It is important to maintain proper communications between Dell and its distributors to coordinate promotions and manage inventory burn-off with the supplier.

Information Communications

Communications with distributors are done over EDI. A relatively small % of the transactions fail and communications occur very quickly.

1.3.2 Drop Ship

Drop ship is the method of fulfillment used when the product is shipped directly from the OEM to the customer. Products fulfilled under this method are generally high cost, low volume niche products such as premier sound systems. Dell works in concert with the supplier of the goods and the product supplier directly fulfills the order to the customer.

Costs

The cost of engaging directly with a supplier is felt internally by Dell. There is no additional overhead paid for this to the supplier; however, engaging directly with suppliers and arranging a drop ship is often more intensive than engaging with distributors. This has costs both in terms of Dell personnel to manage the higher % of order exceptions, the additional time required to fix each, and the loss of inventory visibility.

Advantages

The advantage of drop shipping directly with a supplier is the lack of additional markup on goods.

Relationship Management

Dell can leverage purchase size with suppliers. Becoming a large percentage of a suppliers' sales has both advantages and disadvantages.

Information Communications

Information transfer with all but the largest of suppliers occurs over a series of protocols and file transfers collectively referred to as 'Extranet'. Information transfer may take several hours and a larger percentage of transactions fail. Anecdotal evidence suggests failed transactions are due partially to out-of-sync information availability and partially to capability immaturity of suppliers.

1.3.3 In-Network

Costs

By bringing inventory into the Dell fulfillment network all costs would be registered internally. These would include logistics, capital, fulfillment, and warehouse operations costs.

Current Dell facilities usually run at or near capacity, injecting additional inventory into their systems will create capacity costs that will need to be managed. These in-network costs are not available for S&P products because third-party products are not currently fulfilled in this manner at significant levels, but these costs can be assumed to be near the distributor cost basis.

Advantages

Under this method Dell maintains complete control of all inventory in the system. If we assume that Dell is as efficient as its distributors are then this would be a preferable option for logistics costs.

Relationship Management

There are no relationships to manage under this scenario.

Information Communications

Information would be communicated through Dell's internal systems and deliver performance similar or better than that of the EDI process with distributors.

1.4 Key Terms

There are several terms used purposefully throughout this paper.

Model refers to the approximation of underlying costs created during analysis.

Tool refers to the user interface, guidance, and simulations methods based on an implementation of the model that is presented to end users. The tool we use is presented as an Microsoft Excel worksheet.

2 Problem Description

Dell's Third-party S&P Fulfillment network is essentially a Build-To-Stock system, where Dell pulls orders from a stock of finished goods and sends product to its end customers as the orders come in. However, Dell strives to reduce its inventory risk through an appropriate strategy; the difficulty is determining the fulfillment method which best fits all of Dell's goals.

When adjusting the supply network of third party products it is often difficult to determine the most cost effective way of routing a particular product or family of products. Decision makers are unaware of many of the true costs and make their decisions based on needs of the moment or current political pressures. By

decomposing the cost drivers in each of the three fulfillment methods this problem can be overcome by quantifying the data.

2.1 Internal Considerations

There are several different groups each with a stake in the method of fulfillment finally chosen. Each group is incentivized on a different set of measures and this undoubtedly influences their preference of fulfillment method. In Figure 3 we list a set of performance targets for groups and the fulfillment preference that each target would elicit. These competing groups each exert political influence over the fulfillment method chosen and it is important to keep in mind that these predispositions exist.

The major conflict caused by these internal considerations is between those groups desiring high margins (drop shipment preference) and those groups desiring low order management cost (distributor preference), with those groups desiring a low order management cost.

Performance Target	Fulfillment Preference
Margin	Drop Ship
Order Management Cost	Distributor
Revenue	No Preference
Product Variety	No Preference
Control	In-House

Figure 3. Fulfillment Preferences

Any change to the mix of methods in use has some friction as Dell is capacitized for their current mix, a change to the ratios would result in an adjustment of employee and facility capabilities.

2.2 Current State of Fulfillment Processes

Each geographic region of the world faces different challenges in supplier base, fulfillment networks, and established company presence. To counter that, Dell has historically tuned its distribution choices to the needs and capabilities of a particular region. Each region has its own standard processes, tools, and data formats.

The difference in processes is due to Dell's maturity in the region and the Distributor infrastructure maturity in the region. Outside of North America, the distributor infrastructure (warehouses, fulfillment centers, distribution centers, etc...) exists only to varying levels and Dell uses local suppliers and logistics carriers to fulfill orders. In Europe, the prevailing method of doing business is to not use Distributors as heavily as in the US, which in turn means that the infrastructure will not be as mature, which implies a higher cost for transaction and in turn keeps the volume of distributor enabled transactions down.

2.3 Distribution Industry

The distribution industry is made up of several large players and a long tail of niche players. Large sellers will focus their efforts on a small number of global distributors and then use niche players only when they are forced.

Smaller players will compete in niches based on geography and/or product type. Large distributors have the ability to choose not to service products that don't fit their model. This creates a competitive space for smaller niche distributors.

2.4 Product Ownership

Fulfillment decisions are sometimes overruled by concerns over who will own the product when. If there are significant import costs or difficulties to a particular territory this will override the lowest cost fulfillment method as determined by our model. Changing tax regimes, if not maintained in the model, will have a similar effect.

2.5 Strategic Concerns – When Lowest Cost is not the best choice

There are specific times when the strategic concerns of the business outweigh the transactional costs associated with order fulfillment. At these times, the output of the tool is easily overridden. Some examples of strategic concerns taking precedence over cost concerns include:

- Correcting for poor performance of fulfillment partners
- Inventory Allocation for promotions / bundling
- Large buys to secure inventory when scarcity is projected (high demand situations only; low supply mitigation is usually reactionary and not subject to this method)

2.6 Distributor Markup Complexity

One complexity not easily captured by the model is the dependence of distributors on varying margin between products - a low distributor markup on one product may be compensated by a higher markup on a separate and unrelated product. Removing those products that have high markup may not be in the best interests of the system and could theoretically spark a spiral as distributors cope with the loss of their high markup and cost-offsetting products by increasing markup on the remainder of their products.

It is possible to bundle products and thus remove this sort of markup pairing across non-related products by further increasing the product level that fulfillment decisions are made at.

3 Supply Chain Costs

There are three distinct types of supply chains in a firm: the fulfillment supply chain, the development supply chain, and the reverse supply chain¹. Our tool focuses only on managing the fulfillment supply chain. The fulfillment supply chain we are talking about follows the definition published by the Council of Supply Chain Management Professionals of ‘Supply Chain Management’:

“the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.”²

Inside of the fulfillment model itself there are a number of different product types and specific processes that can be invoked. Products can either be produced by the company (encompassing both assembled and manufactured products) or procured externally and then resold. For each type of product there are three major fulfillment procedures we will investigate: managed by the producing company (in-network), managed by a third-party distributor, or managed directly by the third-party manufacturer (drop ship). ‘Managed’ includes the maintenance of inventory levels, the assumption of risk associated with assets, and the physical transferal of those assets to an external transportation provider. Because Dell manages contracts with transportation providers independent of its fulfillment partners, logistics costs have the same cost basis (by mile) regardless of fulfillment procedure. There are certainly other variations of fulfillment procedures that could be used, but these three represent all main avenues.

In order to determine the optimum fulfillment model we must evaluate cost and quality factors to determine the correct positioning for a company. We will start by exploring the cost-decomposition of activities in the fulfillment supply chain and then look at how service levels can be added into a qualitative framework to determine optimum fulfillment type.

We will start with cost decomposition of each fulfillment procedure, proceed to discuss modeling options and end with a discussion of implementation methods.

3.1 Cost Decomposition

Based on our analysis of these cost producing steps we realize the following set of costs.

