Managing Growth of a Non-Profit Healthcare Supply Chain in Haiti

by

Christine L. Heberley

B.S. Naval Architecture and Marine Engineering
Webb Institute, 2002

and

Matthew F. Hoover

M.P.P. International Security and Public Policy
University of Maryland, 2007

B.S. Economics
Duke University, 2002

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Signature of Authors...
Master of Engineering in Logistics Program, Engineering Systems Division
May 7, 2010

Certified by..
Dr. Jarrod Goentzel
Executive Director, Masters of Engineering in Logistics Program
Thesis Supervisor

Accepted by..
Prof. Yossi Sheffi
Professor, Engineering Systems Division
Professor, Civil and Environmental Engineering Department
Director, Center for Transportation and Logistics
Director, Engineering Systems Division

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Abstract

Partners in Health's (PIH) supply chain in Haiti has become strained over the past five years due to the organization's rapid growth. Under the current system, the majority of PIH's products are obtained through an annually placed order. All goods from this order are stored at the central warehouse in Cange, which acts as a hub, until those goods are needed at individual clinics. As annual orders increase in size to support PIH's expanding operations, the limited size of the central warehouse has become a constraint, making a change in current inventory policies necessary. In order to formulate revised inventory policies for PIH's Haiti operations, we developed a spreadsheet model that uses historical consumption data of drugs and medical supplies to forecast demand over the next three years. This demand data is then be used as input to run and compare the existing annual order policy with ordering policies with more frequent reviews. These inventory policies are then evaluated against the central warehouse size constraints to recommend an inventory policy better suited to meet PIH's needs. We find that more frequent orders drastically reduces warehouse space requirements while maintaining high service levels. It is hoped that PIH can continue to use this model to determine future inventory policy needs.

Thesis Supervisor: Jarrod Goentzel
Title: Executive Director, Masters of Engineering in Logistics Program

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1 Introduction

Partners in Health (PIH) is a global non-profit health care provider. PIH's work began in the impoverished Central Plateau of Haiti with its Zanmi Lasante ("Partners in Health" in Haitian Kreyol) project. What started as a small medical clinic in Cange in 1985 is now a large healthcare complex. The size of PIH's network has since increased to nine additional sites throughout Haiti, with Port Au Prince functioning as a cross dock for PIH goods coming into the country (Figure 1). Care is provided free of charge and all patients are accepted. At least two additional sites, one in Mirebalais and one in Verrettes are planned for the near future.

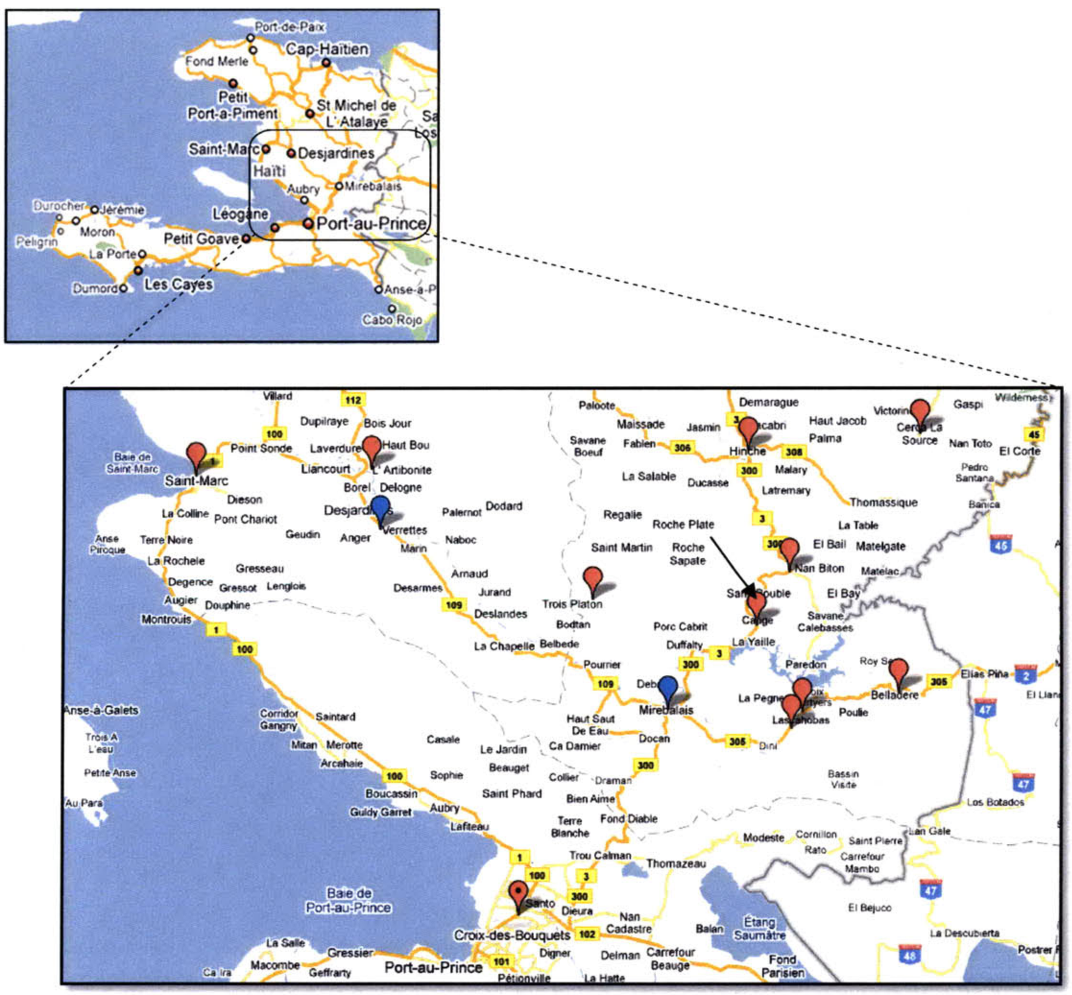


Figure 1: PIH Haiti Existing and Proposed Sites
Source: PIH Haiti ZL Site Map, Google Maps

In the past five years, the number of PIH's clinics in Haiti has nearly doubled, and the number of annual patient encounters has nearly tripled to 2.6 million. PIH's supply chain and inventory strategies, however, have not been altered to accommodate this significant growth. As a result, the supply chain has become strained. Under its current inventory policy, the majority of PIH's products are obtained through an annually placed order. The shipment from this order is received sporadically over the next several months, with the final shipment sometimes not arriving for eight months. Because the products are shipped from the main supplier, International Dispensary Association Foundation (IDA), as they become available, sometimes several containers of product will arrive at once. In one instance, seven containers arrived simultaneously.

All products are stored at a central warehouse located in Cange prior to their distribution to other sites. There have been several incidents recently in which the volume of products coming into the central warehouse has exceeded the storage space there. When the volume of goods arriving at the central warehouse exceeds the storage capacity, the goods must be placed at any sites with available space, making it difficult to accurately track and distribute these goods to the sites where they are needed.

Research conducted in 2009 by a Harvard Business School student provided an analysis of PIH's supply chain through review of stockout rates, consumption data, turnover data and volume calculations. The research concluded that the central warehouse was not sufficiently sized to handle the volume of goods managed by PIH. While the study suggested several options for larger or additional central warehouses, it did not provide a modified inventory policy.

The objective of our thesis is to improve the existing supply chain by developing new inventory policies to support the projected growth of PIH while reducing warehouse volume requirements and emergency procurement costs. Additionally, in January 2010, a 7.0 Mw earthquake just outside of Port Au Prince, Haiti's capital and largest city, devastated the region. While PIH's sites were not damaged in the earthquake, these sites will be subject to much change in the future. As a result of the earthquake, there is expected to be significant internal migration to the Central Plateau and beyond. Therefore, PIH will need to adjust our demand forecast numbers accordingly once it has a good estimate of the population increase in its catchments areas.

In the seven sections below, we will discuss our approach to improving PIH's supply chain. In section 2, Literature Review, we survey publications that address for-profit and non-profit healthcare operations, especially those covering inventory and supply chain challenges. In section 3, Background-Haiti and PIH Operations, we provide background on Haiti and PIH's role in providing health services in the country. Section 4, Methods, explains the forecasting and inventory theories used for our data analysis. In section 5, Data Analysis, the data cleaning is discussed, and a user guide for the spreadsheet model we developed for forecasting and inventory analysis is provided. This section also provides an overview of available warehouse space. In section 6, Results, the findings of our inventory policy review are summarized. In section 7, Additional Factors, further issues that may affect the inventory policy are discussed. Finally, in section 8, Recommendations, some additional ideas for ways PIH can improve its existing supply chain are provided.

2 Literature Review

Our review of the literature included peer-reviewed publications and field guides developed by public health practitioners. These documents survey current academic research and summarize practices that do or do not work in developing countries. Although there is no "one size fits all" answer for health care supply chains in developing countries, our review provides a context for our analytical techniques.

The application of management science (MS) and operations research (OR) to health care and pharmaceutical practices is becoming widespread. The literature provides the theory behind MS and OR techniques and details successful applications of theory-based practices in health care environments. Carter, Golden and Wasil (2009) surveyed eight successful MS and OR applications in various sectors of the health care industry. Only one was specific to pharmaceuticals, however.

HIV treatment in developing countries is a major objective of some NGOs. PIH has performed much HIV work in Haiti already. One of its early successful interventions in Haiti was HIV treatment in the Central Plateau. Koenig, Leandre and Farmer (2004) discuss the successful scale-up of this HIV treatment program. While this paper is a useful reference, much of the scale-up's success was due to the hiring of accompagnateurs. Accompagnateurs are hired to work within their home community, and ensure those receiving medical care in their community are taking their medications per specification and attending scheduled clinic visits. The article did not clearly address the effect the scale-up had on the pharmaceutical supply chain.

World Health Organization (2004) provides a framework for procurement, storage and inventory management of drugs in their "Management of Drugs at Health Centre Level" training manual. Regarding procurement, the concepts of lead time (L), monthly consumption, reorder points (s) and order-up-to levels (S) are described. Regarding storage, the attributes of the storeroom environment, arrangement of drugs on the shelf, use of a first in first out (FIFO) system is discussed. A FIFO system ensures the drugs that were received first should be used first; as long as more recently received drugs do not have shorter expiration dates. Regarding stock management, how to track inventory by the use of manual stock cards is discussed. PIH's current stock monitoring system (a computerized database with internet linkages), is far more advanced. Therefore, the models explained in the WHO manual are not likely to be pursued.

The role of supply chains in the proper functioning of healthcare system are focused on in papers by Hicks, Purcell, Raja and Heinen (2009) and Hicks, Raja and Heinen (2009). Levine, Pickett, Sekhri and Yadav (2008) also address supply chains in healthcare systems, but narrow their focus to the role of forecasting.

Hicks, Purcell, Raja and Heinen (2009) discuss a scenario in which although significant financing for drugs and supplies and supply chain operations was available, overstocks and stockouts were common. The World Bank and Llamasoft were called upon to analyze the issues in the supply chain. It was fortunate that several years of transaction data was available for analysis of the 3285 products offered. The system was comprised of a hybrid single echelon and a two tiered echelon system. This system was evaluated for efficiency using the supply chain modeling tool Llamasoft. A potential decentralized system and a potential centralized system were also evaluated. The analysis also studied the 20 most demanded products, the fill rates for those items, and their largest customers by volume. Overall, fill rate was about 75%. Llamasoft helped determine that the biggest problems in the system were long lead times and high variability in these lead times from the supplier. Further investigation revealed that the high variability in lead times, if improved, would be the greatest source of savings and improvement in supply chain quality. Llamasoft also helped to determine that a centralized system in which all goods were shipped from the central storage to the facility, rather than some sites being served by regional storage facilities, would lower overall costs by about 5%. Other portions of the study identified poor ordering habits at the hospital level. Rather than using monthly orders to obtain the majority of their supplies, daily rush orders were the norm. Habits like this are to some extent fed by the existing supply chain problem, but also the reason these problems in the supply chain continue. This paper's investigation of over/understock issues, direct vs. regional distribution, and poor ordering habits at the clinic level parallel several investigations we will be performing in our own thesis. Our investigation focuses on a smaller product volume, but involves forecasting future demand and warehouse efficiency.

Hicks, Raja and Heinen (2009) investigated the poor fill rate (21%) within KEMSA (Kenta Medical Supplies Agency) system. In the system, 1173 products were sourced from three central warehouses in Nairobi and eight smaller regional depots (though these were mostly used to hold slower moving items). KEMSA used a push system, in which products were shipped six times a year to hospitals and four times a year to health centers. In KEMSA's view, its current warehouse system was at capacity. The focus of the analysis was to determine whether the system should be decentralized, and whether the push system was the most effective for the system's needs. The decentralization study looked at six scenarios, including the existing scenario (one centralized DC), converting all existing regional depots to DCs, and conducting a "Greenfield" analysis to determine the optimum location of a single warehouse. Analysis revealed that while adding regional warehouses would reduce transportation costs significantly, the savings would be partially offset by higher inventory costs. It was determined that the addition of one regional DC would be a good balance. An analysis was then run eight times at potential locations to determine the ideal location for this DC. While the other goal of the analysis had been to compare use of a pull system vice a push system, it was determined that the shortage issue was so severe that it should be investigated instead. The analysis confirmed that warehouse space was an issue, as increasing the fulfillment rate from 21% to 100% would require warehouse space to increase to two to three times. As for improving service rate, demand variability was a major culprit, and a significant increase in inventory would be needed to overcome this variability and achieve a 100% service rate. Overall, the study determined that inadequate financing was the root of the problem, and that additional funds were essential to make the supply chain more efficient. The fact that forecasted demand was not accounted for makes the 21% fulfillment rate even more alarming, if not action is taken. This paper reflects many of the concepts we analyze in our thesis, especially its investigation of adequate warehouse space.

Levine, Pickett, Sekhri and Yadav (2008) discuss the importance of reliable demand forecasts for global health programs. Viewing a reliable forecast as critical in the success of a supply chain, the paper elaborates on the effect a poor forecast can have on the entire supply chain. One example given was a pharmaceutical company overproducing a drug based on an inaccurate forecast from a global health program.

While this paper was relevant to our research as it addresses the importance of forecasting, it focuses more on the effects of forecasting further upstream the supply chain than our thesis does. Many examples are cited where the supplier is greatly affected. In our thesis forecasting is important further downstream, to PIH itself. An accurate forecast will allow PIH to better determine demand, and therefore select the most appropriate inventory policy based on that demand.

Morreale and Prichard (1995) provide rules of thumb for logistics topics ranging from transportation to inventory to warehousing. The inventory subjects addressed included inventory levels, service levels, and carrying costs. The guidance provided on warehousing was of particular interest to us. Information included such topics as storage capacity, rack layout, aisle arrangement, available space and cube utilization. The concepts behind available space and cube utilization will be important in our evaluation of the central warehouse.

While the running, improvement, and scale-up of healthcare systems are common subjects in peer-reviewed publications and field guides, most of them do not focus on supply chain improvement. Even fewer address the importance of forecasting within the context of supply chain improvement. In our thesis, we use forecasting to develop more appropriate inventory policies for PIH while remaining cognizant of the constraints of warehouse size.

3 Background- Haiti and PIH Operations

PIH has been active in Haiti for over twenty years. This section provides a basic background on Haiti and on PIH's efforts there. Current and proposed PIH sites are discussed, as are PIH's existing system for distributing goods throughout that system. Finally, sources of PIH's goods are discussed.

3.1 Haiti

Haiti occupies the western portion of the Caribbean island of Hispaniola. Haiti has long suffered from political violence and poverty, and is considered the poorest country in the Americas. The current population is approximately 9 million. The largest city, and capital, is Port Au Prince. Haiti is divided into ten departments, including the Artibonite and Centre departments that PIH serves (Figure 2). Haitian Creole and French are the official languages. PIH operates eight sites in the Central Plateau and two sites in the Artibonite region of Haiti.

Figure 2: The Ten Departments of Haiti
<http://upload.wikimedia.org/wikipedia/commons/d/de/Haiti_departments_named.png>

3.2 PIH Sites

PIH operates eight sites throughout the Central Plateau of Haiti: Belladere, Boucan Carre, Cange, Cerca La Source, Hinche, La Colline, Lascahobas and Thomonde. PIH also operates two sites in the Artibonite region: Petite Riviere and Saint Marc. Facilities vary at each site, as described below in Table 1.

Table 1: PIH Haiti Sites, By Region

Central Plateau Sites

Site Name	Medical Facility Type	Storage Facility Type	Comments
Belladere	clinic	storage space	
Boucan Carre	clinic (small)	storage space	difficult to reach due to poor road conditions
Cange	Sociomedical Complex	warehouse	
Cerca La Source	hospital	warehouse	remote site
Hinche	hospital	warehouse (large)	
La Colline	hospital (new, full service	storage space	also acts as main storage for Lascahobas
Lascahobas	women's health facility	storage space	ten minutes from La Colline
Thomonde	clinic (small)	storage space (limited)	

Artibonite Sites

Site Name	Medical Facility Type	Storage Facility Type
Petite Riviere	clinic (small)	storage space (limited)
Saint Marc	hospital (large)	warehouse (large)

Future sites will likely be established in Mirebalais (Central Plateau) and Verrettes (Artibonite) to address the need for health care services in these areas. In addition, a large warehouse may also be located in Mirebalais.

All PIH products are shipped into Port Au Prince, which is located in the Quest department (Figure 3). Prior to the earthquake, PIH operated one small facility in Port Au Prince. This facility acted as a cross dock for goods received. Goods were not stored at this facility, but instead were moved to the warehouse located in Cange.

PIH currently only ships goods into Port Au Prince because of the excellent relationship they maintain with customs at that port. While the use of additional ports has been discussed, it is uncertain whether the organization would be able to develop good relationships in customs at new ports. Post-earthquake, PIH is renting a large facility in Port Au Prince. It has yet to be determined if such a facility will become permanent.

Figure 3: Port Au Prince
<http://en.wikipedia.org/wiki/File:Haiti_map.png>

PIH's main site in Haiti is located in Cange. Named the Sociomedical Complex, it is compromised of a full-service hospital (104 beds), an infectious disease center, an outpatient clinic, a women's health clinic, a laboratory, a Red Cross blood bank, radiographical services, and a large warehouse. As discussed previously, the warehouse in Cange acts as a "central" warehouse. All goods are stored at the Cange warehouse until one of the ten regional sites requests a need for them. They are then transported to that site.

