Monitoring and Evaluating Reorder Point System Performance: A Cost-weighted Approach

By

Derrick Cokee Ongchin

B.S. Materials Science and Engineering, Cornell University, 2006

Submitted to the MIT Sloan School of Management and the Department of Electrical Engineering and Computer Science in Partial Fulfillment of the Requirements for the Degrees of

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Signature of Author ____________

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Electrical Engineering and Computer Science
MIT Sloan School of Management

Certified by ____________

Christopher L. Magee, Thesis Supervisor
Professor of the Practice of Mechanical Engineering and Engineering Systems

Certified by ____________

Georgia Perakis, Thesis Supervisor
William F. Pounds Professor of Management

Accepted by ____________

Leslie Kolodziejski, Professor of Electrical Engineering and Computer Science
Chair, EECS Committee on Graduate Students

Accepted by ____________

Debbie Berechman, Executive Director of MBA Program
MIT Sloan School of Management

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Abstract

Organizations are quickly realizing the need to leverage data and analytics to stay one step ahead of the competition as fast-paced global markets continue to emerge and grow and the world becomes increasingly complex. More than ever, corporate executives are executing data-driven decisions and strategies to run businesses. They require scenarios and simulations on alternative courses of action that incorporate complex business parameters in order to make decisions that continuously hone customer focus.

In an environment of global economic uncertainty, Cisco Systems sees itself entering a time of unprecedented opportunity. With the customer as a leading priority, this thesis investigates the monitoring and evaluation of Cisco's reorder point system in increasing supply chain visibility and driving customer satisfaction excellence. We aim to develop a model that will aid in data-driven decision making and provide an organization the capability to quickly respond to changes in a volatile environment without additional costs or impact to customer experience. The model is intended to serve as a tool to bridge strategy and execution by providing lean process and supply planners invaluable insights into optimizing the inventory management system and improving customer service levels.

The model aggregates historical demand data, inventory policy settings, and cost-weighted item performance to gauge system-wide performance. Model testing accurately corroborates previously known issues of insufficient reorder points. Preliminary user feedback suggests strong initial buy-in within the organization.

Thesis Advisor: Christopher L. Magee
Title: Professor of the Practice of Mechanical Engineering and Engineering Systems

Thesis Advisor: Georgia Perakis
Title: William F. Pounds Professor of Management, MIT School of Management

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Table of Contents

Table of Figures

Glossary

Term	Acronym	Definition
Achieved Service Level	ASL	A customer service level metric signifying whether an inventory system is performing as designed
Bill of Material	BOM	Defines the structure, parts, and components of a product
Closed-loop Corrective Action	CLCA	Recursive approach to addressing system issues in which generated feedback is returned to origin of discovery
Contract Manufacturer	CM	Manufacturer of the making the product or assembly
Cycle time to replenishment	CT2R	Total cycle time from the time of issuing an order to the time of material receipt at the ordering node
Demand during lead time	DDLT	The demand exhibited for an item over the period of its replenishment cycle time
Direct Fulfillment	DF	Manufacturing sites that do late definition work to products (configuring products) before shipping them to customers
End of Life	EOL	Taking a product off the market and determining what support is required for products already in the field
Manufacturing Partner	MPa	Contract Manufacturer
Observed Service Level	OSL	The actual customer service level attained which takes into account execution issues
Printed Circuit Board Assembly	PCBA	Primary unit manufactured by CMs, consisting of a printed circuit board and anywhere between ten and tens of thousands of components
Product Identification	PID	Product ID - Product Identifier – The alpha-numeric orderable name of a product
Reorder point	ROP	Inventory level at which an order is place to replenish stock
Statistical Inventory Size	SIS	Safety stock – inventory held as a buffer to protect against demand volatility and delay in orders
Single Unit Kanban	SUK	Item generally issued during a shortage to meet demand
Target Service Level	TSL	Service level used as in input into the ROP sizing algorithm
Top Assembly Number	TAN	All the components combine to form an assembly

1 Introduction

1.1 Thesis Motivation

Customer satisfaction is paramount to the long-term success of any business. Effective control and management of inventory in a supply chain, as well as accurate visibility and expeditious, efficient fulfillment, will not only lead to a reduction in operating costs but also bring satisfied customers back for future business. However, management of inventory, especially in instances where it provides a competitive edge, is not as simple as keeping abreast with the contemporary practices of inventory standards. Most supply chains, particularly those that employ manufacturing processes, require a mix of both simple and complex integrated inventory controls. Additionally, the more complicated the product being manufactured, the more complex the supply chain and controls required.

Cisco Systems requires a highly sophisticated supply chain that oversees the production of high-tech goods which can range from IP phones and cable TV boxes that contain a few components to routers, high-end switches, and mid-range networking products that contain hundreds of components. Most of these products are custom-configured within a series of regional logistics hubs and shipped around the world from facilities located on three continents. These products are built to order and delivered without the services of a single Cisco employee.

In the last decade, Cisco's Customer Value Chain Management (CVCM) organization evolved the company's inventory management system from a supply-push model to a demand-pull model to better prepare itself to deliver solutions that meet exacting customer needs and facilitate Cisco's move into diverse global markets (1). This transition to a demand-pull model meant that products would no longer be produced based on expectations but rather on actual customer orders. Manufacturers would also be freed from having to hold large quantities of inventory of goods that may never sell. However, in order to truly reap the benefits of these gains in efficiency and reductions in risk, high levels of systems responsiveness, as well as lean planning, are required. Thus, it is imperative that managers monitor and evaluate the performance of the inventory management system on an ongoing basis to ensure it is performing as originally designed and take corrective action if necessary.

1.2 Background and Objective

As part of CVCM's supply chain excellence and ongoing improvement efforts, the Global Supply Planning (GSP) and Demand Management and Planning (DM&P) teams of CVCM have embarked upon an initiative to measure the health of the demand-pull model to drive advances in inventory optimization across the supply chain. One of the primary levers driving not only the inventory but the performance of a supply chain is the reorder point (ROP). The logic of the ROP is that material is to be reordered when the stock level of material is used up during the time it takes to bring in additional stock. The ROP is thus a predetermined inventory level at which replenishment action is called for when the on-hand and on-order inventory drops to or below that level.

In the case of a pull-based replenishment system, when the inventory drops to the ROP at a specific node in the supply chain, this triggers replenishment from its supply nodes. When the ROPs are reached at the supply nodes, this triggers replenishment from their supply nodes and so forth. This in turn creates an end-to-end reorder point pull system. Common questions posed by a supply planner include:

- Is the reorder point system performing as intended?
- How can it be determined whether the ROPs for each product within each node are set appropriately?
- If the ROP of a product at a specific node is underperforming, what then?

Clearly, a high ROP will reduce shortage costs and increase holding costs. On the other hand, a low ROP will increase shortage costs and reduce holding costs. At some intermediate value for the ROP, the sum of shortage and holding costs will be minimized.

The purpose of this thesis is not to optimize the ROP for every item at each node of the supply chain but to develop the framework that answers the three questions posed above and drive ROP optimization. The proposed solution will aid supply planners in gaining accurate visibility into ROP performance to enhance decision making. For managers, it will serve as a tool to bridge the gap between strategy and execution at all levels.

1.3 Research Methodology

The methods for establishing a reorder point system are well known across a wide variety of industries. Once the system is established, however, evaluating and maintaining the system poses a major challenge. The framework developed at Cisco serves as a proof of concept that can be extended to any organization facing similar challenges. Its primary intent is to demonstrate the general approach taken in establishing a monitoring system that is not necessarily limited in integration to the specific company and industry used in the study.

Practices for monitoring and evaluating the performance of a reorder point system are not widely common or shared across any industry. Two factors that may contribute to this phenomenon are the compromises in inventory theory made when establishing the system and the large number of items in the typical inventory system, both of which will be discussed in Chapter 2. As a corollary, we strive to develop a model by primarily relying on industry experts and internal subject matter experts (SME) while acknowledging that certain aspects of the model are only applicable to the organization under study. The research included the following tasks:

- **Literature review:** We investigated previous knowledge or practices of monitoring and evaluating a reorder point system that may exist inside and outside of the industry.
- **Polling industry and subject matter experts:** We conducted weekly meetings involving industry and subject matter experts to establish a viable workflow and ensure the model could be integrated into the current reorder point system.
- **Model design and development:** With the input collected from the weekly meetings, we defined much of the logic and structure of the preliminary metrics for evaluating the reorder point system. We employed an iterative approach in refining and simulating the model while aiming to reach a consensus on each aspect of the model.
- **Data collection and analysis:** The model relies extensively on historical demand and ROP data which reside in different databases. One of the biggest challenges involves consolidating the data and streamlining the data collection process to facilitate analysis.

- **Pilot execution:** We first piloted the model on a flagship product family to ensure the results were satisfactory and to further refine the model before moving forward.
- **Data mining and streamlined analytics:** Given the large number of items handled in the inventory system and Bill of Material (BOM) complexity, programming methods were heavily employed to mine the necessary data and analyze it in a streamlined fashion.
- **Integration of framework:** Integration of the model into the current system involved presentations to leadership, end-user training, technical training, meetings with IT for maintaining the framework, and general knowledge transfer.
- **Testing of framework:** We garnered feedback for accuracy, as well as usability of the tool, from supply and lean process planners and SMEs.

1.4 Company Background

Founded in 1984 by Stanford University scientists, Cisco Systems brought disruptive technologies to market that changed the way the world communicates and collaborates. Named after the city of San Francisco which it represented, Cisco's goal was to bring people together – a mission embodied in its logo formed based upon the shape of the Golden Gate Bridge. Now headquartered in San Jose, California, the company has approximately 70,000 employees in more than 200 offices across 60 countries worldwide with annual revenue of $40 billion as of 2010. Every year, the company's influence continues to grow. In 2009, the company became one of just 30 companies to comprise the Dow Jones Industrial Average.

As Cisco grew into a large corporation, leaders became concerned over whether the company could sustain its pace of disruptive innovation. The more time the employees spent on sustaining innovation and existing products, the less bandwidth they had for groundbreaking, disruptive work. Cisco turned to acquisitions as one strategy to bring talent and new products into the company. Since its founding, the company has made over 140 acquisitions ranging from small startup companies to its largest acquisition of Scientific-Atlanta for $6.9 billion. These acquisitions have been crucial in fueling the company's disruptive innovation engine, gaining it entry into markets, such as computing, storage, and voice.

The rewards that Cisco reaps from acquisitions are irrefutable. However, Cisco Senior Vice President, Inder Sidhu, describes in his book, *Doing Both*, that one of the reasons Cisco is a leader in the network routing and switching space and continues its success as a company stems from its ability to pair disruptive and sustaining innovations.

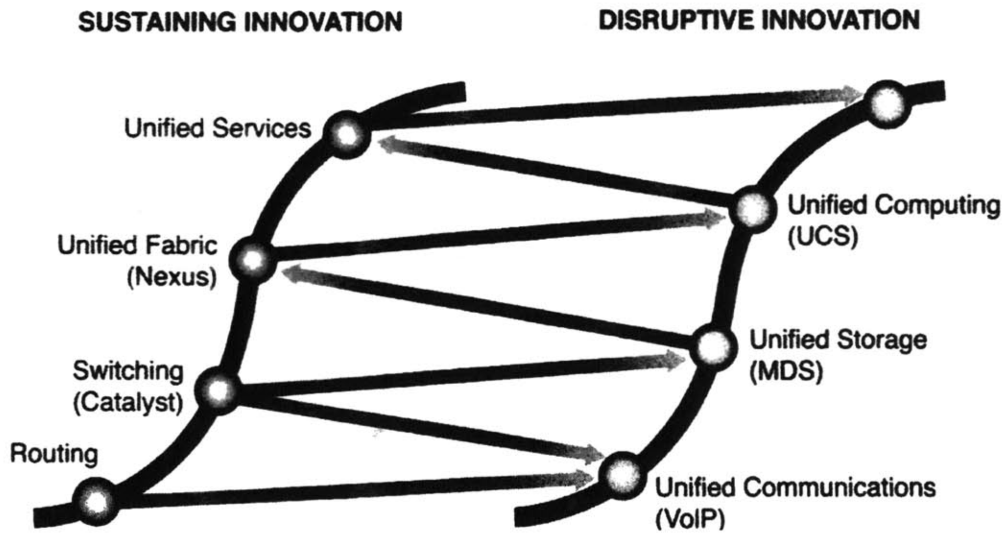


Figure 1: Sustaining and disruptive innovation (Sidhu) (1)

By harnessing a cross-leverage of innovation (Figure 1), a multiplier effect can be achieved that accelerates the next generation of its own technologies while enabling its entry into market adjacencies. With this, Cisco has the flexibility to select the best technologies it deems fit from inside and outside to create a compelling and complementary portfolio of products and services.

The evolution of Cisco's supply chain began in the mid-1990s when Cisco pioneered outsourced manufacturing and began taking a more integrated, holistic approach to manufacturing and supply chain management. Cisco recognized the need for a leaner, more agile and demand-driven supply chain that could adapt to changes in the marketplace and the macro-economy and scale globally to keep pace with Cisco's growth. This awareness helped drive an organization-wide initiative known as Manufacturing Excellence or Mx, which was launched in 2004.

The next phase of organizational transformation was based on an extended supply chain and increased collaboration with Cisco and external partners throughout the product lifecycle, as well as the extension of lean best practices to Cisco's distribution channel. Building on successes in these and other areas, Cisco continued the expansion and integration of its value chain with the formation of CVCM.

CVCM was formed in October 2008 when three organizations within Cisco's Operations, Processes and Systems division joined forces: Corporate Quality, Global Supply Chain Management, and Customer Service and Support. The vision behind the new organization was to improve alignment and integration among these teams to provide an unrivaled customer experience. In a value chain, each activity in the chain adds customer value to a product or solution. Driven by customer preferences and demand, value chain operations are focused on the end-to-end customer quality experience and not just on improving efficiency or reducing costs.

1.5 Thesis Structure

This thesis is organized into six chapters:

- **Chapter 1** describes the thesis motivation, background and objective, as well as the research methodology and company background.
- **Chapter 2** contains a review of existing literature intended to familiarize the reader with relevant inventory theory concepts, the nature of Cisco's current supply chain, and prior work on monitoring and evaluating the performance of reorder point systems.
- **Chapter 3** dives into the modeling methodology by guiding the reader through each step from model scoping, formulation, clarification, and utilization.
- **Chapter 4** discusses the approach to testing the system model and presents the findings. It also presents test cases to convey how the model can quickly be tailored to serve extended analyses.
- **Chapter 5** evaluates the model's effectiveness with regard to accuracy and usability. It also discusses organizational challenges regarding implementation of the tool and recommendations for future work.

2 Inventory Control and Pull Production

2.1 Consumption-based Planning

The role of material requirement planning (MRP) is integral to a supply chain. MRP serves to monitor inventories and automatically generate order proposals for purchasing and production. This is accomplished using various materials planning methods which are covered by different procedures, such as consumption-based planning. The historical consumption of material, as well as the forecasted consumption, are useful for determining planning policies regarding future purchase of stock and help decide the level of inventory that should be maintained at different sites. We will now look at two methods of consumption-based planning.

2.1.1 Reorder point planning

In ROP planning, a system compares the level of warehouse inventory with the ROP. If that level falls below the ROP, an order for additional stock is made. Ideally the replenishment of stock occurs when the inventory drops to zero. At that point, an instantaneous replenishment of stock would bring the level of inventory back to its original value. However, in real life situations, zero lead times do not exist. There is always a delay from the time an order is placed to time when the materials are actually received. Thus, ROPs are always higher than zero so that when the level of inventory falls to the ROP and an order is placed, the material replenishment will arrive before the inventory completely runs out.

Based on this concept, the appropriate ROP value for a good can be determined by averaging the material consumption during the lead time, or demand during lead time (DDLT), with the addition of a buffer, or safety stock (SS), which is the minimum level of inventory held at all times to protect against shortages due to demand volatility.

$$ROP = DDLT + SS \qquad (1)$$

In basic inventory theory, the demand is considered to be independent, continuous, and uniform. In many real life situations, it may be discontinuous and non-uniform, however. The lead time for a material is dependent on the sum of a combination of factors, which may include:

- Supplier or manufacturing lead time
- The review period (daily, weekly, monthly)
- Purchase order preparation time
- Receiving and inspection time

The safety stock calculation generally involves a sophisticated statistical formula that takes into account the average lead time and demand, their respective standard deviations, and the desired service level. A desired service level of 95%, for example, implies that the risk of a stockout is 5% or about 1 in 20 orders. The determination of the level of safety stock to hold involves a tradeoff between the costs associated with carrying additional inventory and the risk of stockout, which would result in customer dissatisfaction and lost business. We now revisit the ROP calculation with the DDLT and SS components substituted with their respective algebraic expressions:

$$ROP = \bar{d} \cdot \bar{L} + z\sqrt{\bar{d} \cdot \sigma_L^2 + \bar{L} \cdot \sigma_d^2} \quad (2)$$

where,

d: *demand or consumption of units per day*

L: *lead time in days*

σ_L: *standard deviation of lead time*

σ_d: *standard deviation of demand*

z: *statistical coefficient determined by service level*

Equation 2 is useful for understanding the relationship between different factors and their impact on the ROP. For example, if the demand rate and lead time were constant ($\sigma_L = 0, \sigma_d = 0$), no safety stock would be warranted, and the ROP would simply equal the DDLT. Along the same lines, the higher the desired service level ($z \uparrow$), the higher the required safety stock. Finally, it is important to note that in terms of manageable levers, being able to reduce the lead time, as well as its variability, is a common method of reducing the safety stock and overall holding costs as a result. However, that technique is often simpler in theory than it is in practice.

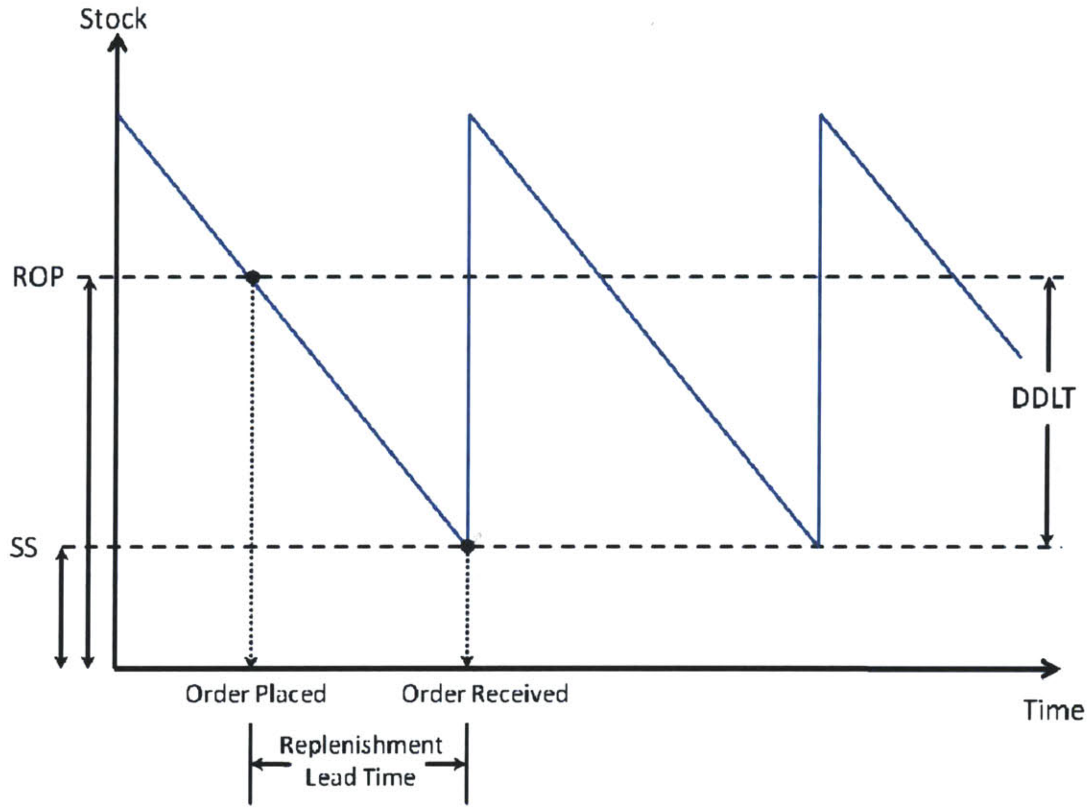


Figure 2: Reorder Point System "Sawtooth" Curve

Figure 2 displays the traditional "sawtooth" inventory profile and its relationship to a reorder point system. Here, the point is to notice that the safety stock is set to at a level to cover any excess consumption during the replenishment lead time, as well as any order delays. Thus, previous consumption patterns or any changes in future requirements, as well as the supplier's delivery timeliness or that of production, must be taken into account in setting safety stock levels.

In reorder point planning, the ROP and SS are key control parameters. In practice, there are two ways in which the parameters are determined, either manually or automatically by the system.

- **Manual Planning:** In this procedure, a supply planner or MRP controller must specify both the ROP and SS values and input them into the system.
- **Automatic Planning:** Both the ROP and SS are calculated by the integrated forecasting software.

In the case of automatic planning, the system's software determines the forecast value for future requirements solely based on historical data. A supply planner or MRP controller then inputs a desired service level, which allows the system to output corresponding ROP and SS values based on forecasted lead time values. As the forecast is carried out regularly, the ROP and SS values will continually adapt to current consumption and delivery schedule patterns, which aids in minimizing inventory levels.

2.1.2 Forecast-based planning

Similar to reorder point planning, forecast-based planning also operates using historical and forecasted consumption data, which determine the future ROP and SS requirements via an integrated forecasting software. Forecasts are still carried out regularly. However, in contrast to reorder point planning, the data only forms the basis for planning.

The potential advantage arises from the fact that future requirements are more closely adapted to suit current consumption needs. If material has been withdrawn from stock, this is taken into account, and the requirement is reduced by the withdrawn amount in the period. Thus, the material that has already been used is not included in the planning again. Additionally, each material can possess its own forecast and number of periods to be included in the forecast. The number of forecast periods to be taken into account in the requirement planning can also be configured. A requirements date would be set on the first workday of the month, when the monthly requirement will be set. This monthly requirement can then be divided into weekly or daily requirements.

At Cisco, the mean demand component of the ROP is sized using a Gross Node Forecast supplied by each demand node. From this forecast, weeks 5 through 17 of the total period are used to estimate the mean demand. The choice of 13 weeks of data starting from week 5 derives from the following:

- The fluctuations and variability that exist in the first 4 weeks, due largely to backlog, may introduce noise into the base ROP value.
- Thirteen weeks provide one quarter's worth of data which reflects one complete business cycle for Cisco. Capturing the entire quarterly profile embeds stability in the ROP and helps ensure that changes in forecast more directly tie in with the direction and degree of changes in ROP levels.
- More or less than 13 weeks of data (such as 8 weeks or 21 weeks) may skew the demand profile due to the inclusion of a partial quarter.
- Higher multiples of 13 weeks are less desirable because of lower confidence in any forecast over longer horizons.

In order to understand the calculation of the SS component of the ROP, we must first take a look at the ROP formula used at Cisco, which assumes a normal demand distribution. The formula follows previous ROP formulas (1 and 2), with some minor differences:

$$ROP = \mu_{ct} + z \cdot \sigma_{ct} \tag{3}$$

where,

μ_{ct}: *average consumption over lead time*

σ_{ct}: *standard deviation of consumption data over lead time*

z: *statistical coefficient determined by service level*

Here, the SS component, referred to at Cisco as the Statistical Inventory Size (SIS), only intends to cover demand variability. Material consumption, in this case, is based on the receipt of purchase orders (PO) and not on their fulfillment. In order to reflect true demand variability more accurately, actually PO data is used, minimizing the need for consumption smoothing. Six months, or two business cycles, of PO consumption data is used to determine SIS requirements unless a representative demand pattern is not reflected in that time period. This generally occurs with items under New Product Introduction (NPI) or when the demand undergoes a dramatic shift. In those cases, 3 months, or 1 business cycle, is used to estimate the SIS.

2.2 Reorder Point System Performance Evaluation

There are currently no metrics to measure the performance of Cisco's reorder point system to understand whether the ROP sizing algorithm of the integrated forecasting software is working per planning requirements. Any metrics that were identified in previous lean initiatives within the company have since been discontinued. Metrics play a crucial role in managing, executing, and optimizing the reorder point system in a manner that is consistent and scalable. Both Cisco and its manufacturing partners (MPa) need to be able to rely on a set of metrics to gauge the performance of the demand pull system, enable root-cause analysis, and measure the effectiveness of the inventory management levers. Once foundational elements and operational stability are established, appropriate improvement targets can be set and ROP optimization efforts can be executed.

In addition to metrics, reporting requirements must be defined. Initially, reporting may be ad hoc and not regularly scheduled. However, reporting is intended to provide information to the necessary stakeholders in order to troubleshoot. A long term goal is to enable all metrics and reporting through consistent automation.

A survey of literature reveals that there have been many refinements to reorder point systems, as well as other inventory management systems. However, the primary focus of past research has been on developing efficient techniques and designing effective control systems. Since inventory systems function at the direction of human operators within dynamic environments, Watts (2) argues that it is reasonable to assume a system's effectiveness is subject both to the discipline of the human operators and to changing environmental conditions. In order to ensure an inventory management system is performing as intended, managers must monitor and evaluate its performance periodically and take any corrective action, if necessary. Unfortunately, prior research has provided few concepts or practices for evaluating the performance of inventory management systems. Based on the current research that does exist, we begin by exploring Pope's model for evaluating the performance of a reorder point system, which lays the foundation for Watts' model which includes a fully integrated monitoring system.

2.2.1 Pope's Model

Pope (3) identifies a number of environmental and performance variables that can be monitored but does not develop an integrated monitoring system. He argues that the techniques for establishing a reorder point system are well known but evaluating and maintaining the system poses challenges due to the comprises with inventory theory made when establishing a system and the large number of items in a typical system. For example, the inventory costs associated with a reorder point system are often estimates and sometimes adjusted to suit company policies, demand may not be smooth or predictable, safety stock is difficult to define and compute, and material managers may be under pressure that causes them to deviate from "ideal" policies. In addition, theoretical models focus on one line item at a time, and thus for a system to derive meaningful insights from thousands of items is overwhelming. A well-designed inventory management system includes continuous monitoring of system performance and either makes or identifies corrective action.

Figure 3: Relationship of Inventory Elements (Pope et al) (3)

According to Pope, the three elements of a reorder point system are data collection, decision making and planning, and implementation, feedback, and control. If the elements are properly related, they form a closed loop (Figure 3). In this model, data is generated continuously and is used to make decisions. Once decisions are implemented, the system performance is monitored through a feedback mechanism to detect deviations from plans and to take corrective action that aligns the outcome with the plans. With a properly designed feedback mechanism, the previously mentioned challenges from evaluating a reorder point system are mitigated.

Pope unfortunately does not discuss specific methods to develop a feedback mechanism and only provides a series of feedback measures that allow management to determine with reasonable precision whether an inventory system is performing as planned. The author remarks that the measures are based on readily available data and may require computerized programming to calculate and present. A major take away from the study is the concept of gaining feedback from a reorder point system by observing the level of customer service. Essentially, Pope argues that customer service can be measured in two ways, and that the data available in most inventory systems lend themselves easily to the following two measures:

- **Cycle service level** is concerned with the ability to meet demand during the reorder cycle, when the possibility of stockout is highest.
- **Fill rate** refers to the percent of demand that is able to met from stock across all time periods.

Pope refers to the evaluations as “snapshots” of customer service which, for every item of inventory, should be checked on a regular basis. This task is not as formidable as it seems, since items that meet customer service standards can be omitted from analysis. Thus, only items that have experienced stockouts need to be reviewed. Furthermore, most computer-based systems have stockout data readily available, making calculations relatively straightforward. A materials manager can then sort out items not meeting customer service standards and determine if the ROPs need to be reevaluated.

2.2.2 Watts' Model

Like Pope, Watts characterizes a reorder point system into three elements, as well: environmental variables, decision rules, and performance measures.