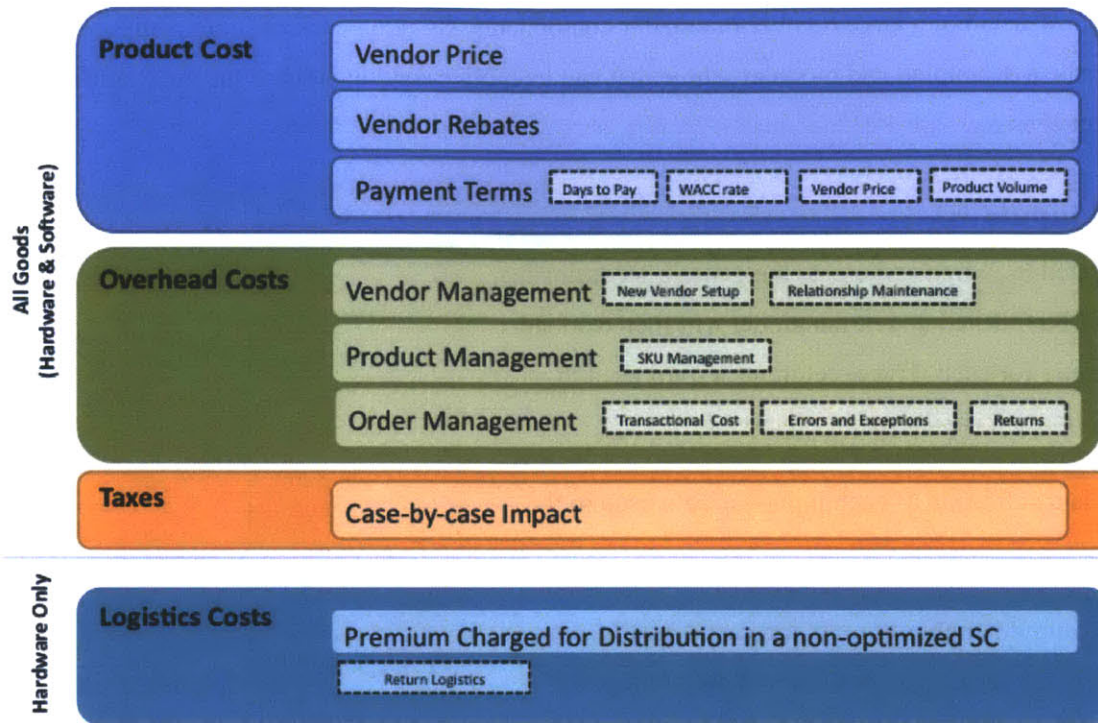


Figure 4

The model is primarily concerned with overhead, product and logistics costs. Software products serviced by the S&P group are not charged any logistics costs because delivery is done over the web, physical product is generally not shipped for software.

3.1.1 Time Determined Activity Based Costing

Time-determined activity based costing method is a useful approach for determining input dependent costs³. We were able to approximate this approach using a simpler activity based approach conducted internal to the Company earlier in that year. Improvements to the model would have been minor under current procedures. As work becomes more modular it may be worthwhile to revisit this task.

4 Discrete Model Components

The model is constructed of a large number of smaller components. By tying each of these components together we create a decoupled and modular whole that can be more easily updated as the costs profiles of each component change.

4.1 Model Inputs

Users are expected to design and create the generic scenarios that a product might be fulfilled under, the model will then respond with cost estimates for each. The excel input wizard used to solicit input from users is pictured in Figure 5.

The following is a definition of each input variable used in the model.

- **Product Volume** Number of units forecast annually. This is used as the mean for an assumed normal distribution of forecasts.
- **Volume StDev** Anticipated deviation from around the product volume predicted in 'Product Volume'. This is treated as the standard deviation for the normal distribution of forecasts.
- **Distributors** The Distributor (or distributors that are competing for the product)
- **Supplier** The name of the Supplier. This will link to knowledge of specific contracts/discounts that Dell has with that supplier.
- **New Supplier** This indicates if the supplier needs to be added to Dell systems. This will impose an additional overhead fee.
- **Product Category, Product Line** These two inputs relate to the distribution markup rates set between Dell and their distributors.
- **Product Type** This affects the markup used as well as shipping & overhead costs. The selection is whether the specific product is a piece of hardware physically shipped to the customer or a piece of software "shipped" via email.
- **Product Cost (direct)** This is the price paid to the supplier or distributor. It does not include any markup. SKUs using a different product cost basis are not accommodated at this time. You should convert products with different cost basis to use a more standard markup model.

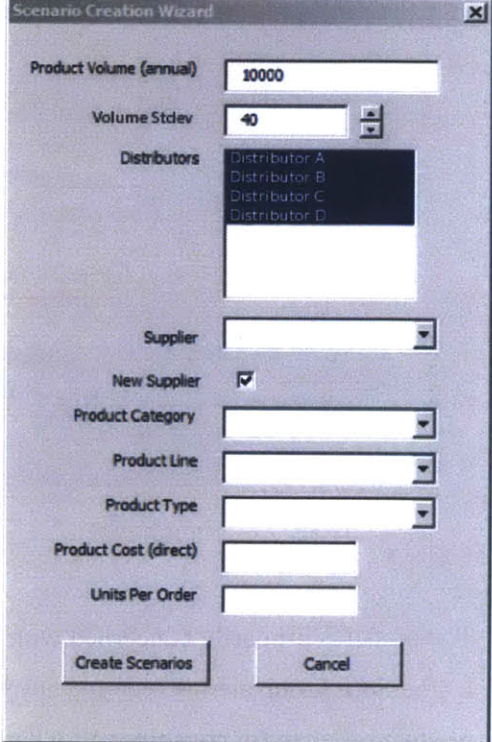


Figure 5. Input Collection Wizard

- **Units Per Order** The average number of units per order. This affects the number of transactions that occur and, consequently, the overhead costs.

4.2 Model Segments and Interrelations

The individual components of the model are inter-related in Figure 6⁴ at right. It becomes possible to see how the various pieces of the model interact with one another; each node in the graph represents a tab on the excel sheet, each arrow represents information from one worksheet being referenced in another.

Descriptions of each node can be found in Appendix D.

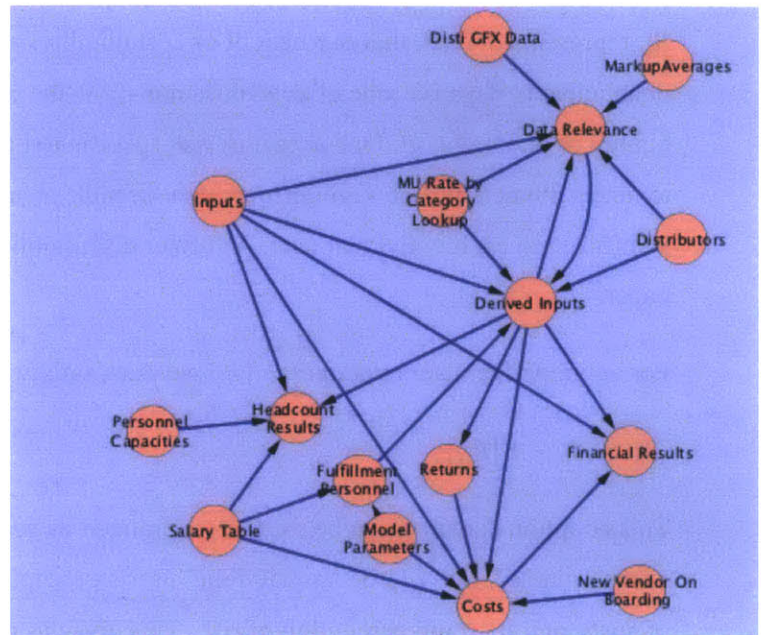


Figure 6. Model Layout

4.3 Managing User Adoption

To ensure user adoption the tool must exhibit a positive customer value proposition. We have adopted Lethbridge’s model⁵ for a customer value proposition in three parts: C_u (cost of use), B_u (benefit of use), and R_u (risk of use). In academic and theoretical circles the threshold for adoption is thought of as:

$$B_u > C_u$$

Equation 1

However, this threshold is not the same does not apply in a commercial environment due to an increased penalty for failure and cost sensitivity. We must include the risk of adoption on the cost side of this equation

The lack of strict process for making a fulfillment method determination lowers the C_u and R_u at Dell because there is no barrier to entry that must be overcome and the current process is not performing at an acceptable level (as evidenced by the creation of an LGO internship on the topic). Though this effect will not be as strong as if our employees were new to the process, having an informal and decentralized process makes it easier for users to adopt a new system.

By building the tool inside of Microsoft Office we can assume that C_u will be lower; specifically the acquisition costs of software, hardware and proficiency. Though these costs are reduced, it is not appropriate to assume any reduction in R_u or increase in B_u .

R_u represents the risk that our benefit or cost numbers are incorrect because the new tool has unanticipated negative side effects, does not allow the user to operate as desired, or suffers from low quality or poor support. One aspect of risk specific to our tool is the risk that the end user will be unable to detect the benefit; the savings may be noticeable at an aggregate, S&P level, but may not be seen as significant to each individual user. A further discussion of the risk variable can be found in Lethbridge's paper.

For an individual user to adopt the tool we must satisfy a variant of the following equation:

$$B_u > C_u - E[R_u] \quad \text{Equation 2}$$

This adoption equation can be further generalized by realizing we are dealing with the user's perceptions of these values. Let pB_u be an individual user's perception of the benefit, likewise for pC_u and perception of costs, and pR_u and perception of risk. This gives us a new equation which must be believed on a per user basis to reach adoption:

$$pB_u > pC_u - pR_u \quad \text{Equation 3}$$

By being aware of the factors that Lethbridge offers, the chance for tool adoption is increased.

4.4 Modeling Needs and Options

In order for our model to create the maximum impact and be adopted by users at Dell we chose to strive for the following characteristics.