3.3 Shipping and Transportation

The majority of products are shipped to PIH by container ship. This is a cost effective method of sending goods but also has the longest lead time. Some shipments are also made by air, either as air-freight, or carried in suitcases by PIH staff when traveling to Haiti.

Transportation between the central warehouse in Cange and the regional sites is adequate, but could benefit from some improvement. Currently, goods are transported between the central warehouse and the regional sites on a weekly or bi-weekly basis. PIH does not own the majority of these vehicles but rather rents them. This is due in part to the high maintenance required on vehicles that travel unpaved roads of rural Haiti. PIH staff also report that the trips are often made with less than a full load, even when multiple sites could be serviced on the same trip.

3.4 Sources of Goods

Approximately two-thirds of the products in our analysis are supplied by IDA. IDA is the world's leading non-for-profit supplier of affordable pharmaceutical products. PIH places an annual order with PIH in July each year.

PIH also orders goods through McKesson Surgical, Brigham and RxElite. PIH receives in-kind donations as well. Emergency orders are often sourced locally from Haiti or Dominican Republic. PIH also sources some infant formula locally due to storage constraints in the central warehouse. Tuberculosis and AIDS drugs are also obtained outside the IDA order.

4 Methods

In order to assess and improve upon the existing supply chain, we looked to PIH's historical demand data. We then chose an appropriate demand forecasting method, and developed inventory policies based on forecasted demand.

In order to describe our process, we first review three common demand forecasting methods: simple exponential smoothing, exponential smoothing with trend, and the Holt-Winters Smoothing Procedure. We then discuss selection of an appropriate forecast method for PIH, and application of this method to an appropriate inventory policy.

4.1 Demand Forecasting: Background

The exponential smoothing approach to demand forecasting is the most appropriate for our research. Exponential smoothing models are preferable to regression models since they give greater weight to recent data. Silver, Pike and Peterson (1998) discuss three exponential smoothing methods.

Simple exponential smoothing:

Underlying model: $x_t = a_t + e_t$ (1)

Where: $\hat{a}_{t,t+1} = \alpha x_t + (1-\alpha)\, \hat{a}_{t-1,t}$ (2)

This model incorporates historical data into projections. Demand is a function of level (a) plus an error term. Higher values of alpha, which ranges from 0 to 1, give more weight to recent demand data. For these equations the "hat" symbol (^) indicates a predicted value for the given variable. In this model, $\hat{a}_{t-1,t}$ is the projected level of a at time (t), based on the projected level at time (t-1) (Silver, Pyke and Peterson 89).

Exponential smoothing with trend:

Underlying model: $x_t = a_t + b_t t + e_t$ (3)

Where: $\hat{a}_{t,t+1} = \alpha x_t + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$ (4)

$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\hat{b}_{t-1}$ (5)

This model builds on simple exponential smoothing by incorporating a trend component (b), which represents the linear increase of demand over time. This approach is appropriate for data in which demand changes linearly over time (Silver, Pyke and Peterson 93). Higher values of beta make the slope component of the model more sensitive to recent changes in demand. The model assumes that demand patterns are somewhat smooth. Although this approach is an improvement upon the simple smoothing model, it is still inappropriate for products with seasonal demand fluctuations.

Holt-Winters Smoothing Procedure:

Underlying model: $x_t = (a_t + b_t t)F_t + e_t$ (6)

Where: $\hat{a}_{t,t+1} = \alpha(x_t/\hat{F}_{t-p}) + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$ (7)

$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\hat{b}_{t-1}$ (8)

$\hat{F}_t = \gamma(x_t/\hat{a}_t) + (1-\gamma)\hat{F}_{t-p}$ (9)

The Holt-Winters Smoothing Procedure builds on exponential smoothing with trend by incorporating a seasonality component (F). This approach is particularly useful for medical products, such as antimalarials, for which demand peaks during certain times of the year. F is a function of current demand divided by a moving average of demand. $\hat{F}_{t-p}$ is the value of F at the same time in the preceding period. A period is the length of time of a demand cycle. For instance, if demand has an annual cycle, the period is 12 months, or 1 year. Higher values of gamma give greater weight to recent demand in the seasonality equations.

4.2 Demand Forecasting: Application

The Holt-Winters method was chosen for forecasting PIH's product demand, as demand for some of PIH's products follows a seasonal pattern. Three years (January 2007- December 2009) of historical data were used to forecast demand. Although product demand is somewhat constant across years, it is volatile from month-to-month. For this reason, instead of using the equation F = (current month's demand / moving average of demand), the numerator in our equation is average demand over a four month period. This time period was chosen to decrease the fluctuations in F, while still allowing some variability over a given year. We use a moving average of 12 months in the denominator of this equation to capture the average monthly demand over a year.

PIH's catchment areas experienced significant internal migration in early 2010 as a result of the Port au Prince earthquake. PIH estimates this migration will cause demand for its service to permanently increase, but does not currently have an estimate for the percent increase.

4.3 Inventory Policies

Currently, PIH places annual orders for its drugs and supplies (PIH staff, personal communication, February 19, 2010). Limiting orders to one annual shipment decreases the complexity of the order management process, but can greatly increase inventory costs. More importantly, PIH's limited warehouse capacity makes it difficult to properly store and monitor large incoming shipments. This lack of storage space will become a more pressing issue as PIH continues to expand its operations and treat more patients. We therefore investigated the benefits of adopting different inventory policies and order frequencies. The focus of our research is the impact on volume requirements and emergency procurement costs from inventory policy changes. The financial implications of holding excess inventory are not a paramount concern to PIH since it is a non-profit organization.

Since PIH lacks a sophisticated inventory monitoring system, which is discussed in section 7, Additional Factors, we use a periodic review policy for drugs and supplies. Furthermore, periodic reviews allow for easier coordination of several items since orders are placed at the same time for all products (Silver, Pyke and Peterson 241). For this study, we place each product into prioritization categories of A and B. A-items are the most important products and thus maintain higher safety stocks to lower the probability of stocking out. For both category A- and B-items, an (R, s, S) policy is used. Under the (R, s, S) policy, inventory is checked after a set period of time (R) and orders are placed when inventory is below the reorder point (s), whereby:

$$s = X_{L+R} + k*\sigma_{L+R} \tag{10}$$

$X_{(L+R)}$ is demand over lead time (L) and the review period (R), k is a safety factor and σ_{L+R} is the deviation of demand over lead time and the review period. $k*\sigma_{(L+R)}$ is the safety stock, and a higher k corresponds to a higher safety stock (Silver, Pyke and Peterson 245). A-items products are assigned higher k values in order to minimize stockouts. The default k values are 2.33 and 1.65 for A- and B-items, respectively.

The order quantity is equal to the difference of (S – current inventory - in-transit inventory) at time of the order (Silver, Pyke and Peterson 241). Order quantities under periodic review systems are difficult to optimize. Therefore we devise S as a multiple of s with the multiple being greater than or equal to 1.

Since demand is not constant across months, S changes each review period. $X_{(L+R)}$ depends on the expected demand over the upcoming lead time and review period, while $\sigma_{(L+R)}$ is constant, since variance takes into account all periods of historical demand. Additionally, the order quantity is rounded up to the nearest unit size for practical purposes, since a supplier will not accept an order for a fraction of a package. For example, if a unit or box of penicillin consists of 100 individual pills, then an order quantity of 255 will be rounded up to 300 pills.

For our model, we use a monthly review policy (R = one month) for PIH's products. A shorter review period would be too onerous for PIH given the resources required to conduct an inventory check and place orders (PIH staff, personal communication, March 30, 2010). A review period of greater than one month, however, would lead to greater storage requirements. We also analyze longer review periods in case monthly orders are too demanding for PIH staff in Haiti.

The initial inventory level set to is $X_{(L+R)} + k*\sigma_{(L+R)}$, or the reorder point. This level was chosen so that each product would be ordered in month two while maintaining sufficient stock for a significant time. The inventory is checked for each product on monthly basis since R = 1. If the current inventory position is below the reorder point, a new order is placed. The inventory position is equal to the physical inventory in the warehouse plus the in-transit inventory. In-transit inventory consists of products that have been ordered, but have yet to arrive in the warehouse.

The importance of taking in-transit inventory into account is best explained through a simple example. Assume L = three months, and that for a certain product s = 1000, S = s, monthly demand is 200 and the initial inventory is 1200. If orders are based solely on physical inventory levels, organizations will make excess purchases until the original order is actually received in the warehouse. The table below illustrates how not incorporating in-transit inventories for order placements causes large, unnecessary spikes inventory levels.

Table 2: Comparison of Reorder Point References

Ordering based on Physical Inventory						Ordering based on Inventory Position					
Physical Inventory	Inventory Position	Order Quantity	In-transit	Order Arrival	Demand	Physical Inventory	Inventory Position	Order Quantity	In-transit	Order Arrival	Demand
1200	0	0	0	0	200	1200	0	0	0	0	200
1000	1000	0	0	0	200	1000	1000	0	0	0	200
800	800	200	200	0	200	800	800	200	200	0	200
600	800	400	600	0	200	600	800	200	400	0	200
400	1000	600	1200	200	200	400	800	200	600	200	200
400	1400	600	1600	400	200	400	800	200	600	200	200
600	1800	400	1600	600	200	400	800	200	600	200	200
1000	2000	0	1000	600	200	400	800	200	600	200	200
1400	1800	0	400	400	200	400	800	200	600	200	200
1600	1600	0	0	0	200	400	800	200	600	200	200
1400	1400	0	0	0	200	400	800	200	600	200	200
1200	1200	0	0	0	200	400	800	200	600	200	200

As mentioned previously, forecasted demand is used to determine inventory policies for each product. Forecasted demand is also used to derive simulated demand, where:

$$\textit{Simulated demand} = \textit{forecasted demand} + Z^*\textit{standard deviation of demand} \qquad (11)$$

Z is the z-score corresponding to a randomly chosen probability of 0 to 1. In our simulations, demand is equal to simulated demand. Simulated demand is utilized to test the robustness of inventory policies regarding stockouts and warehouse volume requirements, the primary objectives of our research. A stockout occurs whenever PIH's inventory is not sufficient to meet demand for a given product.

Simulations are run under numerous lead time and review period scenarios. The current lead time for PIH's orders is four months, which is the default in our model. We also vary R from one month, three months and six months. Finally we compare these results of these review periods to those from annual orders. Below are the seven scenarios under which we run simulations.

Scenario 1: Monthly orders, S = s, L = 4 months

Scenario 2: Quarterly orders, S = s, L = 4 months

Scenario 3: Semi-annual orders, S = s, L = 4 months

Scenario 4: Monthly orders, S = s, L = 2 months

Scenario 5: Quarterly orders, S = s, L = 2 months

Scenario 6: Semi-annual orders, S = s, L = 2 months

Scenario 7: Annual orders, $Q = D + k\sigma_{year}$

For annual orders we assume that all products arrive in January and that order quantity is equal to expected annual demand + k*monthly sigma*sqrt(12). For each scenario, we capture inventory volume, emergency procurement costs and the number of shipping containers arriving in Port au Prince over 250 simulations.

Product volume is the individual cubic meters of a product multiplied by the number of individual units for that product. The volumes of all products are summed to tabulate the monthly required storage space for the warehouse. The storage space at the central warehouse is limited, and therefore the maximum volume associated with an inventory policy would have to take this constraint into account.

The financial analysis of our research focuses on stockout costs, since they are tangible expenses born by PIH. In the private sector, a stockout often results in a lost sale. In the public health environment, though, there are no "lost" sales. First, there is the component of human suffering or possible death associated with a patient not receiving a necessary drug. Furthermore, PIH must locally source depleted products from Haiti or have them flown in. Both actions place significant financial burdens on PIH. The cost of stockout is B_2*product value, where B_2 is the markup or penalty from buying locally or flying a product from Boston compared to normal cost of receiving a product via ship. For this analysis we assume a stockout penalty of 50%, which is the average markup for locally procured drugs and supplies in Haiti.

Theoretically, stockouts will decrease with shorter lead times and more frequent orders because PIH can respond more rapidly to low inventory levels. It will also have more numerous opportunities, rather than just one annually, to place orders through its primary suppliers. Our research tests whether this correlation between stockouts and lead times and order frequency holds.

It is important to analyze both lead times and order frequency since they may be negatively correlated. Currently PIH's suppliers only send shipments when the entire quantity is available for a given product. Therefore suppliers may be able to respond to order requests more quickly if the order quantities are smaller.

5 Data Analysis

This section discusses sources of data, data cleaning, and the application of that data in a spreadsheet that uses forecasting and inventory policies to allow the user to compare various inventory options. This section also discusses the storage capabilities of the central warehouse, as well as a new PIH warehouse in St. Marc.

5.1 Data Sources and Data Accuracy

The main source of data available for our thesis was PIH's online Electronic Medical Records (EMR) system. It is a restricted access system that we were granted use of for the length of our thesis research. The EMR system provides monthly consumption data of all products at each PIH site from December 2001 through the present. For our thesis, we used data from January 2007 to December 2009. While the EMR system had the capability to export to Excel, the exported data was not "clean".

Before analysis could begin, significant data organization and cleaning was undertaken. Historical demand was gathered from the organization's EMR website, while product details and procurement expenses were collected from previous invoices. Demand is measured as the amount requested from the Cange warehouse by the individual clinics.

Data organization was conducted in Microsoft Excel and STATA, a statistical software program. Since PIH has used over 600 products, our analysis only includes items which had demand of at least 250 units in 2009 in order to reduce complexity. We created programs in STATA to automatically eliminate products with insufficient demand and to generate historical demand statistics.

To assess data accuracy we graphed the monthly demand of each product over the past two years. We grouped the charts peak monthly demand so that comparable scales were used across products. The chart analysis revealed which products contained data outliers, each of which we investigated. The charts also revealed that demand is not constant throughout the year, which supports our assumption that demand is seasonal (Figure 4). We therefore chose a demand forecasting model that incorporates seasonality.

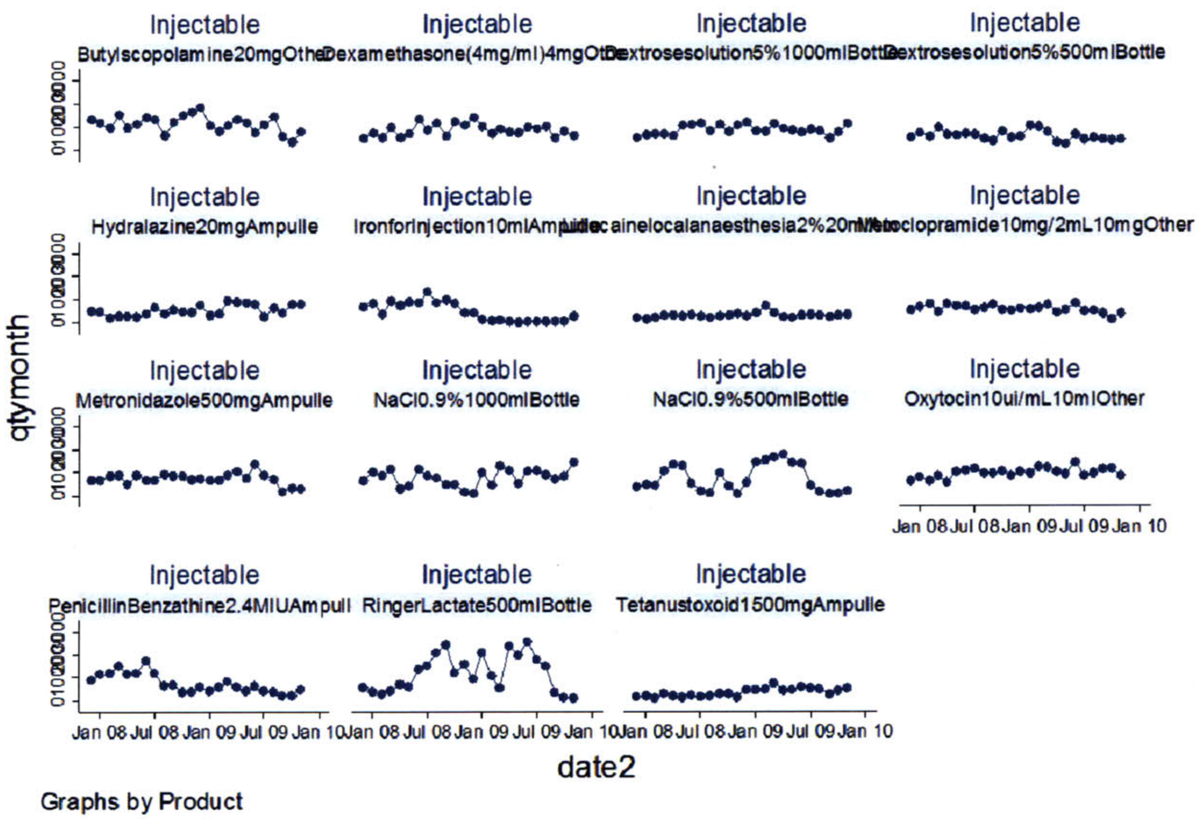


Figure 4: Historical Demand by Product

In some instances, it was obvious that the data was mistakenly placed in an adjacent cell. In these cases, we moved the data to the appropriate cell (Table 3). Other times, outliers were due to changes in availability of similar products with different strengths or sizes for a short period. For example, a surge in consumption of 10mg amoxicillin corresponds with a large drop in 5mg amoxicillin usage. Table 4 shows an example in which similar sized gloves were substituted.