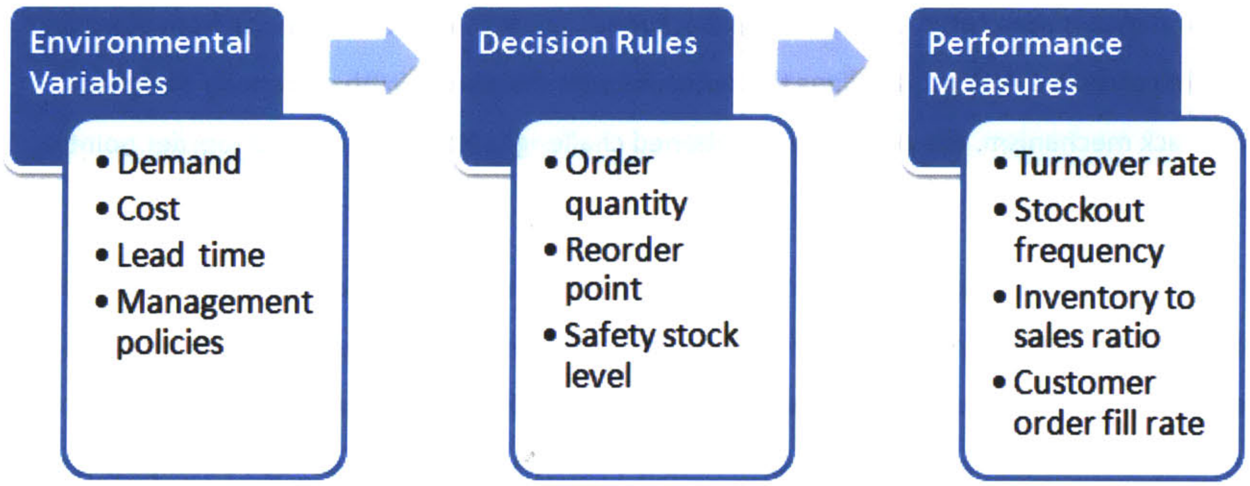


Figure 4: Characterization of ROP system (Watts et al) (2)

The environmental variables are used to design and install the system, which then operates using the appropriate decision rules to signal any actions required of the systems operator. Finally, the performance measures must be monitored to ensure that the system is functioning as originally designed. Since the system may not have the capability of detecting and reacting to changes in its operating environment, a carefully design monitoring system is required.

Watts proposes designing a monitoring system on the foundation of two principles. First, system performance deviations may be attributable to system fitness causes (i.e. faulty design or changes in operating environment), and thus monitoring environmental variables will clarify performance measures and guide corrective action for decision rules. Second, performance deviations may also be attributable to operations-related causes, such as the lack of discipline of a systems operator or an operator unable to properly manage an overwhelming number of product items, which lead to record inaccuracies and ultimately system malfunction. In this case, performance measures can be monitored directly to pinpoint and address operator-induced errors. Watts suggests a properly designed monitoring system take into account the effects of both principles, and therefore both environmental variables and performance measures must be tracked.

Watts' model employs the use of control charts for monitoring three factors: two performance measures (inventory turnover rate and stockouts) and one environmental variable (demand). By using control charts, prompt and continual feedback regarding system performance can be provided. Figure 5 (below) contains a flowchart of the proposed monitoring system.

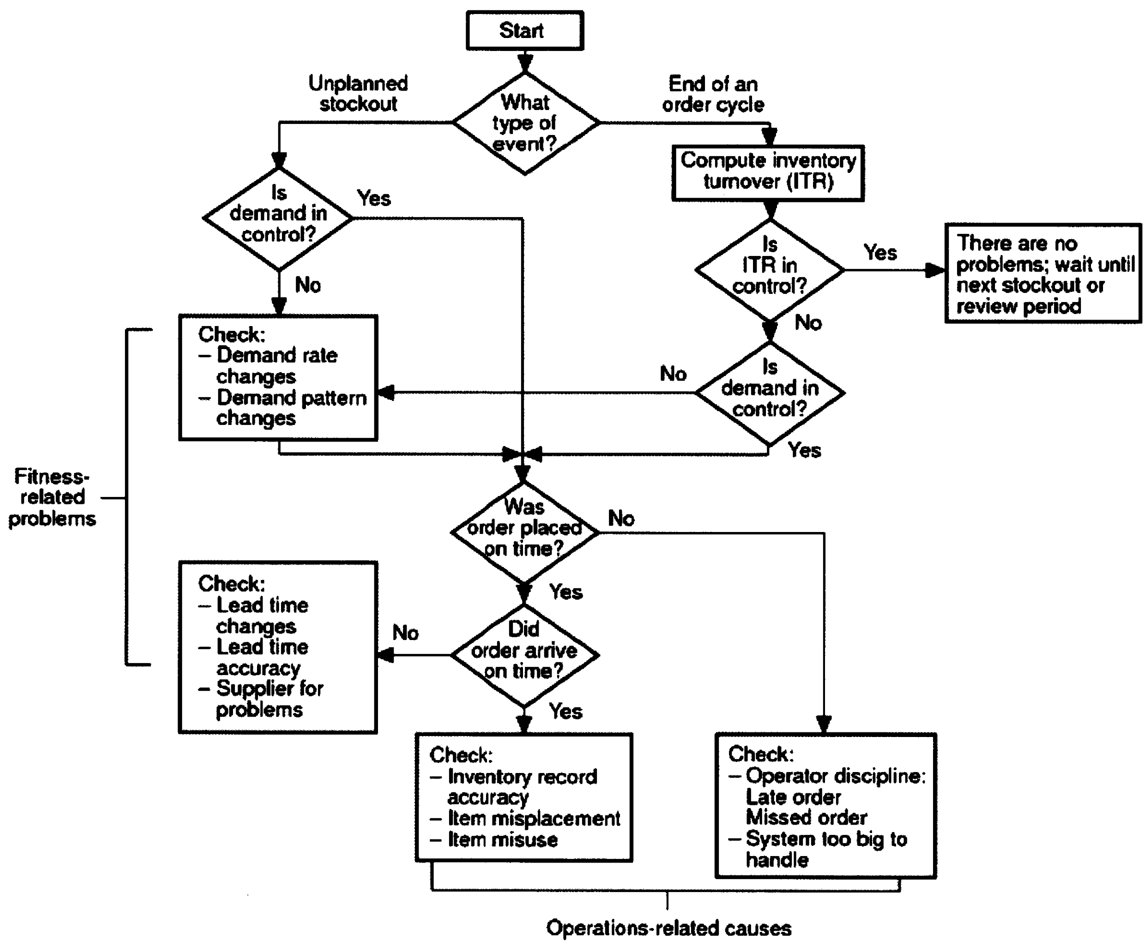


Figure 5: Inventory-monitoring system flowchart (Watts et al) (2)

Triggered by an unplanned stockout or a periodic review of inventory turnover rate, the monitoring system is designed to systematically analyze the causes of performance deviations. The analysis will identify a systems-fitness and/or operations-related cause of deviation.

Watts performs a 250-day simulation of the inventory system, in which control limits are set, using averages and standard deviations during past order cycles, for the three factors to be monitored while demand is simulated. By creating sample out-of-control situations, Watts demonstrates the effectiveness of monitoring environmental variables and performance measures and using the flowchart in being able to isolate the causes of system malfunctions. Using a control chart approach, early warnings can be provided, issues can be identified and resolved quickly, and the system will be generally functioning as intended.

3 Modeling Methodology

This chapter presents the methodology used to develop the monitoring and feedback model for evaluating the performance of a reorder point system. The approach moves sequentially from understanding the current solution and company requirements, through model scoping and development, and ends with model utilization. In Section 3.1, we describe and analyze the performance evaluation method currently employed at Cisco, as well as relevant supply chain attributes. In Section 3.2, we apply Cisco's metrics and reporting requirements in outlining a hierarchical approach for structuring Level 1 and 2 metrics and identify environmental variables and performance measures for input parameters to monitor, as well as associated risks with the overall approach. In Section 3.3, we provide details on the model logic and structure that implement the desired specifications. Finally, Section 3.4 demonstrates how the model is used to identify system performance issues and drive appropriate correction action.

3.1 Problem Clarification

3.1.1 Performance evaluation using financial data

Investigating Cisco's current approach for evaluating the performance of its reorder point system may yield insights into the model scope, input parameters, and system environment. Through stakeholder interviews and internal company research, we discover that the only inventory metrics, currently employed by Cisco, that contain ROP related information are tracked by the finance organization. Indication of root-cause analysis and closed-loop correction action (CLCA) procedures seem to be lacking in the system. In addition, a process for identification of ROP breaks and communication to responsible owners does not exist. The feedback system is comprised primarily of Excel spreadsheets (Figure 6) which are focused on tracking inventory dollars aggregated at company and product family levels and not on monitoring the inventory system.

WK05 - Q410	OTS w/out ISO		Leadtime			Recommit	Inventory APR-FY10 WOS & Turns from Finance			Line Stops
	Current	QTD	Current	QTD	Sched	Current	Turns Actual Goal	WOS By Ship By Plan	OH+OO ($M)	Current
Green Zone	98%		90%			98%	>Goal		ROP+SUK	0
Yellow Zone	>95%		>80%			>95%	<Goal		> +/-10%	
Red Zone	<95%		<80%			<95%	N/A		> +/- 20%	# Stops
[redacted]RBU	88%	88%	23%	34%	15%		3.7	26.8	214	1
[redacted]SBU	89%	90%	56%	46%	45%		5.6	23.1	186 97%	
[redacted]NBU	98%	97% 9517	85% 1706	69%	71%		5.7	18.2	138	
[redacted]CBU	81%	81%	52%	50%	40%		4.3	25.9	325	
[redacted]TBU	98%	88%	33%	21%	28%		3.8	28.7	76	
[redacted]TBU	92%	90% 2137	47%	63%	42% 417		5.9	24.1	136 97%	
[redacted]DBU	98%	97% 983	81% 413	78%	77% 331		6.6	13.6	8.7	
[redacted]CBU	98%	92%	88% 515	79%	84% 513		8.9	12.2	14	
[redacted]CBU	98%	92% 1484	86% 423	76%	63%		17.2	4.5	2.2 92%	
[redacted]EBU	92%	92% 1017	26% 373	29%	19%		4.2	26.5	28 90%	

Note: Image does not reflect true company data.

Figure 6: Cisco's current ROP system performance evaluation

The generated reports can thus only provide snapshots with no insight into reorder point system performance or root-cause analysis. Besides inventory dollars, the three primary parameters being tracked are ROP, on-time shipment (OTS), and lead time. These factors may be inadequate in system performance evaluation even if a properly implemented solution exists. In addition the process of data collection and processing is very manual and time-consuming, and thus prone to operations-related errors.

In order to properly measure and monitor system performance, metric granularity must be heightened, relevant environmental and performance measures must be tracked and siphoned into a data feed, automation must be employed where possible, and a flowchart must be developed to guide corrective action. Most importantly, relevant stakeholders must be identified to monitor and maintain the performance tracking and CLCA process. We next examine the actual inventory management system around which the model is to be developed.

3.1.2 Pull production

Cisco operates on a pull-based replenishment system across multiple echelons of the supply chain, down to the Printed Circuit Board Assembly (PCBA) component level. As of 2010, the supply chain organization oversees more than 300 product families, representing 23,500 products (1), of which the most complex may contain hundreds to thousands of parts and components. Most of these products are custom-configured and built to order through a series of regional logistics hubs.

The supply chain consists of multiple contract manufacturing partners' direct fulfillment (DF) sites and PCBA build sites. The build sites produce PCBAs which are housed at supermarkets (SM) and pulled by DF sites as shown in the representation below. Each triangle in the figure represents a location where inventory is carried to support DDLT and daily demand variability. Inventory is primarily driven at each location via ROP.

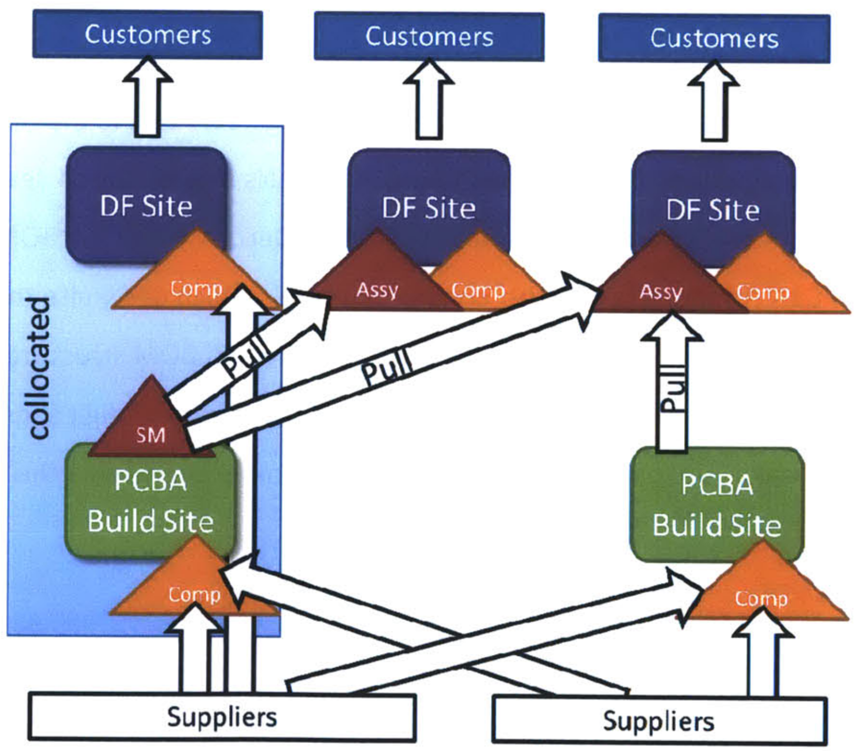


Figure 7: Cisco's supply chain model: pull-based replenishment system

The four types of inventory queues (triangles) can be described as follows:

- **PCBA Component**: Any component that feeds Cisco PCBA production within the confines of the manufacturing partner's facilities.
- **PCBA Supermarket (SM)**: An inventory point from which multiple DF sites using the same PCBA can pull finished PCBAs. The physical location of this inventory may or may not be at the end of the PCBA line.
- **DF PCBA (Assembly)**: This inventory point denotes the finished goods PCBA inventory that each DF site maintains to support its production requirements.
- **DF Component**: This inventory point denotes the inventory of all physical DF components (excluding PCBA) that each DF site maintains to support its production requirements.

3.1.3 Product-level Bill of Material

In order to manage multiple customer product configurations and supply chain complexity, Cisco maintains a product-level bill of material (BOM) process. In a product-level BOM, the Product ID (PID) represents the highest level part name, which is defined by the sales organization and used for customer ordering. Product engineers define the BOM beneath a PID by attaching top assembly numbers (TANs) to the PID. TANs exist at the DF level and represent the DF PCBAs or DF components that comprise the PID. Decomposing the BOM even further will reveal the PCBA component and sub-component levels which designate the material from build sites. Below is an example of what a simple product-level BOM structure might resemble. For a typical TAN or PCBA component label, the first number in the 3-digit sequence may be reserved to flag "make" or "buy" items while the third number represents the item's version.

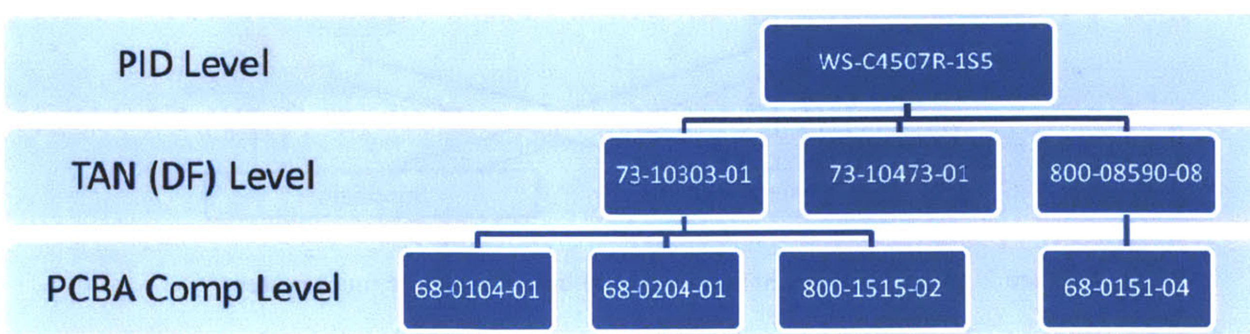


Figure 8: Example BOM structure

The product-level BOM allows customers to select different TAN options for a PID to create a customized product. This method is common across many industries and provides customers the flexibility in product specifications over the alternative of a hard-structured BOM.

However, as the range of Cisco's product offerings increases, so does the complexity of BOMs and their maintenance. This poses a few challenges that need to be addressed in TAN and PCBA component inventory tracking:

- The BOM data files must be carefully maintained as structure changes occur with new product introduction (NPI) as well as end of life (EOL) parts.
- TAN or PCBA components may undergo internal revisions (updates) which require an updated mapping in the BOM while the PID part name will remain unchanged.
- During NPI, EOL, or general changes in the inventory system, the current TAN and PCBA component attributes, such as ROP, SIS, lead times, etc. must be updated to reflect the current state of the supply chain.

According to Lester (4), due to the varied complexity of most Cisco products, the large number of products, and the over 50 business units that manage the BOM, the current process for developing and maintaining the BOM has also resulted in inconsistencies in BOM structure that lead to product launch delays, increased product support costs, and lower customer satisfaction. The nature of the Cisco's demand pull system, as well as its associated BOM complexities, play a crucial role in defining the scope of our model as will be discussed in Section 3.2.3.

3.2 Model Scoping

3.2.1 Metrics and reporting criteria

Based on stakeholder interviews and internal document investigation, we outline a list of criteria for our model to ensure company objectives can be met. The following criteria are not all encompassing, but rather items that Cisco identifies to be important:

- Metrics must unambiguously measure the right performance characteristics and must be designed in a manner to drive appropriate behavior.
- Metrics definitions must be accompanied by data capture requirements that enable root cause analysis.
- Cross-functional collaborative metrics accountabilities must be clearly defined to drive desired behaviors within the company and partner organizations.
- Supply chain visibility requirements must be defined for the metrics that are not available today.

Successful metrics tracking and reporting call for an integrated process that includes people, systems, data, and tools. In order to ensure that the metrics provide the right insights and drive the proper behavior, any proposed metric should be evaluated using the following framework.

- Metric intent: reason for metric, intended use, and behaviors to be driven
- Definition
- Calculation
- Owner: the group owning and defining the metric who can make any changes
- Frequency: how often the metric is published
- Level: granularity of the metric
- Data elements required
- Information for root cause: the workload required to root cause and specific expectations for stakeholders managing the metric

Based on the internal research and establish criteria, the assembled list acts as a useful guide for our model development.

3.2.2 Approach overview

To develop a model that can monitor and measure the performance of a reorder point system, enable root-cause analysis and closed-loop corrective action (CLCA), we begin by establishing a structured hierarchical approach.

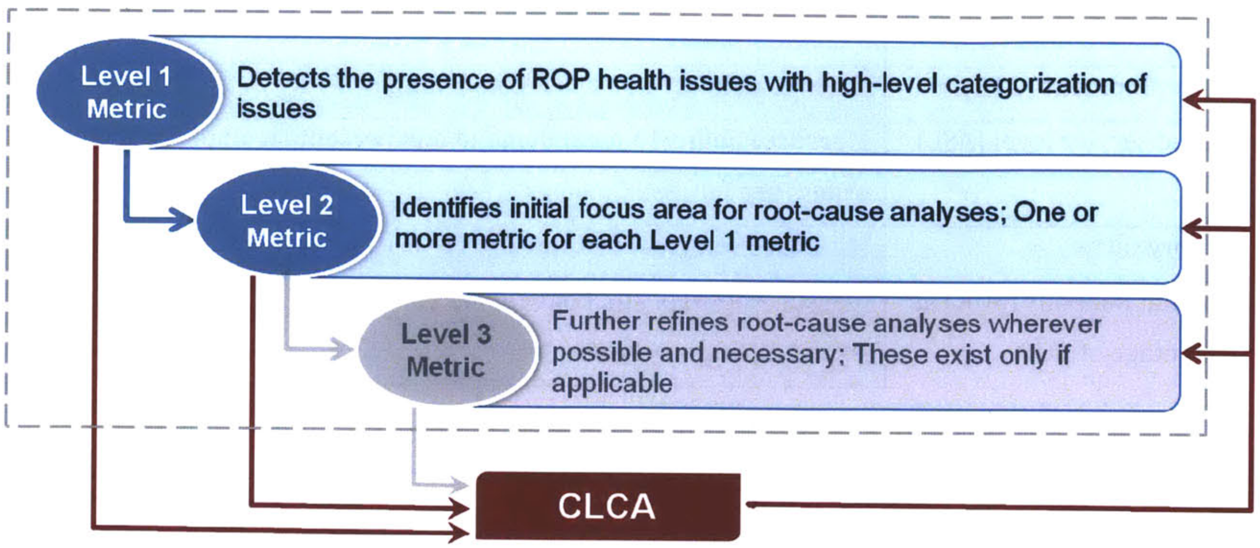


Figure 9: Structured hierarchical approach

The Level 1 through Level 3 metrics framework forms the basis of our model. Given the duration of the study and complexity of reaching meaningful Level 3 metrics, we aim to reach and provide reasonable Level 1 and 2 metrics integrated with corresponding CLCA processes. From a business perspective, the two metrics can be defined as follows:

- **Level 1** metrics are intended as high-level business metrics to capture the overall success of the demand pull system. These metrics are to be presented at the global level as a "snapshot" of how the system is progressing.
- **Level 2** metrics are intended to provide stakeholders a set of indicators to manage the business and the effectiveness of the demand pull processes. These metrics should include "drilled down" versions of the Level 1 metrics, as well as other metrics to monitor process performance and execution. This category of metrics provides the supply chain stakeholders a means to root cause, investigate, and correct issues at more detailed levels. These issues could include processes not being executed properly or provide a basis for tolerances that require adjustments.

Examples of potential metrics candidates to characterize the demand pull system as identified by Cisco are listed in the tables below.

Level 1 Candidates	Definition/Intent
On-time shipment (OTS)	Ensures delivery metrics are still met
Achieved service level (ASL)	Measures ability to meet demand and percentage of periods where orders are fulfilled
Inventory turns	Measures velocity of supply chain
Single unit kanbans (SUK) as a percentage of ROP	Measures level of stockout versus the ROP - SUKs are generally issued during stockout

Level 2 Candidates	Definition/Intent
Kanban replenishment time (KRT) attainment	Measures if KRT is accurate, provides a basis for adjusting it, and also highlights any execution issues at PCBA build sites
Cycle time to replenishment (CT2R) attainment	Measures if the inbound CT2R to DF sites is accurate, provides a basis for adjusting it and also highlights any transit issues
ROP trend	Observe if ROPs are trending upward or downward to help optimize ROP sizing tolerances
SUK as percentage of ROP with categorization	Identifies if SUKs issued are due to ROP break, time sensitive deal, or strategic inventory

As we develop the model and refine its scope, we can better tailor the set of metrics to suit the needs of the system's environment and users. Based on the initial candidate list and the customer-oriented focus of the company's supply chain, we adopt a similar approach as Pope's model (Section 2.2.1) and Watts' Model (Section 2.2.2) by choosing the achieved service level (ASL) as the primary performance measure and Level 1 metric to monitor. The ASL is essentially a cycle service level, which measures the percentage of days over a specified time period in which the ROP was sufficient to fulfill all customer orders – assuming no execution issues. It represents the service level that would be achieved given the consumption data as estimated by actual customer orders and assuming the system is running as designed. Thus, in a similar respect to Watts' model, we employ demand data as our primary environmental variable to track.

The ASL differs from the actual or observed service level (OSL), which takes into account execution issues, such as quality issues, supplier de-commits, holidays, and other uncontrollable operational issues.

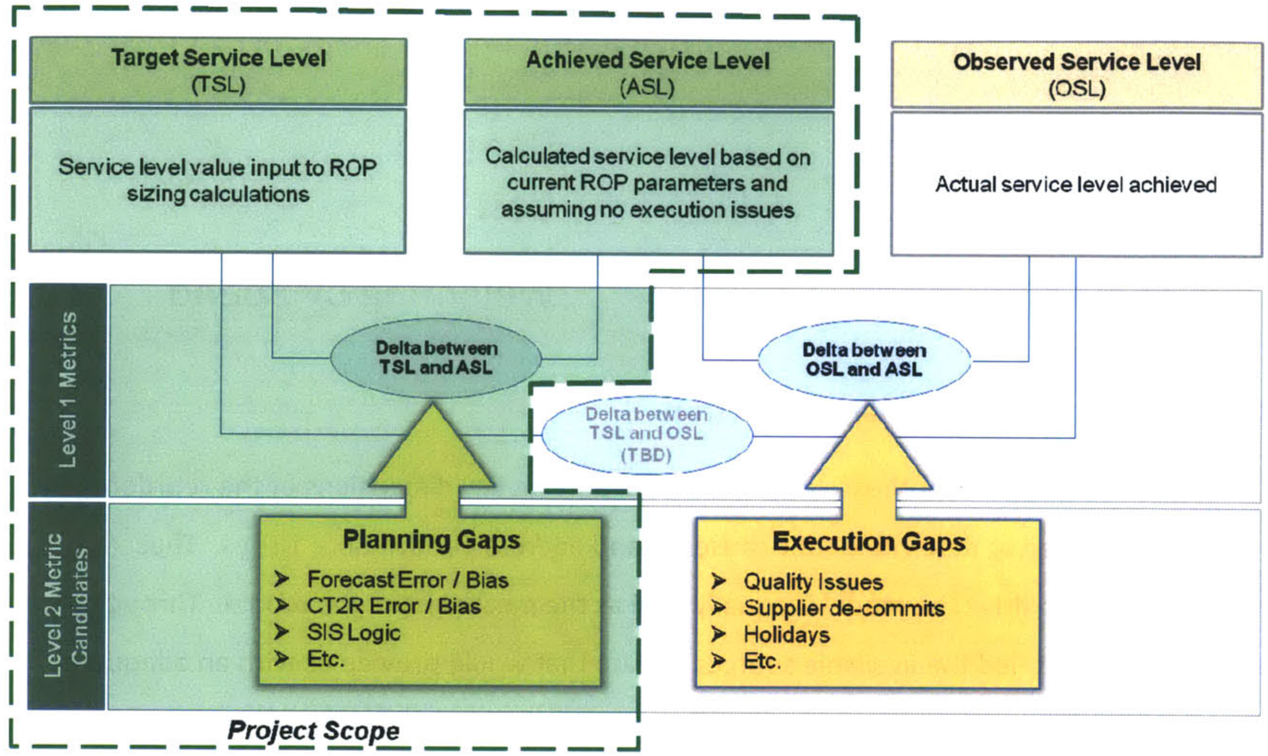


Figure 10: Key terminology and metrics identification

Figure 10 outlines the project scope (green area) and defines an additional Level 1 metric, the difference between the TSL input and the ASL, which can be attributed to fitness causes or environmental variables as discussed in Section 2.2.2. Additional Level 2 metrics candidates to elucidate planning gaps are proposed, but we concede to utilize ROP trends as our primary Level 2 metric due to the readily availability of data. It is important to reiterate that the model primarily focuses on the evaluation of a reorder point system as compared to its intended design and the integrated ROP sizing algorithm. Therefore, tracking of the OSL, as well as the gap between it and respective TSL and ASL values, which highlight execution gaps, are not a focal point of this thesis but are high potential areas for future research.

To summarize our approach to designing a model and framework for system performance evaluation, we plan to monitor three performance measures and three environmental variables with four parameters fulfilling Level 1 metrics requirements and two fulfilling Level 2 metrics requirements to conform to Cisco standards. The table below displays the role of each parameter in our model.

	Performance Measures	Environmental Variables
Level 1	ASL (TSL – ASL)	Demand Cost
Level 2	ROP Trend	Weighting by Spend

3.2.3 Data sources and data collection

The crux of our hypothesis is that historical data on key dimensions of the reorder point system can be used to determine root-causes of and address performance issues. Thus, the input data used to drive the model is equally vital as the mechanics of the model. Through the research, we identified the available sources of data that would provide us with an adequate view of the performance measures and environmental variables outlined in the previous section.

Like many organizations, Cisco houses its supply chain data across an array of information systems. Significant effort was placed in collecting historical data and ensuring its integrity. However, equally important to the data integrity is the data accessibility, interpretability, and the ability to parse the data. When defining the initial model scope, these data challenges often become limiting factors and need to be identified and addressed as early in the modeling process as possible.