1. More consistent results than intuition
2. Broad applicability
3. Low Cost to Use (Shallow Learning Curve and Low Time Consuming)

By achieving these three goals we are able to satisfy the requirements of *Equation 3*.

4.5 Monte Carlo Analysis

4.5.1 Managing Variance to Product Forecast

Predicting sales volumes for a family of products is difficult; predicting approximate volume for a specific item is even harder. The volume parameter is the most important input and we must be able to account for its unpredictability.

4.5.2 Approach

This problem can be mitigated by using Monte Carlo simulations across the 95% confidence range of likely volume values. From the results of simulation we may calculate the percentage that any of the scenarios outlined will be the most cost effective.

Here is an example of this approach with simulated forecast volumes. The volume (left column) is the key input to the scenario and the Lowest Cost (right column) shows the result from our model.

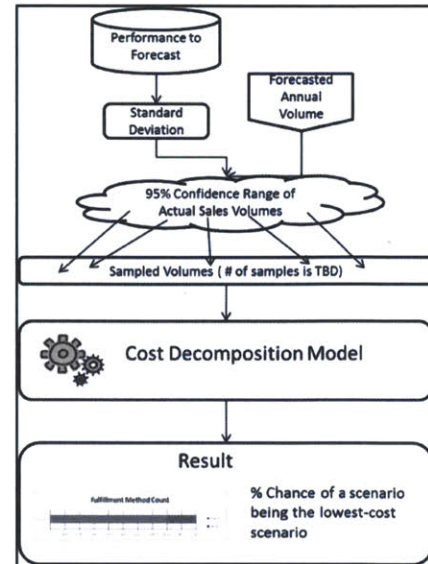


Figure 7. Monte Carlo Analysis Diagram

Volume	Lowest Cost
435342.9	Distributor A
337968.2	Distributor A
613931.7	Distributor A
1140950	Distributor A
378677.9	Distributor A
400463.5	Distributor A
285783.2	Distributor B
57412.21	Distributor B
203091.6	Distributor A
27702.31	Distributor A

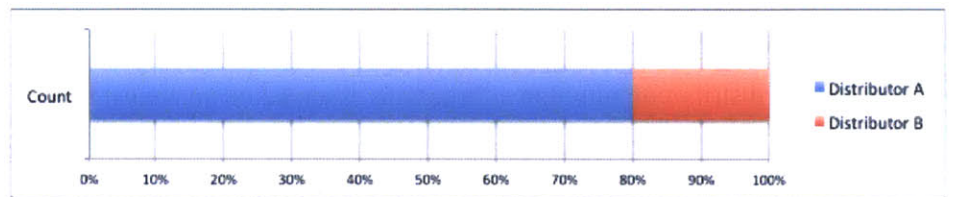


Figure 8. Process Outcomes

In this contrived and simple scenario Distributor A is the lowest cost provider in 80% of cases. This simulation approach approximates the true distribution of answers based on expected forecasts fairly accurately depending on the number of trials run.

It is important to consider the role that statistical error may play in the results of simulation. Statistical error in a Monte Carlo simulation can be measured as:

$$\hat{\sigma}_n = \frac{\sigma}{\sqrt{n}} \quad (\text{Equation 4})$$

Where n is the number of trials. Note that this does not account for error in the model, only statistical error introduced by the Monte Carlo simulation process. To reduce the statistical error in our result we must reduce the ratio in equation 4. Reducing the numerator is accomplished by improving forecasting methods to improve predictions for the distribution of expected volumes. Increasing the denominator is accomplished by increasing the number of trials. The important thing to notice is the square relationship between n and σ , halving the error requires quadrupling the number of runs. In our tool implementation we have chosen a set number of runs for purposes of keeping run time fast and not chasing diminishing returns. Marginally better solutions are available through these methods; but the most effective efforts can be spent improving model accuracy.

4.6 Data Set Creation

Sample volumes to use as input for the Monte Carlo simulation are created assuming a normal distribution and the user-input standard deviation. Further analysis could pull these data from historical values, but anecdotal evidence shows that the forecasts (and their associated variances) are highly product and season dependent. Historical data on performance-to-forecast was not available for analysis.

4.7 Inputs

Forecast Distribution

Normal distribution of volume forecast is assumed on an annual basis. The current performance-to-forecast does not appear to be actually normally distributed however; this indicates poor validity of the forecast and a forecasting process that is statistically out of control.

Forecasting Difficulty

Inside of the S&P business forecasts come from many different sources. With a short product life cycle and frequent introduction of new products the forecasting process has remained non-standard and highly subject to human intuition. Easy to forecast products have fairly steady, known, and high volumes; therefore, producing a forecast for these products is not difficult. Conversely, new or low volume products are more challenging to forecast.

Performance to Forecast Variance

Performance-to-forecast is not a tracked variable for S&P items. Even those items that are consistently forecast currently are done in an environment of poor data quality; promotions, discounts, and other demand-shaping mechanisms are applied manually to the generated forecast.

For example, a promotion being run on a particular SKU for one particular weekend is expected to quadruple sales of that SKU. The impact of this promotion is communicated to the distributor by phone or email and not entered into the system. Even if the adjusted performance (400%) is exactly correct, historical numbers would indicate a 400% performance to forecast number. This type of error occurs at all levels of promotion, price change and forecast adjustment and renders historical performance to forecast numbers suspect.

To better approximate the historical performance to forecast requires a change in the forecasting process that is beyond the scope of this thesis.

4.8 Further Work & Issues to Implementation

Consistent Forecasting Methods

By implementing consistent forecasting across all products we will be better able to judge performance. The wide variety of product types and lifecycle statuses may make this difficult.

Performance to Forecast Tracking

Historical performance to forecast is not tracked. Adding this piece of data would allow the model to be based on historical variances. The model assumes a normal distribution for our performance to forecast, but this cannot be compared against historical results for verification.

Data Coordination and Data Quality

The decentralization at Dell works fantastically to allow flexibility and adoption of local business practices and customs, but it also means that central data stores do not exist or are very limited in the scope of data they hold. Due to the distributed nature of Dell's data, Dell has not experienced a push for data management and consequently the quality of much existing data is suspect.

SKU Level vs Product Family Level Management

At the SKU level forecasting data in general is prone to significant fluctuations. By aggregating the forecast to a product family the forecast can be more accurate, but then ordering information provided by the aggregated forecast is much less useful.

5 Developing a Quantitative Cost Model

With a firm understanding of the operating environment and how to assist with the fulfillment method decision we can develop the cost model.

5.1 Analysis of Current Methods

Several separate groups have, in the past, made attempts to approximate the fulfillment cost model but none were widely adopted. The history of creation by niche groups led to artificial divisions of the cost model for different product types. Each model deviated from the underlying model due to implementation methods or perspectives of the modeling group, not to true differences in the underlying cost model.

While analyzing usage methods of these previous models user studies were conducted by the author. The two users most familiar with existing models were instructed to create the results for one scenario involving a specific product and scenario. Each task took approximately one hour, required intimate knowledge of rates, fees, and results reported by the user were inconsistent with the output of the model – there was user error in output interpretation.

Creating a unified, easy to use, and easy to understand model would be essential to its adoption and use. Additionally, a model presenting usability and value to many groups allows a greater chance for expertise to grow and data maintenance to occur.

5.2 Major Cost Patterns

The two major cost sources of fulfilling an order are the logistical cost of managing the order and the additional cost of order overhead. In the case of a distributor this overhead is a set percentage of the product price, in other cases the order overhead cost is dependent upon whether the order falls into an error condition or not. In the case of many orders there is almost no overhead cost incurred by Dell, but when an error condition occurs (ex: an item is out-of-stock, customer address is incorrect, etc.) there is significant cost. These errors appear to be uniformly distributed across all products

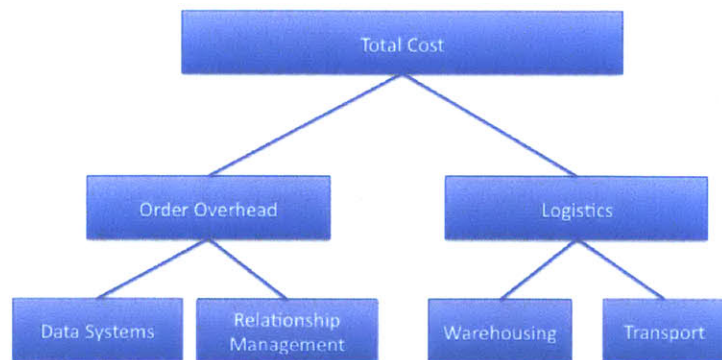


Figure 9. Basic Cost Structure

and fulfillment methods. The cost of these exceptions is volume-allocated by fulfillment type, but this type of allocation may not be appropriate for every fulfillment operation.