Table 3: Data for Efavirenz 200mg and Didanosine 200mg switched in March 2008

Type	Product	Aug-07	Nov-07	Dec-07	Jan-08	Feb-08	Mar-08	Apr-08	May-08
EyeCare	TetracyclineHydrochloride1%5gOther	360	800	374	272	211	241	345	248
EyeCare	Timololeyedrops0.25%10mlOther	181	4	4	1	7	65	6	16
EyeCare	Tropicamideeyedrops0.5%10mlOther	10	0	0	0	0	0	0	0
HIV	AZT+3TC300/1501tabTablet	54523	46681	50623	62597	64480	72266	67342	62832
HIV	Abacavir300mgTablet	12	0	0	0	22	60	90	80
HIV	D4T+3TC+NVP(Triomune-40390mgTablet	0	0	0	0	0	0	0	0
HIV	Didanosine50mgTablet	0	0	0	0	0	0	0	0
HIV	Didanosine200mgTablet	0	0	120	0	60	**2110**	60	0
HIV	Efavirenz200mgTablet	2040	1290	1778	1590	2161	**60**	2251	3062
HIV	Efavirenz600mgTablet	21571	20205	13455	21736	22324	24086	21897	22451
HIV	Indinavir400mgTablet	4320	5940	2482	5760	4680	3438	4210	4500
HIV	Lamivudine150mgTablet	50831	61454	48748	60083	61275	67292	57431	63241

Table 4: Size 7 gloves used as a substitute for size 7.5 gloves in November and December

Type	Product	May-09	Jun-09	Jul-09	Aug-09	Sep-09	Oct-09	Nov-09	Dec-09
SOP	SurgicalGloves-sterile6(size)Other	0	0	0	0	0	0	0	0
SOP	SurgicalGloves-sterile6.5(size)Other	2	0	0	0	0	57	144	0
SOP	SurgicalGloves-sterile7(size)Other	446	450	126	175	449	677	2020	1489
SOP	SurgicalGloves-sterile7.5(size)Other	2838	3568	3228	3994	2503	1513	285	56
SOP	SurgicalGloves-sterile8(size)Other	1741	1367	1032	1188	1541	3314	2040	694
SOP	SurgicalGloves-sterile8.5(size)Other	0	0	0	0	0	11	139	0

Two other measures were taken to ensure data accuracy. First, we compared PIH's weekly consumption data against the monthly consumption data as weekly consumption and monthly consumption are contained in separate databases in the EMR system. When the weekly consumption numbers were aggregated, they equaled the data contained in the monthly consumption database, revealing consistency between the databases. Furthermore, we checked consumption figures from each of the clinics denoted in the EMR system against PIH's aggregate consumption database. We manually aggregated consumption from the individual clinics and found that these data match the data from PIH's aggregate database.

To conduct our data analysis, we linked the product detail database that we created, which includes weight, volume and price, to the historical demand database in order to have an integrated system. Product names across different PIH databases were not similar. For this reason, we created a unique name that is used across all sections of the model. We also created a document that shows a product's unique name, along with the original name used in each database. Having unique names is important so that PIH can efficiently import new demand data to update inventory policies.

5.2 Using the Spreadsheet Model

Our forecasting and inventory policy models were created in Microsoft Excel. The models include includes macros so that projected demand, inventory policies and simulation outputs are automatically generated. In order to tabulate new projections and policies for each product, the user of the model only needs to update historical data. The user can also specify certain parameters such as lead time (L), number of months between orders (R), order-up-to levels (S), and k. The user can also alter parameters, alpha, beta and gamma, in the demand forecasting model to make the model more or less sensitive to recent demand or seasonal effects. Below is a detailed overview of each of the 29 tabs in the spreadsheet model. Each tab falls under one of five categories: Product Data, Forecasting, Inventory Policies, Simulation Results and Warehouse.

In the following pages, product tabs are described in the order they appear from left to right in the spreadsheet. The last four tabs address the Cange warehouse area and available volume for storage of goods. Only the upper level of the Cange warehouse is considered for storage space. Furthermore, the appendix includes snapshots of tabs that do not have snapshots in this section.

Table 5: Overview and Description of Tabs in the Model

Category	Tab	Description
Product Data	Product Details	Weight, volume, price of products
Product Data	Monthly Data	Historical product demand
Product Data	Clean Monthly Data	Cleaned version of historical demand
Forecasting	ForecastModel	Generates forecasted demand for a given product
Forecasting	ForecastOutput	Forecasted demand over 3 years for each product
Forecasting	CleanForecastOutput	Cleaned version of forecasted demand
Inventory Policies	Parameters	User sets key parameters such as L, R, k, and B2
Inventory Policies	Reorder Point	Inventory level at which a new order is placed
Inventory Policies	Order up to Level	Quantity ordered = S - Inventory Position
Inventory Policies	Simulated Demand	Demand simulations for each product
Inventory Position	Physical Stock - Monthly Orders	Inventory of each product at the warehouse
Inventory Position	Emergency - Monthly Orders	Monthly emergency purchases for each product
Inventory Position	Physical Stock - Annual Orders	Inventory of each product at the warehouse with annual orders
Inventory Position	Emergency - Annual Orders	Monthly emergency purchases for each product with annual orders
Inventory Position	Orders	Monthly orders for each product
Inventory Position	Order Arrival	Monthly arrivals of ordered products at the warehouse
Inventory Position	Container Arrival	Number of containers that arrive at Port au Prince each month
Inventory Position	In Transit Stock	Monthly inventory of in-transit products
Inventory Position	Physical + In Transit Stock	Total inventory position
Inventory Position	Volume Reqs - Monthly Orders	Volume of inventory in warehouse each month
Inventory Position	Volume Reqs - Annual Orders	Volume of inventory in warehouse each month under an annual order policy
Simulation Results	Emergency Procurement Sims	Simulation results from each inventory policy for emergency procurement costs
Simulation Results	Volume Sims	Simulation results from each inventory policy for volume of warehouse inventory
Simulation Results	Container Arrival Sims	Simulation results from each inventory policy for container arrivals
Simulation Results	Charts	Charts of simulation results
Warehouse	Cange Warehouse Layout	Warehouse wall lengths
Warehouse	Cange Shelf Storage	Determines available volume of shelves
Warehouse	Cange Available Floor Space	Determines available floor space
Warehouse	% Goods Cange	Percentage of goods that remain in the Cange medical complex

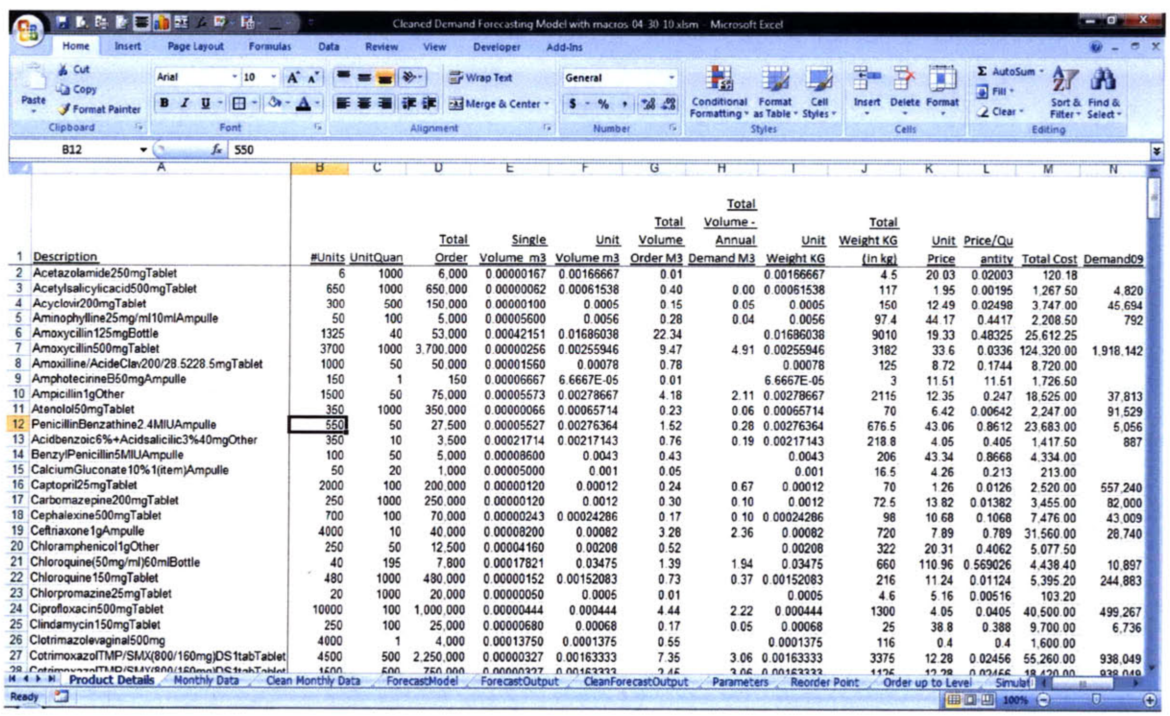


Figure 5: Snapshot of Spreadsheet Model and Tabs

Product Details Tab

This tab contains the unique name, volume, weight and price for each product. The data were collected from PIH's order invoices from IDA and PIH's Google Tracker site, and was entered manually. Other sections of the model draw volume and price data from this tab to calculate stockout costs and volume requirements.

The product details tab also includes a column calculating the ratio of 2009 annual demand to actual order quantity placed by PIH. Although the ratio averages 78%, it varies significantly across products (Figure 6). For some products the ratio is 1%, while it is above 700% for others. A notably low ratio signifies that PIH will have insufficient supply and will incur stockouts and be subsequently forced to place emergency orders for drugs and supplies. A ratio well above 100%, on the other hand, reveals that PIH will have excess inventory and less warehouse space for other items. PIH currently determines order quantity qualitatively through talks with staff in Haiti. Our analysis, however, reveals the importance of quantitative demand forecasting. PIH need not blindly follow our demand forecasts, but it can use them as a base estimate which can then be altered based on the projections of staff in Haiti.

We were unable to obtain volume data for 90 of the 307 products studied in our analysis. Therefore, the inventory volume and emergency procurement costs data produced by the model are underestimates.

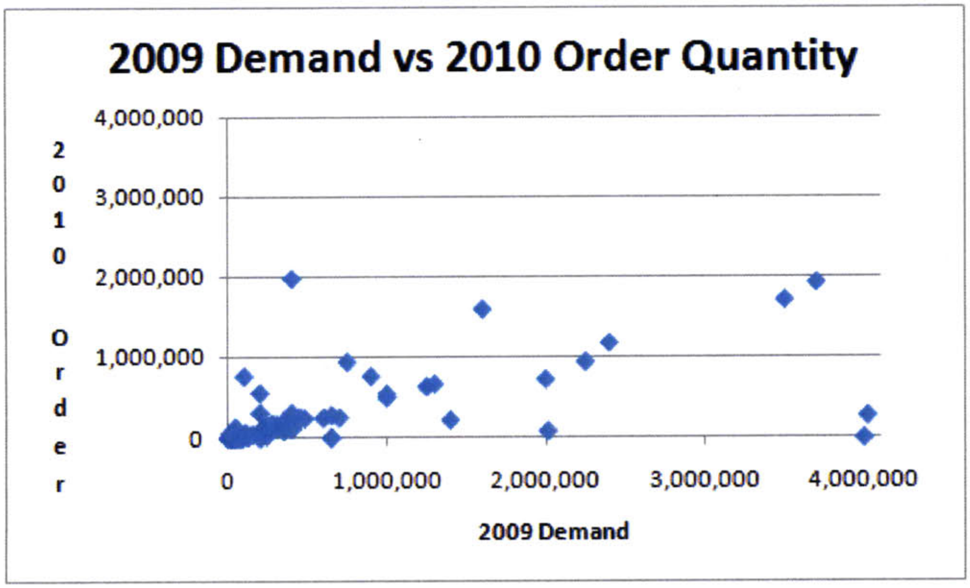


Figure 6: Annual Demand vs PIH'S Annual Order

Monthly Data Tab

The Monthly Data tab includes historical monthly demand for each product from January 2007 to December 2009. The data were all gathered from PIH's EMR website under the "Monthly Consumption Report" link. The months run horizontally and products are organized vertically by type of product, such as Eye Care, HIV and Injectables. PIH can update this tab with new demand data to adjust demand forecasts. The tab also includes summary statistics such as annual demand and maximum monthly demand. It should be noted that there may be accuracy concerns with the data. PIH's clinics in Haiti often lack internet access, so consumption figures are not always entered in the EMR system on a regular basis.

Clean Monthly Data Tab

The demand forecast model does not run properly for products that have no demand over a four month period. Therefore, we created the Clean Monthly Data tab, which automatically replaces each monthly demand value of zero from the Monthly Data tab with a value of one.

Cumulatively the replacement of zeros with ones increases historical demand by 0.003%. For the ten products most impacted by this adjustment, the range of increased historical demand is 5.7% - 12.5%. If demand for a given month is greater than zero, this tab simply imports the value from the Clean Monthly Data tab. Figures 7 and 8 below show how this tab updates the Monthly Data tab for values of zero. Other sections of the model use this historical demand data to forecast product demand.

type	product	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07
EyeCare	Gentamycineeyedrops0.3%10mlOther	503	271	222	381	253	392	323	143	108	288
EyeCare	TetracyclineHydrochloride1%5gOther	208	65	106	193	491	282	127	360	490	640
EyeCare	Timololeyedrops0.25%10mlOther	131	50	15	59	141	9	109	181	23	102
HIV	Abacavir300mgTablet	10	30	34	90	21	20	20	12	20	20
HIV	AZT+3TC300/1501tabTablet	46282	41711	42208	56599	55895	55423	65904	54523	56504	67737
HIV	Didanosine200mgTablet	0	60	120	120	0	60	120	0	60	0
HIV	Efavirenz200mgTablet	2004	1530	2130	1828	1911	1451	2010	2040	1920	1560
HIV	Efavirenz600mgTablet	17245	16518	16013	21398	18336	19074	20949	21571	18974	23819
HIV	Indinavir400mgTablet	5040	4320	3060	4320	3960	5220	4500	4320	3966	4726
HIV	Lamivudine150mgTablet	61999	56641	56742	72405	53787	52616	61592	50831	56632	61813

Figure 7: Monthly Data (Original Data)

type	product	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07
EyeCare	Gentamycineeyedrops0.3%10mlOther	503	271	222	381	253	392	323	143	108	288
EyeCare	TetracyclineHydrochloride1%5gOther	208	65	106	193	491	282	127	360	490	640
EyeCare	Timololeyedrops0.25%10mlOther	131	50	15	59	141	9	109	181	23	102
HIV	Abacavir300mgTablet	10	30	34	90	21	20	20	12	20	20
HIV	AZT+3TC300/1501tabTablet	46282	41711	42208	56599	55895	55423	65904	54523	56504	67737
HIV	Didanosine200mgTablet	1	60	120	120	1	60	120	1	60	1
HIV	Efavirenz200mgTablet	2004	1530	2130	1828	1911	1451	2010	2040	1920	1560
HIV	Efavirenz600mgTablet	17245	16518	16013	21398	18336	19074	20949	21571	18974	23819
HIV	Indinavir400mgTablet	5040	4320	3060	4320	3960	5220	4500	4320	3966	4726
HIV	Lamivudine150mgTablet	61999	56641	56742	72405	53787	52616	61592	50831	56632	61813

Figure 8: Clean Monthly Data (Replaces Values of Zero with One)

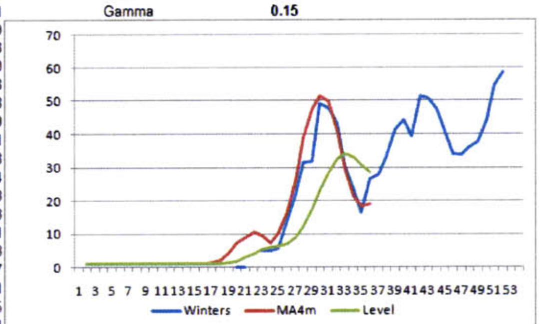
Forecast Model Tab

This tab generates forecasted demand for each product over a two year horizon. The methodology used is the same as described in the "Demand Forecasting" component of the Methods section earlier in this paper. We created a "Forecast" macro that automatically imports monthly data from 2007 – 2009 into this tab, with each product being imported separately. There are columns for the moving average of demand, seasonality factor (F), level demand (a) and the trend of demand over time (b). The model also incorporates more recent data to renormalize F.

Output appears in the "Forecast(t)" column at the right side of the model (Figure 9). This column displays the monthly forecasted demand for a given product. Once demand has been forecasted for a product, the macro imports historical demand from the "Clean Monthly Data" tab for the next product.