As mentioned in Section 3.1.3, the Cisco BOM lends itself to many data inconsistencies resulting from product complexity and customizability. At the PCBA component and sub-component levels, these issues are compounded and difficult to manage. Additionally, the sheer amount of data that maps TANs to their respective components and sub-components at build sites is tremendous – the component mapping file alone is around six million lines of data

– making the ability to parse the data by simple means almost impossible. Finally, gaining direct access and permission to supply chain databases was not allowed due to data security and sensitivity reasons. As such, an entire process had to be made to circumvent this issue by exporting data from IT-secured tools into text files so that they could be used in the project.

Due to data integrity, accessibility, and parsibility issues, our model was reduced in scope to accommodate the system's environment. Ideally, our model would evaluate the performance of the Cisco's entire demand pull system all the way down the BOM to include DF and PCBA build sites. However, given the data challenges recognized upfront and the six month timeframe of the project, we decided to reduce the project scope as to only evaluate the inventory management system at a TAN level (i.e. only DF sites).

Our general strategy and data architecture are represented below:

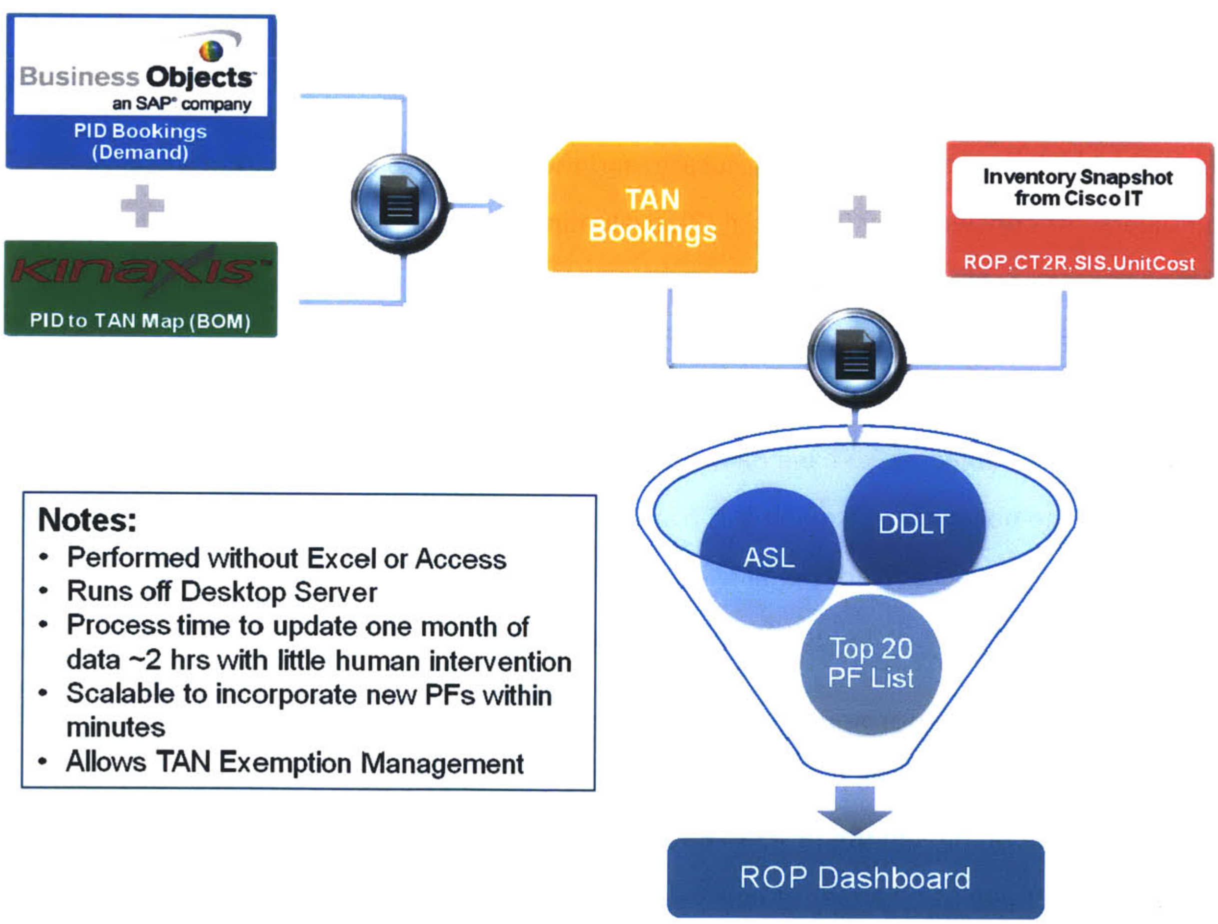


Figure 11: Data architecture

For the purpose of the project, we utilize three of Cisco's supply chain IT tools: Business Objects by SAP, Kinaxis, and Inventory Snapshot. From Business Objects, we extract our daily product consumption or PID Bookings over a month, which estimates customer demand. From Kinaxis, we export the most recent version of the BOM, limited to the PID to TAN mapping. Combining these two data sources allows us to calculate all of Cisco's TAN bookings for an entire month. From Cisco IT, we receive an Inventory Snapshot report once a month, which includes the ROP, CT2R (leadtime), SIS, and unit costs for every TAN. Combining these values with the TAN bookings allows us to calculate DDLT and ASL figures. These figures are then aggregated across every TAN, product family (PF), MPa DF site, and overall company level in a dashboard view.

3.2.4 Tool selection

Deciding what modeling tool to use to calculate and present system information is a critical decision that has to be made prudently. Little (5) claims that the biggest bottleneck in the managerial use of models is not their development but adoption. Thus, the model should be built in a way to ease distribution. Some of the other factors to consider before development include maintainability, accuracy, and the capabilities of the system's stakeholders. As concluded by Pope et al (3), evaluating the performance of an inventory system that contains thousands of items often requires computer-based programming. An initial candidate for the tool incorporated some combination of Microsoft Excel, Access, and Excel's built-in Visual Basic Application (VBA) programming platform for data manipulation. However, given our objective to have daily ASL and DDLT values across an entire year for every Cisco TAN and the potential to expand this framework in the future to include PCBA components, we quickly concluded that Microsoft's suite of tools would be cumbersome and difficult to support for the vast amount of data required.

A recent kaizen performed on a supplier commit process, which involved the heavy use of Excel spreadsheets, for Cisco supply planners revealed that over 90% of the activities performed by the planners in the process were non-value adding. These activities resulted in multiple hours per day per planner of non-value added work, such as collecting data, entering data into spreadsheets and workbooks, requesting and e-mailing information, and idle time. In addition, many of the activities were manual and required rework, leading to reduced data integrity. In the early 2000s, Cisco performed a lean study on its supply chain reporting processes and discovered that almost one thousand spreadsheets were being used to manage the supply chain, urging management to quickly take steps to reduce this number to less than one hundred (1). Initial tests of the data processing for our model revealed that even collecting and calculating one month of DDLT and ASL values took up to four hours and in some cases would crash Excel due to the large amount of data that had to be processed.

In order to ease efficiency concerns, we opted to create an online tool hosted on a desktop server running WAMP (Windows, Apache, MySQL, and PHP) which is suitable for rapid prototyping and requires no financial or IT investment. PHP is a web-based programming language that is efficient and effective in parsing dynamic data and displaying it in an HTML frontend. By having a central location and by automating all the activities following data collection, users of the tools simply are required to import the data from the three primary sources and update the dashboard – a process which takes approximately 2 hours for one month of data. A downside of this approach is that most of the system stakeholders and management are only familiar with traditional Microsoft spreadsheet solutions raising concerns regarding adoption and sustainability of the tool. However, making the tool web-based facilitates the adoption of the model by being able to share metrics and deep analyses with a simple hyperlink. Over time, if the growth in model complexity expands to include additional features or lower BOM levels, additional modeling platforms can be evaluated.

3.2.5 Risk assessment

Adoption and sustainability are just some of the risks imposed by implementing our system. Data quality, accuracy, relevancy, consistency, and integrity are critical to proper metrics management (5). Ideally, all data elements should be stored in a "single source of truth" to minimize data issues. Stakeholders involved with monitoring the performance of the demand pull system must be able to share information with minimal manual processing or data entry. The data architecture supporting the metrics and reporting system must be one that places the information into the hands of the users with few intermediate steps, if any. The less time that is spent on manual reporting and processes, the better the preservation of data and the more time and bandwidth will be available to Cisco employees and manufacturing partners (MPa) teams for value-adding activities. With a "single source of truth," operations and MPa teams can communicate more effectively thereby placing the focus on process improvement and root-cause and trend analysis. By having to rely on three sources of data in our system, we increase our data collection activity time and risks of data inconsistencies and downtime at least three fold.

With the implementation of any new systems architecture, some of the identified potentials risks include but are not limited to:

- Being able to gather all the required data on a regular basis
- Being able to get the data elements into a single feed
- Organizational adoption – users do not find value in the new system
- Organizational adoption – mistrusting the data or system
- Organizational adoption – information drives the wrong behavior
- Greater dependency on the data feed which needs to be addressed in times of system breakdown or failure
- Proliferation of multiple data elements which requires higher maintenance costs

In order to mitigate these risks, it is important that each data element in the feed have a business and IT owner who understands the risks and can facilitate data accuracy issues, make additions to the data feed if necessary, and ensure data consistency. Metrics and governance around the signal and quality of the signal should be established along with procedures and escalation processes to deal with issues.

3.3 Model Formulation

This section describes the model formulation that implements our reorder point system performance evaluation and supporting metrics and reporting management system. Data visible in the model screenshots does not represent true company data. In addition PF and CM names have been masked for confidentiality purposes.

3.3.1 User Interface

The "ROP Health" dashboard resides on a desktop server connected to the Cisco internal corporate network and can be accessed via web browser. Upon entering the homepage, the user is presented with top-level ASL metrics at the company, PF, and DF site levels averaged over a span of six months or two business cycles.

ROP Health

Overall	ASL	Ref
CISCO	91%	

Product Family	ASL	Weight	Ref
2[redacted]	95%	0.0%	
7[redacted]	84%	1.6%	
A[redacted]	94%	4.4%	
C[redacted]	92%	2.9%	
C[redacted]	93%	1.0%	
C[redacted]	92%	1.0%	
C[redacted]	94%	4.3%	
C[redacted]	95%	9.6%	
C[redacted]	89%	4.2%	
C[redacted]	95%	23.2%	
C[redacted]	90%	5.8%	
G[redacted]	92%	2.5%	
M[redacted]	96%	4.7%	
N[redacted]	81%	2.8%	
N[redacted]	85%	13.7%	
P[redacted]	86%	7.9%	
S[redacted]	94%	3.0%	
S[redacted]	92%	0.4%	
U[redacted]	87%	2.5%	
X[redacted]	93%	4.5%	

Site	ASL	Weight
[redacted]TH	87%	2.6%
[redacted]CZ	92%	5.2%
[redacted]HK	81%	1.0%
[redacted]OC	71%	1.5%
[redacted]TX	93%	9.9%
[redacted]AB	91%	7.6%
[redacted]MX	88%	30.3%
[redacted]PE	95%	11.7%
[redacted]EN	98%	14.6%
[redacted]AU	91%	15.6%

Refresh ALL PF data

Spend Chart

Download TAN ASLs

Note: Image does not reflect true company data.

Figure 12: Model UI - ROP Health Dashboard

All the columns in the tables can be sorted by clicking the column headings. To facilitate information absorption, the dashboard presents information regarding the top 20 PFs, which comprise the bulk of Cisco's revenue, and has the ability to display more PFs. Often planners will sort data tables by the "Weight" column in order to quickly visualize which PFs are the highest cost runners to better target root-cause investigation efforts on products that have the largest impact on the business.

For data management purposes, the user has the ability to refresh the data once new data elements have been uploaded to the server, which generally occurs on a monthly basis. The Spend Chart provides a matrix of daily cost run rates organized by PF and DF site, which can be used as the most up to date reference of exactly which areas of the business – PF and DF site combination – have the largest cost-based impact. In addition, the user has the ability to export any metrics on the dashboard into an Excel spreadsheet for reporting and further analysis purposes.

UE OK ASL: 97%

TAN	Site	ASL ▾	Spend	Weight
800-09026-04	CTH	100.0%	50626	13.3%
74-2620-01	CTH	100.0%	9	0.0%
800-08916-18	CTH	100.0%	13977	3.7%
74-2624-02	CTH	100.0%	1	0.0%
74-2621-03	CTH	100.0%	9686	2.6%
800-22843-05	CTH	100.0%	113	0.0%
800-32766-01	CTH	100.0%	3089	0.8%
34-1966-02	CTH	100.0%	3789	1.0%
68-2562-04	CTH	98.9%	8887	2.3%
800-25212-12	CTH	98.3%	199627	52.6%
800-09222-02	CTH	98.3%	4431	1.2%
800-29390-03	CTH	97.8%	12248	3.2%
34-1651-05	CTH	97.8%	2064	0.5%
800-32154-02	CTH	96.7%	49690	13.1%
800-12057-03	CTH	93.9%	1010	0.3%
800-32765-01	CTH	88.4%	5915	1.6%
800-09353-01	CTH	82.3%	2	0.0%
800-32767-01	CTH	71.8%	14479	3.8%
800-09238-03	CTH	32.0%	49	0.0%
74-2623-01	CTH	31.7%	116	0.0%
800-35184-01	CTH	No Data		
800-08941-07	CTH	No Data		
800-05546-08	CTH	No Data		
74-2765-02	CTH	No Data		
74-2625-01	CTH	No Data		
74-2622-01	CTH	No Data		
800-35183-01	CTH	No Data		
800-33189-01	CTH	No Data		
800-35182-01	CTH	No Data		

Manage ASL Exemptions

Download Data for UBR10K

Note: Image does not reflect true company data.

Figure 13: Model UI - PF Breakdown

When a specific PF is selected, a drilldown of the PF metric by TANs is presented (Figure 13). Similar to the home page, the user can sort TANs in a given PF by different fields in order to quickly identify parts to investigate. Each TAN has a value for the DF site from which it originated, as well as the average daily cost run rate figure (Spend) for weighted sorting. As data integrity and inconsistency issues are widespread throughout much of the system, the dashboard attempts to minimize the effects of low signal quality by excluding TANs from ASL calculations if one or more pieces of required data are missing. These TANs are labeled with "No Data" indicators.

HK

TAN	PF	ASL	Spend	Weight ▾
68-3430-01	PHONE	7.2%	217599	12.5%
68-2684-05	PHONE	0.0%	134025	7.7%
800-29858-02	C2960	21.5%	70535	4.0%
68-3429-02	PHONE	23.8%	53558	3.1%
800-27071-04	C2960	50.8%	51187	2.9%
800-30874-04	C2960	50.3%	50346	2.9%
68-3604-01	PHONE	0.0%	46426	2.7%
800-31044-05	C3560	31.3%	46984	2.7%
800-26672-06	C2960	43.6%	44939	2.6%
74-6516-02	PHONE	59.7%	43013	2.5%
800-29857-02	C2960	37.6%	42955	2.5%
800-26673-06	C2960	50.8%	40136	2.3%
800-31041-05	C3750	28.0%	40461	2.3%
800-29859-05	C2960	50.7%	36045	2.1%
800-29397-05	C2960	48.1%	36316	2.1%
74-6520-02	PHONE	68.5%	35678	2.0%
68-2685-03	PHONE	0.0%	33895	1.9%
68-3606-01	PHONE	0.0%	31300	1.8%
800-29826-05	C2960	36.5%	30053	1.7%
800-26849-03	C3560	44.8%	29611	1.7%
68-2739-01	PHONE	12.7%	28677	1.6%
800-31056-04	C3560	28.0%	22275	1.3%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Note: Image does not reflect true company data.

Figure 14: Model UI - DF Site Breakdown

In a similar manner, the user can select a DF site to investigate from the dashboard home page. The user would then be presented with an almost identical view to the PF breakdown but filtered for a specific site instead of a PF. In both the PF and site breakdown views, the user has the ability to exempt a specific TAN from every aggregated ASL calculation (company, site, and PF). In Figure 14 above, the second TAN of the list represents a product that was identified to be under a push model and thereby exempt from inclusion in any aggregated metric calculation. The TAN exemption feature was a highly requested and critical feature identified during initial user testing. Many of Cisco's TANs are under a Build Plan Sequencing (BPS) or push model and thus would severely affect ASL performance metrics since ROPs for those products are listed as zero in the system. As in the case of any supply chain, there are bound to be exceptional products and parts that do not follow standard procedures for one reason or another. Figure 14 shows one site with many low ASL TANs that most likely require investigation for addition to the ASL exemption list.

ASL Exemption List

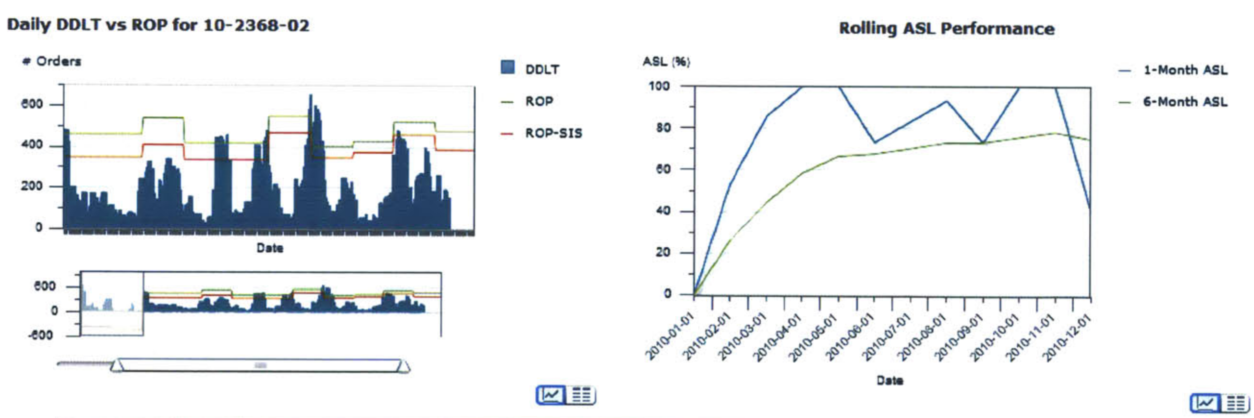
Product Family	TAN	Site
15454W	800-26772	CTR
PHONE	68-2684	FHK
TELPRES	68-3604	FHK

Remove Exemption

Figure 15: Model UI - ASL Exemption List

When a user clicks on the Manage ASL Exemptions link (Figure 13), a popup window is displayed with a list of PF, TAN, and site combinations that have been exempt from aggregate-level ASL calculations. Managing this list (Figure 15) is vital to the data integrity of the entire evaluation system, and hence, it is the responsibility of the supply and material planners who own a specific PF to ensure that the ASL is truly reflective of the operation. The ASL Exemption List is also useful in cases where a specific product's data has been compromised or is inconsistent. Once the data issue has been identified and corrected, the exemption can be removed and the ASL values will update appropriately. Likewise, it is not uncommon for a product to transition from a push to a pull model, in which case the exemption status would have to be removed.

PF: X2 Site: TAU



TAN	Metric	5	05/17	05/18	05/19	05/20	05/21	05/22	05/23	05/24	05/25	05/26	05/27	05/28	05/29	05/30	0
10-2368-02 ASL:86.7% Δ:10.3% TAU	ROP		418	418	418	418	418	418	418	418	418	418	418	418	418	418	
	DDLT		28	52	60	60	188	188	444	444	444	444	452	448	432	408	
	CT2R		12	12	12	12	12	12	12	12	12	12	12	12	12	12	
	SIS		82	82	82	82	82	82	82	82	82	82	82	82	82	82	
	UCost	00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	306.00	
	DSL	%	100%	100%	100%	100%	100%	100%	94.1%	94.1%	94.1%	94.1%	92.5%	93.3%	96.8%	100%	

Note: Image does not reflect true company data.

Figure 16: Model UI - TAN Profile

Finally, in either the PF or site breakdown views, the user has the ability to drill down even further by selecting a specific TAN. This action overlays the most granular breakdown of the evaluation system – an individual TAN profile with daily metrics over the past year (Figure 16). Perhaps the most useful tool when performing a root-cause analysis is the chart of the daily DDLT versus the ROP trend over a one year period (Figure 16, top left), which allows users to quickly see instances in which the ROP was insufficient to meet demand. Within the chart, the user has the ability to zoom in on specific dates for refined trend analysis. An ROP minus SIS line is also plotted to indicate and evaluate the performance of safety stock sizing. The user may also prefer to view the rolling one- and six-month ASL averages in the top right graph to aid in higher-level decision making. These smoothened curves are intended to facilitate visualization of the ASL especially in instances of lumpy demand, such as in the figure above.

A one year dataset is also provided at the bottom for further analysis of individual data points, clarify the charts, and investigate any peculiarities. The dataset includes ROP, DDLT, CT2R, SIS, unit cost, and daily service levels (DSL) over the past year. To the left of the dataset, the colored cell indicates the TAN, site, the ASL (measured over six months, where green: >90%, yellow: 80-90%, red: <80%), and the TSL and ASL difference.

3.3.2 Model Logic

In order to describe the model logic, we adhere to the sequence in which the model was developed from the most granular, product level, up to the most aggregated, company level. In this sense, we are taking a reverse chronological approach that would be experienced by a user running the model as described in the previous section. We aim to explicate the model with a sufficient level of detail by beginning at the theoretical item level in order to assure the understanding of the general mechanics of the model and its progression to a system-wide expansion. We include formulas and calculations that are relevant to justify decisions made in approximating real-world supply chain and business processes. Thus, the equations introduced in this section are intended and stylized in way to describe their logic and application and do not contain the syntax of the PHP program code implemented.

The actual dashboard itself contains little of the model logic and is optimized to serve primarily as a means of visualization. Much of the actual calculation and processing of data occurs in backend scripts which a designated system operator, generally an IT specialist, would run on a monthly basis when the demand data is refreshed. Thus, we intend to focus much of the discussion of the logic residing in these scripts.

3.3.2.1 Demand Approximation

The estimation of product consumption or demand is one of the most crucial aspects of the model. As an input and to increase the accuracy and relevancy of the model, we opt to use actual daily demand data and require the consumption of every Cisco PID on every day across an entire year. Thus, the achievement of TAN bookings is the most data intensive and initial step of the model.

Whenever a customer places an order, a new line item is stored in Cisco's database with a few key pieces of information:

- PID
- Product Family
- Book Date
- DF Site
- Booked Quantity

Since most of Cisco internal data utilizes TAN values, we require the use of the BOM, which contains the most updated mapping of PID to TAN values. The PID to TAN relationship is many-to-many, which means a single PID can map to multiple TANs, and a single TAN can map to multiple PIDs. Thus, if three bookings are made for a specific PID, three bookings must be made to each TAN to which it is mapped; furthermore, any of those TANs may be receiving more bookings from other PIDs to which they are mapped.

Since the model requires the demand of a specific TAN on a specific day, we must also be able to offset the Book Date by a shipping lead time. In general, every PF at Cisco has a corresponding shipping lead time, which typically is around three weeks. This value must be added to the Book Date which results in a ship date. Thus, the actual demand for each TAN is referenced to occur on its corresponding ship date. Only ship dates will be used going forward.

The final nuance to take into account is that a certain product may ship from multiple DF sites. As a corollary, we must be able to distinguish the service level performance of the same product originating from two different DF sites. We accomplish this by calculating the bookings of TAN and site pair combinations, which we store in memory for ease of further calculation.

3.3.2.2 Product-level Daily Service Level

In order to calculate the daily service level (DSL) for a specific product from a specific DF site, we must first be able to calculate the DDLT for the specific TAN-site combination on each day across an entire year. This is the next data intensive and logic involved step in the model due to the recognition of business practices and data integrity issues. At this point, we assume that we have historical TAN-site booking values, which we will refer to as simply bookings going forward, and inventory snapshots containing TAN-site-specific ROP, CT2R, SIS, and unit cost values on a monthly basis over the span of at least one year.

As mentioned in Section 3.1.3, a TAN may undergo version revisions, represented by incremental changes to its last two digits. This introduces a number of complexities when matching the most recent TAN listed in the BOM with its corresponding values in inventory snapshot reports, which often do not get updated appropriately. As a result, the inventory snapshot report may list multiple ROP and CT2R values, for example, for different versions of the same TAN and may not even include the most recent version being sought. In order to address this data inconsistency, we employ versionless TAN matching in our logic. This implies the following for our logic:

- Bookings for different TAN versions will be aggregated
- All ROPs listed for different versions will be summed to one ROP
- All SIS values will for different versions will be summed to one SIS
- The maximum CT2R listed will be used for calculation

- The maximum unit cost listed will be used for calculation
- The most recent TAN version will be listed on the dashboard and actually represent an accumulation of all its previous versions, if any

This practice reduces the chances of matching bookings with the incorrect inventory policies. An assumption that this logic makes is that if an old TAN version is truly sent to EOL then its corresponding inventory policy values should be removed or set to zero.

The DDLT calculation for a product is a straightforward summation of bookings across the product cycle time to replenishment, or CT2R. However, it is important to note that this calculation must be performed for each day, starting one year back and up until one full CT2R before the last date with bookings. This implies that for products with relatively long lead times, such as half a year, the last valid DDLT value would occur a half year ago from today, assuming bookings existed up until today, in order to ensure each DDLT represents a sum over a complete set of bookings data.

DSL values can only be generated on days that have valid DDLT and ROP inputs. The DSL is a measure of how well the ROP is able to fulfill the customer demand on a particular day. As such, it follows the simple formula:

$$DSL = \min\left(1, \frac{ROP}{DDLT}\right) \tag{4}$$

Thus, as long as the ROP is greater than or equal to the DDLT on a given day, the customer service level on that day is 100%. Using the DSL as a building block for evaluating system performance draws potential limitations that will be revisited in Section 4.3.3.

3.3.2.3 Product-level Achieved Service Level

With DSL values for every TAN, we now can derive the key performance measure of the model. Like the DSL, the ASL requires some incorporation of business logic in ensuring its applicability and relevance to the operation. The ASL differs from the DSL in that it measures the percentage of days over a designated time period in which the customer demand was fulfilled by the ROP, or rather when the DSL was 100%.

$$ASL = \frac{n}{t} \tag{5}$$

$where,$

$n: number\ of\ days\ where\ ROP \geq DDLT$

$t: designated\ time\ period\ of\ measurement$

The designated time period chosen to measure the ASL was six months, or two business cycles. The decision to use two business cycles came from the notion that one business cycle may be insufficient due to demand volatility and would incur more noise into the ASL calculation as a result. On the other hand, a time range more than two business cycles may mask potential operations issues.

In order to clarify the relationship between the variables in the model, we walk through an example situation that incorporates bookings, ROP, DDLT, CT2R, and DSL in calculating a final ASL value. For simplification purposes, we assume in the example that the time period needed for an ASL measurement is one week rather than 6 months.