It is often useful to think about which cost types are avoidable and which are unavoidable. Those costs driven by error conditions are avoidable conditions and are costs that we should be concerned with. Most of these error costs come from a small percentage of orders.

5.3 Survey Methods to determine cost accounting

New Supplier Onboarding Costs

There is certainly a cost associated with vetting a new supplier and adding them into Dell's network of IT systems. A cost for this process was determined by surveying those people involved in the process and asking them how long adding a new supplier took. Answers varied widely, with some suppliers taking substantially longer than other suppliers. It was discovered that most time spent processing the addition is idle time waiting for responses from separate groups both internal and external to Dell. No pattern was found in input data to establish predictability.

A standard cost was assigned for addition of a new supplier; there are two reasons this is deemed acceptable (1) the magnitude of cost for onboarding is small relative to other costs, (2) lack of an appropriate distribution pattern. I suspect that the major loss from elongating lead-time would be found in lost revenues from not having the supplier's products available for purchase; that analysis is defined and suggested in Section 8.1

Costs of Exception Management

The cost of exception management was achieved in a similar manner. By conducting a survey of all parties along the chain of exception management we were able to determine an approximate amount of time spent on each activity. Synthesizing this information with other information such as fully burdened salary expenses, volume of exception orders by fulfillment method, and the overall mix of order types we were able to create a specific cost per exception unit.

There was no significant pattern found for the distribution of exceptions so it seems appropriate to spread the exception cost uniformly across all orders of a specific fulfillment method.

5.4 Tax: Duty and Tariff Concerns

Tax concerns are not represented in the model.

Tax concerns can represent a significant percentage of profit, much larger than that gained by choosing the least costly fulfillment model. In cases where one procedure represents a significant tax advantage that advantage will become the deciding factor and override any results produced by the tool.

5.5 Overhead Allocations

5.5.1 Volume Based vs. Activity-Based Costing

In reference to allocation of overhead from the costs associated with order processing we have chosen to use volume based costing filtered by fulfillment method. Though each exception type has a specific sequence of actions needed to repair it, mapping each of these and allocating cost by exception type and processing time for each is not an activity worth undertaking. The relationship between exception type and the product or set of products undergoing simulated fulfillment is not discernable with existing data. Any costing mechanism filtered by exception type or product type would be smoothed back to the larger distribution once the unknown relationship between product and exception is accounted for.

There are some binary cost decisions made from information such as the type of fulfillment method being simulated and whether the supplier is new to Dell or not, but inside of each order type cost is allocated by volume.

5.5.2 Transportation Costs Modeling

Transportation logistics are handled by an external provider no matter the fulfillment method. External transportation providers follow a pricing model with a base cost for handling and then a positive sloping cost based on a function of weight and distance. We make no attempt to optimize choice of external logistics provider in this model as there are other ongoing efforts in that arena. Transportation costs are transferred directly to Dell.

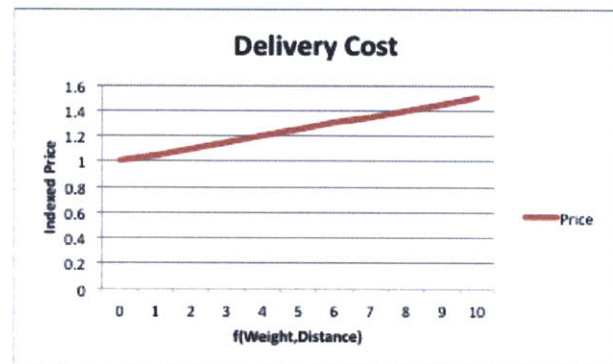


Figure 10. Delivery Cost as $f(\text{weight, distance})$

Though costs are borne by Dell, fulfillment methods each have distinct average costs of transportation. For example, a distribution network with one facility in the United States, the delivery price will be relatively high. A different distribution network with four facilities in the United States would have a lower average delivery distance and achieve lower delivery costs. For direct fulfillment or distribution

models the costs of maintaining fulfillment centers, warehouses or any piece of the supply network besides delivery cost can be ignored – these other costs are in the distributor mark-up or are baked into the product price.

In Figure 11⁶ we can see the magnitude of relationships between delivery costs, warehousing costs and total logistics costs. For this model we are concerned only with transport costs.

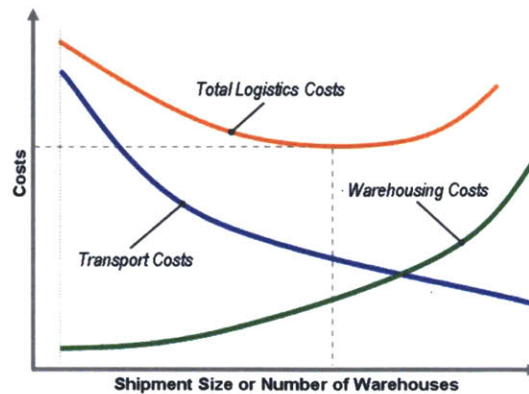


Figure 11. Total Logistics Cost

Direct versus Distribution

Direct suppliers typically have one or two locations that products can be delivered from. This induces a time delay in product delivery, but it also increases the average distance traveled from warehouse to end customer. The cost of per-order delivery is higher for Direct fulfillment than for fulfillment through a Distributor.

In Network Logistics Modeling

In house cost modeling needs to take into account many of the warehousing costs, operations costs and capital costs of the underlying infrastructure as well as the delivery costs. A flat rate was used per-unit for this in-network logistics cost modeling. The error in this would be significantly exaggerated if we were to place low velocity items in the in-network mix; however, low velocity items are not candidates for the in-network method.

Weaknesses

This cost model does not take into account per product differences such as weight or special shipping requirements. Most products sold by Dell are of similar size and weight so this does not become a problem in the vast majority of cases.

5.5.3 Returns Modeling

A third-party reverse logistics provider handles all Dell returns, regardless of fulfillment method or product type. Customers ship product to be returned directly to this third-party provider where it is either returned to the supplier with Dell credit for the product cost or purchased by the third-party provider. The

associated costs to Dell have a set schedule and are handled appropriately. Returns cost are captured and modeled according to the negotiated fee schedule with the third-party. There may be some differences in the cost from product to product due to different logistics costs from consumer to return center but these are non-consequential to the decision the model assists in as the cost difference depends only on product type, not on fulfillment method.

Return costs are incurred independent of fulfillment method and have no bearing on the fulfillment method decision.

The high cost of reverse logistics is often blamed on inflexible return terms from suppliers. It is hoped that, by modeling the return costs separately, product purchasers will take notice and leverage their power to negotiate better return terms with suppliers. Reverse Logistics Costs are not part of the discussion when determining product fulfillment method currently. This would remove much of the burden from Dell's third-party reverse logistics provider and result in increased recoveries for Dell.

5.5.4 Potential Revenue Exclusion

A higher service level, lower lead-time, or any improvement to customer service can result in increased sales leading to increased revenues and profits. It could be argued that this additional profit should be discounted from costs incurred under that fulfillment method. In the future, it may be found that this method sufficiently approximates the true effect.

There are two reasons we chose to exclude this potential revenue: (1) fulfillment method does not necessarily indicate customer service levels and should not be directly linked to even historical levels, and (2) fulfillment decisions should be made on the basis of cost, service level and flexibility required. Modeling a potential revenue or profit removes a decision variable from the end user of the model.

5.6 Global Infrastructure Maturity and Desirable Service Levels

In different areas of the world we need to match or exceed the prevailing expectation for customer service. This means that the correct trade-off for Dell between service levels and cost is variable by

geographies and even by customer. When making a decision for fulfillment method it is up to the tool user to determine appropriate tradeoffs for the region in question.

5.7 Quick Reference

In Figure 12 we can see what is referred to as the quick reference for how products should be fulfilled. This is a non-scientific and not to scale representation of where the results of the model will generally lie. There are four regions in the model, 'Direct' or Drop Ship, 'Distributor', 'In House' and an unlabeled black circle.

Parts are driven to direct fulfillment methods when the price and distributor markup outweighs the exception expenditure of a drop ship engagement and any additional logistical cost.