The user can also adjust the values for alpha, beta and gamma. Alpha determines how sensitive the level of demand is to recent data, beta determines the sensitivity of demand trends to recent data, and gamma determines the sensitivity of F to recent data. The forecast runs from February 2010 to December 2012 and the duration of the forecast can easily be increased by copying the "Forecast(t)" column (column Q) to cells further down.

a0	6.51
b0	0.33
Alpha	**0.19**
Beta	**0.05**
Gamma	**0.15**



I	Month	Demand	Fcst (t+1)	Fcst (t)	MA4m	MA12m	F-Est	F-Renorm	F	Estimate X(t)	Level a	Trend b	Seasonal Factor (f)	F(t+1) Renorm	Forecast (t+1)	Forecast (t)
-23	Jan-07	1	1.0						0.73	1.4						
-22	Feb-07	1	1.0	1.0	1.0				0.76	1.3						
-21	Mar-07	1	1.0	1.0	1.0				0.78	1.3						
-20	Apr-07	1	1.0	1.0	1.0				0.92	1.1						
-19	May-07	1	1.0	1.0	1.0				1.12	0.9						
-18	Jun-07	1	1.0	1.0	1.0				1.19	0.8						
-17	Jul-07	1	1.0	1.0	1.0	1.0	1.00	1.11	1.03	1.0						
-16	Aug-07	1	1.0	1.0	1.0	1.0	1.00	1.11	1.33	0.8						
-15	Sep-07	1	1.0	1.0	1.0	1.0	1.00	1.11	1.27	0.8						
-14	Oct-07	1	1.0	1.0	1.0	1.0	1.00	1.11	1.16	0.9						
-13	Nov-07	1	1.0	1.0	1.0	1.0	1.00	1.11	0.95	1.1						
-12	Dec-07	1	1.0	1.0	1.0	1.0	1.00	1.11	0.78	1.3						
-11	Jan-08	1	1.0	1.0	1.0	1.2	0.86	0.95	0.73	1.4						
-10	Feb-08	1	1.0	1.0	1.0	1.3	0.75	0.83	0.76	1.3						
-9	Mar-08	1	1.0	1.0	1.0	2.1	0.48	0.53	0.78	1.3						
-8	Apr-08	1	1.0	1.0	1.0	3.1	0.32	0.35	0.92	1.1						
-7	May-08	1	1.1	1.0	1.5	3.8	0.39	0.43	1.12	1.3						
-6	Jun-08	1	1.3	1.1	2.0	4.5	0.44	0.49	1.19	1.7						
-5	Jul-08	5	1.8	1.3	4.3	4.9	0.86	0.96	1.03	4.1						
-4	Aug-08	1	2.9	1.8	7.4	5.3	1.40	1.55	1.33	5.5						
-3	Sep-08	19	4.0	2.9	9.0	6.9	1.30	1.44	1.27	7.1						
-2	Oct-08	8	5.3	4.0	10.6	9.7	1.10	1.21	1.16	9.2						
-1	Nov-08	11	6.1	5.3	9.5	13.4	0.71	0.79	0.95	10.1						
0	Dec-08	8	6.3	6.1	7.4	17.9	0.41	0.46	0.78	9.4	6.5	0.3	0.78	0.73	5.0	
1	Jan-09	3	7.1	6.3	10.3	22.2	0.46	0.51	0.73	14.1	6.3	0.3	0.69	0.76	5.1	**5.0**
2	Feb-09	7	8.8	7.1	16.4	26.1	0.63	0.69	0.76	21.5	7.1	0.3	0.80	0.78	5.8	**5.1**
3	Mar-09	35	12.2	8.8	26.4	28.5	0.92	1.02	0.78	34.0	14.6	0.7	1.02	0.90	13.7	**5.8**
4	Apr-09	33	17.3	12.2	38.9	29.1	1.34	1.48	0.90	43.3	19.4	0.9	1.02	1.08	21.9	**13.7**
5	May-09	58	23.0	17.3	47.4	29.1	1.63	1.80	1.08	43.7	26.6	1.2	1.25	1.14	31.5	**21.9**
6	Jun-09	52	28.4	23.0	51.4	30.1	1.71	1.88	1.14	45.2	31.2	1.4	1.22	0.98	31.9	**31.5**
7	Jul-09	58	32.4	28.4	49.8		21.71		0.98	50.8	37.6	1.6	1.06	1.26	49.3	**31.9**
8	Aug-09	42	34.1	32.4	41.0				1.26	32.7	38.1	1.6	1.23	1.20	47.8	**49.3**
9	Sep-09	36	33.2	34.1	29.6				1.20	24.6	37.9	1.5	1.17	1.10	43.3	**47.8**
10	Oct-09	4	31.0	33.2	21.3				1.10	19.3	32.6	1.1	0.95	0.91	30.6	**43.3**
11	Nov-09	15	28.6	31.0	18.5				0.91	20.4	30.4	1.0	0.85	0.75	23.7	**30.6**
12	Dec-09	29	26.8	28.6	19.0				0.75	25.2	32.7	1.0	0.77	0.77	16.4	**23.7**
1	Jan-10								0.73							**16.4**
2	Feb-10								0.76							**26.6**
3	Mar-10								0.78							**27.8**
4	Apr-10								0.90							**33.1**
5	May-10								1.08							**41.1**
6	Jun-10								1.14							**44.3**
7	Jul-10								0.98							**39.3**
8	Aug-10								1.26							**51.6**
9	Sep-10								1.20							**50.7**
10	Oct-10								1.10							**47.6**
11	Nov-10								0.91							**40.2**
12	Dec-10								0.75							**34.1**
13	Jan-11								0.73							**33.7**
14	Feb-11								0.76							**36.1**
15	Mar-11								0.78							**37.6**
16	Apr-11								0.90							**44.4**
17	May-11								1.08							**54.7**
18	Jun-11								1.14							**58.5**
19	Jul-11								0.98							**51.5**
20	Aug-11								1.26							**67.3**
21	Sep-11								1.20							**65.8**
22	Oct-11								1.10							**61.3**
23	Nov-11								0.91							**51.6**
24	Dec-11								0.75							**43.6**
25	Jan-12								0.73							**42.9**
26	Feb-12								0.76							**45.7**
27	Mar-12								0.78							**47.3**
28	Apr-12								0.90							**55.6**
29	May-12								1.08							**68.3**
30	Jun-12								1.14							**72.7**
31	Jul-12								0.98							**63.8**
32	Aug-12								1.26							**83.0**
33	Sep-12								1.20							**80.9**
34	Oct-12								1.10							**75.1**
35	Nov-12								0.91							**62.9**
36	Dec-12								0.75							**53.0**

Figure 9: Forecast Model

Forecast Output Tab

The “Forecast” macro automatically imports the data from the “Forecast(t)” column in the “Forecast Model” tab into the “Forecast Output” tab. The layout of this tab is similar to that of the "Monthly Data" tab with months running horizontally and products running vertically organized by type. The tab contains the demand forecasts for each product.

Clean Forecast Output Tab

Forecasted demand is negative for some products for which demand decreases over time. This forecast of negative demand is a problem for two reasons. First, actual demand for a product cannot be less zero. Second, the inventory policy model is thrown off by negative values, specifically when calculating inventory volume. Therefore this tab changes negative values in the "Forecast Output" tab to zero (Figures 10 and 11).

Type	Product	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
EyeCare	Gentamycineeyedrops0.3%10mlOther	160	174	197	234	247	225	208
EyeCare	TetracyclineHydrochloride1%5gOther	244	253	299	346	320	299	320
EyeCare	Timololeyedrops0.25%10mlOther	40	40	36	38	52	59	59
HIV	Abacavir300mgTablet	461	620	762	856	852	646	636
HIV	AZT+3TC300/1501tabTablet	105,361	110,128	117,311	122,931	127,936	127,622	127,743
HIV	Didanosine200mgTablet	56	49	45	44	69	80	80
HIV	Efavirenz200mgTablet	5,352	4,417	2,345	1,045	2,319	3,280	3,243
HIV	Efavirenz600mgTablet	38,685	41,470	46,364	49,921	51,692	49,588	48,777
HIV	Indinavir400mgTablet	4,229	4,270	4,180	4,242	4,509	4,531	4,414
HIV	Lamivudine150mgTablet	114,320	109,801	109,583	112,356	116,608	111,266	109,488
HIV	LamivudineSuspension10mg/10ml240mlBottle	98	111	120	120	123	97	76
HIV	Lopinavir/Ritonavir250mgTablet	15,978	16,373	17,022	17,039	17,535	8,754	9,636
HIV	Nevirapine200mgTablet	115,468	118,465	122,331	125,438	127,362	125,891	126,220
HIV	Nevirapinesusp50mg/5ml240mlBottle	34	32	35	38	39	37	35
HIV	Stavudine30mgCapsule	105,205	111,996	126,096	147,920	178,345	196,959	211,302
HIV	Stavudine40mgTablet	-1,531	-3,450	-6,780	-13,756	-13,256	-15,066	-12,225
HIV	Tenofovir300mgTablet	2,596	2,634	2,755	2,848	3,093	3,016	2,923
HIV	Zidovudine300mgCapsule	12,089	7,637	6,420	7,491	4,871	3,487	4,670
HIV	Zidovudinesuspension200mlBottle	145	168	191	201	217	190	144

Figure 10: Original Forecast Output

Type	Product	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
EyeCare	Gentamycineeyedrops0.3%10mlOther	160	174	197	234	247	225	208
EyeCare	TetracyclineHydrochloride1%5gOther	244	253	299	346	320	299	320
EyeCare	Timololeyedrops0.25%10mlOther	40	40	36	38	52	59	59
HIV	Abacavir300mgTablet	461	620	762	856	852	646	636
HIV	AZT+3TC300/1501tabTablet	105,361	110,128	117,311	122,931	127,936	127,622	127,743
HIV	Didanosine200mgTablet	56	49	45	44	69	80	80
HIV	Efavirenz200mgTablet	5,352	4,417	2,345	1,045	2,319	3,280	3,243
HIV	Efavirenz600mgTablet	38,685	41,470	46,364	49,921	51,692	49,588	48,777
HIV	Indinavir400mgTablet	4,229	4,270	4,180	4,242	4,509	4,531	4,414
HIV	Lamivudine150mgTablet	114,320	109,801	109,583	112,356	116,608	111,266	109,488
HIV	LamivudineSuspension10mg/10ml240mlBottle	98	111	120	120	123	97	76
HIV	Lopinavir/Ritonavir250mgTablet	15,978	16,373	17,022	17,039	17,535	8,754	9,636
HIV	Nevirapine200mgTablet	115,468	118,465	122,331	125,438	127,362	125,891	126,220
HIV	Nevirapinesusp50mg/5ml240mlBottle	34	32	35	38	39	37	35
HIV	Stavudine30mgCapsule	105,205	111,996	126,096	147,920	178,345	196,959	211,302
HIV	Stavudine40mgTablet	0	0	0	0	0	0	0
HIV	Tenofovir300mgTablet	2,596	2,634	2,755	2,848	3,093	3,016	2,923
HIV	Zidovudine300mgCapsule	12,089	7,637	6,420	7,491	4,871	3,487	4,670
HIV	Zidovudinesuspension200mlBottle	145	168	191	201	217	190	144

Figure 11: Clean Forecast Output

Parameters Tab

The "Parameters" tab contains the user-set parameters for inventory policies. The parameters, which are highlighted in yellow in the model, include stockout penalty percentage (B_2), k for A-items and B-items, lead time in terms of months (L), review period in terms of months (R), and the ratio of S/s (Figure 12). Items were determined as A-items or B-items based on directions from PIH, who referred us to the Daily Report the EMR system compiled for each site. PIH considers the products tracked in this Daily Report to be "essential" items of which they cannot stock out.

If R = 1, orders will be placed every month that the inventory position is below the reorder point. If R = 3 orders will be only placed quarterly. Although the default for R is 1, PIH can adjust this value if monthly orders are too cumbersome. An increase in k will lead to an increase in safety stock and inventory volume, but a reduction in emergency purchases. PIH can also adjust B_2 from the default value of 50% if emergency procurement markups deviate from this average.

Actual stockout figures, inventory volume and total emergency procurement costs are calculated automatically in the "Parameters" tab. Further down in the sheet are k values, standard deviations of demand, safety stocks, purchase costs, transportation costs and unit sizes for each product. For products for which we lack unit sizes, we assume 100 individual items per unit.

This tab also includes parameters for inventory holding costs (r), order cost (A), shipping costs, and the volume of a shipping container. The inputs can be adjusted if PIH wants to see additional financial implications of inventory policies and the number of containers required per shipment.

r	0.15
A (total)	200
Number products/order	100
Shipping Cost/m3	133.60
Container Volume (m3)	55
Stockout Penalty/Markup (B2)	50%
k: A-items	2.33
k: B-items	1.65
Stockout % A-items	0.816%
Stockout % B-items	2.929%
Average Volume	84.0
Lead Time (months)	4
Review Period (months)	1
L+R	5.0
Order-up-to/Reorder Point (S/s)	1.0
Annual Emergency Procurement Costs	$4,936
Average Containers/Month	

Type	Product	Class	pu(k)	k	sigma	r	Safety stock $(k^*\sigma_{(L+R)})$	v(product)	v(transp)	v(total)	A	Actual UnitSize	Sim UnitSize
EyeCare	Gentamycineeyedrops0.3%10	B	1.65	1.65	140	0.15	516	0.425	0.008016	0.433016	2	100	100
EyeCare	TetracyclineHydrochloride1%5	B	1.65	1.65	153	0.15	563	0.2568	0.005961	0.262761	2	50	50
EyeCare	Timololeyedrops0.25%10mlOt	B	1.65	1.65	46	0.15	170	1.88	0.002672	1.882672	2	1	1

Figure 12: Parameters Tab (Inputs Highlighted In Yellow)

Reorder Point Tab

This tab automatically calculates every product's monthly reorder point, or s. As discussed previously $s = X_{(L+R)} + k^*\sigma_{(L+R)}$ and changes monthly because forecasted demand changes over time. The formula for reorder points in the model is lengthy since s is dependent upon the values of L and R. Longer lead times and review periods mean that s incorporates more months of forecasted demand and thus requires several "if" statements in Excel. Whenever product inventory falls below the respective s in a review period, a new order is placed automatically in the "Orders" tab.

Order up to Level Tab

The formula to determine S is simple. It is merely the S/s ratio, defined by the user in the "Parameters" tab, multiplied by the relevant month's s. Since S is determined by s, there is a different value for each month and each product. Data from this tab is used to calculate the order quantity.

Simulated Demand Tab

If the model used the exact forecasted demand numbers in consumption simulations, there would never be a stockout since s and S are based on forecasted demand plus a safety stock component. Therefore we use simulated demand in our simulations to test the robustness of inventory policies on inventory volume, emergency procurement costs and other benchmarks.

We created a "Simulations" macro that automatically generates random numbers from 0 to 1 at the bottom of the "Simulated Demand" tab. A unique random number assigned to each product and each month. The tab incorporates these random numbers to calculate simulated monthly demand for each product via the excel function MAX(NORMINV(Random number, Forecasted demand, Standard deviation of demand),0). Since the formula for simulated demand can generate negative values, we use the max of zero or the simulated demand for each month. This function assumes that demand follows a normal distribution. The table below shows that demand for the drug AZT and plastic pipettes are distributed normally since the chi-square value is well below the threshold of 9.49, assuming four degrees of freedom, for rejecting the null hypothesis that demand is distributed normally.

Table 6: Chi-Square Tests to Assess Normalcy of AZT and Plastic Pipette Demand

Bin	Frequency	Expected Freq	X2	Bin	Frequency	Expected Freq	X2
40000	1	2.32	0.75	2000	4	3.46	0.09
60000	10	8.35	0.33	4000	10	10.52	0.03
80000	14	13.56	0.01	6000	15	13.72	0.12
100000	8	9.03	0.12	8000	5	6.88	0.51
120000	3	2.45	0.12	10000	2	1.32	0.35
			1.33				**1.10**

Physical Stock – Monthly Orders Tab

This tab calculates the number of items for each product that are physically in the warehouse for each month. The physical inventory is equal to the previous month's inventory – simulated demand for the month + orders arriving at the warehouse at the beginning of the month. Since simulated demand differs from forecasted demand, inventory levels occasionally drop below zero, signifying a stockout (Figure 13). Columns AM-AP of the tab shows the minimum inventory level over the two years, the number of stockouts, the CSL and cumulative shortage for each product. These numbers are summarized in the "Parameters" tab.

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	1,543	1,413	1,120	793	793	2,304	2,195
EyeCare	TetracyclineHydrochloride1%5gOther	1,935	1,891	1,693	1,241	981	3,356	2,983
EyeCare	Timololeyedrops0.25%10mlOther	408	295	261	197	136	582	546
HIV	Abacavir300mgTablet	3,455	2,542	1,682	989	162	4,891	4,423
HIV	AZT+3TC300/1501tabTablet	604,499	518,754	384,826	276,728	162,098	860,553	713,263
HIV	Didanosine200mgTablet	498	409	253	172	105	658	543
HIV	Efavirenz200mgTablet	61,838	61,838	61,838	52,557	52,557	128,298	121,991
HIV	Efavirenz600mgTablet	222,955	189,376	165,189	121,313	76,559	385,357	326,524
HIV	Indinavir400mgTablet	23,417	19,268	15,256	11,100	6,834	31,311	27,400
HIV	Lamivudine150mgTablet	563,575	465,213	365,668	243,502	96,360	779,167	675,589
HIV	LamivudineSuspension10mg/10ml240mlB	572	460	354	224	130	787	704
HIV	Lopinavir/Ritonavir250mgTablet	79,694	60,965	38,892	21,711	221	92,037	78,026
HIV	Nevirapine200mgTablet	623,584	550,992	448,770	293,782	188,401	902,509	752,190
HIV	Nevirapinesusp50mg/5ml240mlBottle	192	158	113	81	63	326	299
HIV	Stavudine30mgCapsule	733,825	605,093	517,809	377,261	197,563	1,108,094	866,690
HIV	Stavudine40mgTablet	122,219	84,127	23,854	-20,207	-20,207	173,993	173,993
HIV	Tenofovir300mgTablet	13,391	9,957	5,827	2,099	-1,745	15,681	13,256
HIV	Zidovudine300mgCapsule	62,112	58,080	52,413	52,413	35,710	104,810	104,810
HIV	Zidovudinesuspension200mlBottle	1,055	836	673	443	165	1,344	1,268

Figure 13: Physical Stock – Monthly (Stockouts Highlighted in Yellow)

Emergency – Monthly Orders Tab

This tab calculates the amount of emergency purchases in the event of a stockout. If there is a negative inventory for any product in the warehouse, an emergency purchase is automatically placed. The magnitude of the emergency purchase is only intended to cover an inventory shortfall for the given month, so that it does not augment any in-transit inventory. The right side of the tab shows the cumulative amount of emergency purchases and the emergency procurement costs for each product. The emergency procurement costs are the penalty or markup over the normal purchase price and are equal to purchase quantity*purchase price*B_2.

Physical Stock – Annual Orders Tab

This tab reveals the physical inventory level of each product under an annual order system and was created to compare the inventory volume and emergency procurement costs associated with monthly and annual orders. A month's inventory position equals the prior month's inventory – simulated demand + emergency purchases. Each January, an annual shipment of each product arrives at the warehouse. The magnitude of this shipment is equal to forecasted annual demand + annual safety stock – current inventory position.

Emergency – Annual Orders Tab

This tab is similar to the "Emergency – Monthly Orders" tab, but the size of the emergency purchase is different. Here, the order quantity is equal to the shortage + S * ((months remaining in the year) / (L+R)). For example, if a product has a shortfall of 300 in October the emergency purchase will be 300 + S*2 / (L+R) since there are two months until the next shipment arrives in January.

Orders Tab

This tab determines when product orders are placed and is thus crucial in minimizing stockouts and excess inventory. If the sum of inventory in the warehouse plus the in-transit inventory is less than the current month's reorder point, an order is made. The size of the order is equal to S – inventory position. Furthermore, the order size must be a multiple of the unit size for a given product. The model accomplishes this by rounding up the order quantity to the nearest multiple of the unit size. The model is also set up so that orders can only be placed if the number of the current month is a multiple of R.

Order Arrival Tab

The "Order Arrival" tab calculates when a shipment will arrive in PIH's warehouse. Lead times and order date are used to determine when the order will actually arrive. For example, with a lead time of 4 months an order placed in June will arrive in October. The model is able to automatically calculate the arrival time through a series of "If" statements in Excel. Figures 14 and 15 below assume L = 4 and illustrate how the "Orders" and "Order Arrival" tabs interact.