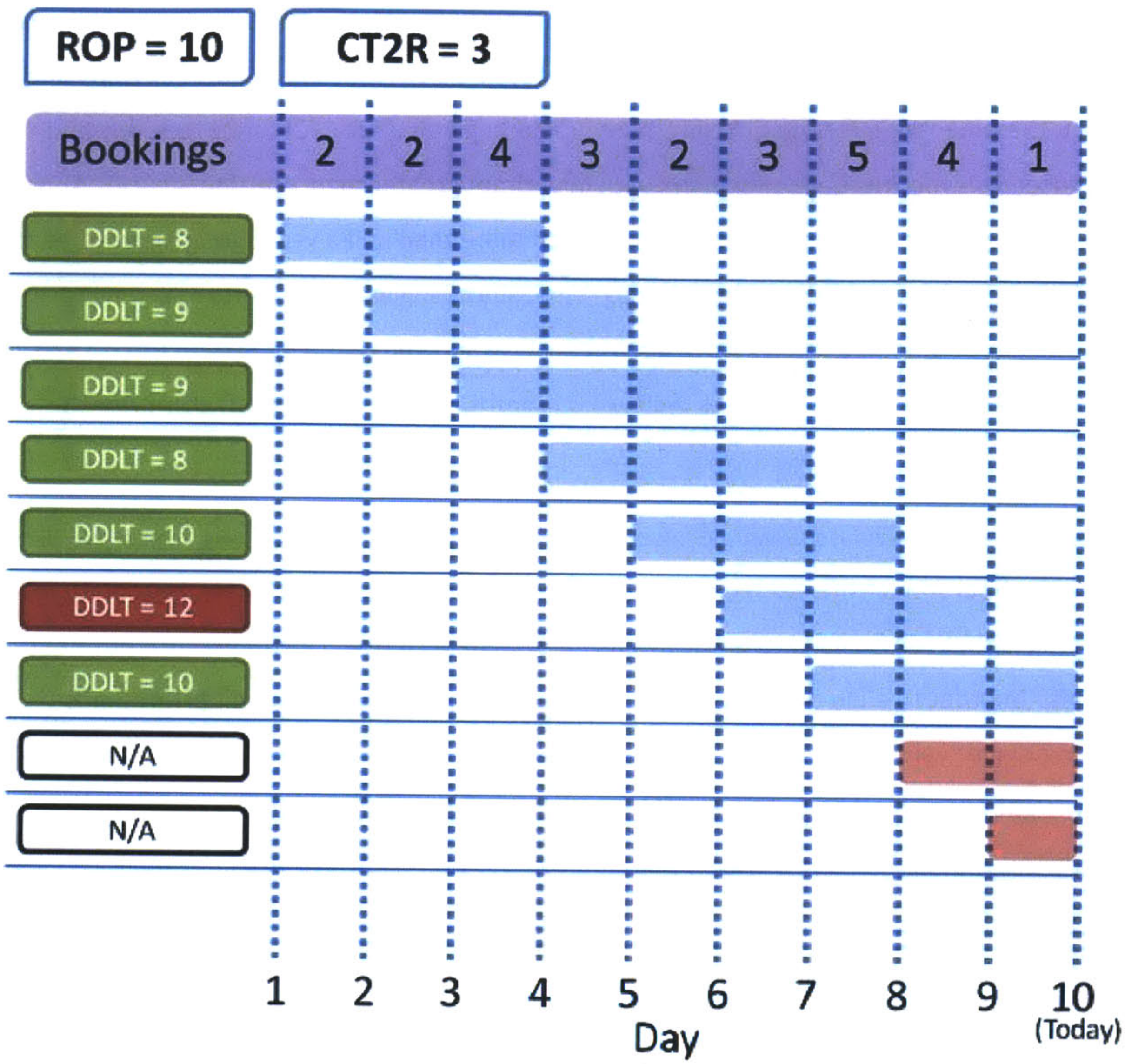


Figure 17: Example ASL Calculation

The first detail to make note of from the example is that the product CT2R is 3 days, and thus the last valid DDLT and DSL measurement can be performed on day 7. Given that the ROP is set at 10, it follows that the DSL is 100% for 6 out of the 7 days. The ROP break occurs on day 6 where the DSL = 10/12 or 83.3%. Finally, given that the customer demand is fulfilled 6 out of the 7 days of the specified time period, the resulting ASL is 6/7 or 85.7% for this product as of when the measurement is taken. Our ASL would then be benchmarked against our TSL. If the the TSL were 95%, the resulting TSL – ASL performance measure would yield 9.3%.

Since the ASL is retrospective by relying on a set of valid historical DSL measurements, it follows from the example that to achieve an ASL measurement for today's date for a specific product, the time range for the measurement would begin one full CT2R prior to today and then proceed six months back. For TANs with lead times greater than 2 business cycles, this implies the ASL would represent performance from more than half a year ago. Little can be done in terms of logic to address this time lag issue, since long lead time parts in general are difficult to address operationally. However, an analysis showed that over 90% of Cisco TANs had lead times less than one business cycle, or 3 months, and those generally comprise the higher valued items.

3.3.2.4 Aggregate-level Achieved Service Level Average

In the final step of the model, we convert product-level ASLs into higher-, aggregate-level ASL averages that can be used to quickly visualize system performance and execute business decisions. In order to align our model with business practices of focusing on performance managing higher valued and current items over lower valued and noncurrent items, we employ a cost-weighted approach in averaging ASL metrics for any aggregated-item level. In our model, we apply the approach to generate PF, site, and company level ASL averages.

The justification to use a cost-weighted approach stems from the anticipated business impracticality of using a straight ASL average in understanding how the inventory system is performing for a given PF or site, or in general. A straight ASL average may flag a low performing product family for review by a planner, but the product family may have such a miniscule financial impact or be time-irrelevant to the business to even be worthy of review. Granted, it may raise severe inventory system issues that may not be prevalent in higher valued or current products, but the issue would still remain low from a business priority standpoint, unless the part were critical to a customer's supply chain.

In order to incorporate objective weighting to inventory items, we employ a cost of daily run rate average in determining the value, or weight, of a product and its impact to the business as of *today*. The measurement to determine a product weight is again over six months and calculated simply by multiplying the unit cost of a product with its daily bookings and taking an average. However, a fine distinction must be made between the six month time range used for the ASL calculation and the six month time range for the cost of daily run rate average. The following figure highlights two situations in which the distinction can be made:

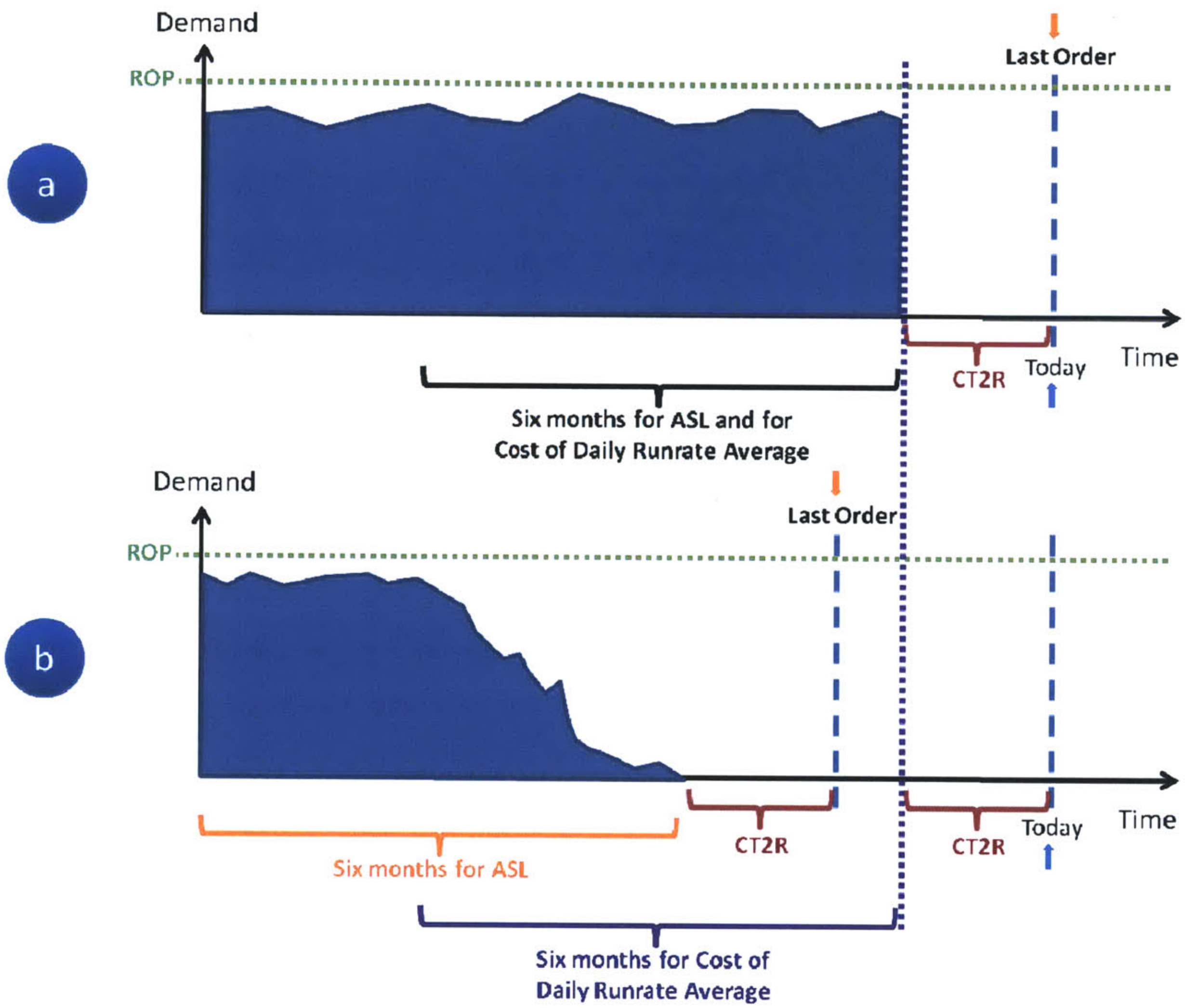


Figure 18: (a) Same and (b) different time ranges for ASL and weight calculation

This distinction is made clear by the fact that the six-month period for the ASL calculation depends on when the last bookings were made, which may not necessarily be today. Thus, our approach to weighting products not only reduces the impact of low valued parts on an aggregate-level ASL metric but also reduces the contribution of products with little to no recent activity in terms of customer orders. This is especially important in situations where high valued products have been sent to EOL many business cycles ago, which may take on a demand profile similar to Figure 18b. In cases such as this, if the six month time range for the weight calculation were identical to that for the ASL, a high valued part would always have a large and constant impact on any aggregate-level ASL metric. Our approach to weighting will "phase" out the contribution of any product as customer demand reaches zero in order to ensure the execution of accurate and relevant business decisions.

Finally, the aggregate-level ASL average for an n-item set of inventory, m, follows the equation:

$$A_m = \sum_{i=1}^{n} r_i a_i \Big/ \sum_{i=1}^{n} r_i \tag{6}$$

where,

r_i: *cost of daily runrate average for item i*

a_i: *achieved service level for item i*

n: *number of items in the inventory set*

The expression can be applied to any set of inventory items in the system to aid in filtering and identifying factors affecting overall ASL performance. In our initial model, we take all the TANs in the top 20 highest cost-running product families as our item set to represent the overall reorder point system. We then perform two parallel analyses to generate ASL averages for each PF and DF site subset along with their respective total weights, or spend, and weight percentages. The final output would resemble Figure 12.

3.4 Model Utilization

This section discusses use of the model within various roles of the organization through a use case diagram. We then provide detailed examples and process flows of how the model can be used to evaluate the performance of the reorder point system, guide root-cause analysis, and drive appropriate CLCA. Finally, we discuss the approach to aid adoption and incorporation of the model into primarily supply and material planner work regimes.

3.4.1 Use case diagram

The figure below provides a system overview to understand the functionality of the system in terms of actors, their goals (represented as use cases), and any dependencies between the use cases. By utilizing a use case diagram in the Unified Modeling Language (UML), we can better understand the roles of the system's users, as well as their behavior and interactions with the system, before diving into further detail on role-specific workflows.

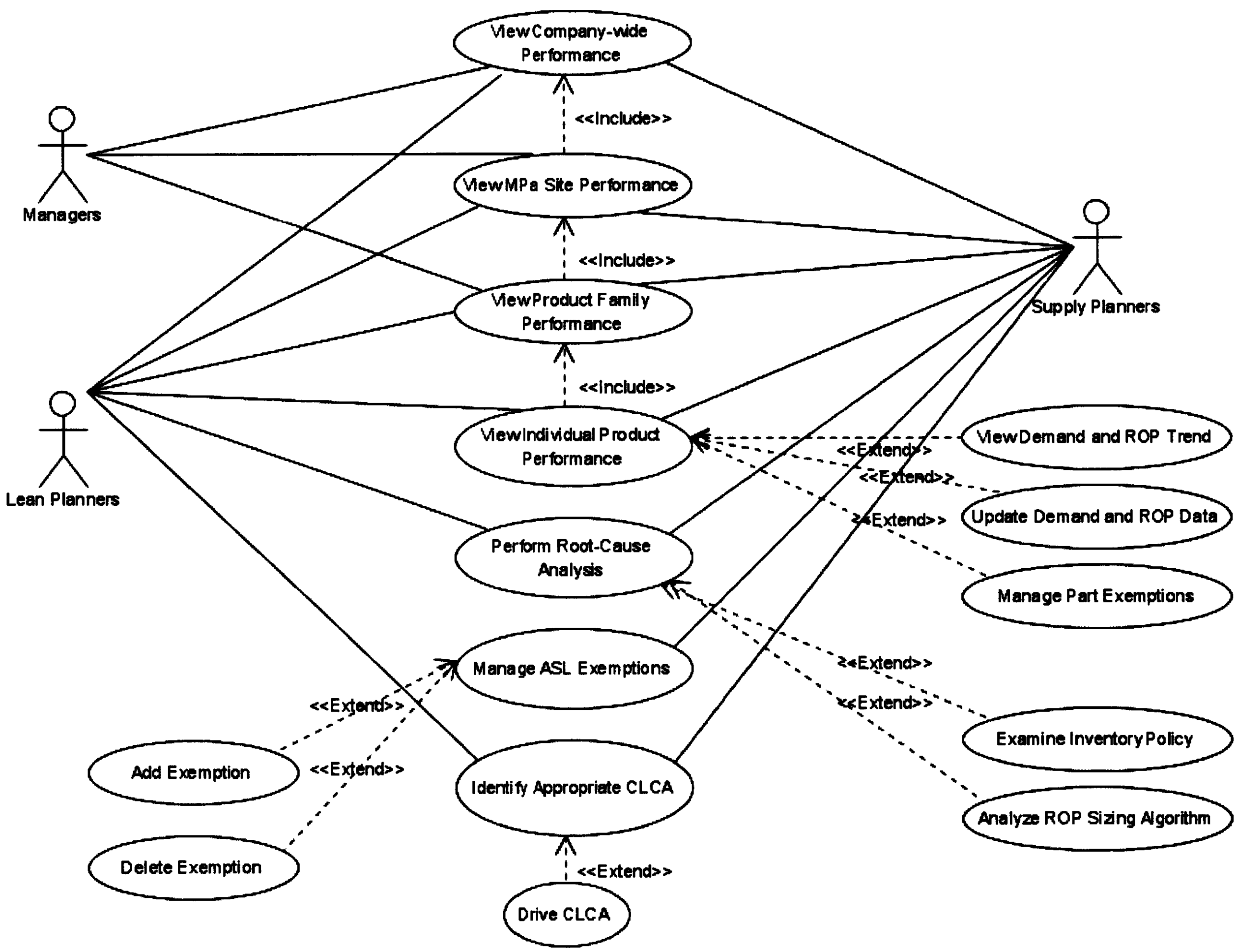


Figure 19: Use case diagram

The three main actors of our system model are managers, lean planners, and supply planners. Managers use the system to review top-level metrics to make necessary high-level decisions and drive appropriate corrective actions. Thus, much of their key interaction with the system stems from viewing aggregate-level ASL metrics of the overall company or reorder point system, product families, or DF sites. As depicted in Figure 19, lean planners and supply planners share similar use cases with one another. However, the purposes of their interactions with the system differ dramatically.

Both lean planners and supply planners must be able to view performance metrics from the company level down to the product level, as well as identify and root-cause any issues and drive appropriate CLCA. A lean planner primarily performs these tasks in regard to monitoring the drivers of inventory policies, such as investigating or understanding the backend functioning of the ROP sizing algorithm, to potentially propose amendments. A supply planner performs the same use cases in order to monitor the performance of an assigned PF or contract manufacturer in order receive feedback on PF ROP settings and/or work with a manufacturing partner who may be performing below expectation.

Finally, the management of ASL exemptions is a use case shared only among supply planners and is critical to the system functionality as previously discuss in Section 3.3.1. Since supply planners have distributed ownership of the top cost-running PFs, they are responsible for ensuring that exemptions are up to date and representative of the operations. This will drive ASL accuracy throughout the aggregate levels.

3.4.2 Driving strategic decision-making

As stated, the intent of the model is to be able to evaluate reorder point system performance, identify issues for root-cause analysis, and drive appropriate CLCA. With a general understanding of the system's functionality and operators, we explore how the model can be used for decision-making with the aid of process flows. We begin with general purpose process flows to understand the reporting and action layers and necessary logic and parameters in the near and long term. Then we examine role-based flows with more elaborate process steps and decision-making.

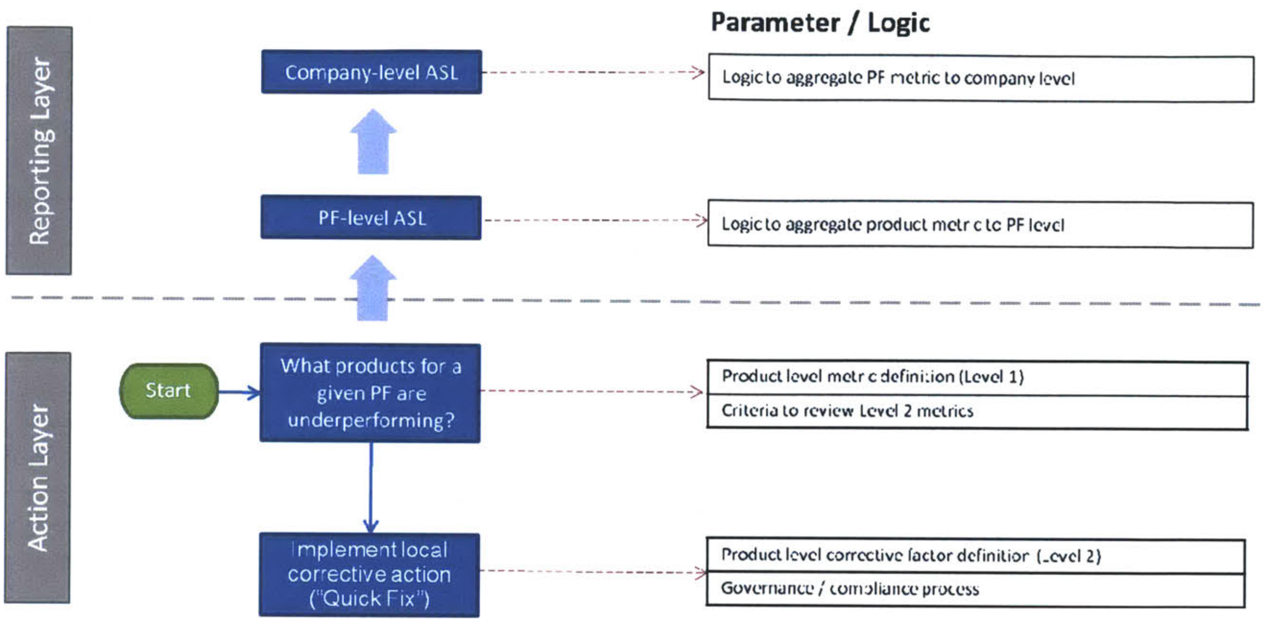


Figure 20: Near Term - general process flow and key parameters

We use the PF-level ASL as our example intermediate metric for the initial process flow; however, the substitution of any intermediate metric, such as the site-level ASL, would work just as well. The process flow in Figure 20 begins with the desire to understand which items in the pull system are underperforming. Based on that motive, we draw a reporting layer upwards through the aggregation of product-level metrics to a PF-level and ultimately a system- or company-level metric. In the action layer, being able to clarify product performance requires the support of Level 1 and Level 2 metrics. In the near term, the objective would be to implement an immediate solution, or "quick fix", to respond to an identified issue. This action would require the understanding of the corrective factor that needed to be implemented, as well as a supporting governance/compliance process to oversee the action. In a true supply planner workflow, a "quick fix" generally implies a manual correction of the ROP level based on the Level 2 metric, the ROP trend.

Using the near-term process flow as a framework, we can extrapolate the strategy necessary for a long term process flow.

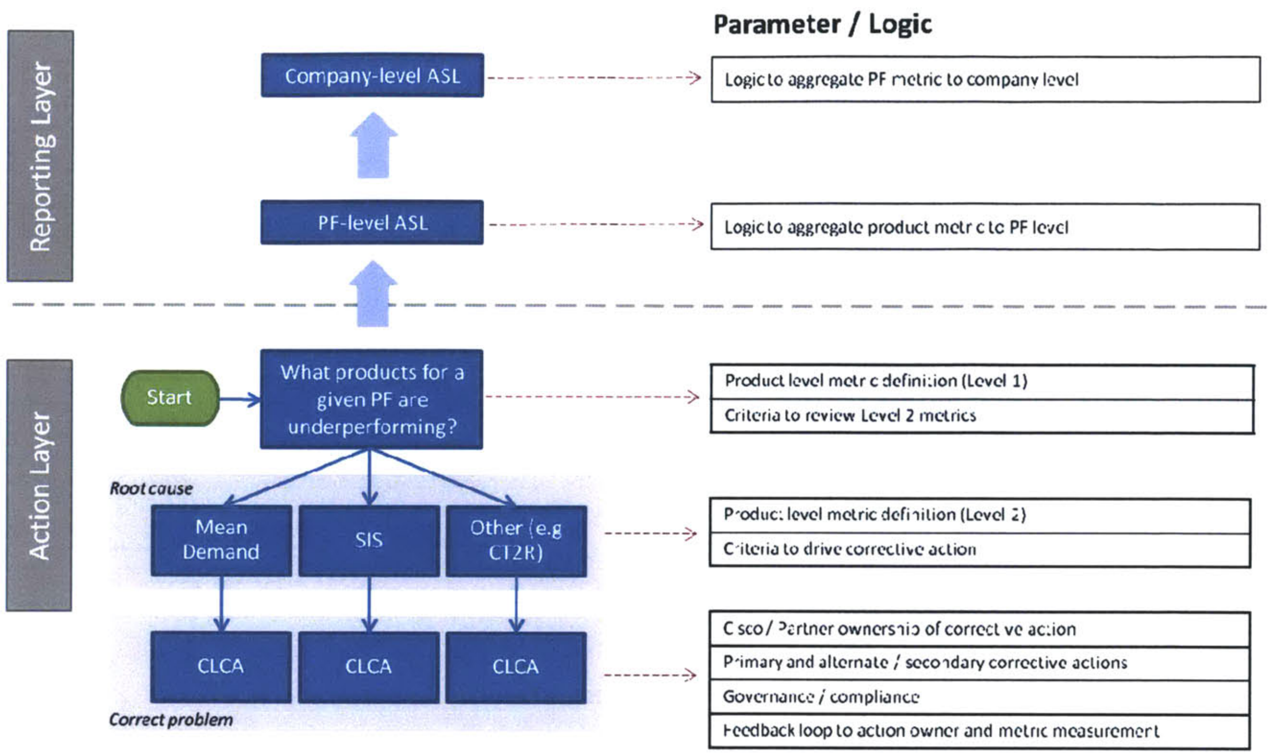


Figure 21: Long Term - general process flow and key parameters

The long-term strategy focus is to address the root cause of an identified issue rather than to simply apply a quick fix solution such as in the case of the near term process flow. Performing a root-cause analysis requires well-defined Level 2 metrics and criteria to drive corrective action. Based on the category of the discovered root cause, appropriate CLCA can be administered. The execution of a CLCA requires an understanding of the ownership of the action, as well as primary and alternate corrective action options. A governance/compliance process is necessary to ensure standards and policies are being met, and finally, a feedback loop must be established to the action owner along with a means of metrics management in order to gain insight into the magnitude of the action.

As shown in Figure 21, the most common root causes involve the two primary components of ROP sizing, the mean demand and SIS calculations. Theoretically, there is truly only one error of relevance – namely that between the ROP for a product and that required to realize a desired service level. The need to decompose the action into two parts, one to investigate the mean demand and another for the SIS, is due to Cisco's current methodology of deriving the components of ROP size from two different data sources. In addition, actions to correct mean demand error can be complex and span multiple nodes, while those for addressing SIS will reside with the node under consideration.

In order to incorporate the model into planner workflows, we develop role-based flowcharts to aid in driving strategic decision-making. These flowcharts are tailored from the general process flows but refine each step into more specific decisions for systematically analyzing and addressing performance deviations, similar to the flowchart in Watts' Model (Figure 5, Watts' Model).

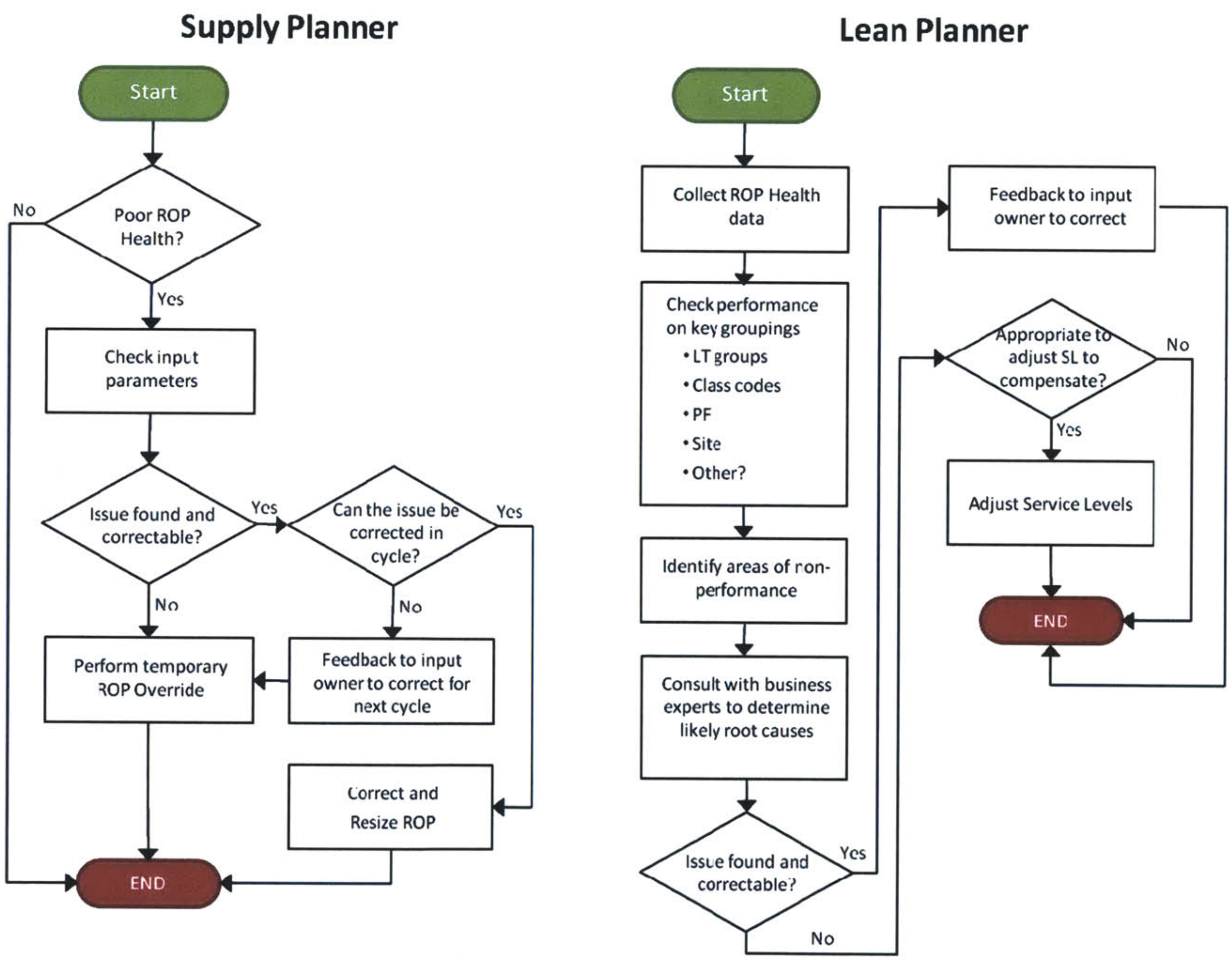


Figure 22: Flowcharts for supply and lean planners

Both the supply and lean planners possess similar goals of addressing ROP performance deviations but differ on their approaches due to the functions of their roles. As seen in Figure

22, a supply planner is more concerned with the current status of reorder point system and whether an identified issue can be corrected in the present business cycle. Even in the case where an issue is deemed uncorrectable, a supply planner would likely implement a quick fix solution to temporary address the symptom of an underlying issue in order to maintain daily operations.

A lean planner takes a drastically different approach to addressing low performance. Lean planners often engage with subject matter experts (SMEs) and work to attack systemic, underlying issues of the supply chain. Thus, a lean planner is more focused on driving continuous improvement in processes rather than applying temporary fixes such as in the case of a supply planner. However, in the event that an identified root cause of an issue is deemed uncorrectable, a lean planner must be able to work with process owners in order to modify target service levels to compensate for the inability to repair an underperforming ROP. This would assist in achieving acceptable ASL or OSL values in the system.