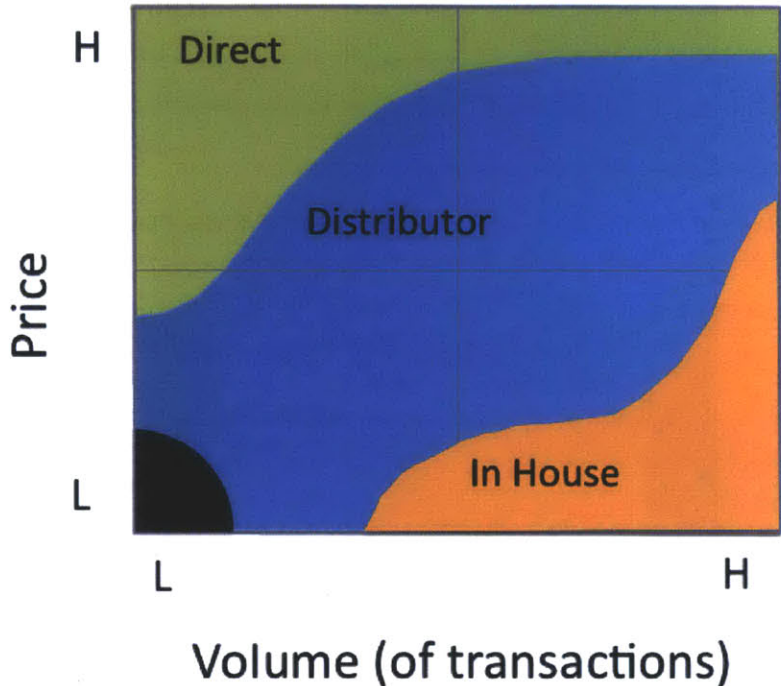


Figure 12. Quick Reference Chart

Parts are driven to a distribution model of fulfillment by default. Most parts should be fulfilled in this manner as distributors, due to economies of scale and operations excellence, have a lower cost base and logistics cost than Dell internally does.

Parts are driven in-network when high volume sales can induce attachment into the same shipping box as a new system (items such as keyboard, mice, monitors, and carrying cases) Other items driven in-house would include those with a low-value and mid to high volume. Demand for lower volume parts more cost effectively served when aggregated by a distributor.

Parts that are low-volume and low-value are losing parts. If necessary to carry them as part of a bundle (cabling or replacement components, etc.) then fulfillment should be managed in the most cost effective way possible, most likely a distributor. Standalone parts in this bin should be pruned from inventory whenever possible.

5.7.1 Product Classification Examples

Some examples of products that would fall into each category can be seen in Figure 13.

Fulfillment Method	Product Examples
Direct	High End Sound Systems Large UPS Systems
Distributor	Software Products GPS Systems Media Players (Zune, iPods, etc...)
In House	Dell Branded Mice Laptop Case
No Value	SD Cards Network Cables Replacement Parts

Figure 13

5.8 Model Usage

New Product Implementation

The initially imagined use case for the tool is new product implementation. New products present a certain set of circumstances in that they have no forecast history and will not upset any existing relationships. Lack of forecast history can be overcome if there are appropriate products from a similar product family, but oftentimes this is not the case.

Product Family Fulfillment Optimization

The tool can be used to suggest a change of fulfillment method for a family of products. Moving a high-value product from a distributor to a direct model can be triggered by rerunning the model with current inputs. Conversely, moving a once valuable item that has become commoditized (a common scenario in the consumer electronics business) from direct engagement to a distributor can also be triggered through use of the tool.

Rate Negotiation

If the proper fulfillment method has been determined to be distribution then rate negotiation will sometimes occur. By exposing all costs associated with a specific distributor, users of the tool can create an apples-to-apples comparison of the markup rates being offered by competing distributors.

5.9 Use Examples

5.9.1 Comparing one Distributor Rate against another

The comparison of one distributor markup rate against another is often difficult to conduct. By carefully accounting for the benefit from special pricing, employee offset costs and other benefits given by distributors we are able to meaningfully compare one against the other. The tool has been used to successfully determine the costs associated with using one distributor versus a combination of others. By creating two different scenarios in the model, on using each of the distributors in play, we are able to see the full cost of using each. By looking at this full cost number it becomes visible that the markup rates offered by one distributor cannot be directly compared to those offered by another distributor.

5.9.2 Headcount Modeling

Based on the employee surveying and activity/process mapping to attain accurate costs for transactions and exception management our model was required to capture data about the process capacities many workers and processes. By using this process and capacity data it is to reverse the data flow through the model to show the headcount adjustment necessary given a percentage order growth.

This proved useful to the business, and by integrating headcount modeling into the tool we are able to ensure data maintenance and wider enthusiasm and support of the model from higher levels of the organization.

5.10 Validation

Validation will be constructed by determining a cost basis for the S&P group from Dells published financials and then comparing it to the cost basis for a selection of products in Dell's portfolio.

S&P Cost Basis Determination

It is possible to validate the results of this model from the aggregate financial numbers released by Dell. The model was originally built based on costing information for a specific set of specific products, if the model results are consistent with aggregate results then we can claim that the model is valid.

We assume that each of these six reported groups (Servers and Networking, Storage, Services, Software & Peripherals, Mobility, and Desktop PCs) has a cost basis specific to that group. Let us refer to this as B_i . Dell reports the revenues broken down by these product groups for each of the time periods in question, let us refer to this revenue as $R_{i,x}$. The cost generated by a product group for a specific time period is thus given by $B_i * R_{i,x}$.

We can further translate this to the calculated cost as a percentage of SG&A Operational Expenses.

$\frac{R_{i,x} * B_i}{O_x}$ where O_x is the operating expense incurred under period x. Let $P_{i,x}$ be the percentage of revenue attributable to group i at time x as reported by Dell. We use solver to minimize the following:

$$\sum_i \sum_x \left(\frac{R_{i,x} * B_i}{O_x} - P_{i,x} \right)^2$$

The time periods chosen for this analysis were the six quarters from Q3-FY11 thru Q3-FY12 and Q3 FY08. This data can be seen in Appendix A.

Using this method to determine the cost basis for each division we come up with Figure . The figure of 6.44% cost basis seems intuitively reasonable and is what we will check specific products against.

Assumed Cost Basis	
Servers and Networking	6.78%
Storage	6.19%
Services	6.68%
Software & Peripherals	6.44%
Mobility	6.47%
Desktop PCs	6.02%

Figure 14. Assumed Cost Basis

Validation thru specific product

Determining the cost basis for specific products is done by looking at the publicly-available price on Dell.com, then determining the actual cost paid and any mark-up added to the product. We can then run the products through our model and should expect to see the model predict an overhead + markup cost of approximately 6.44% of the product.

Comparing the pricing to internal cost information, we do not match the expected 6.44% figure. It is believed that this is a false rejection due to the test data set being limited to list prices for product, rather than from a weighted average of the price a product was actually sold for. According to Dells 2010 10-K, 23% of revenues came from the Consumer group, with the remaining 77% from Small and Medium Businesses, Large Enterprises, or Public (Government) customers. In 2011, only 20% came from the

consumer group. An adjustment that lowered the average sales price would bring our model projects in line with cost basis calculated above.

6 Model Factors

The model was constructed in Excel to promote our principle of low cost to use. By providing the tool in a medium that most users already have access to and familiarity with, the learning curve becomes very shallow.

The potential issue incurred by using this method is that users could tweak the tool. Efforts were made to secure its function against possible tampering, but customized versions could become desirable and may be hard to detect and control. Providing a web-based, centralized solution will become preferable with continued expansion of the tool's adoption and complexity.

Despite the problems with the tool, it is important to remember the purpose of our implementation. By implementing the model and tool we are providing a process for Dell to use in its fulfillment method. Once a process is established the tool can be changed and tweaked, but the tool and model overcomes a hurdle for Dell by applying even a rough estimation of the process.

6.1 Continued Implementation

Due to the decentralized nature of the tool and the pull for continued development of tool abilities we expect to see development continue. Dell does not have a centralized development group that the tool will be adopted by, nor are there formal processes to manage quality in the current implementation of the tool. If we wish to continue on track with the current adoption rate and have the largest effect upon the organization as possible we must move to a centralized and controllable system. Continued development with uncontrolled developer quality and update quality the tool may end up with little benefit and significant cost to Dell as an organization.⁷

7 Implementation Methods

7.1 Data Maintenance

Data should not need to be manually maintained unless Dell’s method of data dissemination changes. If this occurs, the large adoption base may create a need to update linkages. However, the decentralized and independent nature of each instance of the tool will make updating difficult.

As long as the tool remains in use in its current form it will serve as an impediment to changing the nature of data dissemination.

7.2 Feedback to the Model

During implementation the development model of ‘release early, release often’⁸ was used. When a new development milestone was reached it was important to get it in front of users and incorporate their feedback. In this way we were able to increase exposure of the product, increase buy-in from future users, create easy to interpret user interfaces, and correct misinformation / misapplication of the model. In general this feedback process followed that seen in Figure 15.