Type	Product	3/1/2010	4/1/2010	5/1/2010	6/1/2010	7/1/2010	8/1/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	300	200	400	200	100	300
EyeCare	TetracyclineHydrochloride1%5gOther	200	250	500	500	500	150
EyeCare	Timololeyedrops0.25%10mlOther	49	51	125	136	0	72
HIV	Abacavir300mgTablet	800	800	400	400	400	200
HIV	AZT+3TC300/1501tabTablet	146,000	108,600	102,000	118,900	136,600	85,400
HIV	Didanosine200mgTablet	100	0	100	0	0	100
HIV	Efavirenz200mgTablet	16,900	21,400	9,600	1,800	700	500
HIV	Efavirenz600mgTablet	51,000	56,000	37,300	46,400	51,200	38,200
HIV	Indinavir400mgTablet	4,300	5,500	3,800	3,600	3,000	4,600
HIV	Lamivudine150mgTablet	147,900	120,400	105,000	98,400	120,000	152,900
HIV	LamivudineSuspension10mg/10ml240mlBo	200	100	0	200	0	100
HIV	Lopinavir/Ritonavir250mgTablet	6,900	12,500	13,400	16,400	14,300	19,900
HIV	Nevirapine200mgTablet	139,500	108,200	117,800	110,200	102,800	136,800
HIV	Nevirapinesusp50mg/5ml240mlBottle	100	0	100	0	0	100
HIV	Stavudine30mgCapsule	213,400	172,800	100,200	37,400	106,600	84,500

Figure 14: Orders Tab

Type	Product	3/1/2010	4/1/2010	5/1/2010	6/1/2010	7/1/2010	8/1/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	0	0	0	300	200
EyeCare	TetracyclineHydrochloride1%5gOther	0	0	0	0	200	250
EyeCare	Timololeyedrops0.25%10mlOther	0	0	0	0	49	51
HIV	Abacavir300mgTablet	0	0	0	0	800	800
HIV	AZT+3TC300/1501tabTablet	0	0	0	0	146,000	108,600
HIV	Didanosine200mgTablet	0	0	0	0	100	0
HIV	Efavirenz200mgTablet	0	0	0	0	16,900	21,400
HIV	Efavirenz600mgTablet	0	0	0	0	51,000	56,000
HIV	Indinavir400mgTablet	0	0	0	0	4,300	5,500
HIV	Lamivudine150mgTablet	0	0	0	0	147,900	120,400
HIV	LamivudineSuspension10mg/10ml240mlBo	0	0	0	0	200	100
HIV	Lopinavir/Ritonavir250mgTablet	0	0	0	0	6,900	12,500
HIV	Nevirapine200mgTablet	0	0	0	0	139,500	108,200
HIV	Nevirapinesusp50mg/5ml240mlBottle	0	0	0	0	100	0
HIV	Stavudine30mgCapsule	0	0	0	0	213,400	172,800

Figure 15: Order Arrival tab

Container Arrival Tab

The "Container Arrival" tab calculates the projected number of containers that will arrive at Port au Prince every month. First, the tab calculates the volume of each product arriving at the port for a given month. The number of containers is equal to the sum of the arriving order volume divided by 55 m^3, an approximate usable amount of available space in a shipping container. This tab does not include the volume of products for which we do not have volume data.

In-Transit Stock Tab

The "In-Transit Stock" tab measures the inventory that has been ordered, but not yet arrived in the warehouse. As mentioned previously, it is important to track this amount to prevent numerous orders from being placed for the same inventory shortfall. The in-transit inventory for a month is equal to the previous month's in-transit inventory + new orders – orders that arrived in the current month.

Physical + In-Transit Stock Tab (Inventory Position)

This tab measures the inventory position by summing the inventory located at the warehouse and the in-transit inventory. The inventory position is then checked against the reorder point to determine if a new order should be placed for each product.

Volume Reqs – Monthly Orders Tab

This tab calculates the monthly cumulative volume of the products in the warehouse. It does this by importing the individual product volume from the "Product Details" tab and multiplying this number by physical inventory in the "Physical Stock – Monthly Orders" tab. Since the physical inventory in our model is negative during stockouts, the volume equation is set up so that the volume cannot be lower than zero.

The top portion of the tab includes the monthly volumes for each product. At the bottom are the total monthly volumes for each month along with summary statistics on average, maximum and minimum volume requirements. Below the monthly totals on the spreadsheet are data regarding storage capacity at the warehouse.

The storage location for that month's volume is shown. Per review of consumption by site data over the past six months, it was determined that approximately 15.6% of goods were used in the Cange Sociomedical Complex, while the remainder went to regional sites. The warehouse is arranged such that goods remaining in the Cange complex are stored on the shelves, while goods that will be shipped to regional sites are placed on the floor. Therefore, the volume of goods for shelf storage is approximately 15.6% of the total volume. The remaining goods are stored on the floor. Based on the available storage volume on the shelves and floor, it is then calculated whether there is sufficient storage on the shelving and the floor. Instances in which insufficient space is available are shown as a bold "NO".

It should be noted that products for which there is no individual volume data are not included in the cumulative volume requirements. Therefore the number presented in this model should be viewed as an underestimate of true storage requirements.

Volume Reqs – Annual Orders Tab

This tab is similar to the "Volume Reqs – Model Orders" tab but displays cumulative volume data under an annual order system. Due to the larger quantities associated with annual orders, we expect this inventory policy to require greater storage capacity, particularly towards the beginning of the year. Figures 16 and 17 below reveal that the discrepancy between inventory volumes in a monthly order system versus an annual order system is greatest at the beginning of the year. Additionally, the figures show that model does not include data for the HIV drug Abacavir since we do not have individual volumes for this product.

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010	9/30/2010	10/31/2010	11/30/2010	12/31/2010	1/31/2011
EyeCare	Gentamycineeyedrops0.3%10mlOther	0.085433	0.073534	0.05049	0.031793	0.018603	0.010581	0.007601	0.028755	0.0407555	0.0422736	0.0573553	0.065005
EyeCare	TetracyclineHydrochloride1%5gOther	0.089494	0.080492	0.06282	0.045536	0.028812	0.035266	0.030326	0.032128	0.0371577	0.0492222	0.0434362	0.052261
EyeCare	Timololeyedrops0.25%10mlOther	0.007564	0.006932	0.004811	0.002062	0.002062	0.000571	0.001104	0.002903	0.0052935	0.0050349	0.005083	0.005083
HIV	Abacavir300mgTablet												

Figure 16: Product Volume under a Monthly Order System

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010	9/30/2010	10/31/2010	11/30/2010	12/31/2010	1/31/2011
EyeCare	Gentamycineeyedrops0.3%10mlOther	0.164275	0.152376	0.129332	0.110635	0.097445	0.071424	0.056443	0.053598	0.0535978	0.0491159	0.0461976	0.09923
EyeCare	TetracyclineHydrochloride1%5gOther	0.207217	0.198215	0.180543	0.163259	0.146535	0.144065	0.127972	0.107466	0.0901882	0.079945	0.0674667	0.160053
EyeCare	Timololeyedrops0.25%10mlOther	0.015165	0.014533	0.012412	0.009663	0.009663	0.007192	0.006704	0.006004	0.0056741	0.0054156	0.0040237	0.010519
HIV	Abacavir300mgTablet												

Figure 17: Product Volume under an Annual Order System

Emergency Procurement Sims Tab

The monthly emergency procurement costs for each simulation iteration are placed in this tab. For each iteration, costs are calculated automatically by the "Simulations" macro for the seven inventory policy scenarios listed in section 4.3. Since 250 iterations were run, each inventory policy has 250 lines of data.

Volume Sims Tab

The inventory volumes in the warehouse from each simulation iteration are placed in this tab. For each iteration, the volume is calculated automatically by the "Simulations" macro for the seven inventory policies.

Container Arrival Sims Tab

The number of arriving containers from each simulation iteration is placed in this tab. For each iteration, the number of containers is calculated automatically by the "Simulations" macro for the seven inventory policies.

Charts Tab

The "Charts" tab provides summary statistics from the "Emergency Procurement Sims", "Volume Sims" and "Container Arrival Sims" tabs. For these outputs, the mean, fifth percentile and 95th percentile are automatically calculated under each inventory policy. The tab also contains charts illustrating the simulation results for these outputs from 2010 through 2012.

Cange Warehouse Tab

This tab allows for the user to enter the length of the Cange warehouse walls. The output is the total area of the warehouse.

Shelf Storage Tab

This tab allows for entry of shelving length, depth, average aisle width, number of (each variation) of shelves and the number of rows of shelves. The tab also allows the user to alter height between shelves, the number of shelves holding boxes, the number of shelves holding loose goods, and the approximate volume cube used on each shelf. The outputs are total area required for the shelving footprint, and total available volume of the shelving units.

Available Floor Space Tab

This tab allows for input of the exterior aisle width, entry length and width, back aisle width and length, AC units length and width, and the maximum box stacking height. The outputs are the total footprint area available on the warehouse floor, and the total available volume of goods that can be stacked on the warehouse floor. The total maximum available storage volume in the warehouse (shelf storage plus floor storage) is also an output.

% Goods Cange Tab

This tab calculates the percentage of goods that remain at the Cange Sociomedical complex based on historical consumption data. We used the six month period from July 2009 to December 2009 as the relevant historical period when calculating the percentage of goods that remain in Cange. An alternative historical window could be chosen, if desired.

5.3 Data Analysis Concerns: Missing Product Volumes

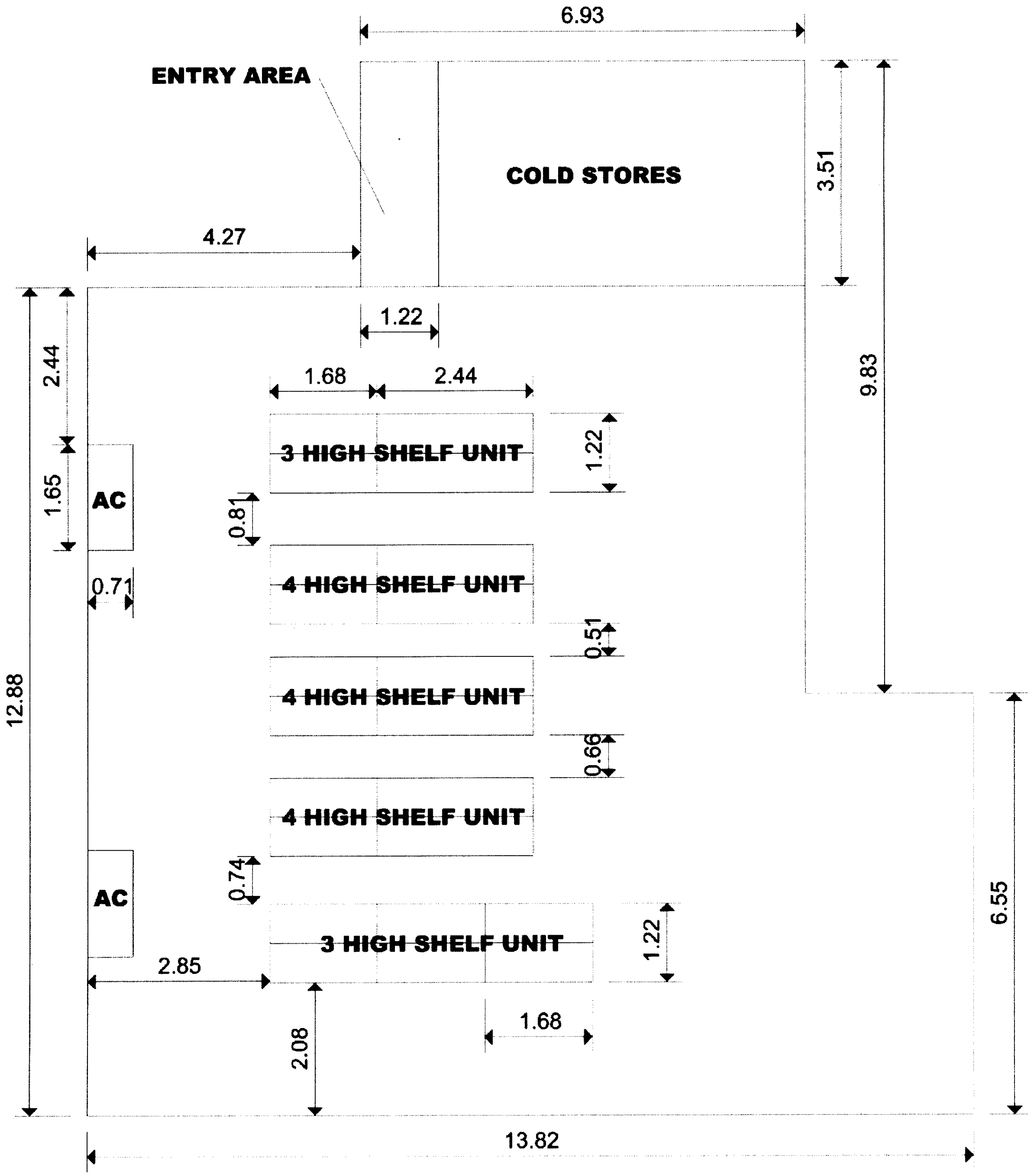
As mentioned previously, volume data for approximately one-third of PIH's products was unavailable. This makes evaluation of inventory policies in relation to the available storage volume in the central warehouse difficult.

5.4 Storage Capabilities of the Central Warehouse

The building that houses the central warehouse in Cange consists of two floors (Figure 18). The lower level is used to store equipment, while the upper level contains both office space and storage space. The storage area on this upper level is used to store the products discussed in this thesis. A site visit and subsequent measurements of the upper level found the area to be approximately 185 square meters. This 185 square meters includes a 24 square meter section of the warehouse devoted to cold stores. Therefore, total floor space available for general storage was limited to approximately 161 square meters (See Figure 19).

Storage in the warehouse is split between shelving and the floor. A portion of the goods is stored on plastic shelving. These are goods that will stay on site at the Cange Sociomedical Complex facility. The remaining goods are stored in their original shipping boxes on the warehouse floor. Per review of the last six months of consumption data in 2009, about 15.6% of goods were used within the Cange Sociomedical Complex, and the rest were distributed to regional sites.

Figure 18: Central Warehouse (Cange)
Source: PIH Picasa Web Albums-ZL



AREA=161.4 sq m (EXCLUDING COLD STORES)

Figure 19: Central Warehouse Floor Plan

Shelving Units

Shelving units consist of three or four shelves (Figure 20). The shelves are approximately 0.61 meters (2 feet) deep, with 0.61 meters height between shelves. Each of the shelf units is placed back to back with another shelf unit, resulting in a total shelf depth of 1.22 m (4 feet). There are two shelf lengths used: 1.68 meters (66 inches) and 2.44 meters (96 inches). A total of fourteen 1.68 meter length shelves and eight 2.44 meter length shelves are used in the warehouse. The lowest shelf is used to store boxes of products. The two (three shelf units) or three (four shelf units) upper shelves are used to store loose items.

Figure 20: Shelving in the Central Warehouse
Source: PIH Picsa Web Albums-ZL

Shelving Footprint

There are two components to consider for the shelving footprint: the footprint of the shelves themselves and the footprint of the aisles running between parallel shelves. The footprint of the shelving in the central warehouse consumes approximately 26 square meters. The footprint of the aisle between the shelves adds approximately 11 square meters. Therefore, the total footprint consumed by the shelving and interior aisles is approximately 37 square meters (Figure 21).

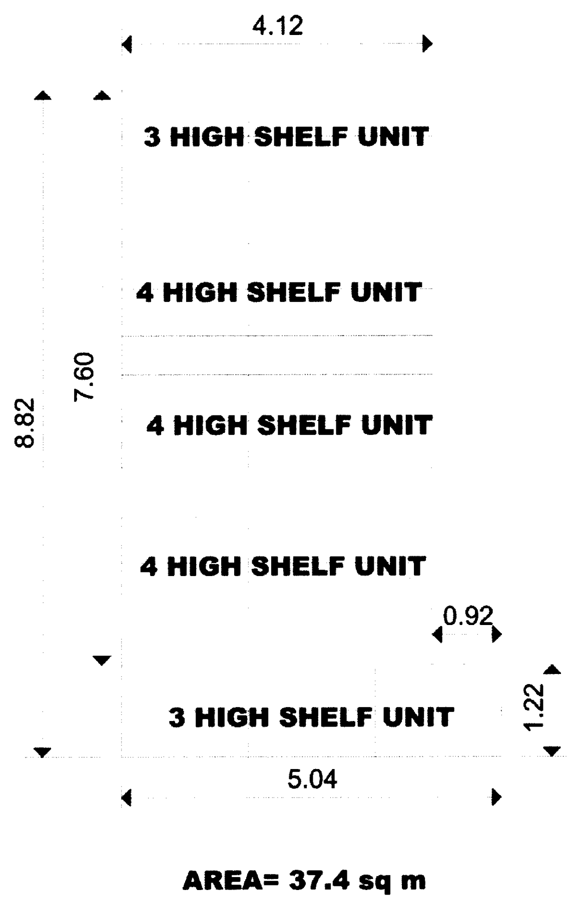


Figure 21: Shelving Footprint, including interior aisles (all dimensions in meters)

Perimeter Aisle Footprint

The footprint of the 0.86 meter (34 inch) aisle that surrounds the perimeter of the shelving is approximately 27 square meters.

Shelving Available Volume

For the purpose of this thesis, we assumed that the utilization of cube on the box storing shelves (lowest shelf on each unit) was 80%. This means that 80% of the volumetric space between the lowest shelf and the shelf above it is used. For the upper shelves that store loose goods, we assumed that the utilization of cube was 20%. We assumed such a low utilization of cube for these shelves as when loose goods are stored at the individual level, they are often small, and use only a small portion of the available volume between shelves. Based on these assumptions, a total of approximately 32.6 cubic meters is available for storage on the shelving units.

Shelving Issues

Staff at PIH Boston considers the current shelving system to be less than optimal. The shelving is plastic, with each shelf consisting of a plastic grid. The opening in the grid pattern is considerable, and causes loose bottles to sit unevenly. Very small bottles can fall through the grid unless cardboard or a similar object is laid on the grid first. The shelf height is not flexible, and therefore cannot be adjusted to suit the storage of the particular items on that shelf.