3.4.3 Organizational implementation

Little (5) stresses the importance of simplicity and suggests leading users through multiple iterations of a model in achieving organizational implementation. We eliminated much of the manual labor in process steps, with the exception of data collection, in order to make the model simple to maintain and execute. The user interface is designed in such a way to allow quick assimilation even for infrequent use. For example, ASL metrics are always automatically generated and displayed on the website in a hierarchical format to allow intuitive breakdown of values. For tool sustainability, the data collection procedures are heavily documented and laid out in a linear, stepwise fashion to achieve data consistency and reproducibility on a monthly basis. As an ancillary benefit, this approach also circumvented the high cost and labor of internal IT resources, which allowed quicker development and testing cycles of our model, a more visible iterative feedback process, and a more "home-grown" solution that is familiar to users and more likely to be adopted. Thus, the major outstanding issue to seamless integration besides automated data collection is data reliability.

4 Model Testing

This chapter opens by discussing the methodology to test our model. We then review some of the previously raised limitations of our approach, as well examine further limitations. To test our model, we investigate different system scenarios that might be experienced by a planner or user. Finally, we further test our model by demonstrating its applicability and adaptability in extended, auxiliary analyses.

4.1 Methodology

The purpose of testing our model is to determine whether or not our framework and tool can be used to evaluate the performance of the reorder point system, enable root-cause analysis, and drive CLCA. Given that there exists no previous benchmark against which we can evaluate our model output, we mainly rely on planner feedback in confirming our results and using the tool to identify ROP issues. To establish our test run, we gather data from 09/01/2009 to 12/01/2010 to allow for PF shipping lead time offsets of up to 3 months in the beginning of our dataset. This would ensure that we possess a full year of bookings data starting from 12/01/2009.

We focused our testing efforts on the top 20 PFs initially which represent the highest cost-running products of the business. This would drive a more dedicated review from the six supply planners who have distributed ownership of the PFs and could vouch for observable output and raised issues. We also held numerous meetings to garner feedback regarding tool usage, output, and general feedback of the model.

Finally, the model is designed in a way as to be portable and adaptable for extended or applicable analyses. As such, we test our model under different case scenarios in which we investigate related supply chain applications. In the first case, we examine refining the ROP sizing window used in forecasting models. In the second, we decide between two inventory management schemes. Finally, we assess the difficulties of expanding our performance evaluation model into the PCBA component level. From these cases, we test the limits of our model, as well as establish a foundation for future revisions and improvements to the model.

4.2 Limitations of our approach

Although we believe our testing methodology represents the soundest option given the system and its environment, we recognize some limitations. First and foremost, just as the accuracy of historical data on which the model is built is questionable, the accuracy of data used to determine ASL averages is also questionable. Inaccurate inventory snapshot or bookings data will yield incorrect ROP and DDLT values which will lead to inaccurate product-level ASLs, inaccurate aggregate-level ASL averages, and an undermining of the entire system integrity.

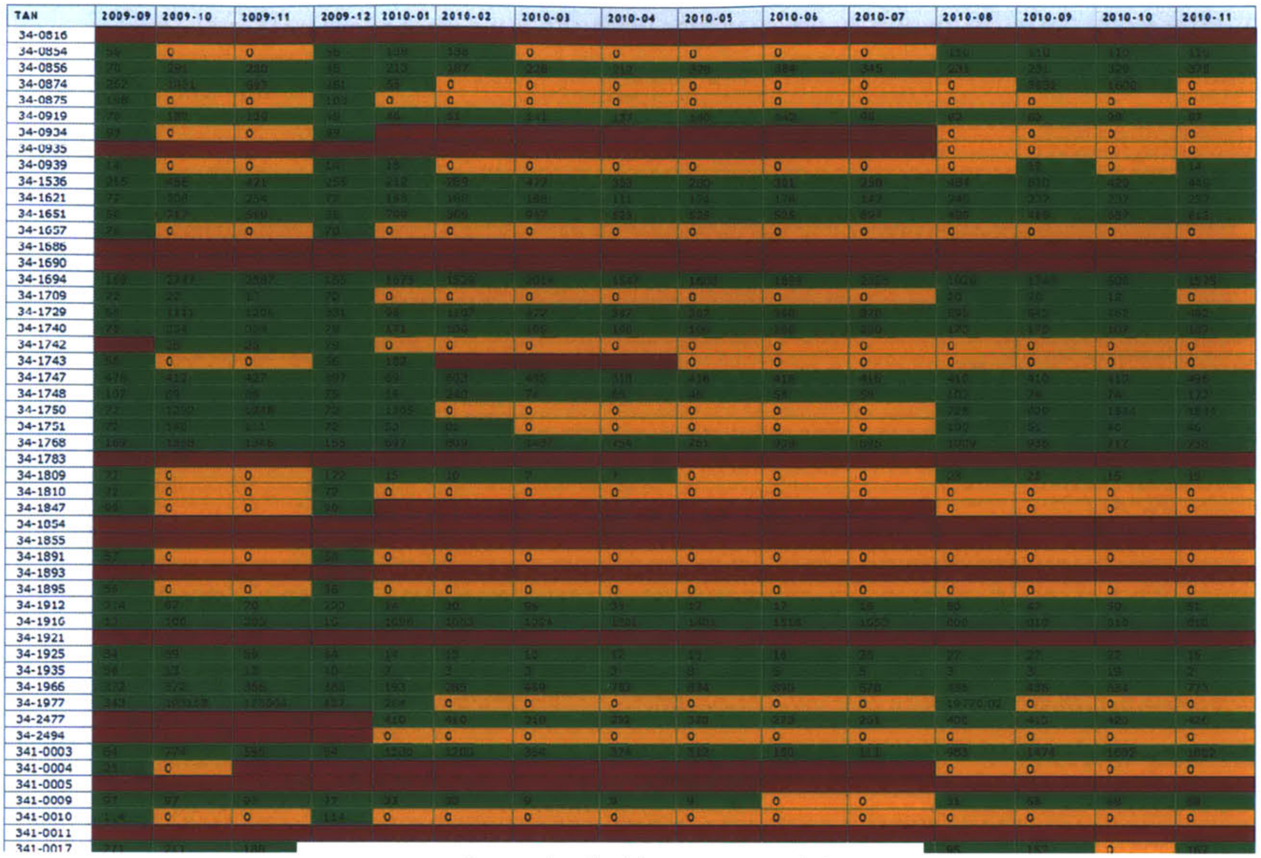
Some limitations of our approach, such as BOM inconsistencies and product version mapping, have already been identified and addressed in this thesis. Other limitations that may or may not have been mentioned include:

- Inventory policy and data misalignment
- Missing inventory policy data
- ASL exemption maintenance

The first two limitations listed above stem from the dependence on receiving a monthly inventory snapshot report with inventory policy figures from IT. This process step is due to the inability to directly query Cisco's supply chain database, which also precludes our model from expanding down to the PCBA component level. The third limitation involves a human element of motivating supply planners to maintain the ASL exemption list and also significantly impacts the integrity of our model results.

In a true supply planner workflow, inventory policies are renewed on a monthly basis according to a fiscal calendar which usually does not coincide with a traditional calendar. As a result, ROP, SIS, CT2R and other inventory policy values may be adjusted mid month. In an ideal data system, these values would be pipelined to our model which would display any inventory policy changes in real-time and update any performance metrics immediately. However, given the limitations and dependency on IT for data requirements, inventory snapshot reports are requested on an ad hoc, approximately monthly basis with no visibility into the exact date the inventory policy values were set. This introduces potential phasing issues where a planner may adjust ROPs to address a sudden shift in a demand. The ROP adjustment would not be reflected in our data until the first day of the following month while DDLT values would have already underwent the increase. This limitation could be addressed by receiving permission to read the supply chain database or by improving communications with IT and aligning IT processes with ROP adjustments, which takes time. Fortunately, for model testing purposes, the limitation will not impede our ability to interpret example system scenarios.

Missing inventory policy data creates a number of issues for our approach, especially in cases where certain products may be missing months' worth of inventory policy values for one reason or another. This issue was identified when addressing TAN version mapping issues (Section 3.3.2.2) where often the inventory snapshot reports generated by IT lacked the necessary values to calculate a valid product ASL. To improve transparency and assist lean planner efforts in addressing the issue, we created a heatmap to quickly visualize ROP inconsistencies for versionless TANs across an entire year.



ioes not reflect true company data.

Figure 23: Heatmap of versionless TAN ROPs by month

The heatmap allows planners to quickly identify when ROP breaks and other issues may be related to data inconsistencies. Cells in red represent months where no ROP values were found for any version of a specific TAN. Cells in yellow represent months where ROP values were set to zero, which often is the case when a product is sent to EOL or under a push model. Finally, cells in green represent the aggregated ROP value across all versions of a specific TAN. Figure 23 displays the many inconsistencies and fluctuations that might exist in our historical dataset. However, for model testing purposes, we focus on product families with more consistent datasets.

Lastly, maintenance of the tool may induce a number of limitations which may impact our testing. Since the tool was rolled out to supply planners near the end of the project timeframe, many of the planners were still becoming familiar with the metrics and processes of using the tool. The critical process of managing ASL exemptions was a topic of discussion in a number of meetings in order to ensure supply planners understood their responsibilities in overseeing respective PF-level ASLs appropriately. However, complete usage of the tool by supply planners was not achieved by the time of model testing. Thus, in our testing, we avoid examining scenarios involving PFs with many products under a push model.

4.3 Testing Results

Given the limitations of our approach, we examine the model's capability in evaluating system performance, assisting root-cause analysis, and driving the appropriate CLCA by observing a number of system scenarios in which relatively low ASL values are reported and leveraging the tool to identify the issue and drive an action. This exercise is much more meaningful than attempting to benchmark model output against the output of an alternate approach to system evaluation. We present three scenarios in which ROP breaks occur for various reasons.

4.3.1 Testing Scenario #1 – ROP Sizing Error

In the first scenario, we investigated one of the lowest performing PFs, 15454W, which had an ASL of 38%. When raised in a meeting, the supply planner who owned the PF sorted the products by weight to begin the process of root-cause analysis. What was discovered is displayed in the figure below.

15454W ASL: 38%

TAN	Site	ASL	Spend	Weight ▾
800-26772-05	CTR	0.0%	73212	15.0%
800-31649-01	CTR	30.4%	59135	12.1%
800-22341-03	CTR	0.0%	41903	8.6%
800-33952-01	CTR	28.7%	36289	7.4%

Note: Image does not reflect true company data.

Figure 24: Scenario 1 – Root-cause analysis

The top ten products by weight (not all shown) comprised about 75% of the entire PF's running cost. Five of the ten possessed an ASL value of 0%. The supplier planner raised the issue that these TANs matched products under a BPS or push model and proceeded to exempt them from ASL calculations (shown in Figure 24). Upon investigating these five TANs, a TAN profile similar to the one below was displayed (see Figure 25).

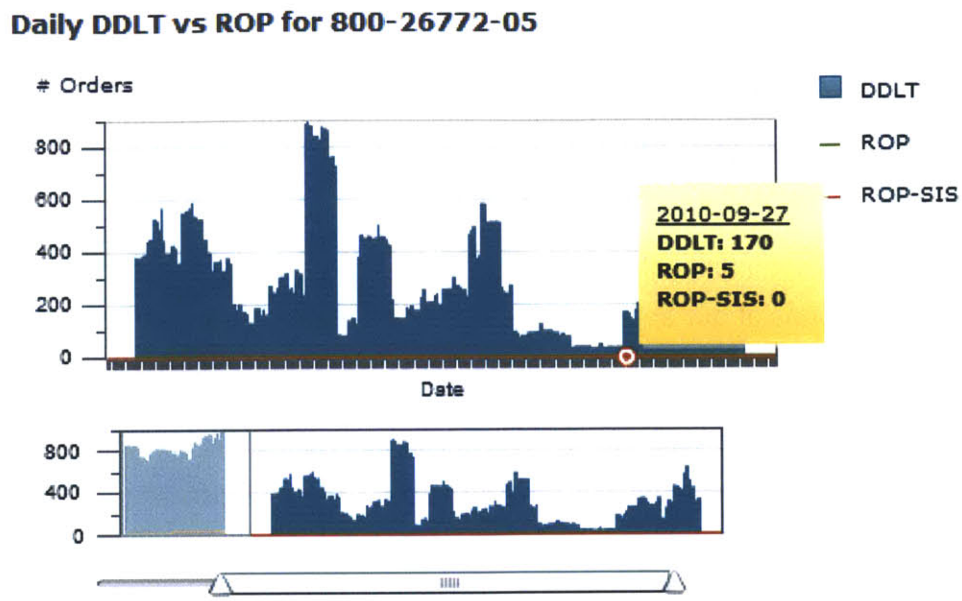


Figure 25: Scenario 1 – BPS (push model) product profile

Thus, the supply planner's suspicions were verified as, indeed, the TANs only possessed safety stock as shown in the DDLT and ROP trend chart. However, the second and fourth heaviest products had respective ASLs of 30.4% and 28.7% (shown in Figure 24). Their TAN profiles and respective ROP trends bore a drastically different shape and form as seen in Figure 26.

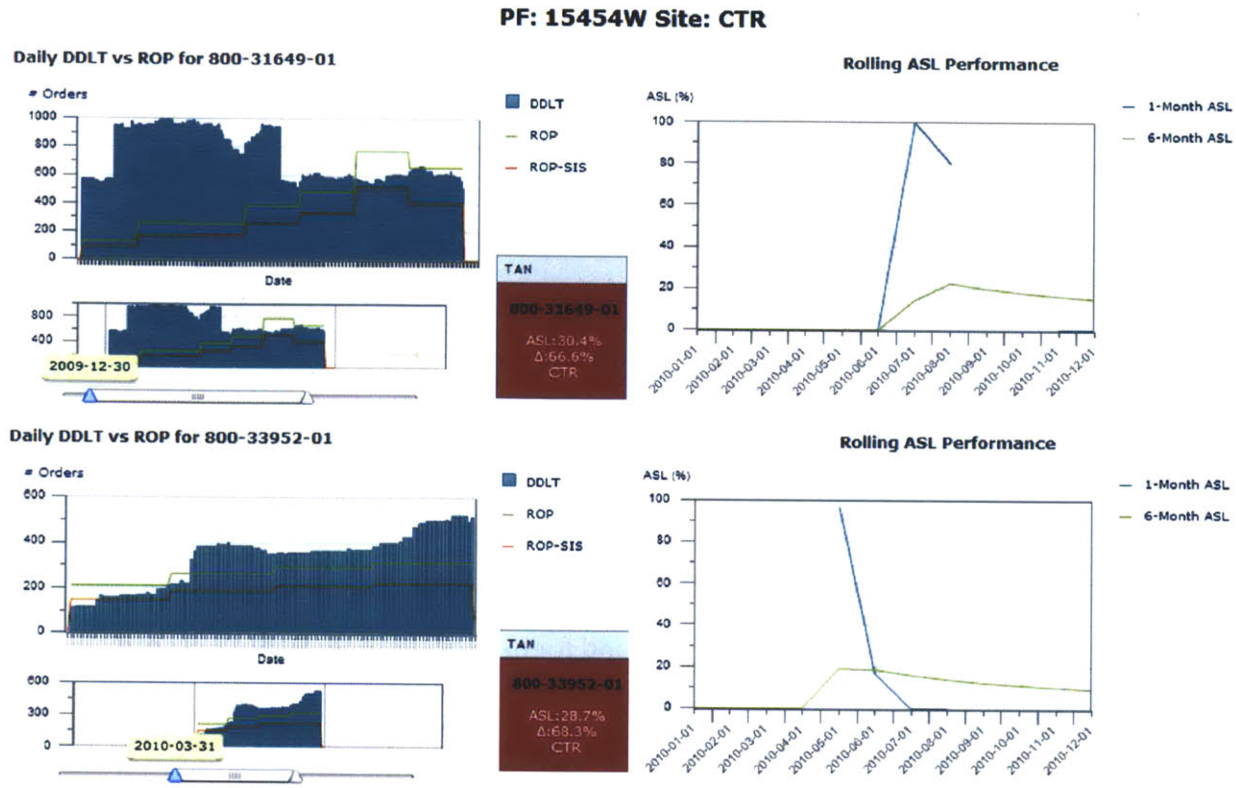


Figure 26: Scenario 1 – Stepwise ROP adjustment

The figure shows the two TANs across an eight and five month span, respectively. From the figure, we see that either the ROP sizing software or the supply planner was making stepwise adjustments to meet the demand requirements but was unsuccessful. The supply planner verified that there was a high demand forecast bias being applied to the PF during that specific time period and that many costly SUKs were issued as a result of still not being able to meet the demand.

The scenario demonstrates the events that transpire when a large ROP sizing error exists. A supply planner will likely adjust an ROP upwards to address the matter for the current cycle, but the quick fix solution may only be temporary especially if the demand increases by a greater margin in the next cycle. The supply planner alternatively might raise the issue to a subject matter expert (SME) or lean planner. This action is especially useful in cases such as the first TAN in Figure 26 (top) where the demand was greatly underestimated, and the ROP took six months to catch up to the actual demand by ultimately overshooting it. The second TAN (bottom) experienced an opposite effect, as seen in the rolling ASL performance charts, by initially covering the demand and ultimately falling behind.

4.3.2 Testing Scenario #2 – Demand Volatility

A cornerstone of the model is that it provides an organization with supply chain visibility, one of the key objectives of Cisco's most recent lean initiatives. Being able to visualize demand patterns overlaid with inventory policy settings is invaluable to a planner in periods of demand volatility. As reported by the most recent SCM World (6) survey, "Demand volatility continues to be the key challenge facing supply chain executives for 2011." The survey reports that 62.7% of supply chain executives identified demand volatility as their key pressure point in 2011 as the impact of the global recession continues to affect demand patterns. Cisco was certainly not a spectator to the recession as demand for networking equipment entered a tremendous flux.

In the second scenario, we examine one of the many products with a volatile demand pattern (Figure 27). As seen in the figure, the product underwent multiple demand spikes over a span of eight months.

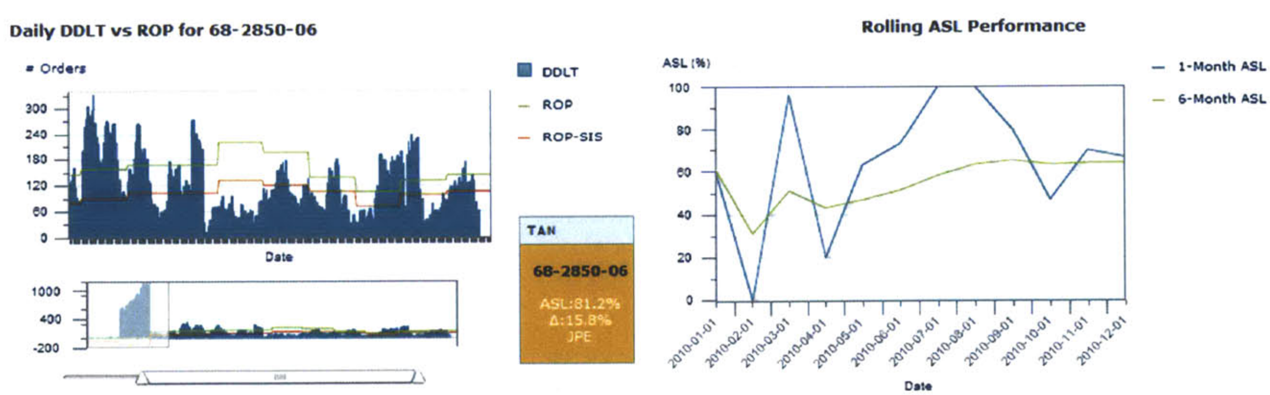


Figure 27: Scenario 2 – Demand Volatility

The specific TAN in this scenario had a CT2R of 8 to 10 days. In this scenario, the relatively short lead time would allow a planner using the tool to visualize a demand spike with a 1-2 week delay. Some of the minor demand spikes can be attributed to the change in the CT2R, which a planner could verify with the data tables listed on the TAN profile display. However, with much larger demand increases, a supply planner would need to make a decision using demand forecast data whether a temporary ROP adjustment is warranted.

An issue that may arise, especially with longer lead time products, is that given the delay of DDLT information arriving to a planner incurred by a product's CT2R, the demand may actually have returned to normal levels while a planner is in the process of deciding whether or not to modify the ROP. This concept reaffirms the core intent of the model – as a tool to evaluate current performance, root-cause, and drive action, and not to aid forecasting objectives. In such a scenario of high demand volatility, a low ASL may drive the resizing of the mean demand or SIS, which may result in higher holding costs. In typical scenarios, however, Cisco relies on its process of issuing SUKs for periods of demand spikes, which is an effective but costly solution in achieving customer satisfaction.

4.3.3 Testing Scenario #3 – Investigating Holding Costs

As important as it is for a supply planner to investigate products with low ASL performance, it is equally important for a planner to investigate and understand the contributing factors of high ASL performance. With the model's capability to generate ROP trends overlaid with demand profiles, an organization can drive lean initiatives to reduce holding costs. In this scenario, we examine a product with a 97% ASL which is causing 30%, or the most weight, of a particular high-performing PF.

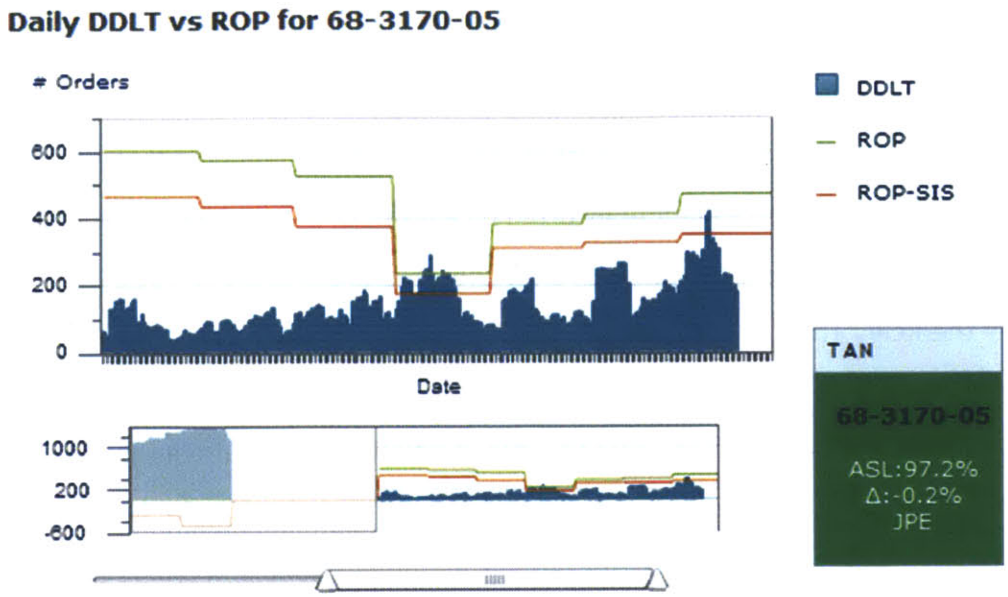


Figure 28: Scenario 3 - Excessive holding costs

The product possesses an ROP that is as high as three times the DDLT over a duration of three months as seen in Figure 28. The ROP trend indicates that marginal adjustments were being executed on a monthly basis to reduce the ROP in order to better align with demand projections. Although the ASL of the particular TAN obtained a 97.2% ASL, a supply planner using the tool may have realized the excessive holding costs being incurred in the first three months of the chart and may have carried out a lean initiative beginning with a manual ROP adjustment and then following up with an investigation into the ROP sizing algorithm. In order to maximize the impact of a lean initiative, the process of tackling high holding cost products can be iterated following a sort by weight function across each PF.

A potential viewed limitation of the model may be its inability to flag products with excessive holding costs when examining a PF or site. This limitation is derived from two sources. First, the DSL calculation (Equation 4) takes the minimum of 100% and any service level value in order to maintain consistency with general supply chain practices and theory. This practice disguises holding costs of every size. Second, the ASL formulation uses a cycle service level rather than a fill rate service level, which takes excess inventory into account. If we were to make the assumption that the excess inventory on one day can satisfy the unmet demand on another day then a fill rate ASL could be defined in such a way to highlight the remaining excess inventory over a given time period. However, even in such a metric, it is likely that business needs would mandate a maximum value of 100% for consistency and to avoid ambiguity.

4.4 Test Case #1 – Improving ROP sizing

In instances of unsatisfied demand and low customer service levels, SUKs are a costly solution to mitigate the effects of a low performing reorder point system. Our model of using the ASL and weighted spending as a means to evaluate system performance is valid but may not be the most effective in associating cost and performance data. Furthermore, it represents only one combination of measurement parameters that are at our disposal. In this test case, we look to apply the same foundation and framework to adapt our model to utilize another Level 1 metric, namely SUK as a percentage of ROP (refer to table in Section 3.2.2), in order to investigate ROP effectiveness with regards to the current sizing approach.

4.4.1 Mean demand calculation

The mean demand is a critical component that contributes to the ROP calculation (Equation 3). A problem that exists with the ROP sizing calculation is that a proxy lead time is used for various reasons, described in Section 2.1.2, to determine the mean demand over the lead time (MDLT) rather than the actual lead time of the product. In our test case, we seek to measure the impact of using various sizing windows on the ASL, which we define in this case as the number of weeks an SUK was not issued divided by a designated time period, in this case one year.

The various sizing windows based on forecasted weeks of demand yield the following MDLT formulas:

$$MDLT_1 = \frac{L_1}{13} \sum_{w=5}^{17} d_w \tag{7}$$

$$MDLT_2 = \frac{L_1}{8} \sum_{w=2}^{9} d_w \tag{8}$$

$$MDLT_3 = \frac{1}{4}\left(\sum_{w=2}^{2+L_2} d_w + \sum_{w=3}^{3+L_3} d_w + \sum_{w=4}^{4+L_4} d_w + \sum_{w=5}^{5+L_5} d_w\right) \tag{9}$$

where,

d_w: *forecasted demand on week w*

L_w: *forecasted product lead time (in weeks) on week w*

$MDLT_1$ represents our control and the current method for ROP sizing which uses a 13 week window starting on week 5 of the demand forecast. $MDLT_2$ investigates using a shorter time horizon of 8 weeks starting on week 2, which generally contains more fluctuations in forecasted demand due to backlog. Finally, $MDLT_3$ addresses the need to use actual product lead times in the sizing window rather than proxies and takes the average of four time horizons to minimize demand variation.

Using the calculated MDLT values, we can determine ROP_1, ROP_2, and ROP_3 values by making an SIS addition. Finally, we subtract the same DDLT value from each ROP in order to determine SUK quantities that would result from each ROP sizing method. These SUK quantities can then be used to generate metrics for the remainder of the analysis.

4.4.2 Results

In order to achieve meaningful output, we use a much smaller sample in our case by focusing on one of Cisco's premier PFs in order to ensure high data quality and integrity. In this case, the PF contains 38 products which exist at the DF level – simplifying our analysis. By essentially modifying the logic of our model in the program code and pipelining one year's worth of forecast data to replace the historical data in our testing, we can quickly transform our model into a tool for root-cause analysis.