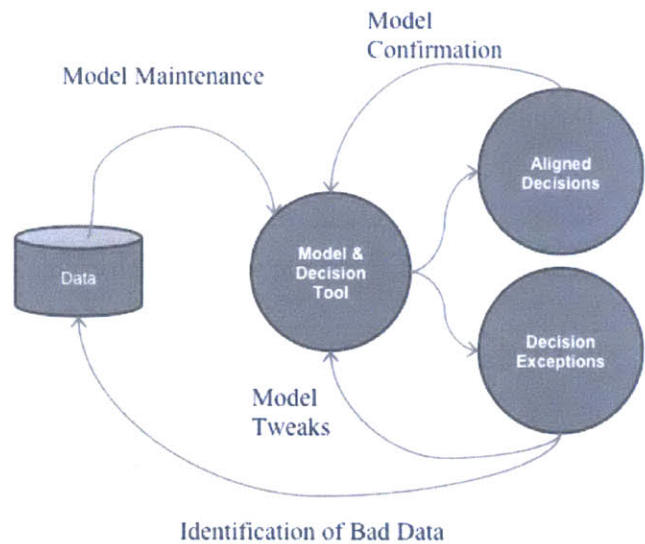


Figure 15. Feedback Process for Tool/Model Testing

7.3 Impact, Accuracy, and Adoption

Because the tool is designed to be used by a large number of purchasers and fulfillment experts we can understand the impact to be a function of tool accuracy (related to complexity) and tool adoption. To achieve the maximum impact for Dell we need to focus on the correct combination of accuracy and adoption. Though the relationship between these functions cannot be known exactly, their combinatorial magnitude is represented well in the figure at right.

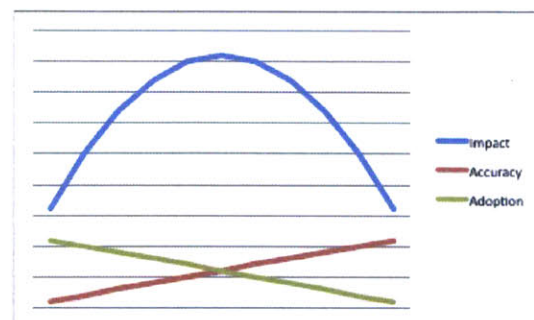


Figure 16. Impact Function

We assume that model accuracy/complexity and model adoption have an inverse relationship. The impact function is based on those two impact and greater than the sum of their parts.

7.4 Regionalization Methods

Regionalization can occur if users supply their own data. This will mean replacing Americas data on S&P spend and volumes with similar data from their own regions. A region as defined by this tool does not have to match the organizational regions that Dell breaks the world into; a single country's data is sufficient.

To get truly meaningful results users will need to determine capacities and process flows for the exception management process and feed the results of this into the tool as well.

8 Conclusions

Dell's S&P group has had great success managing the changing demands of their customers, growth of their scope, and nature of their products over the last decade. They have proven many times over that flexibility is what wins the day; but it is this flexibility that creates opportunities for some pieces of their business to be more optimized.

Creating a tool that will continue to offer speed of execution and combining it with human judgment should increase both the flexibility and speed of the overall system while reducing cost. Allowing expert users to quantify the fulfillment method decision and choose the correct set of tradeoffs to meet market needs is the type of strategy that Dell will need to succeed in the decade to come.

By creating a tool whose focus is accuracy we aim to implement a strict and data-driven decision making process. Though the model has not been sufficiently proven to be accurate, it is more consistent and predictable than the decision method in use prior to its implementation. With this process in place we can continue to improve the process systemically and have these improvements felt across the S&P group and eventually on the balance sheet.

8.1 Areas for Future Study

Supplier Onboarding Standardization

Establishing process metrics around supplier onboarding methods and determining a proper method to account for expected revenues lost could lead to improved accuracy of the model.

Supplier Communications Improvements

As supplier capability matures it becomes possible to improve information communications with them and reduce a significant driver of cost for drop ship fulfillment methods. Conducting an analysis of this opportunity may expose opportunities for Dell to help mature the infrastructure of its fulfillment network.

Reverse Logistics Analysis

Although the cost of reverse logistics is not a deciding factor for the initial fulfillment method, the cost is still significant and does not appear in many product calculations. There appear to be opportunities where the cost of reverse logistics could be brought farther forward in the planning process and streamlined to reduce overall cost and customer service.

Distributor Network Optimization

As discussed in Section 5.5.2, the geographical distribution of a fulfillment network significantly determines the associated transportation costs. Synthesizing information between demand patterns and fulfillment specialties may lead to a more optimized distribution of product. For example, it may be found that the preferred distributor for a product may vary by customer location.

Dell Branded Product in External channels

The focus of this analysis extended on to non-Dell branded product. By analyzing the effect of placing Dell branded product in external distributors we may discover an additional method of optimizing the fulfillment network.

S&P Forecasting

Improving S&P forecasting process and metric tracking would greatly benefit any optimizations done to the fulfillment network.

Fulfillment Method by Accuracy of Forecast

Dell may wish to investigate allocating product by taking into account the ability to forecast demand for that product. Those products that are high volume and have low variability associated with the forecast could be held closely at Dell to reduce margin. As products become more difficult to forecast Dell would want to reduce their risk and aggregate demand nearer the product – distributors would carry items that benefit from a geographic aggregation and those low-volume \ specialty items could be carried by the supplier.

There would certainly be opposition to a plan like this from the distributor base, it can be assumed that they make a certain amount of profit from those items (as discussed in 2.6) that exhibit stable demand and can be controlled well especially when aggregated.

Split Fulfillment Methods

Under Dell's S&P group's current fulfillment methods a particular SKU is fulfilled entirely in-network, entirely by distributors, or entirely by the direct supplier. Under certain conditions in certain portions of the world it may be more profitable for Dell's upfront fulfillment strategy to include more than one of these methods. For example, Dell may want to fulfill forecast to the 80% probability level in-network and then fulfill the remainder of demand with a distributor. This still removes much of the risk while avoiding much of the mark up cost paid to distributors.

Appendix A. Selected Dell Financials From Q3 FY12 10-K

	Quarterly Financials						Annual Financials		
	Q3-FY08	Q3-FY11	Q4-FY11	Q1-FY12	Q2-FY12	Q3-FY12	FY09	FY10	FY11
Revenues by product (in Millions)	15,646	15,394	15,692	15,017	15,658	15,365	61,101	52,902	61,494
Servers and Networking	1,651	1,844	2,090	1,973	2,054	2,089	6,512	6,032	7,609
Storage	624	543	574	481	502	460	2,666	2,192	2,295
Services	1,355	1,924	1,943	1,984	2,036	2,123	5,352	5,622	7,673
Software & Peripherals	2,533	2,579	2,651	2,567	2,569	2,528	10,603	9,499	10,261
Mobility	4,729	4,858	4,850	4,716	4,761	4,750	18,604	16,610	18,971
Desktop PCs	4,754	3,646	3,584	3,296	3,736	3,415	17,364	12,947	14,685
% of Total Revenue by Product									
Servers and Networking	12%	12%	13%	13%	13%	14%	11%	11%	12%
Storage	4%	3%	4%	3%	3%	3%	4%	4%	4%
Services	13%	12%	12%	13%	13%	14%	9%	11%	12%
Software & Peripherals	17%	17%	17%	17%	16%	16%	17%	18%	17%
Mobility	30%	32%	31%	32%	31%	31%	30%	31%	31%
Desktop PCs	24%	24%	23%	22%	24%	22%	29%	25%	24%
Operating Expenses (in Millions)									
SG&A	1900	1816	1977	2025	2174	2107	7102	6465	7302
R&D	159	163	169	195	205	220	665	624	661
Total Operating Expense	2059	1979	2146	2220	2379	2327	7767	7089	7963