Floor storage

The remainder, and majority, of goods are stored on the floor of the warehouse, in the original shipping packages (Figure 22). Most of the goods are stored along the walls of the warehouse, two boxes deep. If an additional row or two of boxes is desired beyond two deep, an aisle is formed. The average aisle width between boxes is 0.61 meters (24 inches). To determine the (maximum) amount of available floor storage space, the following method was used:

Area of warehouse - (area of shelving including aisles) - area of air conditioning unit footprint - area of entryway - area of back aisle

The area described as "back aisle" refers to theoretical 0.86m wide aisle that would run the length of the back wall of the warehouse. It represents what would be considered the minimal amount of aisle spacing needed in order to have adequate access to stacked rows of boxes.

We assumed for the model that boxes were stacked 2.44 meters (8 feet) high. Even with these generous assumptions for use of floor storage space, it was determined that only 200 cubic meters of goods can be stored on the floor.

Figure 22: Floor Storage in the Central Warehouse
Source: PIH Picasa Web Albums-ZL

5.5 The St. Marc Warehouse

A new warehouse (Figures 23, 24) has recently been constructed at the St. Marc hospital and clinic in the Artibonite region. At approximately 282 square meters (Figure 11), it is the largest PIH warehouse in Haiti. While the warehouse is already being used for storage, shelving has yet to be installed. Currently, the warehouse only serves its operations in St. Marc. However, due to its large size, the warehouse has potential to serve other areas in the Artibonite region.

Figure 23: Exterior of the St. Marc Warehouse (during construction)
Source: PIH Picasa Web Albums-ZL

Figure 24: Interior of the St. Marc warehouse (during construction)
Source: PIH Picasa Web Albums-ZL

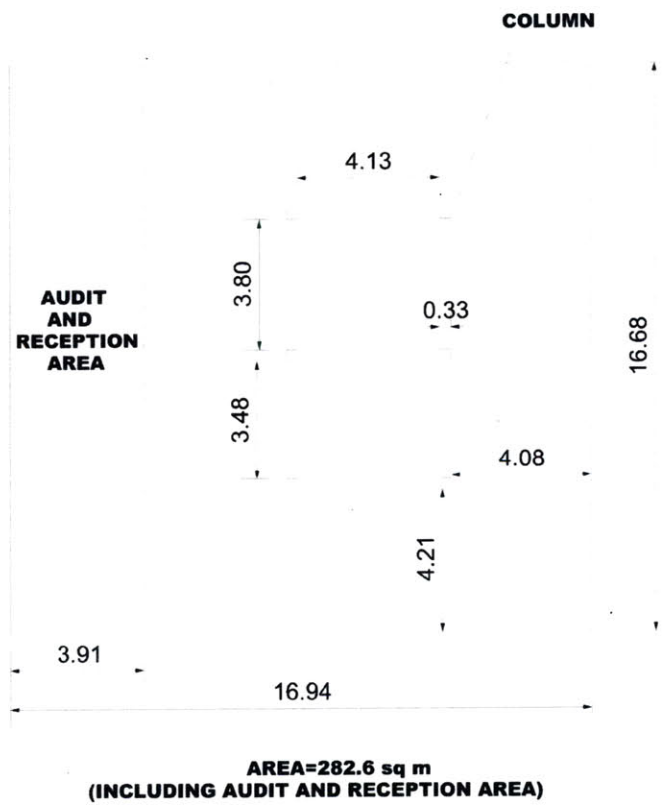


Figure 25: St. Marc Warehouse Layout

6 Results

We ran 250 simulations for each of the five scenarios covered in the Methods section of the paper. Below are the results by metric.

Warehouse Inventory Volume

A review period of one month produces the smallest inventory volume in the warehouse. Furthermore, the inventory volume of all policies from R=1 to R=6 is significantly lower than the volume resulting from an annual order system. A decrease in L from four to two also reduces inventory volume, but the change is relatively small. For example when R=3, a reduction in lead time from four to two months causes inventory volume to decrease 16%. On the other hand changing from annual to quarterly orders reduces inventory volume 56% when L=4. Table 7 details the average inventory volume under different inventory policies.

The first chart (Figure 26) illustrates the monthly volume associated with each inventory policy under one simulation iteration. The second chart (Figure 27) graphs the quantity of amoxicillin contained in the warehouse over time for each inventory policy. The final chart (Figure 28) shows the mean, 5^{th} percentile and 95^{th} percentile of monthly inventory volumes from the 250 simulation iterations when L=4 and R=3. As this chart shows, the range of inventory volumes is narrow in a given month. This finding held for each of the inventory policies.

Table 7: Average Inventory Volume by Policy from 250 Simulations

Policy	Average Volume	Min Volume	5% Volume	95% Volume	Max Volume
L=2,R=1	62	36	47	97	160
L=2,R=3	125	43	62	201	264
L=2,R=6	222	51	81	360	398
L=4,R=1	85	42	59	201	264
L=4,R=3	147	50	72	292	355
L=4,R=6	235	59	88	417	480
Annual	339	66	102	610	673

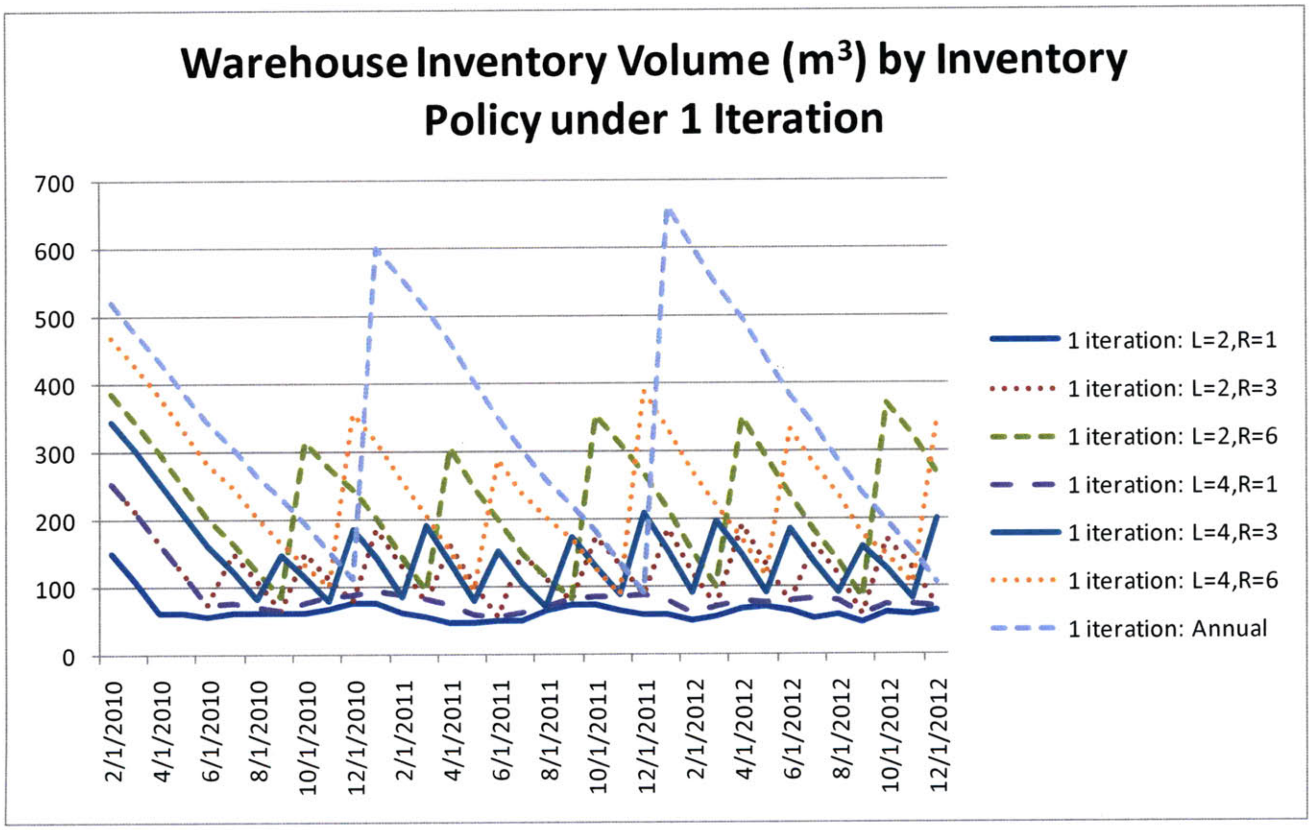


Figure 26: Warehouse Inventory Volumes by Inventory Policy

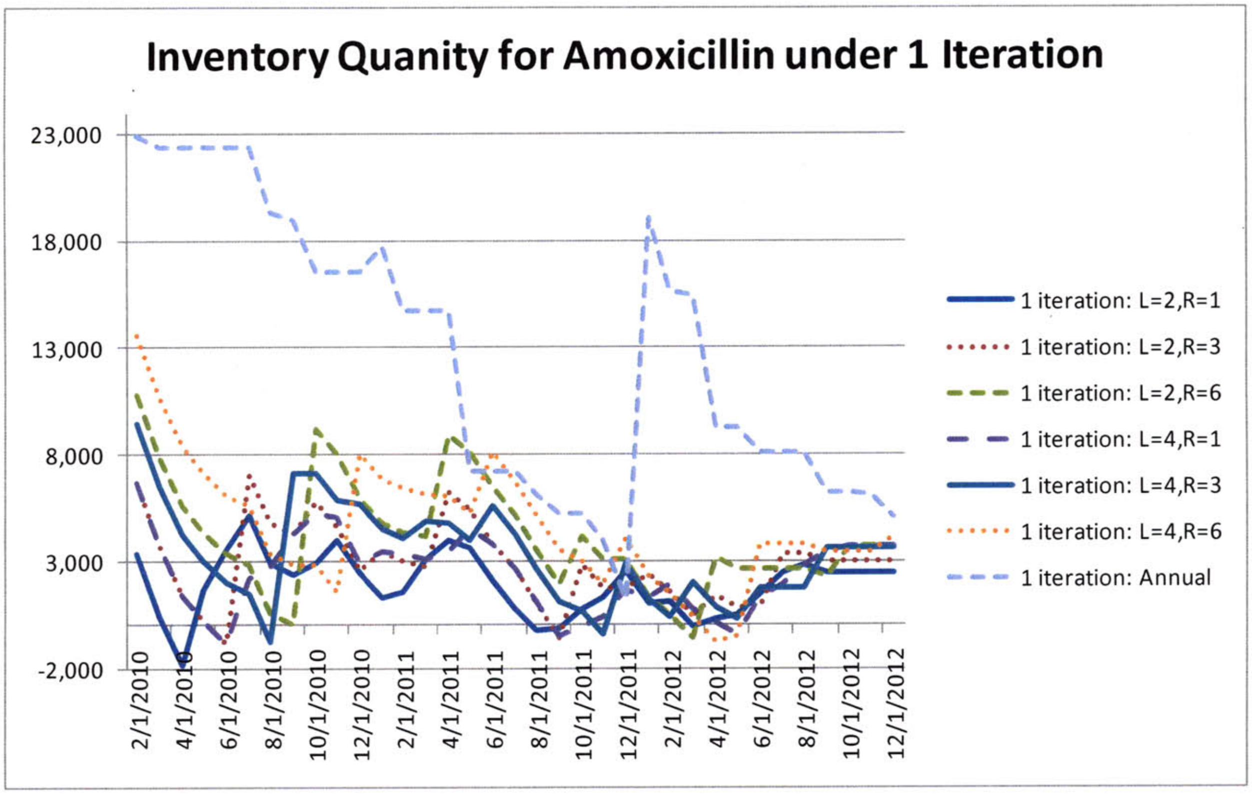


Figure 27: Quantity of Amoxicillin by Inventory Policy

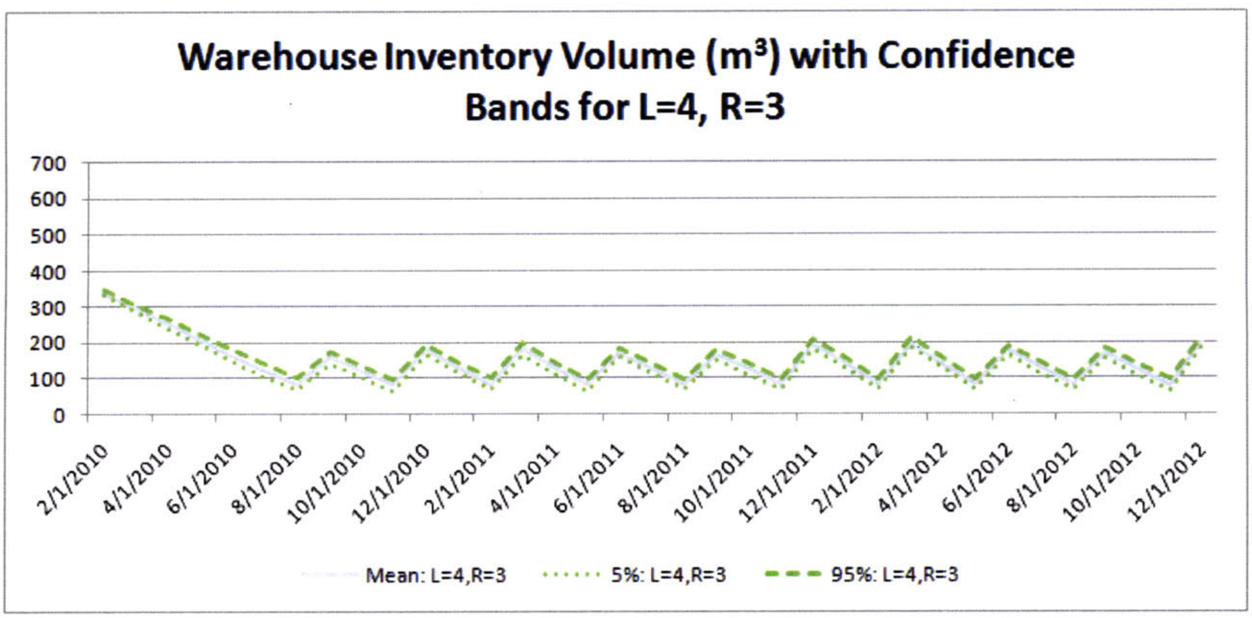


Figure 28: Warehouse Inventory Volume with Confidence Bands

Emergency Procurement Costs

In our model emergency procurement costs, are summed over the three years of the simulation and are volatile over the 250 simulations. The second column in Table 8 shows the total emergency procurement costs over the three year forecasted period for each inventory policy. The remaining columns show the summary statistics for monthly emergency procurement costs. The first chart (Figure 29) shows the monthly emergency procurement costs from one iteration for each inventory policy. Generally, an increase in R leads to a reduction in emergency procurement costs. However, there is a tradeoff between emergency procurement costs and inventory volume (Figure 30). The final chart (Figure 31), which shows the mean, 5th percentile and 95th percentile of emergency procurement costs from the 250 simulation iterations, reveals that these costs are much more volatile than inventory volume.

Table 8: Average Emergency Procurement Costs from 250 Simulations

Policy	Average Total Emerg Procurement Costs	Min Total Emerg Procurement Costs	5% Total Emerg Procurement Costs	95% Total Emerg Procurement Costs	Max Total Emerg Procurement Costs
L=2,R=1	$16,956	$8,299	$10,662	$25,469	$36,897
L=2,R=3	$11,233	$4,170	$5,626	$19,288	$33,979
L=2,R=6	$8,647	$2,400	$3,288	$17,513	$30,219
L=4,R=1	$17,554	$7,551	$10,277	$27,534	$42,756
L=4,R=3	$12,005	$3,986	$6,170	$20,989	$32,794
L=4,R=6	$10,809	$2,433	$4,286	$21,450	$41,827
Annual	$11,432	$2,454	$4,216	$21,914	$55,028