The new dashboard focuses on the presentation of four SUK weekly metrics by corresponding MDLT approach:

- Number of parts (out of 38) that had an SUK
- SUK quantity
- SUK dollars (SUK quantity x product unit cost)

- Average SUK as % of ROP

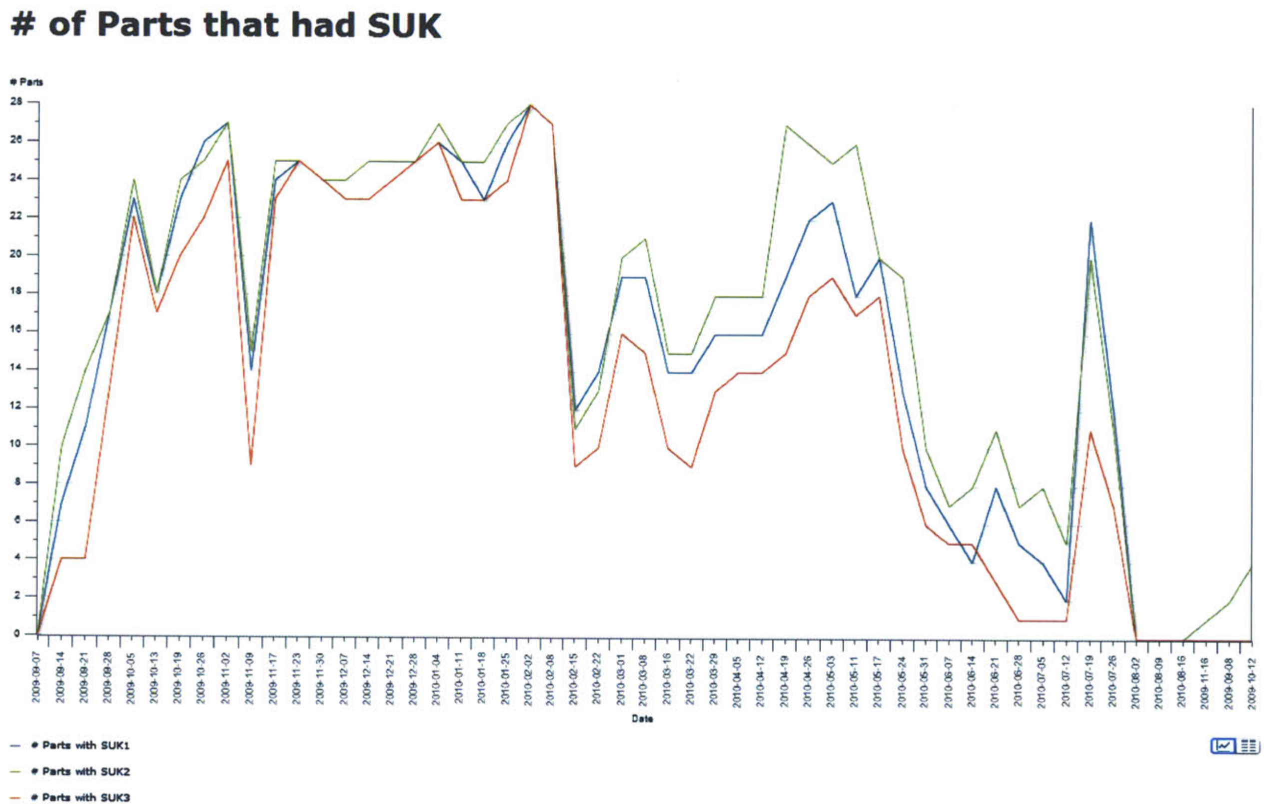


Figure 29: Number of parts that had an SUK by week

The charts generated in the dashboard allow a lean planner to quickly visualize the performance trends of each ROP sizing method (method 1 in blue, method 2 in green, and method 3 in red). From Figure 29, we see that method 3 of ROP sizing consistently reduces the number of products being issued SUKs, as well as reduces the overall quantity issued (Figure 30) per product and resulting associated costs (Figure 31). Further statistical analysis can be performed by exporting the data using the "Export to Excel" function for use in a statistical software program, such as JMP. Since the primary focus of the test case is to demonstrate the portability and adaptability of our model to enable root-cause analysis, the statistical analysis is not a focus of the case.

SUK Quantity

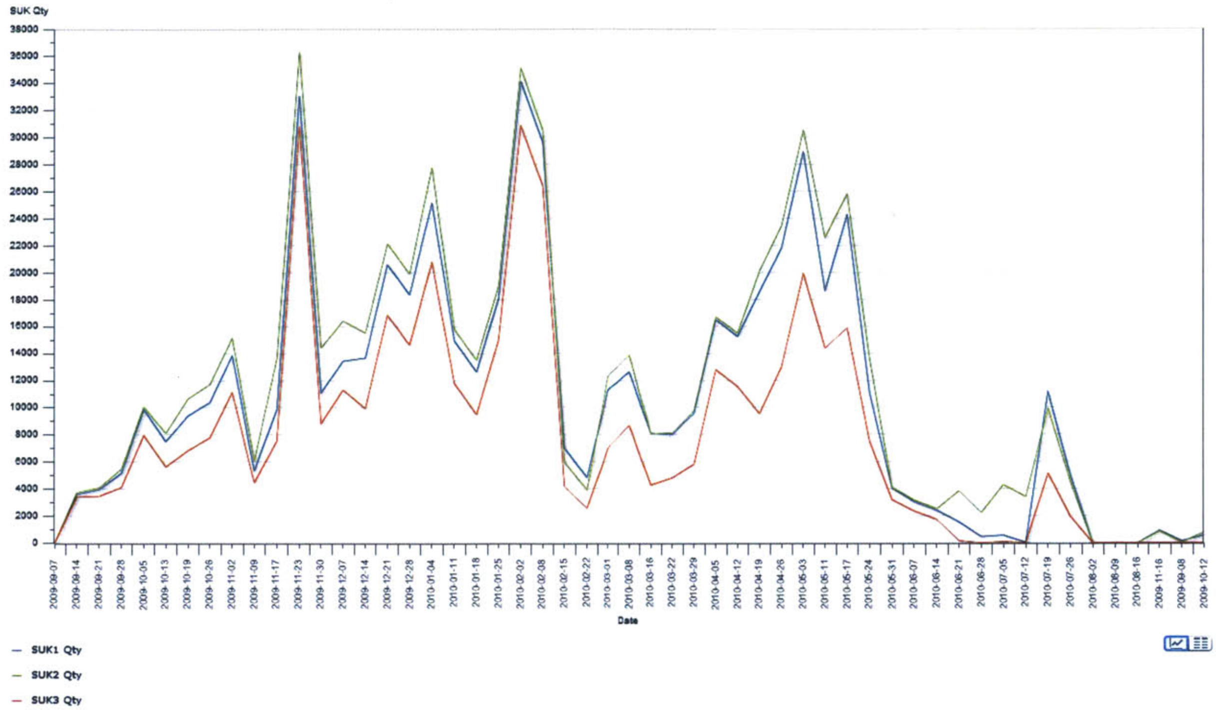


Figure 30: SUK quantity by week

SUK Dollars

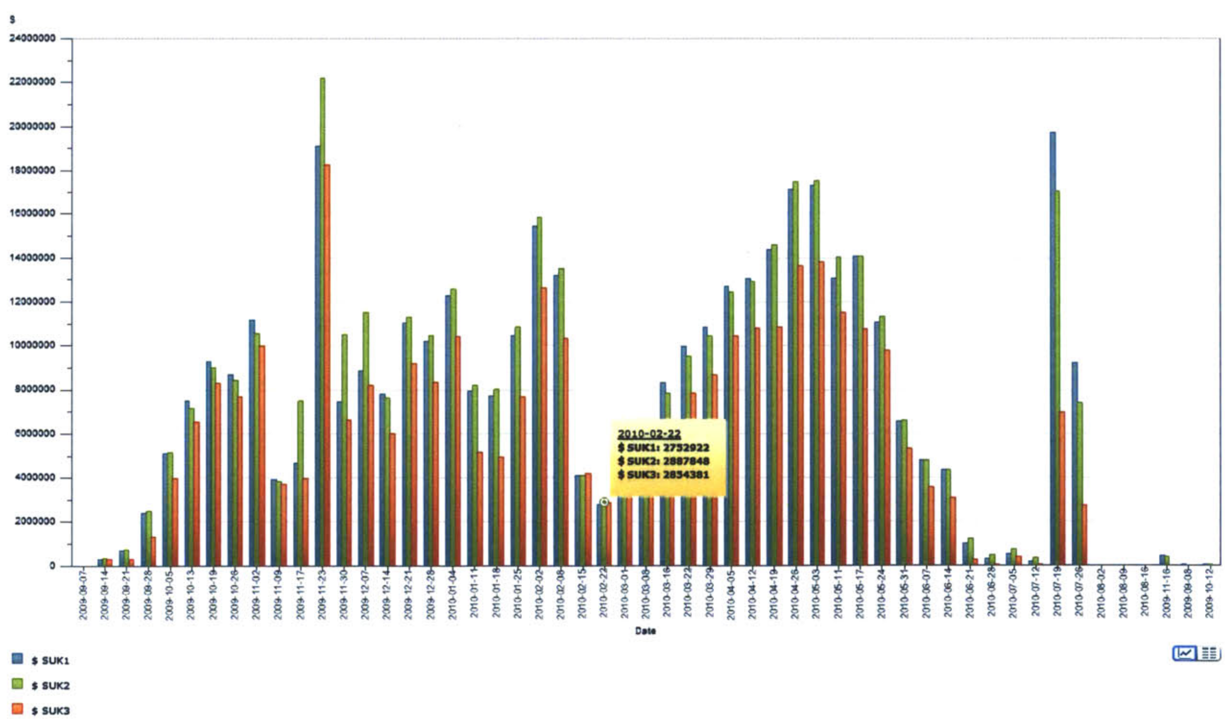
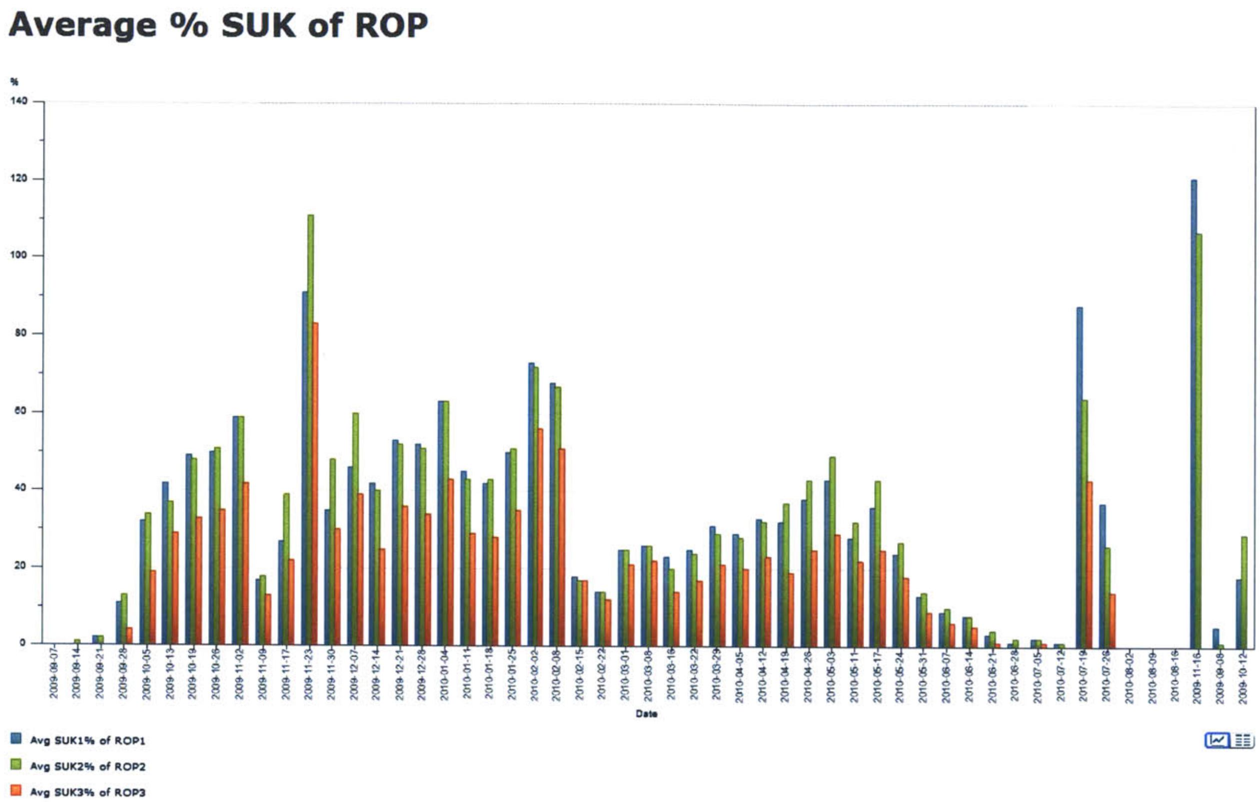


Figure 31: SUK dollars by week



#1 Sizing Window: 5-17	Average SUK as % of ROP #1: 34%
#2 Sizing Window: 2-9	Average SUK as % of ROP #2: 35%
#3 Sizing Window: (2-CT2R),(3-CT2R),(4-CT2R),(5-CT2R)	Average SUK as % of ROP #3: 24%

Figure 32: Average SUK as a percentage of ROP

One of the dashboard's primary focuses is on the average SUK as percentage of ROP. From the chart and table, the output makes intuitive sense. We would expect that due to the increased noise inherent in weeks 2 through 4 of the demand forecast, method 2 would result in a less optimized ROP sizing which is evident in its slightly higher SUK percentage compared to the control, or method 1. Moreover, method 3 exhibits a much improved average SUK as a percentage of ROP result, which supports our initial theory of using actual product lead times in sizing windows to enhance ROP effectiveness.

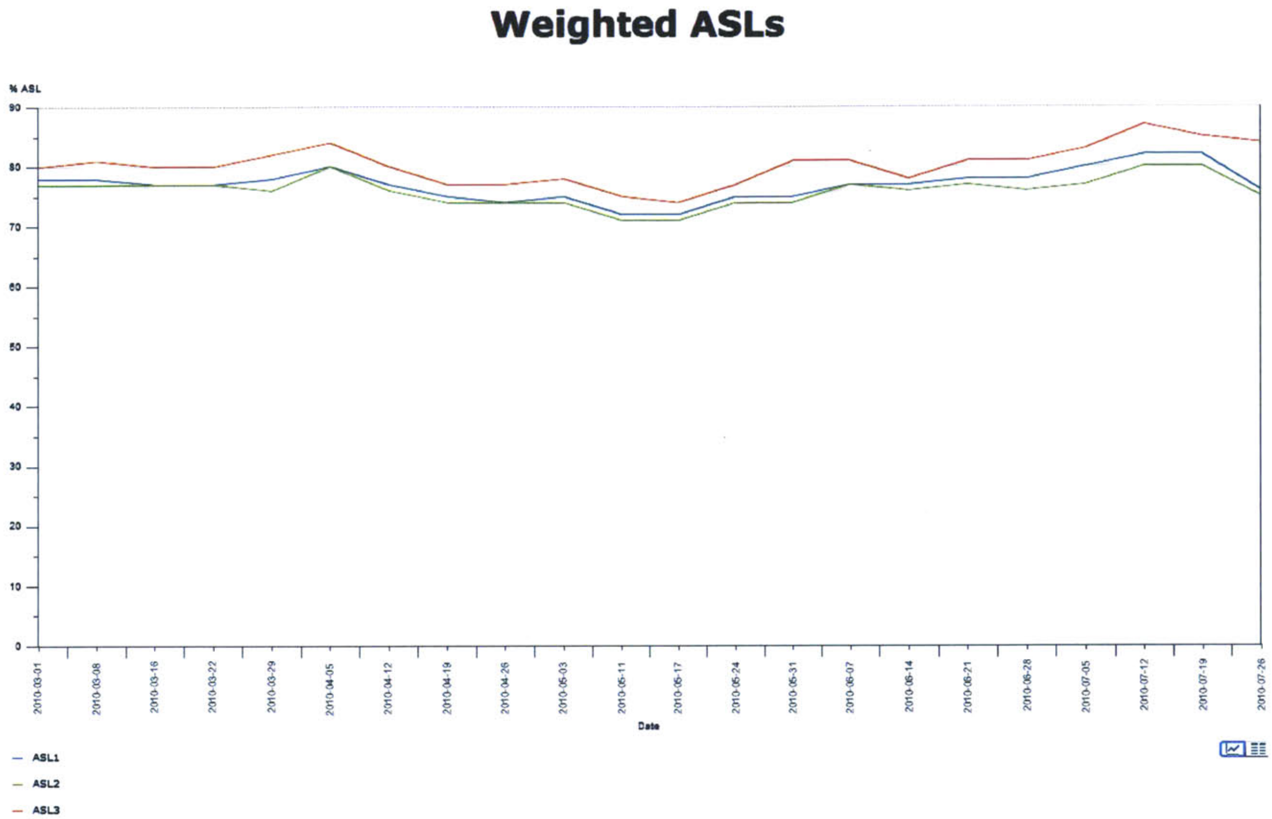


Figure 33: ASL by week for ROP sizing methods

Finally, we perform a weighted ASL calculation for the PF to monitor the performance of each ROP sizing method over a year. This visualization allows a planner to quickly rank order various methods and sizing windows. Again, it shows method 3 as the predominant leader in obtaining higher service levels. An interesting addendum to the model would be to monitor holding costs to ensure ROP values are not too high, especially for high-cost products.

The novelty of our model and approach is that it allows flexibility in the data pipeline and sizing logic to allow quick benchmarking of various combinations of PFs and sizing windows. The dashboard dynamically updates all analytics to correspond with the test sample, which allows users to focus on experimentation and decision-making rather than setup and data analysis. This feature becomes invaluable as we compare and contrast more complex methods and systems.

4.5 Test Case #2: Comparing integrated inventory management software

Cisco uses an integrated inventory management software by FlowVision®, a common inventory optimization solution used by many supply chain organizations, which accurately drives ROP and SIS levels using business rules based on proprietary, industry-leading lean methodology algorithms (7). The software platform allows decision makers to create multiple inventory-sizing rules to address different business needs and has other key functions that include:

- Recommending optimum ROP thresholds to improve service levels
- Performing "what-if" simulations for a project or region "on the fly" after planners change key parameters such as demand, CT2R, SIS or service levels; then evaluates results before establishing reorder point thresholds
- Configuring workflow-based approvals for ROP values
- Automatically writing back the ROP & SIS values to the ERP systems

Cisco is debating whether to replace its current solution in favor of an in-house optimization system, which it dubs NextGen, in supporting its supply chain management needs. The vast number of features associated with such a system introduces many levers for tuning the ROP and other inventory policy values. Unlike in Case #1, which uses our model to simulate the effect from simply implementing various ROP sizing windows, we investigate the robustness of our model in comparing the performance of two entirely different inventory optimization systems. The exact features of NextGen that differ from those of FlowVision® are kept confidential and are irrelevant for the purpose of the test case.

4.5.1 System benchmarking

In order to adapt our model, we pipeline two sources of ROP data, one from FlowVision® and another from NextGen, and one set of historical demand data. Unlike in Case #1, modification to the logic is not necessary since we need only compare and contrast ROP output. Thus, we need only modify the frontend of the dashboard in order to enhance visualization for comparison purposes. Like Case #1, we use the same PF as our sample due to the difficulty of obtaining NextGen ROP data for all PFs.

The premise of the dashboard frontend is to perform a side-by-side comparison of the overall ASL values as a result of the FlowVision® and NextGen system implementations. At the time of case, NextGen was being piloted in parallel with the current system in order to allow benchmarking of products over the same time period. On the dashboard, planners are able to see the PF ASL resulting from each optimization system. Upon looking at the PF breakdown, a comparison of individual product ASLs is presented. Given the vast number of system factors contributing to a particular PF's or product's performance, perhaps the most value of the benchmark test can be drawn from individual TAN profiles.

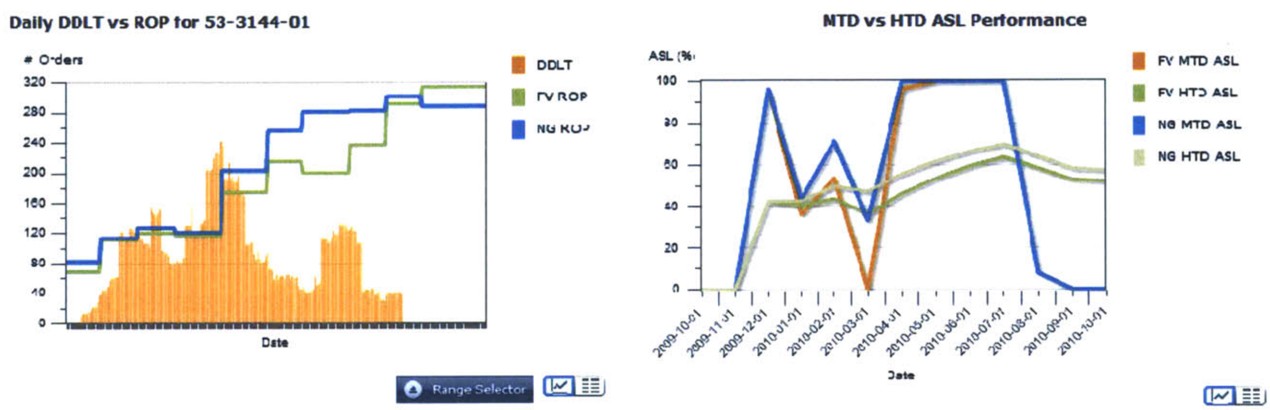


Figure 34: Comparison of two inventory optimization options

Under individual TAN profiles, visual representations of both ROPs are overlaid onto a yearlong demand profile, allowing a planner to quickly confirm the specific areas of discrepancy for root-cause analysis. The rolling ASL charts become even more invaluable for such an analysis as it aids in targeting the exact months in which an investigation of the ROP sizing or demand forecast should be made. Raw data is also made available for extended statistical analysis.

4.5.2 Results

In our particular simulation, products under the NextGen optimization system outperformed those under FlowVision® in over 75% of product comparisons. However, further analysis is required once data from all PFs are readily available. In addition, similar to Case #1, a possible additional metric to monitor and compare is the overage costs associated with each system in order to ensure that "improved" product performance is not a result of holding an exorbitant amount of excess inventory.

4.6 Test Case #3: PCBA component-level performance

In the final case, we examine the key remaining challenge in achieving a complete, end-to-end, system evaluation model – establishing PCBA build site performance metrics. In Section 3.2.3, we discussed the associated difficulties precluding a formal implementation of PCBA component-level ASL metrics into our model. Thus, the purpose of this test case is to simulate, using a sample PF dataset, the extension of our model in generating component-level performance metrics. This exercise not only ensures our model can be utilized at the build level but also completes the model testing by coming full circle through all nodes of the pull system.

4.6.1 TAN to PCBA component relationship

In a similar vein that PF-level ASLs can be disaggregated into individual TAN ASLs, TAN ASLs can be disaggregated into individual PCBA component ASLs. Moreover, in Section 3.3.2.1 we discussed the many-to-many relationship between PID and TAN items. By expanding downward into the PCBA component level, we again allow for the many-to-many relationship that exists between TAN and PCBA components. Thus, in order to perform a demand approximation for PCBA components, two levels of many-to-many relationships must be traversed, since bookings only exist at the PID level.

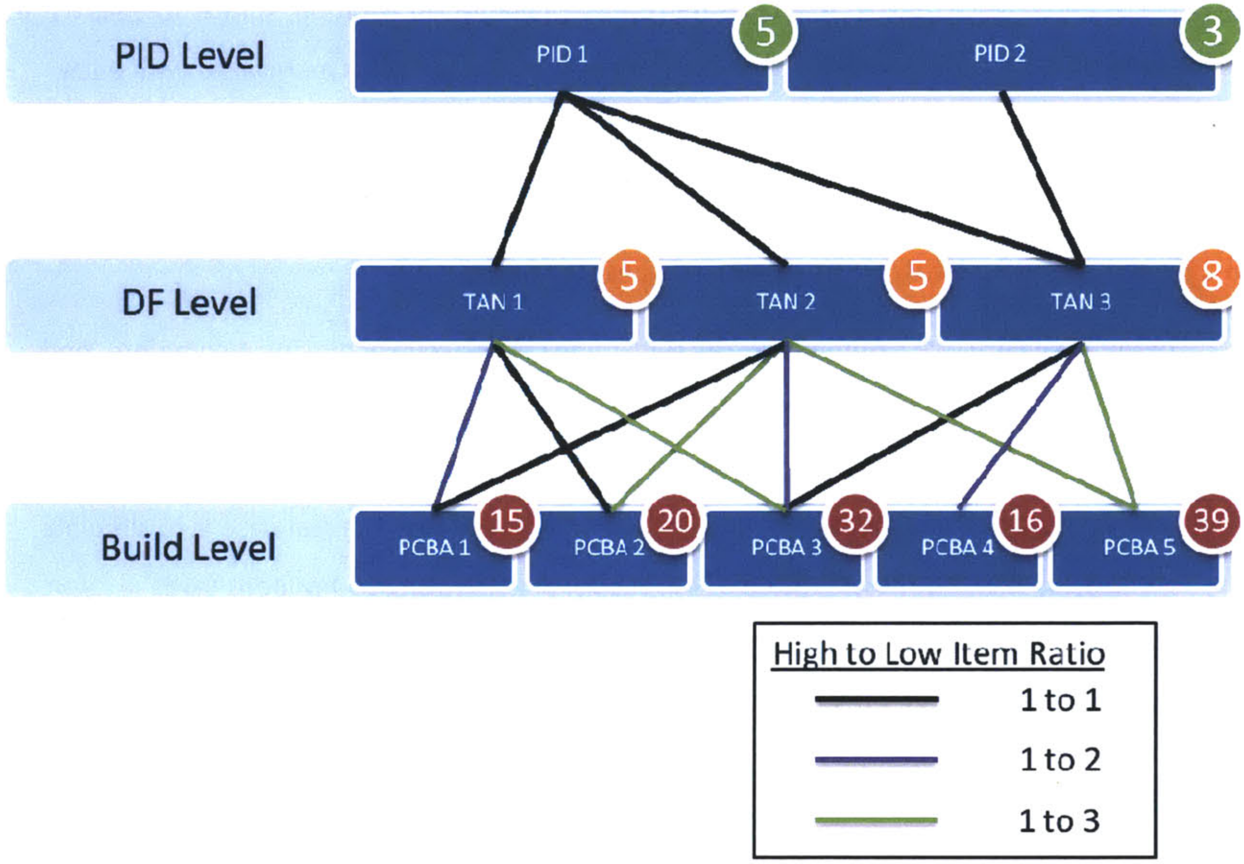
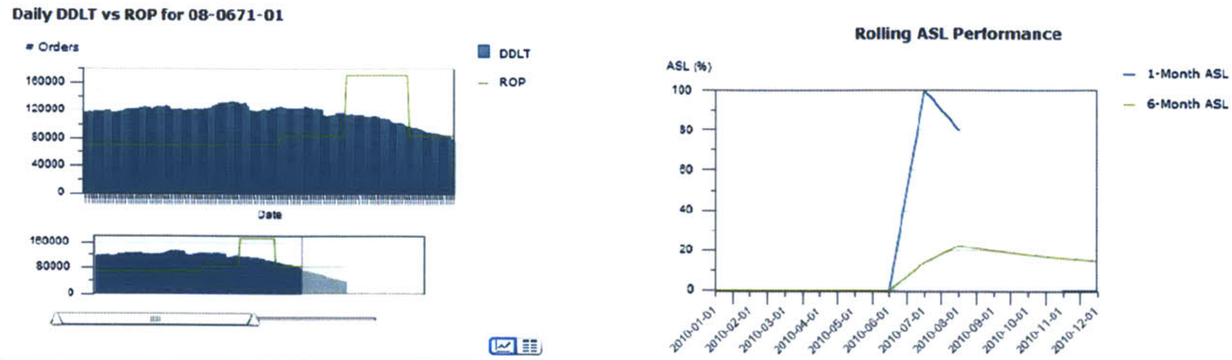


Figure 35: Orders per item map

Another consideration to bear in mind is that the many-to-many relationships between the two levels are not necessarily identical in nature. Figure 35 exemplifies the added complexity stemming from the build level as TAN to PCBA component booking ratios are not necessarily 1:1. It is not uncommon for a single TAN to consist of scores of the same component. This multiplier effect is not a major issue as TAN bookings are simply multiplied by their respective component to TAN ratio before being aggregated at the PCBA component level, as shown in the figure.