Appendix B. Generic Code for Running Monte Carlo Simulations

```
1 Public Sub RunMonteCarloSimulation(entries As Integer)
2
3 ThisWorkbook.Sheets("MonteCarloSimulations").Activate
4 ActiveSheet.Cells(2, 1).Select
5
6 'will need to recode distribution so it's actually correct
7 Dim i As Integer
8 For i = 1 To entries
9 'values can be created by using the excel built-in function
10 "NORMINV(probability,mean,stddev)"
11
12 'creating these values on the fly
13 Dim volume As Double
14 'volume = center - (center * variance) + (Rnd() * 2 * center * variance)
15
16 volume = ThisWorkbook.Sheets("MonteCarloSimulations").Cells(i + 1, 1).value
17
18 'Set the scenarios created to have the calculated volume.
19 AdjustForecast (volume)
20
21 'The scenario is run and winner determined as a side-effect of RunQuiet. Sorry.
22 Call RunQuiet
23
24 'get the scenario arrays
25 Dim names() As String
26 Dim values() As Double
27
28 Dim scenarioSheet As Worksheet
29 Set scenarioSheet = ThisWorkbook.Sheets("Scenarios")
30
31 Dim costPerUnitRow As Integer
32 Dim distributorNameRow As Integer
33
34 costPerUnitRow = getRowTitled("Cost Per Unit", scenarioSheet)
35 distributorNameRow = getRowTitled("Distributor", scenarioSheet)
36
37 Dim scenarioCount As Integer
38 scenarioCount = DevLib.getFirstEmptyColumn(scenarioSheet, 2, costPerUnitRow) - 2
39 ReDim names(scenarioCount - 1) As String
40 ReDim values(scenarioCount - 1) As Double
41
42
43 For j = 0 To scenarioCount - 1
44 values(j) = scenarioSheet.Cells(costPerUnitRow, j + 2).value
45 names(j) = scenarioSheet.Cells(distributorNameRow, j + 2).value
46 Next
47
48 Call DevLib.CoSortDoubleArray(values, names)
49
50 'Because of the way GoToFirstEmptyRow and PrintOut functions work our subject
51 sheet must be the active sheet
52 ThisWorkbook.Sheets("MonteCarloSimulations").Activate
```



```

53 Call DevLib.GoToFirstEmptyRow(2)
54 DevLib.PrintOut (volume)
55 For j = 0 To 2
56     If j <= UBound(names) Then
57         Call DevLib.PrintOut(names(j), values(j))
58     End If
59 Next
60 DevLib.PrintOut ("\n")
61
62
63 Next
64 'Calculate the Percentage that each wins
65 Call CreatePTForMonteCarloResults
66 End Sub
67
68 Private Sub CreatePTForMonteCarloResults()
69     'This is just slightly modified from the macro recorder. It's ugly but it does the
70     trick
71
72     'Remove any other pivotTables on the page
73     On Error Resume Next
74     Dim pt As PivotTable
75     Set pt = ActiveSheet.PivotTables("MonteCarloResults")
76     pt.ClearTable
77
78
79     On Error GoTo 0
80     If Not pt Is Nothing Then
81         'do nothing
82     Else
83         On Error Resume Next
84         ActiveWorkbook.PivotCaches.Create(SourceType:=xlDatabase, SourceData:= _
85             "MonteCarloSimulations!A:G", Version:=xlPivotTableVersion14). _
86             CreatePivotTable TableDestination:="MonteCarloSimulations!R1C13", TableName
87             :="MonteCarloResults", DefaultVersion:=xlPivotTableVersion14
88
89         ActiveWorkbook.ShowPivotTableFieldList = True
90     End If
91
92
93
94     ActiveSheet.PivotTables("MonteCarloResults").AddDataField
95     ActiveSheet.PivotTables( _
96         "MonteCarloResults").PivotFields("1st"), "Count of 1st", xlCount
97     ActiveSheet.PivotTables("MonteCarloResults").AddDataField ActiveSheet. _
98     PivotTables("MonteCarloResults").PivotFields("1st"), "Percentage", _
99     xlCount
100
101
102     With ActiveSheet.PivotTables("MonteCarloResults").PivotFields( _
103         "Percentage")
104         .Calculation = xlPercentOfTotal
105         .NumberFormat = "0.00%"
106     End With
107
108
109     With ActiveSheet.PivotTables("MonteCarloResults").PivotFields("1st")

```



```

110         .Orientation = xlRowField
111         .Position = 1
112         .pivotItems("(blank)").Visible = False
113     End With
114     On Error GoTo 0
115     pt.RefreshTable
116 End Sub
117
118
119 Public Sub testpopvolumes()
120     Dim samples As Integer
121     samples = 30
122     Dim mcSheet As Worksheet
123     Set mcSheet = ThisWorkbook.Sheets("MonteCarloSimulations")
124
125     'clear data from columns A and B
126     Dim lastRow As Integer
127     lastRow = DevLib.GetFirstEmptyRow(mcSheet, 1, 1) - 1
128     mcSheet.Range(mcSheet.Cells(2, 1), mcSheet.Cells(lastRow + 1, 2)).Clear
129
130     'Set the mean and standard Deviation
131     mcSheet.Cells(1, 11).value = 100000
132     mcSheet.Cells(2, 11).value = 30000
133
134     'Create the volume entries
135     Dim i As Integer
136     i = 1
137     While i <= samples
138         mcSheet.Cells(i + 1, 1).formula = "=NORMINV(RAND(),$K$1,$K$2)"
139         i = i + 1
140     Wend
141
142     Application.ScreenUpdating = False
143     Call RunMonteCarloSimulation(samples)
144     Application.ScreenUpdating = True
145 End Sub

```

Appendix C. Code for Enabling Scenario Exploration in Excel

```
1 Public Function RunQuiet() As String
2
3   Dim scenarios As Worksheet
4   Set scenarios = ThisWorkbook.Sheets("Scenarios")
5
6   ScreenUpdating = False
7   Call RunScenarios
8   ScreenUpdating = True
9
10  'Determine the best result
11  Dim minCostPerUnit As Range
12  Dim costPerUnitRow As Integer
13  costPerUnitRow = DevLib.getRowTitled("Cost Per Unit", scenarios)
14  Set minCostPerUnit =
15  DevLib.GetMinCellInRange(Range(scenarios.Cells(costPerUnitRow, 2),
16  scenarios.Cells(costPerUnitRow, DevLib.getFirstEmptyColumn(scenarios, 2,
17  costPerUnitRow) - 1)))
18
19
20
21  RunQuiet = scenarios.Cells(DevLib.getRowTitled("Distributor", scenarios),
22  minCostPerUnit.column).value
23  End Function
24
25  Public Function RunAllScenarios()
26
27    Call RunScenarios
28
29    Dim scenarios As Worksheet
30    Set scenarios = ThisWorkbook.Sheets("Scenarios")
31
32    'Report out on best scenario
33    Dim strResult As String
34    strResult = "The best scenario is ""
35
36    'Determine the best result
37    Dim minCostPerUnit As Range
38    Dim costPerUnitRow As Integer
39    Dim lastScenarioColumn As Integer
40
41
42    costPerUnitRow = DevLib.getRowTitled("Cost Per Unit", scenarios)
43    Set minCostPerUnit =
44    DevLib.GetMinCellInRange(Range(scenarios.Cells(costPerUnitRow, 2),
45    scenarios.Cells(costPerUnitRow, DevLib.getFirstEmptyColumn(scenarios, 2, 29) - 1)))
46
47    'Build the message String
48    If minCostPerUnit Is Nothing Then
49      Exit Function
50    End If
51    strResult = strResult + scenarios.Cells(6, minCostPerUnit.column).value
52    strResult = strResult + "". This result suggests we "
```



```

53
54   If scenarios.Cells(DevLib.getRowTitled("Distributor", scenarios),
55   minCostPerUnit.column).value = "Direct" Then
56       strResult = strResult + "go direct with the supplier."
57   Else
58       strResult = strResult + "use " +
59   scenarios.Cells(DevLib.getRowTitled("Distributor", scenarios),
60   minCostPerUnit.column).value + " as our distributor."
61   End If
62
63   MsgBox (strResult)
64
65 End Function
66
67
68 Private Sub RunScenarios()
69     Dim scenarioColIndex As Integer
70     scenarioColIndex = 2
71
72
73     If ScenarioLabelsAreBad() Then
74         Exit Sub
75     End If
76     'Verify all scenarios are labeled
77     If getFirstEmptyColumn(ThisWorkbook.Sheets("Scenarios"), 2, 6) <>
78     getFirstEmptyColumn(ThisWorkbook.Sheets("Scenarios"), 2, 7) Then
79         MsgBox ("The scenario names and volumes have not been entered correctly. Please
80 correct and retry.")
81     End If
82
83     Dim scenarios As Worksheet
84     Set scenarios = ThisWorkbook.Sheets("Scenarios")
85     While scenarios.Cells(6, scenarioColIndex).value <> ""
86         Call RunOneScenario(scenarioColIndex, scenarios)
87         scenarioColIndex = scenarioColIndex + 1
88     Wend
89
90
91 End Sub
92
93
94 Public Function ScenarioLabelsAreBad()
95     ScenarioLabelsAreBad = False
96
97     'Verify all scenarios are labeled
98     If getFirstEmptyColumn(ThisWorkbook.Sheets("Scenarios"), 2, 6) <>
99     getFirstEmptyColumn(ThisWorkbook.Sheets("Scenarios"), 2, 7) Then
100         MsgBox ("The scenario names and volumes have not been entered correctly. Please
101 correct and retry.")
102         ScenarioLabelsAreBad = True
103     End If
104
105 End Function
106 Public Function RunOneScenario(scenarioColIndex As Integer, scenarioSheet As
107 Worksheet)
108     Dim inputSheet As Worksheet
109