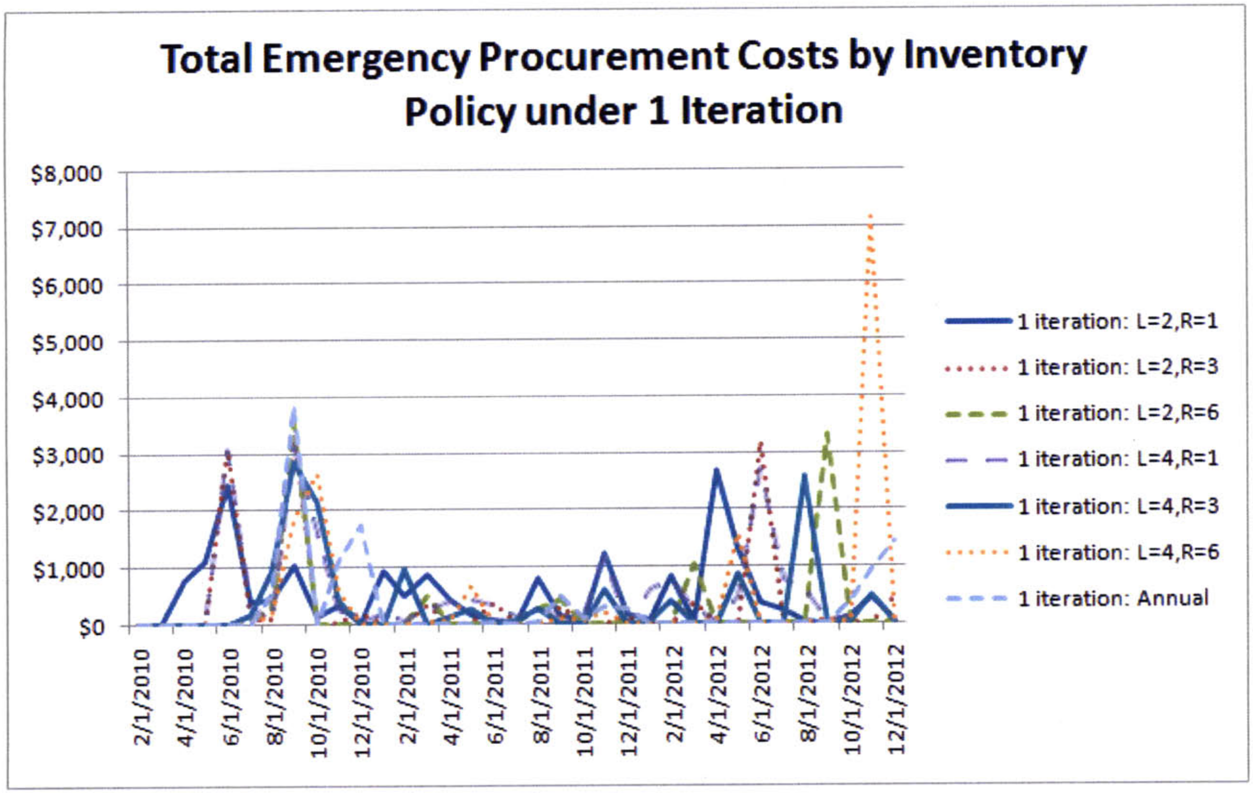


Figure 29: Emergency Procurement Costs by Inventory Policy

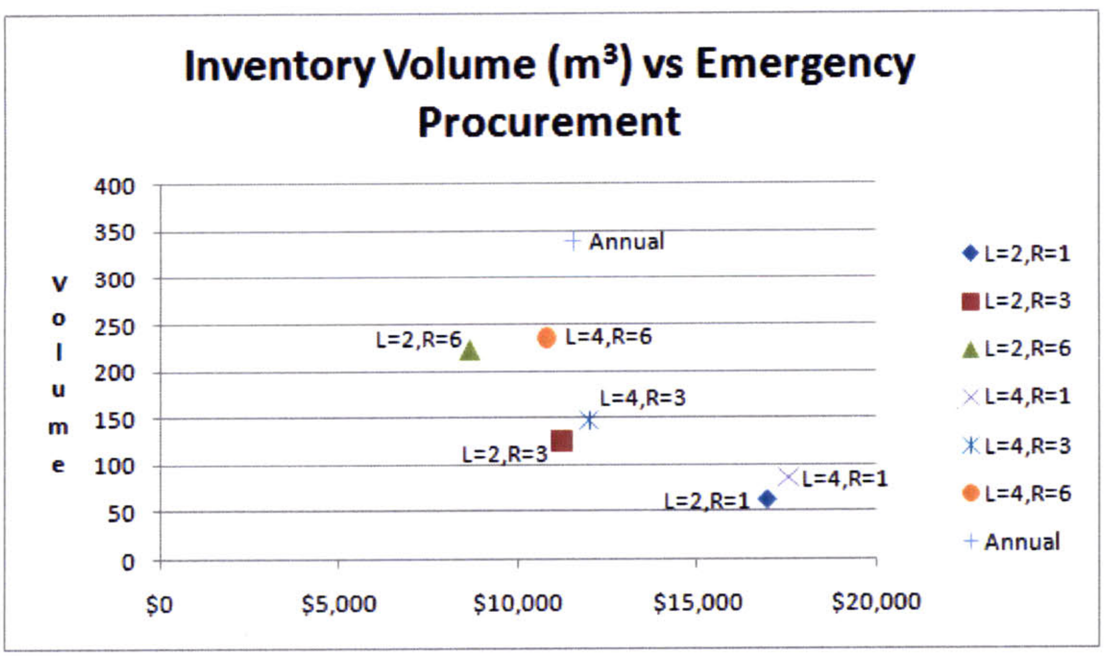


Figure 30: Trade-Off Between Inventory Volume and Emergency Procurement Costs

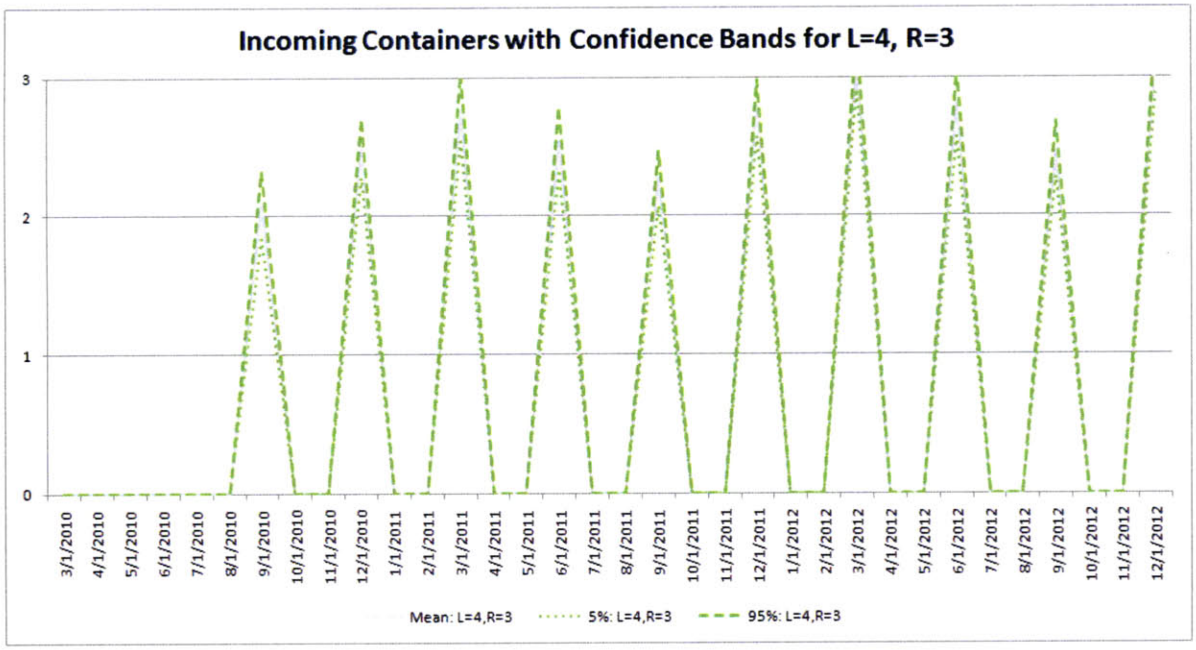


Figure 31: Emergency Procurement Costs with Confidence Bands

Container Arrivals

The number of containers arriving annually is fairly constant across all inventory policies (Table 9). However, the distribution of containers over time is significantly different across inventory policies (Figure 32). The number of containers remains level over time when R=1. The curve gets significantly choppier, though, as R increases. Finally, the volatility of the number of containers is minimal across simulations as illustrated in Figure 33.

Table 9: Annual Containers by Inventory Policy

Policy	Average Annual Containers	Min Annual Containers	5% Annual Containers	95% Annual Containers	Max Annual Containers
L=2,R=1	9.6	9.2	9.4	9.8	10.0
L=2,R=3	9.0	8.6	8.8	9.3	9.4
L=2,R=6	9.5	9.1	9.2	9.7	9.8
L=4,R=1	9.0	8.6	8.8	9.2	9.4
L=4,R=3	9.3	8.9	9.1	9.5	9.7
L=4,R=6	9.4	9.0	9.2	9.6	9.7
Annual	10.7	10.4	10.5	10.9	11.1

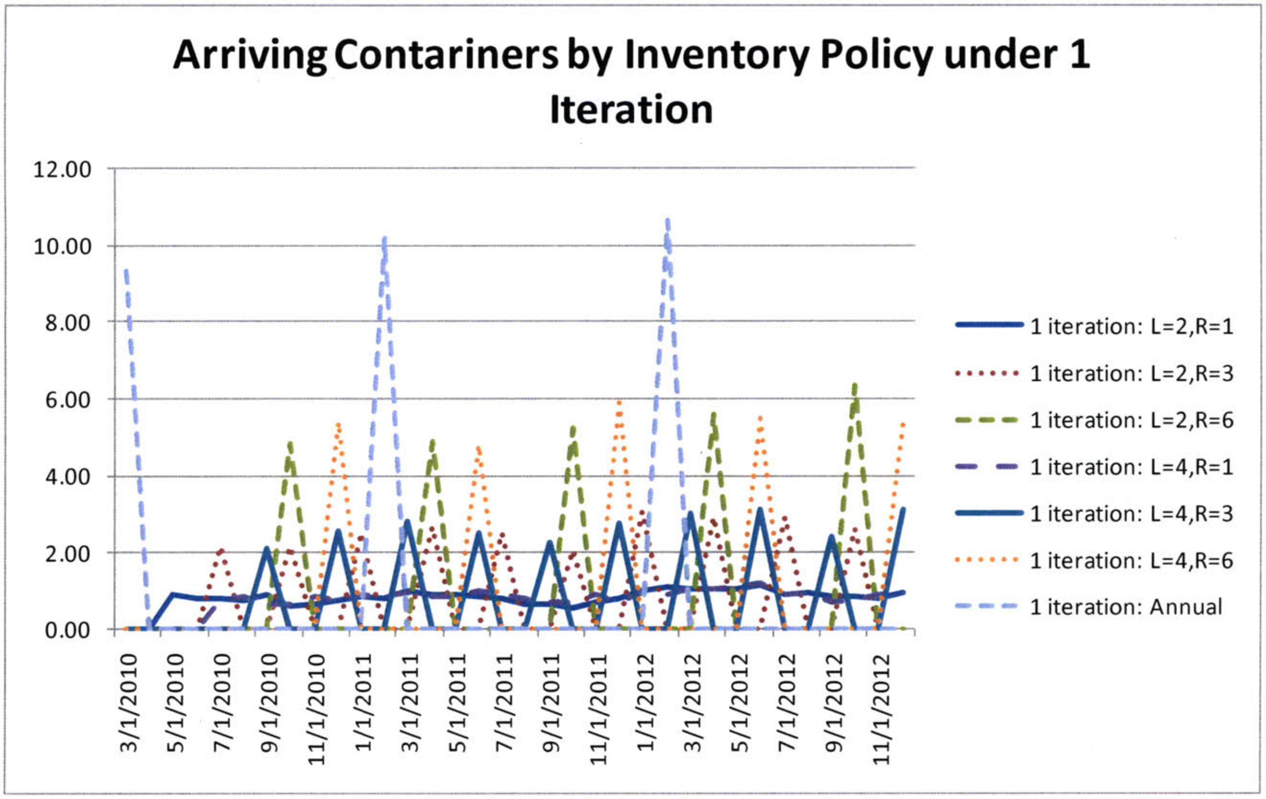


Figure 32: Monthly Containers by Inventory Policy under 1 Simulation

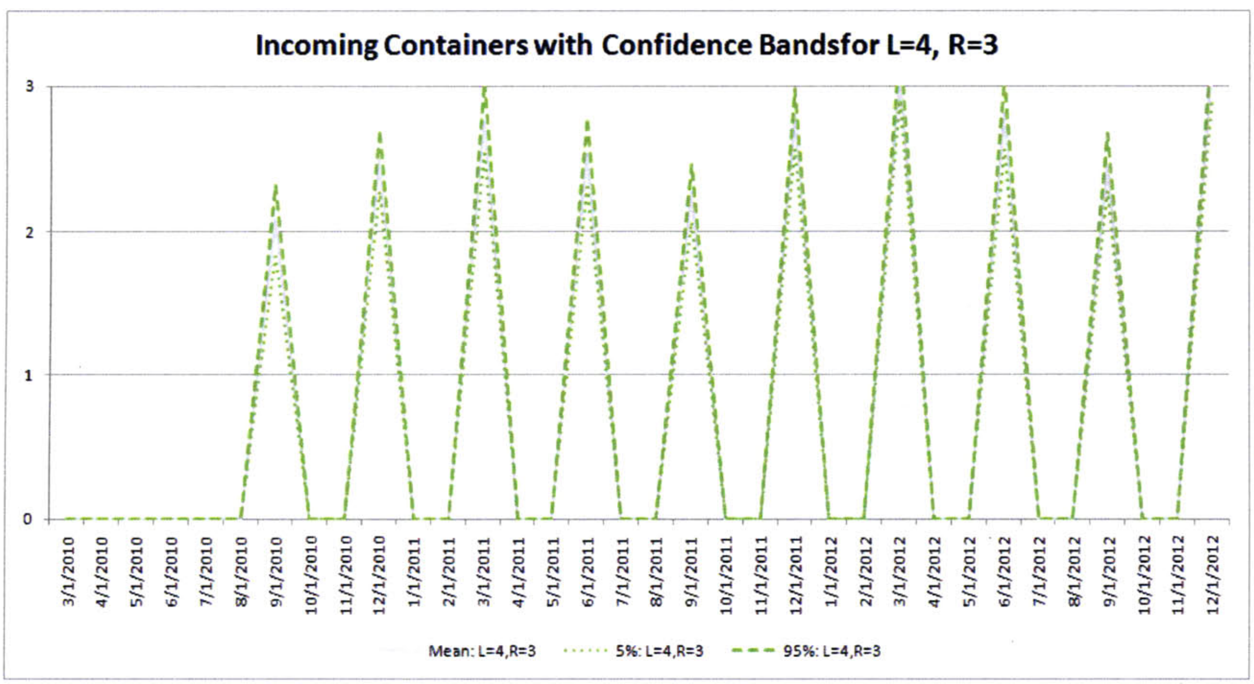


Figure 33: Monthly Incoming Containers with Confidence Bands

7 Additional Factors

7.1 Tracking of Goods

PIH currently performs stock keeping by hand at all sites. Three or four times a year, each site takes a total inventory. A basic barcode system holds the potential to improve the ease and accuracy of stock keeping greatly. The use of Radio Frequency Identification (RFID) tags is another possibility. While RFID tags would provide the least labor intensive way of tracking goods, it might not be practical as it would not allow goods to be tracked at the individual level. In addition, the costs of creating an RFID system are very high.

7.2 January 2010 Earthquake

In January 2010, a 7.0 Mw earthquake struck Haiti outside of Port Au Prince. It is estimated that at least150,000 lives were lost. Fortunately, neither the Sociomedical Complex nor the regional sites were immediately affected by the quake. However, there will be a permanent increase in the population served by PIH's catchment areas due to internal migration.

It is expected that 500,000 people will move permanently from Port Au Prince. Prior to the earthquake, the city's population was estimated to be between 2.5 and 3 million people. It is expected that a large portion of the population leaving Port au Prince will settle in the Central Plateau. This will affect the number of patients seeking care from PIH's seven Central Plateau sites greatly.

In order to facilitate the movement of goods into Port Au Prince post quake, PIH has rented a large facility in the city. It currently serves as a warehouse for goods and provides PIH with a sense of how an additional large warehouse could help with the flow of goods. PIH is uncertain whether it will continue renting this facility in the long-term. It has not been ruled out that a facility in Port au Prince could someday serve as an additional centralized warehouse.

Post-earthquake, the plans for the proposed hospital in Mirebalais accelerated quickly from a potential site to a definite site. There is also discussion of constructing a large warehouse at this site. However, at the time of the writing of this thesis, the warehouse construction plans are far from definitive.

7.3 Compounding Issues

Several intangible issues affect the PIH inventory system in Haiti, including hoarding, untimely reporting of stockouts, and political issues. PIH Boston staff considers hoarding to be an issue at the site level. If sites are uncertain if or when they will receive a stock, they will often request more than they actually need as a hedge. Hoarding has long term effects, as it skews the demand figures for that site.

Sites are also guilty of not requesting a good until its inventory is depleted, or has been depleted for some time. Not only does this create an unnecessary emergency order to be generated, but it also skews the reported demand for that product.

Political issues are another source of problems to PIH. Security problems can undermine the safe transportation between sites, and politics often influences the selection of locations for new sites.

8 Recommendations and Conclusion

8.1 Central Warehouse

Even with improved inventory policies, the current size of the second level of the central warehouse is barely large enough to support required storage of goods. One potential area for improvement would be more appropriate shelving. Use of shorter distances between shelves containing smaller items or use of a bin system could allow for additional goods to be stored on the shelves. As stated previously, the use of shelving in the central warehouse is exclusive to those items which will remain for use in the Cange complex. Based on current site usage numbers, limiting shelf usage to only the Cange site does not maximize the amount of goods that could be stored on the shelves. However, with the changes of catchment population the earthquake has brought, this may change.

Another potential area for improvement would be better usage of the lower level of the warehouse. If a portion of the lower level could be used to store the products discussed in this thesis, less aggressive inventory policies could be pursued.

8.2 IDA Order

IDA has made two offers to PIH that would improve stock keeping and stock levels. The first offer was to color code boxes of goods for PIH prior to their shipment to PIH. These color coded boxes could be used to differentiate between categories of products or intended final user (site).

IDA has also offered to decrease lead times on goods if PIH can provide a forecast to IDA with estimated needs prior to their annual order. This "heads up" would allow IDA to obtain goods before the order is finalized. PIH has been reticent to follow through with this offer, though, as it does not feel confident providing such information.

8.3 Inventory Policies

If PIH were a for-profit company in which processes could be easily changed, we would recommend shifting to a monthly periodic review policy. Ordering products every month results in a much lower inventory volume, while sacrificing less than $2000 annually in terms of additional emergency procurement costs. Furthermore, the inflow of shipping containers is much more manageable as approximately one container arrives each month, as opposed to ten containers arriving over a three to four months.

However, PIH has indicated that moving to monthly orders may be too onerous for its Haiti staff. Additionally, it is likely that the annual cost of placing and receiving orders would increase with more frequent shipments due to customs and the increased variable cost associated with sending more partially filled containers. Therefore, changing to quarterly or semi-annual review policies would be preferable to annual orders. Doing so will significantly free up warehouse space without causing an increase in emergency procurement costs. Additionally, more frequent shipments will make the warehouse more manageable and allow for easier tracking of PIH's products.