Once PCBA component bookings have been calculated, we simply treat the PCBA component in the same manner as we would a TAN by retrieving its inventory policy values from monthly inventory snapshot reports and calculating an ASL value. The process would result in an output similar to the figure below:

Component: 08-0671-01



PCBA	Metric	12/01	12/02	12/03	12/04	12/05	12/06	12/07	12/08	12/09	12/10
08-0671-01 ASL:18.1%	ROP	69589	69589	69589	69589	69589	69589	69589	69589	69589	69589
	DDLT	115738	115864	116669	116294	117831	117417	117528	117451	118041	119737
	CT2R	112	112	112	112	112	112	112	112	112	112
	SIS	200.66	200.66	200.65	200.66	200.66	200.66	200.65	200.66	200.66	200.66
	DSL	60.1%	60.1%	59.6%	59.8%	59.1%	59.3%	59.2%	59.2%	59.0%	58.1%

PCBA	Metric	12/11	12/12	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/
08-0671-01 ASL:18.1%	ROP	69589	69589	69589	69589	69589	69589	69589	69589	69589	69
	DDLT	119891	116175	116097	116291	116615	117346	117349	121036	121774	12
	CT2R	112	112	112	112	112	112	112	112	112	11
	SIS	200.56	200.66	200.66	200.66	200.56	200.65	200.66	200.66	200.66	20
	DSL	58.0%	59.9%	59.9%	59.8%	59.7%	59.3%	59.3%	57.5%	57.1%	57

TANs this PCBA reports to

TAN	Metric	12/01	12/02	12/03	12/04	12/05	12/06	12/07	12/08	12/09	12/10	12/11	12/12
68-2805-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	236	361	396	336	298	286	297	349	358	351	329	199
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	112	112	112	112	112	112	112	112	112	112	112	112
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-2516-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	470	880	920	822	732	656	662	670	678	676	618	184
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	98	98	98	98	98	98	98	98	98	98	98	98
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-3156-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	95	117	126	108	90	83	85	95	96	96	76	56
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	10	10	10	10	10	10	10	10	10	10	10	10
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-3501-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	0	0	0	5	5	5	5	5	5	5	5	5
	CT2R	14	14	14	14	14	14	14	14	14	14	14	14
	SIS												
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	ROP	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	DDLT	[illegible]	[illegible]	[illegible]	[illegible]								

TAN	Metric	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25
68-2805-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	203	208	267	273	214	213	227	328	397	422	413	399
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	112	112	112	112	112	112	112	112	112	112	112	112
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-2516-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	210	230	294	326	304	382	392	588	614	578	610	574
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	98	98	98	98	98	98	98	98	98	98	98	98
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-3156-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	69	83	88	88	76	83	82	134	167	171	160	144
	CT2R	10	10	10	10	10	10	10	10	10	10	10	10
	SIS	10	10	10	10	10	10	10	10	10	10	10	10
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
68-3501-01	ROP	0	0	0	0	0	0	0	0	0	0	0	0
	DDLT	5	5	5	5	0	0	0	0	0	0	3	3
	CT2R	14	14	14	14	14	14	14	14	14	14	14	14
	SIS												
	DSL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	ROP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0
	DDLT							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

e does not reflect true company data.

Figure 36: PCBA component profile with TAN report

The PCBA component profile (Figure 36) resembles the TAN profile with some minor differences. First, the DDLT profile represents a bookings aggregation of multiple TAN items that contain varying quantities of the PCBA component and uses the component's specific CT2R for the lead time. Second, directly beneath the raw data of the component is the raw data and hyperlinks to each TAN that contains the component. In the specific example above, no ROPs and thus no ASLs exist for any of the TANs, implying the TANs may fall under a push model. This reiterates the importance of performing separate, independent ASL calculations at both the build and DF level.

4.6.2 Results

Extending our model to the build level provides a wealth of information and additional tools for planners to more accurately address system issues, perform root-cause analysis, and execute more targeted CLCA. Using the example in Figure 36, a planner would immediately see the PCBA component is underperforming with an ASL of 18%. The planner could then quickly determine which TANs, if any, are being impacted further down the line as a result of a shortage of the specific component. Regardless of a shortage, the actual TAN ASL value still remains an independent formulation and would remain unaffected. However, the actual on-hand and on-order inventory and resulting OSL may be impacted by the shortage.

As valuable as it is to a planner to possess a TAN ASL report for each PCBA component in the BOM, it is equally valuable to possess a PCBA component ASL report for each TAN. This was deemed a more useful feature for planners due to the general hierarchy and reporting structure of TANs and PCBA components. The visualization would be symmetrical to Figure 36, except with a PCBA component breakdown below the TAN ASL profile. If an issue was flagged for a certain product, a planner could first investigate the corresponding TAN to root-cause any ROP issues. If no problems are detected, the planner could continue down the BOM to investigate the performance of PCBA components comprising the TAN.

Although the TAN profile and PCBA component performance report are essentially the inverse of what is displayed in Figure 36, the process of generating the proper output is nontrivial and nonsymmetrical to the process of generating the TAN performance report for a PCBA component profile. It is relatively simple to generate a TAN performance report for a PCBA component profile because in formulating metrics for a PCBA component, the respective TAN performance data must be aggregated and cached into memory beforehand. Thus, once the PCBA component metrics have been finalized, a TAN report can easily be generated from the cache. On the flip side, in order to calculate TAN ASL metrics, aggregating corresponding PCBA component data is not a requirement. Thus, in order to generate a PCBA component report, multiple iterations of the above process must be performed for each component in a TAN which requires the processing of what can be hundreds of linked TANs. This processing is memory intensive and not feasible given the memory constraints of the system used in the case. Finally, scalability of the process to all PFs is another barrier due to the millions of TAN to PCBA component mappings, as well as inconsistencies, that exist in the BOM.

5 Conclusions and Recommendations

The model presented in this paper allows an organization to evaluate the performance of a reorder point system, identify potential system issues, perform root-cause analysis, and execute appropriate CLCA. It utilizes historical consumption data to approximate item level demand which is benchmarked against the respective ROP to derive a customer service level to signify system performance. The model also aggregates item level performance metrics into metrics at the PF, DF site, and system or company level using a cost-weighted approach for high-level strategy and decision making. Using Little's framework (5), we evaluate the project's effectiveness in the context of accuracy, usability, and organizational implementation. Finally, we make general recommendations and recommendations for future work.

5.1 Model accuracy

Little suggests that in cases where objective accuracy is not attainable, which is most of the time, the user be left in control. Although we selected a reasonable approach to testing the model accuracy by simulating different system scenarios, full testing of the model is challenging due to the lack of precedent data for benchmarking and the inability to prospectively evaluate the accuracy of such a model. Much of our confidence in the accuracy of model stems from the underlying principles of the modeling approach rather than from the testing. However, in all cases, the model represents the operations as the user sees it, highlights potential inaccuracies, and leaves the user in control.

Additionally, many of the known accuracy issues of the model stem from the limitations and questionable integrity of the historical data, as detailed in Section 4.2. The model can only be as accurate as the data that drives it. Thus, improvements made to the entry and maintenance of the datasets will drive increasingly accurate system performance evaluation.

5.2 Model usability

Regarding usability, Little suggests a model should be simple, robust, easy to control, adaptive, easy to communicate with, and as complete as possible. In our model, the simple, concise display of performance metrics aligns with the monitoring routine of planners, as well as the business processes of investigating system issues. Feature implementations, such as the ASL item exemption, are a result of recommendations to improve robustness and user control. The straightforward procedure of importing of data enables the model to be adaptive and easy to update. Planners and managers provided valuable feedback so that the model could be understandable and communicated with on a daily basis. Leadership particularly found value in the quick turnaround of generating real-time analytics as well as the visualization of inventory policy scaled across the inventory system which enhances supply chain visibility and provides a near complete view of the pull system dynamics.

5.3 Organizational implementation

As Little's research suggests, we achieved organizational adoption by making the tool easy to access online and by assimilating our initial users to tool updates. Stakeholder meetings were held to facilitate model implementation and inform users of changes. Ownership and sustainability of the tool was transitioned to the lean planning team as discussions of formal institutionalization of the model by IT were underway. Formal support from IT is a costly and time-consuming option; however, with IT resources the model has the ability to reach its full potential of end-to-end system evaluation due to proper access to supply chain backend data. Without IT support, only a partial evaluation of the system can be made.

5.4 General recommendations

Organizations seeking to capture value from data are becoming increasingly aware that analytics-driven opportunities are central to growth and success. In an environment of volatile demand, companies continue to strive to achieve better visibility into supply chain activities. Our model appears to be capable of driving supply chain visibility within an organization as system issues are continually brought to the forefront of discussion. Furthermore, the model establishes the proper business processes to root-cause and address issues which are equally essential in becoming a lean, competitive company in any industry.

For Cisco, we recommend seeking formal institutionalization of the tool through IT while continuing the implementation of the current tool within CVCM organization. Planners leveraging the tool should target four areas: improving customer focus, managing volatility, improving and scaling system responsiveness, and collaboration. The model provides a means to systemically examine customer satisfaction and allow fact-based decision making for process improvement. This will enable a superior quality experience, improve node optimization, and ultimately offer a competitive advantage to Cisco.

5.5 Opportunities for model expansion

5.5.1 End-to-end performance evaluation

Once the model has been thoroughly tested and approved for IT implementation, performance evaluation within all nodes and items of the inventory system should be the first priority. With direct access to the supply chain database, the BOM can be directly queried on an item to item basis rather than imported all at once, which currently makes our model expansion to the build level infeasible. This would allow a true end-to-end system performance evaluation, as briefly mentioned in Section 4.6.

In addition, the premise of our model is to evaluate whether or not a reorder point system is functioning as designed. The next most valuable area for model expansion is to measure actual system performance, which includes execution issues. This would require numerous new datasets, such as on-hand and on-order inventory, as well as the logic to calculate OSL values at each node of the supply chain. Establishment of additional strategy and decision-making processes for CLCA would subsequently be required. Such an extension would be invaluable for cost reduction and customer service and bring the model one step closer to true supply chain visibility.

5.5.2 Reorder point optimization

Pipelining model output into the ROP optimization engine would allow for the employment of machine-learning techniques in advancing inventory optimization and reducing costs throughout the supply chain. Although this may not be trivial or even possibly not feasible, at least leveraging the data in some capacity to investigate the sizing of ROPs, such as in Test Case #1 (Section 4.4), would be a sensible extension to the model rather than relying on temporary ad-hoc solutions.

As briefly touched upon throughout the case, overage costs are of equal concern as shortage costs when investigating product performance. A possible extension of the model would be to employ a newsvendor model to ensure that ROP levels are assisting in achieving TSLs rather than excessively satisfying the demand. This type of analysis, if performed properly, would yield tremendous cost savings. Establishment of OSL metrics may be a necessary prior step in order to ensure actual customer service levels are not being impacted due to a misalignment between ROP and actual inventory levels, as well as between reported demand and true demand.

5.5.3 Refined CLCA and business processes

One topic omitted from the research is the establishment of boundary lines to distinguish high, mediocre, and low ASL performance. For the purpose of the project, boundaries were arbitrarily established at 90% and 80% to separate the three categories, colored green, yellow, and red, respectively. This becomes more important especially as service quality begins to converge and decisions must be prioritized more effectively. In order to implement such a change to the model, a better understanding of the financial or business impact of varying service levels must be executed either through a sensitivity analysis or utilizing a newsvendor model. Finally, a consensus must be reached on boundaries in order to ensure alignment with business practices. An early organizational concern of the model implementation was that planners would overreact to information presented on the dashboard and immediately set ROPs excessively high. Fine-tuning business and CLCA processes will ensure that standards are maintained when monitoring and addressing system performance.