```



```

110 If Application.Calculation <> xlCalculationAutomatic Then
111     MsgBox ("Running the scenarios requires the Calculation mode to be automatic.
112 This has been changed for you.")
113     Application.Calculation = xlCalculationAutomatic
114 End If
115
116
117
118     Set inputSheet = scenarioSheet.Parent.Sheets("Inputs")
119     inputSheet.ClearCircles
120
121 Call CopyScenarioInputsToModel(scenarioColIndex, scenarioSheet, inputSheet)
122 Call ValidateModelInputs(scenarioColIndex, scenarioSheet, inputSheet)
123
124 'Now gather that input back and store the results
125 Call SaveModelOutputs(scenarioColIndex, scenarioSheet)
126
127
128
129
130 End Function
131
132 Private Sub SaveModelOutputs(scenarioColIndex As Integer, ByRef scenarioSheet As
133 Worksheet)
134     'Copy outputs to the appropriate spot.
135
136     Dim finResults As Worksheet
137     Set finResults = ThisWorkbook.Sheets("Financial Results")
138     Set costSheet = ThisWorkbook.Sheets("Costs")
139
140     scenarioSheet.Cells(getRowTitled("Fulfillment Costs", scenarioSheet),
141 scenarioColIndex).value = finResults.Range("FulfillmentCosts")
142     scenarioSheet.Cells(getRowTitled("Recoveries", scenarioSheet),
143 scenarioColIndex).value = costSheet.Range("ReturnsRecoveries")
144     scenarioSheet.Cells(getRowTitled("Distributor Rebate", scenarioSheet),
145 scenarioColIndex).value = costSheet.Range("DistributorRebate")
146     'scenarioSheet.Cells(getRowTitled("1", scenarioSheet), scenarioColIndex).value =
147 ThisWorkbook.Sheets("Costs").Range("Credits").value
148     scenarioSheet.Cells(getRowTitled("Disti Markup", scenarioSheet),
149 scenarioColIndex).value = finResults.Range("ProductAcquisitionPremium")
150     scenarioSheet.Cells(getRowTitled("Product Acquisition Base", scenarioSheet),
151 scenarioColIndex).value = finResults.Range("ProductAcquisitionCost_Base")
152     scenarioSheet.Cells(getRowTitled("Total Fulfillment Cost", scenarioSheet),
153 scenarioColIndex).value = finResults.Range("TotalFulfillmentCost")
154     scenarioSheet.Cells(getRowTitled("Cost Per Unit", scenarioSheet),
155 scenarioColIndex).value = finResults.Range("CostPerUnit_Inclusive")
156
157     scenarioSheet.Cells(getRowTitled("Markup Used", scenarioSheet),
158 scenarioColIndex).value = ThisWorkbook.Sheets("Derived
159 Inputs").Range("DistributorMarkup").value
160     scenarioSheet.Cells(getRowTitled("Markup Based On", scenarioSheet),
161 scenarioColIndex).value = ThisWorkbook.Sheets("Data
162 Relevance").Range("MU_Source").value
163
164     scenarioSheet.Cells(getRowTitled("Rebate Used", scenarioSheet),
165 scenarioColIndex).value = ThisWorkbook.Sheets("Derived
166 Inputs").Range("DistributorRebateRate").value

```



```

167 scenarioSheet.Cells(getRowTitled("Rebate Based On", scenarioSheet),
168 scenarioColIndex).value = ThisWorkbook.Sheets("Data
169 Relevance").Range("Rebate_Source").value
170
171
172
173 Dim hcResults As Worksheet
174 Set hcResults = ThisWorkbook.Sheets("Headcount Results")
175
176
177 'Get Array of headcount activity names
178 Dim hcTitles() As String
179 Dim firstActivityRow As Integer
180 Dim lastActivityRow As Integer
181
182 firstActivityRow = getRowTitled("Activity", hcResults) + 1
183 lastActivityRow = DevLib.GetFirstEmptyRow(hcResults, 1, firstActivityRow) - 1
184
185 ReDim hcTitles(lastActivityRow - firstActivityRow)
186
187 Dim i As Integer
188 i = 0
189 While (i + firstActivityRow) <= lastActivityRow
190 hcTitles(i) = hcResults.Cells(firstActivityRow + i, 1).value
191 i = i + 1
192 Wend
193
194 For Each title In hcTitles
195 scenarioSheet.Cells(getRowTitled(title, scenarioSheet), scenarioColIndex).value =
196 hcResults.Cells(getRowTitled(title, hcResults), 3).value
197 Next
198
199 End Sub
200
201
202 Private Sub ValidateModelInputs(scenarioColIndex As Integer, scenarioSheet As
203 Worksheet, ByRef inputSheet As Worksheet)
204 Dim errorsExist As Boolean
205 errorsExist = False
206 Dim cell As Range
207 For Each cell In inputSheet.UsedRange
208 If Not cell.Validation.value Then
209 errorsExist = True
210 End If
211 Next
212
213
214 If errorsExist Then
215 MsgBox ("Input Errors Exist in scenario " &
216 scenarioSheet.Cells(getRowTitled("Scenario Names", scenarioSheet),
217 scenarioColIndex).value & ". Please correct circled inputs.")
218 inputSheet.CircleInvalid
219 End If
220
221
222 End Sub
223

```

```

224 Public Sub CopyScenarioInputsToModel(scenarioColIndex As Integer, ByRef
225 scenarioSheet As Worksheet, ByRef inputSheet As Worksheet)
226
227     'Copy inputs to the Inputs Sheet
228     inputSheet.Range("AnnualVolume") = scenarioSheet.Cells(getRowTitled("Expected
229 Volume (annual)", scenarioSheet), scenarioColIndex).value
230     inputSheet.Range("ProductCost") = scenarioSheet.Cells(getRowTitled("Product Cost
231 (Direct)", scenarioSheet), scenarioColIndex).value
232     inputSheet.Range("ProductType") = scenarioSheet.Cells(getRowTitled("Product Type",
233 scenarioSheet), scenarioColIndex).value
234     inputSheet.Range("UnitsPerOrder") = scenarioSheet.Cells(getRowTitled("Average
235 Units per Order", scenarioSheet), scenarioColIndex).value
236     inputSheet.Range("ProductCategory") = scenarioSheet.Cells(getRowTitled("Product
237 Category", scenarioSheet), scenarioColIndex).value
238     inputSheet.Range("DistiName") = scenarioSheet.Cells(getRowTitled("Distributor",
239 scenarioSheet), scenarioColIndex).value
240     inputSheet.Range("MarkupOverride") = scenarioSheet.Cells(getRowTitled("Markup
241 Override", scenarioSheet), scenarioColIndex).value
242     inputSheet.Range("VendorName") = scenarioSheet.Cells(getRowTitled("Supplier Name",
243 scenarioSheet), scenarioColIndex).value
244     inputSheet.Range("NewVendor") = scenarioSheet.Cells(getRowTitled("New Supplier",
245 scenarioSheet), scenarioColIndex).value
246     inputSheet.Range("ProductLine") = scenarioSheet.Cells(getRowTitled("Product Line",
247 scenarioSheet), scenarioColIndex).value
248     inputSheet.Range("RebateOverride") = scenarioSheet.Cells(getRowTitled("Rebate
249 Override", scenarioSheet), scenarioColIndex).value
250
251 End Sub
252
253 Public Sub AdjustForecast(newForecast As Double)
254     Dim scenarios As Worksheet
255     Set scenarios = ThisWorkbook.Sheets("Scenarios")
256
257     Dim forecastRowIndex As Integer
258     forecastRowIndex = DevLib.getRowTitled("Expected Volume (annual)", scenarios)
259
260     Dim i As Integer
261     i = 2
262     While scenarios.Cells(forecastRowIndex, i).value <> ""
263         scenarios.Cells(forecastRowIndex, i).value = newForecast
264         i = i + 1
265     Wend
266 End Sub
267
268

```


Appendix D. Worksheet Listing and Explanation for Model Implementation

Sheet Name	Type	Purpose
Disti GFX Data	Data	Contains information on the contracts between Dell and major distributors
Narkup Averages	Data	Contains average data for scenarios that do not have actual. For ex: Products currently drop shipped do not have distributor rates assigned, we calculate an approximate rate here.
MU Rate by Category Lookup	Data	Contains the distributor markup rates used for different categories of product.
Distributors	Data	A list of distributors and specific products that they service
Salary Table	Data	A list of the companies salary bands and their fully burdened cost in a variety of countries. Used for modeling overhead costs of fulfillment processes.
Personnel Capacities	Data	Stores the salary band and transaction capacity for each job type.
Derived Inputs	Input	Creates additional input points that can be derived without prompting the user for them. Things like the number of orders are calculated here and referenced elsewhere.
Inputs	Input	Stores user input for the current scenario.
Model Parameters	Input	Stores parameters such as cost of capital, default payment terms, and historical transaction breakdowns
Scenarios	Input / Output	This stores user input for all scenarios, and displays results after those scenarios are run.
Data Relevance	Model	The is the control sheet for matching inputs with data. Ex: This is the sheet responsible for linking a product to it's markup rate
Headcount Results	Model	Calculates the number and cost of personnel to support the fulfillment secenario.
Fulfillment Personnel	Model	Calculates transaction costs based on personnel usage from headcount results
Returns	Model	Calculates the overhead costs and recovery amounts for the reverse logistics process.
New Vendor On Boarding	Model	Models the new vendor on-boarding process.
Costs	Output	Brings together all costs for presentation.
Financial Results	Output	Brings together costs and credits for final presentation

-
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