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Appendix: Additional Tables and Figures

Description	#Units	UnitQuan	Total Order	Single Volume m3	Unit Volume m3	Total Volume Order M3	Total Volume - Annual Demand M3	Unit Weight KG	Total Weight KG (in kg)	Unit Price	Price/Quantity	Total Cost	Demand09	Annual Demand/Order
Acetazolamide250mgTablet	6	1000	6,000	0.00000167	0.00166667	0.01		0.00166667	4.5	20.03	0.02003	120.18		
Acetylsalicylicacid500mgTablet	650	1000	650,000	0.00000062	0.00061538	0.40	0.00	0.00061538	117	1.95	0.00195	1,267.50	4,820	1%
Acyclovir200mgTablet	300	500	150,000	0.00000100	0.0005	0.15	0.05	0.0005	150	12.49	0.02498	3,747.00	45,694	30%
Aminophylline25mg/ml10mlAmpulle	50	100	5,000	0.00005600	0.0056	0.28	0.04	0.0056	97.4	44.17	0.4417	2,208.50	792	16%
Amoxycillin125mgBottle	1325	40	53,000	0.00042151	0.01686038	22.34		0.01686038	9010	19.33	0.48325	25,612.25		
Amoxycillin500mgTablet	3700	1000	3,700,000	0.00000256	0.00255946	9.47	4.91	0.00255946	3182	33.6	0.0336	124,320.00	1,918,142	52%
Amoxilline/AcideClav200/28.5228.5mgTablet	1000	50	50,000	0.00001560	0.00078	0.78		0.00078	125	8.72	0.1744	8,720.00		
AmphotecirineB50mgAmpulle	150	1	150	0.00006667	6.6667E-05	0.01		6.6667E-05	3	11.51	11.51	1,726.50		
Ampicillin1gOther	1500	50	75,000	0.00005573	0.00278667	4.18	2.11	0.00278667	2115	12.35	0.247	18,525.00	37,813	50%
Atenolol50mgTablet	350	1000	350,000	0.00000066	0.00065714	0.23	0.06	0.00065714	70	6.42	0.00642	2,247.00	91,529	26%
PenicillinBenzathine2.4MIUAmpulle	550	50	27,500	0.00005527	0.00276364	1.52	0.28	0.00276364	676.5	43.06	0.8612	23,683.00	5,056	18%
Acidbenzoic6%+Acidsalicilic3%40mgOther	350	10	3,500	0.00021714	0.00217143	0.76	0.19	0.00217143	218.8	4.05	0.405	1,417.50	887	25%
BenzylPenicillin5MIUAmpulle	100	50	5,000	0.00008600	0.0043	0.43		0.0043	206	43.34	0.8668	4,334.00		
CalciumGluconate10%1(item)Ampulle	50	20	1,000	0.00005000	0.001	0.05		0.001	16.5	4.26	0.213	213.00		
Captopril25mgTablet	2000	100	200,000	0.00000120	0.00012	0.24	0.67	0.00012	70	1.26	0.0126	2,520.00	557,240	279%
Carbomazepine200mgTablet	250	1000	250,000	0.00000120	0.0012	0.30	0.10	0.0012	72.5	13.82	0.01382	3,455.00	82,000	33%
Cephalexine500mgTablet	700	100	70,000	0.00000243	0.00024286	0.17	0.10	0.00024286	98	10.68	0.1068	7,476.00	43,009	61%

Figure A1: Product Details Tab

Type	Product	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
EyeCare	Gentamycineeyedrops0.3%10mlOther	2,663	2,615	2,546	2,468	2,363	2,259	2,207
EyeCare	TetracyclineHydrochloride1%5gOther	3,857	3,972	4,006	3,957	3,873	3,826	3,871
EyeCare	Timololeyedrops0.25%10mlOther	607	594	583	576	569	550	523
HIV	Abacavir300mgTablet	7,887	7,712	7,455	7,337	7,368	7,704	8,339
HIV	AZT+3TC300/1501tabTablet	1,319,751	1,316,952	1,319,746	1,328,837	1,337,826	1,352,964	1,371,495
HIV	Didanosine200mgTablet	893	902	923	936	942	922	888
HIV	Efavirenz200mgTablet	104,997	103,308	102,608	103,304	104,456	104,564	102,692
HIV	Efavirenz600mgTablet	486,545	487,788	488,935	488,963	488,710	491,811	500,794
HIV	Indinavir400mgTablet	50,470	50,530	50,555	50,617	50,658	50,369	50,069
HIV	Lamivudine150mgTablet	1,164,412	1,178,370	1,199,676	1,218,840	1,230,565	1,238,743	1,253,781
HIV	LamivudineSuspension10mg/10ml240mlBottle	967	940	930	942	969	1,013	1,070
HIV	Lopinavir/Ritonavir250mgTablet	149,829	151,352	155,013	159,650	164,618	170,173	183,493

Figure A2: Reorder Point Tab

Type	Product	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
EyeCare	Gentamycineeyedrops0.3%10mlOther	2,663	2,615	2,546	2,468	2,363	2,259	2,207
EyeCare	TetracyclineHydrochloride1%5gOther	3,857	3,972	4,006	3,957	3,873	3,826	3,871
EyeCare	Timololeyedrops0.25%10mlOther	607	594	583	576	569	550	523
HIV	Abacavir300mgTablet	7,887	7,712	7,455	7,337	7,368	7,704	8,339
HIV	AZT+3TC300/1501tabTablet	1,319,751	1,316,952	1,319,746	1,328,837	1,337,826	1,352,964	1,371,495
HIV	Didanosine200mgTablet	893	902	923	936	942	922	888
HIV	Efavirenz200mgTablet	104,997	103,308	102,608	103,304	104,456	104,564	102,692
HIV	Efavirenz600mgTablet	486,545	487,788	488,935	488,963	488,710	491,811	500,794
HIV	Indinavir400mgTablet	50,470	50,530	50,555	50,617	50,658	50,369	50,069
HIV	Lamivudine150mgTablet	1,164,412	1,178,370	1,199,676	1,218,840	1,230,565	1,238,743	1,253,781
HIV	LamivudineSuspension10mg/10ml240mlBottle	967	940	930	942	969	1,013	1,070
HIV	Lopinavir/Ritonavir250mgTablet	149,829	151,352	155,013	159,650	164,618	170,173	183,493

Figure A3: Order up to Level Tab

Type	Product	Feb-10	Mar-10	Apr-10	May-10	Jun-10	Jul-10	Aug-10
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	247	325	83	428	559	130
EyeCare	TetracyclineHydrochloride1%5gOther	324	108	215	399	323	444	487
EyeCare	Timololeyedrops0.25%10mlOther	24	0	27	94	69	32	29
HIV	Abacavir300mgTablet	753	923	659	1,317	1,026	450	954
HIV	AZT+3TC300/1501tabTablet	119,027	132,932	147,225	117,568	96,835	113,655	160,269
HIV	Didanosine200mgTablet	4	28	0	60	85	68	24
HIV	Efavirenz200mgTablet	0	16,090	9,003	0	9,321	4,197	10,412
HIV	Efavirenz600mgTablet	36,615	47,807	47,231	48,920	41,460	59,802	43,327
HIV	Indinavir400mgTablet	4,360	4,879	5,533	4,176	4,104	5,195	5,269
HIV	Lamivudine150mgTablet	128,718	105,105	94,158	138,527	113,059	120,967	49,756
HIV	LamivudineSuspension10mg/10ml240mlBo	67	78	101	126	125	144	91
HIV	Lopinavir/Ritonavir250mgTablet	15,890	17,240	20,456	13,661	20,406	8,202	11,507

Figure A4: Demand Amounts on Simulated Demand Tab

EyeCare	Gentamycineeyedrops0.3%10mlOther	0.810055	0.688397	0.809566	0.132136	0.890704	0.990337	0.273993
EyeCare	TetracyclineHydrochloride1%5gOther	0.742197	0.208592	0.349933	0.706638	0.505149	0.872906	0.903942
EyeCare	Timololeyedrops0.25%10mlOther	0.401011	0.061705	0.46552	0.910274	0.730783	0.356974	0.338519
HIV	Abacavir300mgTablet	0.938749	0.922482	0.055993	0.988498	0.791216	0.016922	0.935626
HIV	AZT+3TC300/1501tabTablet	0.738382	0.860461	0.923943	0.390339	0.08313	0.242009	0.940956
HIV	Didanosine200mgTablet	0.167493	0.350607	0.062317	0.616249	0.650636	0.420233	0.150582
HIV	Efavirenz200mgTablet	0.189817	0.868536	0.737999	0.253862	0.771121	0.566682	0.764301
HIV	Efavirenz600mgTablet	0.533664	0.847779	0.688337	0.630272	0.25394	0.942295	0.451039
HIV	Indinavir400mgTablet	0.509074	0.721611	0.928435	0.415172	0.27798	0.731457	0.800633
HIV	Lamivudine150mgTablet	0.887957	0.61416	0.414374	0.965592	0.673896	0.853068	0.010689
HIV	LamivudineSuspension10mg/10ml240mlBo	0.155608	0.149753	0.3191	0.713981	0.781603	0.984642	0.794917
HIV	Lopinavir/Ritonavir250mgTablet	0.596788	0.704034	0.907018	0.232873	0.899978	0.493852	0.7685

Figure A5: Random Numbers at the Bottom of the Simulated Demand Tab

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010	9/30/2010	10/31/2010	11/30/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	0	0	0	0	0	0	0	0	109
EyeCare	TetracyclineHydrochloride1%5gOther	0	0	0	0	0	0	0	0	0	0
EyeCare	Timololeyedrops0.25%10mlOther	0	0	0	0	0	0	0	0	0	0
HIV	Abacavir300mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	AZT+3TC300/1501tabTablet	0	0	0	0	0	0	0	0	0	0
HIV	Didanosine200mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	Efavirenz200mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	Efavirenz600mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	Indinavir400mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	Lamivudine150mgTablet	0	0	0	0	0	0	0	0	0	0
HIV	LamivudineSuspension10mg/10ml240mlBottle	0	0	0	0	0	0	0	0	0	0
HIV	Lopinavir/Ritonavir250mgTablet	0	0	0	0	0	0	0	0	0	0

Figure A6: Emergency – Monthly Orders Tab

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	2,848	2,601	2,276	2,193	1,765	1,207	1,076
EyeCare	TetracyclineHydrochloride1%5gOther	3,949	3,840	3,626	3,227	2,904	2,460	1,972
EyeCare	Timololeyedrops0.25%10mlOther	628	628	601	508	439	407	378
HIV	Abacavir300mgTablet	7,563	6,640	5,981	4,664	3,638	3,189	2,235
HIV	AZT+3TC300/1501tabTablet	1,318,285	1,185,353	1,038,128	920,560	823,725	710,070	549,801
HIV	Didanosine200mgTablet	981	953	953	893	808	740	717
HIV	Efavirenz200mgTablet	115,471	99,381	90,379	90,379	81,057	76,860	66,448
HIV	Efavirenz600mgTablet	493,492	445,685	398,455	349,535	308,075	248,273	204,946
HIV	Indinavir400mgTablet	51,105	46,226	40,693	36,517	32,412	27,218	21,949
HIV	Lamivudine150mgTablet	1,167,760	1,062,655	968,497	829,970	716,911	595,943	546,187
HIV	LamivudineSuspension10mg/10ml240mlBottle	977	899	798	672	547	403	312
HIV	Lopinavir/Ritonavir250mgTablet	152,192	134,952	114,496	100,835	80,429	72,227	60,720

Figure A7: Physical Stock – Annual Orders

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	0	0	0	0	0	0
EyeCare	TetracyclineHydrochloride1%5gOther	0	0	0	0	0	0	0
EyeCare	Timololeyedrops0.25%10mlOther	0	0	0	0	0	0	0
HIV	Abacavir300mgTablet	0	0	0	0	0	0	0
HIV	AZT+3TC300/1501tabTablet	0	0	0	0	0	0	0
HIV	Didanosine200mgTablet	0	0	0	0	0	0	0
HIV	Efavirenz200mgTablet	0	0	0	0	0	0	0
HIV	Efavirenz600mgTablet	0	0	0	0	0	0	0
HIV	Indinavir400mgTablet	0	0	0	0	0	0	0
HIV	Lamivudine150mgTablet	0	0	0	0	0	0	0
HIV	LamivudineSuspension10mg/10ml240mlBottle	0	0	0	0	0	0	0
HIV	Lopinavir/Ritonavir250mgTablet	0	0	0	0	0	0	0

Figure A8: Emergency – Annual Orders Tab

Type	Product	3/1/2010	4/1/2010	5/1/2010	6/1/2010	7/1/2010	8/1/2010	9/1/2010	10/1/2010	11/1/2010	12/1/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	0	0	0	0	0	0.03	0	0	0.042
EyeCare	TetracyclineHydrochloride1%5gOther	0	0	0	0	0	0	0.049077	0	0	0.046846
EyeCare	Timololeyedrops0.25%10mlOther	0	0	0	0	0	0	0.00096	0	0	0.00286
HIV	Abacavir300mgTablet										
HIV	AZT+3TC300/1501tabTablet										
HIV	Didanosine200mgTablet										
HIV	Efavirenz200mgTablet										
HIV	Efavirenz600mgTablet										
HIV	Indinavir400mgTablet										
HIV	Lamivudine150mgTablet										
HIV	LamivudineSuspension10mg/10ml240mlBottle										
HIV	Lopinavir/Ritonavir250mgTablet										

Figure A9: Container Arrival Tab (no volume data for HIV drugs)

Type	Product	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	0	0	500	500	500	1,200
EyeCare	TetracyclineHydrochloride1%5gOther	0	0	1,100	1,100	1,100	2,150
EyeCare	Timololeyedrops0.25%10mlOther	0	0	48	48	48	191
HIV	Abacavir300mgTablet	0	0	1,900	1,900	1,900	3,600
HIV	AZT+3TC300/1501tabTablet	0	0	394,000	394,000	394,000	689,000
HIV	Didanosine200mgTablet	0	0	100	100	100	300
HIV	Efavirenz200mgTablet	0	0	21,600	21,600	21,600	38,800
HIV	Efavirenz600mgTablet	0	0	133,400	133,400	133,400	264,200
HIV	Indinavir400mgTablet	0	0	14,800	14,800	14,800	27,800
HIV	Lamivudine150mgTablet	0	0	336,100	336,100	336,100	760,600
HIV	LamivudineSuspension10mg/10ml240mlBottle	0	0	100	100	100	500
HIV	Lopinavir/Ritonavir250mgTablet	0	0	43,400	43,400	43,400	101,600

Figure A10: In-transit Stock Tab

Type	Product	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
EyeCare	Gentamycineeyedrops0.3%10mlOther	2,095	1,848	1,523	1,940	1,512	954	1,524
EyeCare	TetracyclineHydrochloride1%5gOther	2,268	2,160	1,945	2,646	2,323	1,879	2,442
EyeCare	Timololeyedrops0.25%10mlOther	447	447	420	374	305	273	387
HIV	Abacavir300mgTablet	5,401	4,477	3,818	4,401	3,375	2,926	3,672
HIV	AZT+3TC300/1501tabTablet	846,770	713,838	566,613	843,045	746,210	632,555	767,286
HIV	Didanosine200mgTablet	645	617	617	658	572	504	681
HIV	Efavirenz200mgTablet	85,570	69,479	60,477	82,077	72,755	68,559	75,347
HIV	Efavirenz600mgTablet	320,260	272,454	225,223	309,703	268,243	208,442	295,914
HIV	Indinavir400mgTablet	32,057	27,178	21,644	32,268	28,164	22,969	30,700
HIV	Lamivudine150mgTablet	701,408	596,303	502,145	699,718	586,659	465,691	840,435
HIV	LamivudineSuspension10mg/10ml240mlBottle	728	649	548	523	398	254	563
HIV	Lopinavir/Ritonavir250mgTablet	94,765	77,525	57,069	86,807	66,401	58,199	104,893

Figure A11: Physical + In-transit Stock Tab

L=2,R=1, S=s	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
1	0	1.529094	754.9361	1108.68	2459.653	414.7972	436.8792
2	0	2.010361	951.9289	1680.435	581.424	377.669	22.93716
3	0	0	81.18212	87.11694	64.49318	169.8114	426.0513
4	0	0	145.5624	340.5019	39.81957	20.2967	568.9099
5	0	0	913.9205	915.5154	76.6351	241.9465	589.299
6	0	0	95.20619	652.0485	449.3989	1506.502	107.5392
7	0	0	485.6311	129.9745	875.6231	199.0163	181.8347
8	0	1.786065	1902.317	948.7163	560.461	54.86108	337.5746
9	0	0	129.2144	438.4999	715.1361	308.6196	631.2162
10	0	22.48213	99.81429	300.5753	88.67926	3540.932	1696.734
11	0	0.942614	1427.077	1075.555	174.6578	644.9992	76.54977
12	0	37.36208	216.8549	24.54711	438.8139	135.9448	124.1808
13	474.4279	3767.885	884.3781	1066.366	622.9787	95.81842	1056.691

Figure A12: Emergency Procurement Sims Tab

L=2,R=1, S=s	2/28/2010	3/31/2010	4/30/2010	5/31/2010	6/30/2010	7/31/2010	8/31/2010
1	148.8269	107.3425	62.15246	61.60583	55.77249	59.87705	62.79633
2	142.1537	89.74997	51.81979	57.24979	64.17462	51.63648	49.53593
3	153.7051	107.2775	71.42244	62.44629	68.00204	64.72125	72.60621
4	137.9841	89.82356	42.57616	52.34394	59.69051	61.88461	61.25429
5	140.4507	96.22331	50.82569	61.62839	61.94106	63.15993	58.51918
6	151.925	108.9685	63.24501	66.68482	61.16927	56.45975	46.06539
7	139.9142	93.56144	55.17992	64.49739	65.45464	56.28977	52.01657
8	154.7294	105.2881	56.63884	53.0896	59.05828	69.3456	66.00748
9	154.2446	101.7647	59.00005	47.15901	54.5327	49.34911	49.73985
10	149.2292	98.27845	53.35294	51.98968	61.18116	51.58056	56.95356
11	140.04	100.2181	52.88786	58.84486	52.25837	53.63829	57.45345
12	149.8751	106.0822	61.7072	59.86537	63.06185	65.2194	63.63126
13	129.4594	87.713	44.65695	59.04087	62.23452	55.53812	56.28308

Figure A13: Volume Sims Tab

L=2,R=1, S=s	3/1/2010	4/1/2010	5/1/2010	6/1/2010	7/1/2010	8/1/2010	9/1/2010
1	0	0	0.884954	0.814685	0.775654	0.748671	0.904967
2	0	0	0.897424	0.96387	0.615473	0.794902	0.685109
3	0	0	0.689938	0.852325	0.577122	0.768405	0.623926
4	0	0	0.97681	0.882392	0.792299	0.712467	0.630217
5	0	0	0.931046	0.811467	0.754297	0.641477	0.690428
6	0	0	0.723014	0.786295	0.764506	0.571067	0.785166
7	0	0	0.943488	0.846635	0.624262	0.687698	0.712333
8	0	0	0.675501	0.898234	0.811194	0.657404	0.664415
9	0	0	0.679093	0.966292	0.705791	0.802184	0.717143
10	0	0	0.775757	0.930039	0.744091	0.726779	0.627832
11	0	0	0.938562	0.728068	0.807414	0.726198	0.718958
12	0	0	0.757901	0.800544	0.741482	0.694901	0.640594
13	0	0	1.151512	0.892644	0.711669	0.72485	0.678222

Figure A14: Container Arrival Tab