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Appendix A: ROP Health Dashboard code

```
<?php
ini_set("memory_limit","2000M");
set_time_limit(1800);$time = microtime();
$time = explode(' ', $time);
$time = $time[1] + $time[0];
$start = $time;?>
<html>
<head>

<link rel=stylesheet href="table.css">
<title>ROP Health</title>
<script src="sorttable.js"></script>
<script type="text/javascript" src="overlib.js"></script>
<script type="text/javascript" src="swfobject.js"></script>
<script type="text/javascript" src="cue_charts.js"></script>

<script language="JavaScript" type="text/javascript">
function profile ( opn )
{
  document.send.pf.value = opn ;
  document.send.submit() ;
}

function site ( opn )
{
  document.send.site.value = opn ;
  document.send.submit() ;
}

function refresh ( opn )
{
  document.send.pf.value = opn ;
  document.send.refresh.value = 1 ;
  document.send.submit() ;
}

function exempt ( pf,tan,site )
{
   var retVal = confirm("Do you want to exempt "+tan+","+site+" from "+pf+" ASL?");
   if( retVal == true ){
          document.send.pf.value = pf ;
          document.send.tan.value = tan ;
          document.send.site.value = site ;
          document.send.submit() ;
          return true;
   }else{
          return false;
   }
}

function popup (c) {
window.open(c,'window','width=800,height=600,scrollbars=yes,status=yes');
}
</script>
<style>
.chartContent {
        height:300px;width:500px;
        position:relative;
        z-index:1;

}
</style>
</head>
<body>


<?php
//Author: dongchin@cisco.com
```

```
//Copyright 2011 MIT Leaders for Global Operations & Cisco Systems, Inc. All rights reserved.

//form vars POST
if  (@$_POST{'pf'}) $pfselect=$_POST{'pf'};
else $pfselect="";
if  (@$_POST{'tan'}) $tanexempt=$_POST{'tan'};
else $tanexempt="";
if  (@$_POST{'site'}) { $siteexempt=$_POST{'site'}; $siteviewselect=$siteexempt;} //site view
select is for displaying all TANs in site
else {$siteexempt="";$siteviewselect="";}
if  (@$_POST{'refresh'}) $refresh=$_POST{'refresh'};
else $refresh="";

if  (@$_GET{'siteselect'}) $siteselect=$_GET{'siteselect'}; //site select is for displaying one
tan's graph
else $siteselect="";

if (@$_GET["tanselect"]){
$pfselect=@$_GET["pfselect"];
$vtanselect=@$_GET["tanselect"];
$temp=explode("-",$vtanselect);
$tanselect="$temp[0]-$temp[1]";
} else $tanselect="";

function list_by_ext($extension, $path){
    $list = array();
    $dir_handle = @opendir($path) or die("Unable to open $path");
    while($file = readdir($dir_handle)){
        if($file == "." || $file == ".."){continue;}
        $filename = explode(".",$file);
        $cnt = count($filename); $cnt--; $ext = $filename[$cnt];
        if(strtolower($ext) == strtolower($extension)){
            array_push($list, $file);
        }
    }
    if($list[0]){
    return $list;
    } else {
    return false;
    }
}

if (!$tanselect) print "<div id='banner'><h1>ROP Health</h1></div>";
print "<div id='centercontent'><div align='center'>";

$file="exempt.txt";
// get exempt TANs to exclude from ASL
if (file_exists($file)) {
       $handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
       while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {

              $exempt[$data[0].",".$data[1].",".$data[2]]=1; //pf,tan,site combination

       }
       fclose($handle);
} else print "$file does not exist";

//if TAN exempt made, update exempt list
if ($tanexempt && $siteexempt){
       $exempt[$pfselect.",".$tanexempt.",".$siteexempt]=1;
       foreach ($exempt as $row=>$mark) $exemptlist[]=$row;
       $exemptlist=array_unique($exemptlist);
       sort($exemptlist);
       $write="";
       foreach ($exemptlist as $row){
              $write.=$row."\r\n";
       }
       $fp = @fopen($file, "w");
       fwrite($fp,$write);
       fclose($fp);
}
```

```
$file="ciscoasl.txt";
// get CISCO ASL
if (file_exists($file)) {
        $handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
        $data = fgetcsv($handle, 1000, ","); //first line is CISCO ASL
        $CISCOASL=$data[1];
        $totalsiterunrate=0; //for weighting
        while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                // get site ASLs
                $SITEASL[$data[0]]=$data[1];
                $SITERUNRATE[$data[0]]=$data[2];
                $totalsiterunrate+=$data[2];
        }
        fclose($handle);
} else print "$file does not exist";

$file="top25.txt";
// get PIDs and dates to track
if (file_exists($file)) {
        $totalpfrunrate=0; //for weighting
        $handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
        while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                $PF[]=$data[0];
                @$PFASL[$data[0]]=$data[1];
                @$PFRR[$data[0]]=$data[2]; //runrates for weighting
                $totalpfrunrate+=$data[2];
        }
        fclose($handle);
} else print "$file does not exist";

//delete dupes

$PF=array_unique($PF);
sort($PF);

if ($tanselect){

} else {
        print "<table summary='ASL PF' cellspacing='1'>";
        print "<tr><td class='ciscohead'>Overall</td><td class='ciscohead'>ASL</td><td
class='ciscohead'>Ref</td>";
        print "</tr>";
        print "<tr>";
        print "<td style='padding-top:3px;padding-bottom:3px;'><img src='cisco.png' height='40'
width='90'></td>";
        print "<td
bgcolor='".(@$CISCOASL>=90?"forestgreen":(@$CISCOASL>=80?"goldenrod":"firebrick"))."'><font
color=white size='+1'>".@$CISCOASL."%</font></td>";
        print "<td style='border-bottom: 0px;border-left: 0px;background-color: #F0F0F0;'><a
href='updatecisco.php' onclick='popup(this.href); return false'><img border=0 src='refresh.gif'
alt='Refreshes CISCO and Site ASL' title='Refreshes CISCO and Site ASL'></a></td>";
        print "</tr>";
        print "</table>";

        print "<table>";
        print "<tr><td style='border:0px' valign='top'>";
        print "<form action='' name='send' method='post'>";
        print "<input type='hidden' name='pf'>";
        print "<input type='hidden' name='tan'>"; // for exemption purposes
        print "<input type='hidden' name='site'>";
        print "<input type='hidden' name='refresh'>";

        //print PF Table
        print "<table summary='ASL PF' class='sortable' cellspacing='1'>";
        print "<tr><td class='ciscohead'>Product Family</td><td class='ciscohead'>ASL</td><td
class='ciscohead'>Weight</td><td class='ciscohead'>Ref</td>";
        print "</tr>";

        foreach ($PF as $p){
```

```
		print "<tr>
		<td".($p==$pfselect?" bgcolor=orange":"")."><a
href=\"javascript:profile('$p');\">$p</a></td>";
		if (@$PFASL[$p]==0) print "<td>No Data</td>"; // assuming all 0% ASL are a data
issue
		else print "<td
bgcolor='".(@$PFASL[$p]>=90?"forestgreen":(@$PFASL[$p]>=80?"goldenrod":"firebrick"))."'><font
color=white>".@$PFASL[$p]."%</font></td>";
		print "<td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'>".@sprintf("%01.1f",100*$PFRR[$p]/$totalpfrunrate)."%</td>";
		print "<td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'><a href=\"javascript:refresh('$p');\"><img border=0 src='refresh.gif' alt='Refreshes PF
ASL ONLY when NEW Demand and ROP data is loaded' title='Refreshes PF ASL ONLY when NEW Demand and
ROP data is loaded'></a></td>";
		print "</tr>";

	}
	print "</table></form>";
	print "</td><td style='border:0px' valign='top'>";

	//print site table
	print "<table summary='ASL Site' class='sortable' cellspacing='1'>";
	print "<tr><td class='ciscohead'>Site</td><td class='ciscohead'>ASL</td><td
class='ciscohead'>Weight</td></tr>";
	foreach ($SITEASL as $site=>$aslsite){
		print "<tr><td".($site==$siteviewselect?" bgcolor=orange":"")."><a
href=\"javascript:site('$site');\">$site</a></td>";
		print "<td
bgcolor='".(@$aslsite>=90?"forestgreen":(@$aslsite>=80?"goldenrod":"firebrick"))."'><font
color=white>".@$aslsite."%</font></td>";
		print "<td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'>".@sprintf("%01.1f",100*$SITERUNRATE[$site]/$totalsiterunrate)."%</td>";
		print "</tr>";
	}

	print "</td></tr></table>";
	print "</table>";
	print "<p><a href='update.php' onclick='popup(this.href); return false'>Refresh ALL PF
data</a></p>";
	print "<p><a href='bookings.php' onclick='popup(this.href); return false'>Spend
Chart</a></p>";
	print "<p><a href='TANASL.csv'>Download TAN ASLs</a></p>";

}

if (!$pfselect && !$tanselect && !$siteviewselect) { print ""; }

elseif($pfselect || $tanselect){
	$file="PID to TAN.csv";
	// get PIDs and dates to track
	if (file_exists($file)) {
		$handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
		$data = fgetcsv($handle, 1000, ",");
		$data = fgetcsv($handle, 1000, ",");
		while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
			$temp=explode("-",$data[1]);
			$tantemp="$temp[0]-$temp[1]";

			if (@!in_array($tantemp,$pftotan[$data[6]])) {
				$pftotan[$data[6]][]=$tantemp; //versionless
				$vTAN[$tantemp]=$data[1]; //version map
			}
		}
		fclose($handle);
	} else print "$file does not exist";

	//specific tan selection
	if (@$tanselect) {
		unset($TAN);
		$TAN[]=$tanselect;
	} else {
```

```
        $TAN=$pftotan[$pfselect];
        sort($TAN);
    }
    $txt = list_by_ext("txt", "./ROPCT2R");

    sort($txt);
    $txt=array_reverse($txt);


    //get first of THIS month, go back 1 year, and create array of all dates and months in
that year.

    $csv = list_by_ext("csv", "./TANBookings");
    sort($csv);
    $csv=array_reverse($csv);
    $month=str_replace(".csv","",$csv[0]);

    $firstofmonth=$month."-01"; //get the first of the month of the most recent file
    $enddate=date("Y-m-d",strtotime($firstofmonth . " +1 month")); //add one month to that to
find the last date of data
    $lastyear = date("Y-m-d",strtotime($enddate . " -1 year"));

    $tempdate=$lastyear;
    while ($tempdate < $enddate){
        $date=explode("-",$tempdate);
        if ($date[2]=="01") $months[]=$date[0]."-".$date[1];
        $dates[]=$tempdate;
        $tempdate=date("Y-m-d",strtotime($tempdate . " +1 day"));
    }

    $SITES=array();


    // if DDLT file already exists and Refresh button was NOT pushed, pull file to create
ddlt array
    $file="./PFDDLT/$pfselect.csv";

    if (file_exists($file) && !$refresh){ //pull current files if refresh button not pushed
        $handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
        $column = fgetcsv($handle, 1000, ","); //get header

        while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
            for ($i=3;$i<=8;$i++){
                @$ddlt[$data[0]][$data[1]][$data[2]][$column[$i]]=$data[$i];
            }
            if (!in_array($data[0],$SITES)) $SITES[]=$data[0];
        }

    }

    //else create the file, or overwrite current file, and update the PF ASL list
    else {

        //get TAN bookings and ROP/CT2R
        foreach ($months as $month){
            //GET TAN BOOKINGS
            //Get SITE as well
            $file="./TANBookings/$month.csv";

            if (file_exists($file)){
                $handle = @fopen($file, "r");

                while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                    @$temp=explode("-",$data[1]);
                    @$tantemp="$temp[0]-$temp[1]";
                    if (in_array($tantemp,$TAN))
                        $tbookings[$data[0]][$data[1]][$data[2]]=$data[3];
//store bookings by SITE, TAN, DATE
                        if (!in_array($data[0],$SITES)) $SITES[]=$data[0];
                }
```

```
                    } else print "$file does not exist<BR>";


                    //fill in 0s where blank data exists
                    foreach ($SITES as $site){
                            foreach ($TAN as $t){
                                    $valid=0; //valid bookings data count
                                    foreach ($dates as $d){
                                            if (@$tbookings[$site][$t][$d] > 0) $valid++;
                                            elseif ($valid>0) @$tbookings[$site][$t][$d]=0;
                                    }
                            }
                    }

                    //get ROP/CT2R
                    $file="./ROPCT2R/$month.txt";
                    if (file_exists($file)) {
                            $handle = @fopen($file, "r") or die("<b>Could not find file
:'(</b>");
                            //grab column headers for mapping
                            $data = fgetcsv($handle, 5000, ",");

                            $comp=""; //component column
                            $ct2r=""; //ct2r column
                            $rop=""; //rop column
                            $pf=""; //pf column, is 0 usually

                            foreach ($data as $k=>$d){
                                    if ($d == "PRODUCT_FAMILY") $pf=$k;
                                    elseif ($d == "ITEM") $comp=$k;
                                    elseif ($d == "CT2RQTY") $ct2r=$k;
                                    elseif ($d == "ROPQTY") $rop=$k;
                                    elseif ($d == "SISQTY") $sis=$k;
                                    elseif ($d == "MPA_SITE") $site=$k;
                                    elseif ($d == "UNITCOST") $cost=$k;
                            }

                            if ($comp && $ct2r && $rop && $sis && $site && $cost){
                                    //if component and CT2R and ROP columns exist then pull
data
                                    while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                                            if ($data[$pf]==$pfselect && $data[$rop]){
                                                    //versionless tan
                                                    @$temp=explode("-",$data[$comp]);
                                                    @$tantemp="$temp[0]-$temp[1]";


        @$ropct2r[$data[$site]][$tantemp][$month]['rop']+=sprintf("%01.0f",$data[$rop]);   //add
ROPs up by versionless TAN (since that is what we're comparing too)

        @$ropct2r[$data[$site]][$tantemp][$month]['sis']+=sprintf("%01.0f",$data[$sis]);   //add
up SIS of all versions

                                                    if
(@$data[$cost]>@$ropct2r[$data[$site]][$tantemp][$month]['cost'])

        $ropct2r[$data[$site]][$tantemp][$month]['cost']=sprintf("%01.2f",$data[$cost]);   //grab
the highest UNITCOST of all versions
                                                    if
(@$data[$ct2r]>@$ropct2r[$data[$site]][$tantemp][$month]['ct2r'])

        $ropct2r[$data[$site]][$tantemp][$month]['ct2r']=sprintf("%01.0f",$data[$ct2r]); //grab
the highest CT2R of all versions
                                            }
                                    }
                            } else {
                                    print (!$comp?"Component ":"").(!$ct2r?"CT2R
":"").(!$rop?"ROP ":"").(!$sis?"SIS ":"").(!$site?"MPA_SITE ":"").(!$cost?"UNITCOST ":"")."column
missing or doesn't match in $file<br>";

                            }
```

```
                        fclose($handle);
                        } else print "$file does not exist";

                }

                // calculate Demand over CT2R (DDLT)
                foreach ($tbookings as $site=>$tanarray){
                        foreach ($tanarray as $k=>$tan){

                                //last date of data minus ct2r
                                $lastdate="";
                                //last ct2r recorded
                                $lastct2r="";
                                foreach ($dates as $d){
                                        if (@$tbookings[$site][$k][$d]>0) $lastdate=$d;
                                        $m=substr($d,0,7); //get month

                                        if (@$ropct2r[$site][$k][$m]['ct2r']>0)
                                                $lastct2r=@$ropct2r[$site][$k][$m]['ct2r']; // get
ct2r of that month

                                }

                                if ($lastdate) $lastdate = date("Y-m-d",strtotime(date("Y-m-d",
strtotime($lastdate)) . " -$lastct2r day"));

                                foreach ($tan as $dat=>$book){

                                        $m=substr($dat,0,7);//get month

                                        $rop=@$ropct2r[$site][$k][$m]['rop']; //get rop of that
month
                                        $ct2r=@$ropct2r[$site][$k][$m]['ct2r']; // get ct2r of that
month
                                        $sis=@$ropct2r[$site][$k][$m]['sis']; // get sis of that
month
                                        $cost=@$ropct2r[$site][$k][$m]['cost']; // get unitcost of
that month
                                        $ct2rdate = date("Y-m-d",strtotime(date("Y-m-d",
strtotime($dat)) . " +$ct2r day")); // for comparison

                                        @$ddlt[$site][$k][$dat]['rop']=$rop;
                                        @$ddlt[$site][$k][$dat]['ct2r']=$ct2r;
                                        @$ddlt[$site][$k][$dat]['sis']=$sis;
                                        @$ddlt[$site][$k][$dat]['cost']=$cost;


                                        if ($dat<=$lastdate){
                                                foreach ($dates as $d){
                                                        //if the date is within the interval, sum
it, goes up to but not include ct2rdate
                                                        //cut off acquisition at the last date there
is data minus ct2r
                                                        if ($d>=$dat && $d<$ct2rdate){

        @$ddlt[$site][$k][$dat]['ddlt']+=$tbookings[$site][$k][$d];

                                                        }
                                                }

                                                //calculate ASL
                                                if (@$ddlt[$site][$k][$dat]['rop'] &&
@!$ddlt[$site][$k][$dat]['ddlt']) @$ddlt[$site][$k][$dat]['dsl']=100; //if no bookings, we
assuming SL is 100%
                                                else
@$ddlt[$site][$k][$dat]['dsl']=min(100,@sprintf("%01.1f",@$ddlt[$site][$k][$dat]['rop']/@$ddlt[$s
ite][$k][$dat]['ddlt']*100));

                                        }
                                }
```

```
                }

            }


            //write or overwrite the file for the PF
            $write="Site,TAN,Date,rop,ddlt,ct2r,sis,cost,dsl\n";
            foreach (@$ddlt as $site=>$tanarray){
                    foreach ($tanarray as $t=>$tan){
                            foreach ($tan as $d=>$info){
                                    $write.="$site,$t,$d,"
                                    .@$info['rop'].","
                                    .@$info['ddlt'].","
                                    .@$info['ct2r'].","
                                    .@$info['sis'].","
                                    .@$info['cost'].","
                                    .@$info['dsl']."\n";
                            }
                    }
            }
            //write file
            $fp = @fopen('./PFDDLT/'.$pfselect.'.csv','w');
            fwrite($fp,$write);
            fclose($fp);

    }
    //print_r($ddlt);
    sort($SITES);

    //if only one TAN selected
    if (@$tanselect) {

            if (@$siteselect) {
                    unset($SITES);
                    $SITES[]=$siteselect;
            }

            //create the XML for ROP and DDLT chart
            $xml = "<document>\n";
            foreach ($dates as $d){
                    $xml.="<row>\n";
                    $xml.="<date>$d</date>\n";
                    $xml.="<ddlt>".@$ddlt[$siteselect][$tanselect][$d]['ddlt']."</ddlt>\n";
                    $xml.="<rop>".@$ddlt[$siteselect][$tanselect][$d]['rop']."</rop>\n";
                    $xml.="<ropminussis>".@($ddlt[$siteselect][$tanselect][$d]['rop']-
$ddlt[$siteselect][$tanselect][$d]['sis'])."</ropminussis>\n";
                    $xml.="</row>\n";
            }
            $xml.="</document>";

            $fp = @fopen('chart.xml','w');
            if(!$fp) {
                    die('Error cannot create XML file');
            }
            fwrite($fp,$xml);
            fclose($fp);

            //calculate Month-to-date (MTD) and horizon-to-date (HTD) ASL
            foreach ($dates as $d){
                    //return the 1st of the next month for calculating ASL MTD and HTD
                    $m=date("m", strtotime($d)); //get month
                    if ($m != 12) {
                            $m++;
                            $y=date("Y", strtotime($d));
                    }
                    else {
                            $m=1;
                            $y=date("Y", strtotime($d))+1;
                    }
                    if ($m<10) $m="0".$m;
```

```
                        //for MTD go 30 days back from the 1st of each month
                        $firstofmonth=$y."-".$m."-01";
                        $firstofmonths[]=$firstofmonth;
                        if (!@$tempfirstofmonth) $tempfirstofmonth=$firstofmonth;
                        $thirtybackdate=date("Y-m-d",strtotime(date("Y-m-d",
strtotime($firstofmonth)) . " -30 day")); // for comparison

                        //calculations for MTD
                        if ($d >= $thirtybackdate && $d < $firstofmonth){
                                //new weighted ASL calc
                                if (@$ddlt[$siteselect][$tanselect][$d]['dsl'] == 100)
        @$MTD[$tanselect][$firstofmonth]['targetmet']++;
                                if (@$ddlt[$siteselect][$tanselect][$d]['rop'])
@$MTD[$tanselect][$firstofmonth]['count']++; //count valid data points
                                if (@$MTD[$tanselect][$firstofmonth]['count']>0)
@$MTD[$tanselect][$firstofmonth]['asl']=sprintf("%01.1f",100*@$MTD[$tanselect][$firstofmonth]['ta
rgetmet']/@$MTD[$tanselect][$firstofmonth]['count']);
                        }

                        //calculations for HTD
                        if ($tempfirstofmonth == $firstofmonth){
                                if (@$ddlt[$siteselect][$tanselect][$d]['dsl'] == 100)
        @$HTD[$tanselect][$firstofmonth]['targetmet']++;
                                @$HTD[$tanselect][$firstofmonth]['count']++; //count valid data
points
                                if (@$HTD[$tanselect][$firstofmonth]['count']>0)
@$HTD[$tanselect][$firstofmonth]['asl']=sprintf("%01.1f",100*@$HTD[$tanselect][$firstofmonth]['ta
rgetmet']/@$HTD[$tanselect][$firstofmonth]['count']);
                        } else {

                                if (@$ddlt[$siteselect][$tanselect][$d]['dsl'] == 100)
        @$HTD[$tanselect][$firstofmonth]['targetmet']=@$HTD[$tanselect][$tempfirstofmonth]['targe
tmet'];
                                else
@$HTD[$tanselect][$firstofmonth]['targetmet']=@$HTD[$tanselect][$tempfirstofmonth]['targetmet'];

        @$HTD[$tanselect][$firstofmonth]['count']=@$HTD[$tanselect][$tempfirstofmonth]['count'];
//count valid data points
                                if (@$HTD[$tanselect][$firstofmonth]['count']>0)
@$HTD[$tanselect][$firstofmonth]['asl']=sprintf("%01.1f",100*@$HTD[$tanselect][$firstofmonth]['ta
rgetmet']/@$HTD[$tanselect][$firstofmonth]['count']);
                        }
                        $tempfirstofmonth=$firstofmonth; //temp value for comparison

                }
                $firstofmonths=array_unique($firstofmonths);



                print "<h2>PF: $pfselect Site: $siteselect</h2>";
                //graph using the XML
                print "<table>";

                print "<tr>";
                print "<td style=\"border: 0;\" valign=top>";
                print "<h3>Daily DDLT vs ROP for $vTAN[$tanselect]</h3>";
                print "<div class='chartContent' id='chartcontainer'></div>";
                print "</td>";
                print "<script type=\"text/javascript\">
                var so = new SWFObject('zoompancolumnchart.swf', 'zoompanchart', '100%', '100%',
'9', '#869ca7');
                so.useExpressInstall('expressinstall.swf');
                so.addVariable('serverPath', 'HTTP://sj-pse-ue:8080/cues_charts');
                so.addVariable('chartId', 'zoompanchart');
                so.addParam('allowScriptAccess', 'always');
                so.addParam('wmode', 'transparent');
                so.addVariable('dataurl', 'chart.xml');
                so.addVariable('chartdefurl', 'chart_def.xml');
                so.write('chartcontainer');
                </script>";
```

```
                //create the XML for ASL chart while displaying Table
                $xml = "<document>\n";
                $i=1;
                foreach ($firstofmonths as $m){
                        //print "<tr
class='d".(($i++)%2)."'><td>$m</td><td>".@$MTD[$tanselect][$m]['asl']."</td><td>".@$MTD[$tanselec
t][$m]['count']."</td>
        <td>".@$HTD[$tanselect][$m]['asl']."</td><td>".@$HTD[$tanselect][$m]['count']."</td></tr>
";

                        //XML
                        $xml.="<row>\n";
                        $xml.="<date>$m</date>\n";
                        $xml.="<mtd>".@$MTD[$tanselect][$m]['asl']."</mtd>\n";
                        $xml.="<htd>".@$HTD[$tanselect][$m]['asl']."</htd>\n";
                        $xml.="</row>\n";
                }
                $xml.="</document>";

                $fp = @fopen('chart2.xml','w');
                if(!$fp) {
                        die('Error cannot create XML file');
                }
                fwrite($fp,$xml);
                fclose($fp);


                //display ASL Chart
                print "<td style=\"border: 0;\"><div align='center'><h3>Rolling ASL
Performance</h3>";
                print "<div class='chartContent' id='chartcontainer3'></div>";
                print "</td>";
                print "<script type=\"text/javascript\">
                var so = new SWFObject('linechart.swf', 'linechart', '100%', '100%', '9',
'#869ca7');
                so.useExpressInstall('expressinstall.swf');
                so.addVariable('serverPath', 'HTTP://sj-pse-ue:8080/cues_charts');
                so.addVariable('chartId', 'linechart');
                so.addParam('allowScriptAccess', 'always');
                so.addParam('wmode', 'transparent');
                so.addVariable('dataurl', 'chart2.xml');
                so.addVariable('chartdefurl', 'chart2_def.xml');
                so.write('chartcontainer3');
                </script>";

                print "</div></td>";

                print "</tr>";

                print "</table>";


        }



        //need to find last date with DDLT date to calculate the ASL (over 6 month)

        unset($lastdate);
        foreach (@$ddlt as $site=>$tanarray){
                foreach ($tanarray as $t=>$tan){
                $tempdate="0";
                        foreach ($tan as $date=>$info){
                                if (@$info['ddlt']>0 && $date>$tempdate) {
                                        $lastdate[$site][$t]=$date;
                                        $tempdate=$date;

                                }
```

```
                }
            }
        }

        //calculate 6 month horizon to date ASL value
        foreach (@$ddlt as $site=>$tanarray){
                foreach ($tanarray as $t=>$tan){
                        //foreach lastdate, calculate date for six months back for ASL weighting
                        @$sixmonthsback=date("Y-m-d",strtotime(date("Y-m-d",
strtotime($lastdate[$site][$t])) . " -180 days"));

                        //need to find the last value of DDLT, get the CT2R, and subtract that
from "today" for daily run rate averaging (over 6 month)
                        @$rrlastdate=date("Y-m-d",strtotime(date("Y-m-d", strtotime($enddate)) . "
-".$ddlt[$site][$t][$lastdate[$site][$t]]['ct2r']." day"));
                        @$rrsixmonthsback=date("Y-m-d",strtotime(date("Y-m-d",
strtotime($rrlastdate)) . " -180 days"));
                        foreach ($tan as $d=>$info){
                                if ($sixmonthsback <= $d && $d <= @$lastdate[$site][$t]){

                                        if (@$ddlt[$site][$t][$d]['dsl'] == 100)
@$HTD[$site][$t]['targetmet']++;
                                        if (strlen(@$ddlt[$site][$t][$d]['rop'])>0)
@$HTD[$site][$t]['count']++; //count valid data points

                                        if (@$HTD[$site][$t]['count']>0){

        @$HTD[$site][$t]['asl']=sprintf("%01.1f",100*@$HTD[$site][$t]['targetmet']/@$HTD[$site][$
t]['count']);

                                        }
                                }
                                if ($rrsixmonthsback <= $d && $d <= $rrlastdate){

        @$runratetotal[$site][$t]+=@$ddlt[$site][$t][$d]['ddlt']/$ddlt[$site][$t][$d]['ct2r']*$dd
lt[$site][$t][$d]['cost'];//changed to spend, so daily runrate * unitcost

        @$runrate[$site][$t]=sprintf("%01.0f",@$runratetotal[$site][$t]/180); //update sixmonth
runrate average
                                }

                        }
                }
        }

        if (!$tanselect){
                print "</div></div>";
                print "<div id='centercontent'><div align='center'>";
                //calculate PF level ASL
                $count=0;
                if (@$runrate){
                        foreach ($runrate as $site=>$tanarray){
                                foreach ($tanarray as $t=>$r){
                                        if ($r>0 && @!$exempt[$pfselect.",".$t.",".$site]){ //
runrate greater than 0 and not in exempt list
                                                @$productsum+=$r*$HTD[$site][$t]['asl'];
                                                @$runratesum+=$r;

                                        }
                                }
                        }
                }
                @$asl=sprintf("%01.0f",$productsum/$runratesum);
                print "<h3>$pfselect ASL: <font
color='".(@$asl>=90?"forestgreen":(@$asl>=80?"goldenrod":"firebrick"))."'>".$asl."%</font></h3>";

                //if refresh button pushed, update the PF file
                if ($refresh){
                        $write="";
                        foreach ($PF as $p){
                                if ($p==$pfselect) $write.="$p,".$asl.",$runratesum\r\n";
```

```
                        else $write.="$p,".$PFASL[$p].",".$PFRR[$p]."\r\n";
                }

                $fp = @fopen('top25.txt','w');
                if(!$fp) {
                        die('Error cannot create PF file');
                }
                fwrite($fp,$write);
                fclose($fp);

                print "PF ASL updated. Refresh page or re-run PF to update top
table.<br>";


        }
        //if TAN is exempt display notice
        if ($tanexempt && $siteexempt){
                print "<b>Notice:</b> $tanexempt @ $siteexempt has been exempt from
$pfselect ASL calculation.<br>";
                print "PF Refresh button <img border=0 src='refresh.gif'> will need to be
pushed to update ASL table.";
        }

}

if ($tanselect){
        $t=$tanselect;
        $site=$siteselect;
        //print "<div style='border:1px  solid; width:95%;
height:".($tanselect?"25":"75")."%; overflow:auto;'>

        print "<table><tr><td style='border:0px;padding:0px;' valign='top'>";
        print "<table summary='ROP Health' style='float: left; width: 90px; margin-left:
20px;' class='sofT' cellspacing='1'>";
        print "<tr><td class='ciscohead'>TAN</td><td class='ciscohead'>Metric</td>";

        print "</tr>";
        print "<tr><td
bgcolor='".(@$HTD[$site][$t]['asl']>=90?"forestgreen":(@$HTD[$site][$t]['asl']>=80?"goldenrod":"f
irebrick"))."' rowspan=7 nowrap><div align=center>
        <a href='/rop/?pfselect=$pfselect&siteselect=$site&tanselect=$vTAN[$t]'
target='_blank'>$vTAN[$t]</a><br><br>
        <font color=white>ASL:".@$HTD[$site][$t]['asl']."%</font><br>
        <font color=white>&#916;:".@sprintf("%01.1f",97-
$HTD[$site][$t]['asl'])."%</font><br>
        <font color=white>$site</font>
        </div></td>";
        print "</tr>";
        print "<tr class='d".(($i++)%2)."'><td>ROP</td></tr>";
        print "<tr class='d".(($i++)%2)."'><td>DDLT</td></tr>";
        print "<tr class='d".(($i++)%2)."'><td>CT2R</td></tr>";
        print "<tr class='d".(($i++)%2)."'><td>SIS</td></tr>";
        print "<tr class='d".(($i++)%2)."'><td>UCost</td></tr>";
        print "<tr class='d".(($i++)%2)."'><td>DSL</td></tr>";
        print "</table>";

        print "</td><td style='border:0px;padding:0px;' valign='top'>";

        $i=1;
        print "<div style='overflow-x: auto; width: 800px;float:left;padding-bottom:
10px;'>";

        print "<table summary='ROP Health' style='float: left;' width='100%' class='sofT'
cellspacing='1'>";
        foreach ($dates as $d) print "<td class='ciscohead'>".date("m/d",
strtotime($d))."</td>";
        foreach ($SITES as $site){
                foreach ($TAN as $t){
                        if (@$ddlt[$site][$t]) {
```

```
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".@$ddlt[$site][$t][$d]['rop']."</td>";
					print "</tr>";
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".@$ddlt[$site][$t][$d]['ddlt']."</td>";
					print "</tr>";
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".@$ddlt[$site][$t][$d]['ct2r']."</td>";
					print "</tr>";
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".@$ddlt[$site][$t][$d]['sis']."</td>";
					print "</tr>";
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".@$ddlt[$site][$t][$d]['cost']."</td>";
					print "</tr>";
					print "<tr class='d".(($i++)%2)."'>";
					foreach (@$dates as $d) print
"<td>".(@$ddlt[$site][$t][$d]['dsl']>0?$ddlt[$site][$t][$d]['dsl']."%":"")."</td>";
					print "</tr>";
				}

			}
		}
		print "</table></div></td></tr></table>";
		print "<p>If graphs are not refreshing, go to Internet Options -> Settings ->
Check for newer versions of stored pages: 'Every visit to the page'</p>";


	} else {

		print "<table summary='ROP Health' class='sortable' cellspacing='1'>";
		print "<tr><td class='ciscohead'>TAN</td><td class='ciscohead'>Site</td><td
class='ciscohead'>ASL</td><td class='ciscohead' alt='avg. daily runrate * unitcost (over 2
quarters)' title='avg. daily runrate * unitcost (over 2 quarters)'>Spend</td><td
class='ciscohead'>Weight</td><td style='border:0px;'></td>";

		print "</tr>";

		foreach ($SITES as $site){
			if ($site != "GLO"){
				foreach ($TAN as $t){
					if (@$ddlt[$site][$t]) {
						print "<tr>
						<td style='border-bottom: 0px;border-left:
0px;background-color: #F0F0F0;'><a href=\"javascript:void(0);\" onclick=\"return overlib('<iframe
src=./index.php?pfselect=$pfselect&siteselect=$site&tanselect=$vTAN[$t] height=600
width=100%></iframe>',STICKY,CAPTION, '$vTAN[$t] @ $site',FGCOLOR, 'darkblue', BGCOLOR,
'darkblue', BORDER, 4, WIDTH, 1200, HEIGHT, 400,RELX,50,RELY,10);\">$vTAN[$t]</a></td>

						<td style='border-bottom: 0px;border-left:
0px;background-color: #F0F0F0;'>$site</td>";
						if (strlen(@$HTD[$site][$t]['asl'])==0) print "<td
style='border-bottom: 0px;border-left: 0px;background-color: #FFFFFF;'>No Data</td><td
style='border-bottom: 0px;border-left: 0px;background-color: #FFFFFF;'></td><td style='border-
bottom: 0px;border-left: 0px;background-color: #FFFFFF;'></td><td style='border:0px;'></td>";
						else{
							print "<td
bgcolor='".(@$HTD[$site][$t]['asl']>=90?"forestgreen":(@$HTD[$site][$t]['asl']>=80?"goldenrod":"f
irebrick"))."'><font color=white>".@$HTD[$site][$t]['asl']."%</font></td>";
							print "<td style='border-bottom: 0px;border-
left: 0px;background-color: #F0F0F0;'>".@$runrate[$site][$t]."</td>";
							print "<td style='border-bottom: 0px;border-
left: 0px;background-color:
#F0F0F0;'>".@sprintf("%01.1f",$runrate[$site][$t]/$runratesum*100)."%</td>";
```

```
                                                        if (@$exempt[$pfselect.",".$t.",".$site])
print "<td style='border:0px;'><img border=0 src='exempt.gif' alt='TAN exempt from PF ASL'
title='TAN exempt from PF ASL'></td>";
                                                        else print "<td style='border:0px;'><a
href=\"javascript:exempt('$pfselect','$t','$site');\">
                                                        <img border=0 src='exempt.gif' alt='Exempt
this TAN from PF ASL' title='Exempt this TAN from PF ASL'
                                                        style='opacity:0.3;filter:alpha(opacity=30)'

        onmouseover='this.style.opacity=1;this.filters.alpha.opacity=100'

        onmouseout='this.style.opacity=0.3;this.filters.alpha.opacity=30'></a></td>";

                                                }
                                                print "</tr>";

                                        }

                                }
                        }
                }
                print "</table>";
                print "<p><a href='exempt.php' onclick='popup(this.href); return false'>Manage ASL
Exemptions</a></p>";
                print "<p><a href='./PFDDLT/$pfselect.csv'>Download Data for $pfselect</a></p>";
                //timer end
                $time = microtime();
                $time = explode(' ', $time);
                $time = $time[1] + $time[0];
                $finish = $time;
                $total_time = round(($finish - $start), 4);
                echo '<p>Page generated in '.$total_time.' seconds.'."</p>";
        }




}
///////////////////////////////////////////////////SITE VIEW
elseif ($siteviewselect) {
        print "</div></div>";
        print "<div id='centercontent'><div align='center'>";

        $file="PID to TAN.csv";
        // get PIDs and dates to track
        if (file_exists($file)) {
                $handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");
                $data = fgetcsv($handle, 1000, ",");
                $data = fgetcsv($handle, 1000, ",");
                while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                        $temp=explode("-",$data[1]);
                        $tantemp="$temp[0]-$temp[1]";

                        if (@!in_array($tantemp,$pftotan[$data[6]])) {
                                $pftotan[$data[6]][]=$tantemp; //versionless
                                $vTAN[$tantemp]=$data[1]; //version map
                        }
                }
                fclose($handle);
        } else print "$file does not exist";

        $runratesum=0;
        //straight data dump
        $file="TANASL.csv";
        if (file_exists($file)){
                $handle = @fopen($file, "r");
                $data = fgetcsv($handle, 1000, ","); //skip header
                //PF,TAN,SITE,ASL,SPEND
                while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
                        if ($data[2]==$siteviewselect){
                                $HTD[$data[0]][$data[1]]['asl']=$data[3];
```

```
                        $HTD[$data[0]][$data[1]]['spend']=$data[4];
                        $runratesum+=$data[4];
                    }
                }

        } else print "$file does not exist<BR>";

        $site=$siteviewselect;
        print "<h3>$siteviewselect</h3>";
        print "<table summary='ROP Health' class='sortable' cellspacing='1'>";
        print "<tr><td class='ciscohead'>TAN</td><td class='ciscohead'>PF</td><td
class='ciscohead'>ASL</td><td class='ciscohead'>Spend</td><td class='ciscohead'>Weight</td><td
style='border: 0px;'></td>";
        print "</tr>";
        foreach ($HTD as $pfselect=>$pfarray){
                foreach ($pfarray as $t=>$info){
                        print "<tr>
                        <td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'><a href=\"javascript:void(0);\" onclick=\"return overlib('<iframe
src=./index.php?pfselect=$pfselect&siteselect=$site&tanselect=$vTAN[$t] height=600
width=100%></iframe>',STICKY,CAPTION, '$vTAN[$t] @ $site',FGCOLOR, 'darkblue', BGCOLOR,
'darkblue', BORDER, 4, WIDTH, 1100, HEIGHT, 400,RELX,50,RELY,10);\">$vTAN[$t]</a></td>
                        <td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'>$pfselect</td>";
                        print "<td
bgcolor='".(@$info['asl']>=90?"forestgreen":(@$info['asl']>=80?"goldenrod":"firebrick"))."'><font
color=white>".@$info['asl']."%</font></td>";
                        print "<td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'>".@$info['spend']."</td>";
                        print "<td style='border-bottom: 0px;border-left: 0px;background-color:
#F0F0F0;'>".@sprintf("%01.1f",@$info['spend']/$runratesum*100)."%</td>";

                        if (@$exempt[$pfselect.",".$t.",".$site]) print "<td
style='border:0px;'><img border=0 src='exempt.gif' alt='TAN exempt from PF ASL' title='TAN exempt
from PF ASL'></td>";
                        else print "<td style='border:0px;'><a
href=\"javascript:exempt('$pfselect','$t','$site');\">
                        <img border=0 src='exempt.gif' alt='Exempt this TAN from PF ASL'
title='Exempt this TAN from PF ASL'
                        style='opacity:0.3;filter:alpha(opacity=30)'
                        onmouseover='this.style.opacity=1;this.filters.alpha.opacity=100'

        onmouseout='this.style.opacity=0.3;this.filters.alpha.opacity=30'></a></td>";
                }
        }
        print "</table>";
        //timer end
        $time = microtime();
        $time = explode(' ', $time);
        $time = $time[1] + $time[0];
        $finish = $time;
        $total_time = round(($finish - $start), 4);
        echo '<p>Page generated in '.$total_time.' seconds.'."</p>";
}


?>

</div>
</div>
</body>
</html>
```

Appendix B: DDLT calculation logic code

```
<?php
ini_set("memory_limit","20000M");
set_time_limit(180000);

$time = microtime();
$time = explode(' ', $time);
$time = $time[1] + $time[0];
$start = $time;

//What this script does: Calculates all DDLT across all DF level TANs for a certain month,
aggregates information with ROP and CT2R values
//Author: dongchin@cisco.com
//Copyright 2011 MIT Leaders for Global Operations & Cisco Systems, Inc.

//Get month from URL in YYYY-MM format
//$monthselect=$_GET{'month'};
if (@$_GET{'m'}) $monthselect=$_GET{'m'};
else $monthselect="";


// Get LTs by PF
$file="PF LT Goals.csv";
if (file_exists($file)) {
	$handle = @fopen($file, "r") or die("<b>Could not find file :'(</b>");

	while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
		$LT[$data[2]]=sprintf("%01.0f",$data[3]);
	}
	fclose($handle);
} else print "$file does not exist";


//determine PIDs and TANs to track
$file="PID to TAN.csv";
if (file_exists($file)) {
	$handle = @fopen($file, "r") or die("<b>Could not $file :'(</b>");
	$data = fgetcsv($handle, 1000, ",");
	$data = fgetcsv($handle, 1000, ",");
	while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
		$temp=explode("-",$data[1]);
		@$tantemp="$temp[0]-$temp[1]";
		$TAN[]=$tantemp; // versionless
		$vTAN[$tantemp]=$data[1]; //versioned
		//$PF[$tantemp]=$data[6]; //Product Family
		//$BU[$tantemp]=$data[7]; //Business Unit
		$tantopid[$tantemp][]=$data[0]; // creates PID array for each TAN
		$PID[]=$data[0]; //store PIDs to track

	}
	fclose($handle);
} else print "$file does not exist";

$TAN=array_unique($TAN);
sort($TAN);
$PID=array_unique($PID);

if ($monthselect){
	// if TAN file already exists and there is no overwrite flag, return file exists message
	$file="./TANBookings/$monthselect.csv";

	if (file_exists($file)){
		echo "TAN Bookings file for $monthselect already exists! If you would like to
overwrite, please delete the current file, then rerun script. <br>";

	}

	//else create the file, or overwrite current file
	else {
```

```
		// Offset Book date by Lead Time Goals to Calculate Ship Dates
		// Aggregate Demand for each Ship Date by PID
		// Start with previous month in order to get ship dates for current month
		// Place 4 week LT cap for NOW so we only have to go back 1 month

		// Column order in files: "Business Unit","Product Family","PID","Cisco Book
Date","Sales Order Number","Ship Set No","Request Date","Organization Code","Daily - Total Booked
Quantity"
		$lastmonth=date("Y-m",strtotime(date("Y-m-d", strtotime($monthselect."-01")) . " -
1 day"));
		$demandpull=array();
		$demandpull[]=$lastmonth;
		$demandpull[]=$monthselect;
		$missingLT=array(); // array to track Missing LTs for PFs
		foreach ($demandpull as $file){
			$fileopen="./Demand/".$file.".csv";
			if (file_exists($fileopen)) {
				print $fileopen." processing...<br>\n";
				$handle = @fopen($fileopen, "r") or die("<b>Could not find
$fileopen :'(</b>");
				$data = fgetcsv($handle, 1000, ",");
				while (($data = fgetcsv($handle, 1000, ",")) !== FALSE) {
					if (in_array($data[2],$PID) && $data[7] != "GLO"){
						// add LT Goal to the Cisco Book Date based on PF
						$pf=str_replace(" ","",$data[1]);// remove spaces
from the PF string

						//if LT goals are missing offset by 3 weeks
						if (@$LT[$pf]){
							$date = date("Y-m-d",strtotime(date("Y-m-d",
strtotime($data[3])) . " +".$LT[$pf]." day"));
						} else {
							if (!in_array($pf,$missingLT))
$missingLT[]=$pf;
							$date = date("Y-m-d",strtotime(date("Y-m-d",
strtotime($data[3])) . " +21 day"));
						}

						//round negatives to 0
						if ($data[8]<0) $data[8]=0;

						//store aggregated bookings by PID (2), DATE, and
SITE (7)

						if (@$pbookings[$data[2]][$date][$data[7]])

	$pbookings[$data[2]][$date][$data[7]]+=$data[8];
						else

	$pbookings[$data[2]][$date][$data[7]]=$data[8];

					}
				}
				fclose($handle);
			} else print "$fileopen does not exist. You will need to upload last
month's demand bookings as well to calculate this month due to PF lead time offsets.<br/>\n";

			//map to TAN bookings
			unset($tbookings);

			foreach ($tantopid as $k=>$tan){

				foreach ($tan as $p){
					$c=0;
					$startdate=$file."-01";
					while ($c<date('t',strtotime($startdate))) {
						$date=date("Y-m-d",strtotime(date("Y-m-d",
strtotime($startdate)) . " +$c day"));
						if (@$pbookings[$p][$date]){
```

```
                                            foreach ($pbookings[$p][$date] as
$site=>$book){
                                                 @$tbookings[$site][$k][$date]+=$book;
//store TAN bookings by SITE,TAN,DATE
                                            }
                                    }

                                    $c++;
                            }
                    }
            }

            if ($file==$monthselect){ //if you are on the month you want to write then
write a file
                    //write to file
                    $write="";

                    foreach ($tbookings as $sitekey=>$site){
                            foreach ($site as $tankey=>$tan) {
                                    foreach ($tan as $date=>$book) {
                                            $write.="$sitekey,$tankey,$date,$book\n";
                                    }
                            }
                    }

                    //write file
                    $fp = @fopen('./TANBookings/'.$file.'.csv','w');
                    fwrite($fp,$write);
                    fclose($fp);
            }
        }

        print "Missing LTs for the following PFs: ".join(",",$missingLT);


    }
} else print "No month specified. Attach ?m=(the month in YYYY-MM format) after URL (e.g.
rop.php?m=2010-10)<br>";

$time = microtime();
$time = explode(' ', $time);
$time = $time[1] + $time[0];
$finish = $time;
$total_time = round(($finish - $start), 4);
echo 'Page generated in '.$total_time.' seconds.'."\n";

?>
```