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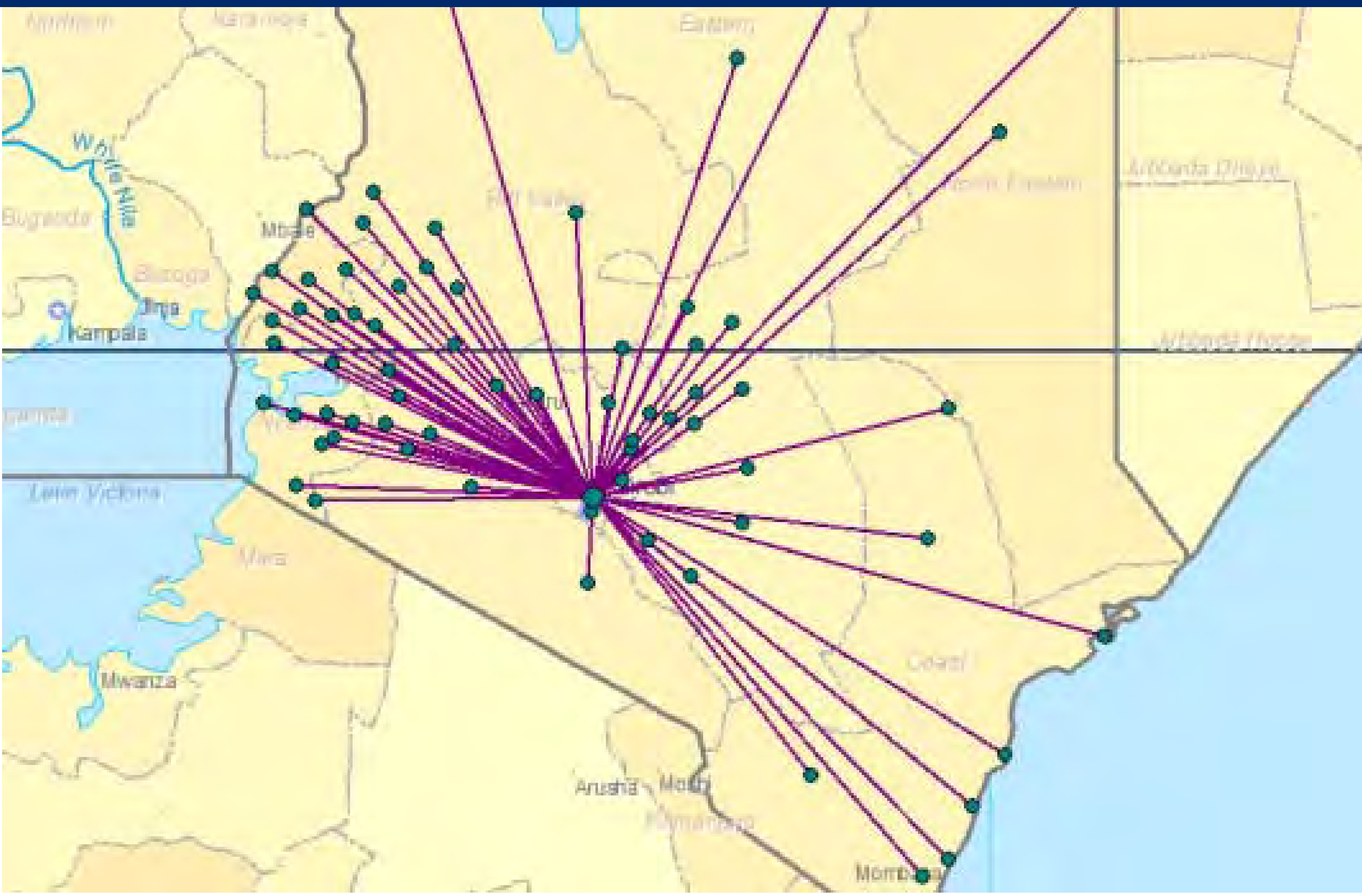
Kenya: 2020 Supply Chain Modeling

Forecasting Demand from 2020–2024



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Kenya: 2020 Supply Chain Modeling

Forecasting Demand Over 2020–2024

USAID | DELIVER PROJECT, Task Order 1
The USAID | DELIVER PROJECT, Task Order 1, is funded by the U.S. Agency for International Development under contract no. GPO-I-01-06-00007-00, beginning September 29, 2006. Task Order 1 is implemented by John Snow, Inc., in collaboration with PATH; Crown Agents Consultancy, Inc.; Abt Associates; Fuel Logistics Group (Pty) Ltd.; UPS Supply Chain Solutions; The Manoff Group; and 3i Infotech. The project improves essential health commodity supply chains by strengthening logistics management information systems, streamlining distribution systems, identifying financial resources for procurement and supply chain operations, and enhancing forecasting and procurement planning. The project also encourages policymakers and donors to support logistics as a critical factor in the overall success of their health care mandates.

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Abstract
In 2010, LLamasoft, with technical assistance from the USAID | DELIVER PROJECT, Task Order 1, developed a modeling framework to forecast public health supply chain needs and enable policymakers to strengthen the logistics situation.

Here, the model was applied to understand and analyze the current and future state (2020–2024) supply chain requirements for procuring and distributing essential medical commodities in Kenya. The developed methodology in this report can be employed in any country for any future time frame.

Cover photo: Current network structure in Kenya.

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Acronyms

3PL	third-party logistics provider
KEMSA	Kenya Medical Supplies Agency
MDG	Millennium Development Goals
PHeNOM	Public Health Network Optimization and Modeling tool
WHO	World Health Organization

Acknowledgments

The team would like to thank the staff at John Snow, Inc., for all their guidance and support. This study would not have been possible without them all. The team would also like to thank the staff of the Kenya Medical Supplies Agency for providing us with much of the data used in this project. The U.S. Agency for International Development contracts funded the technical assistance, in-country projects, and research that enabled the authors to produce the experience and lessons learned here. We are deeply grateful to the team of professionals in the Commodity Security and Logistics Division in the Office of Population, Health, and Nutrition, and the Office of HIV and AIDS who provided the support for the production of this publication.

Executive Summary

In the developing world, logistical shortcomings can have a serious impact on the quality of human health care. As such, the USAID | DELIVER PROJECT has partnered with LLamasoft, Inc., to develop a reusable modeling framework to forecast developing countries' public health supply chain needs for future time periods. The model was designed to be robust and general so that it can be applied to any country for any future time frame and provide policymakers with key data to guide effective design of their supply chain networks. Here, the framework was applied to Kenya for the years 2020 through 2024 with the goal of demonstrating how the modeling approach can be utilized to help policymakers accurately visualize and understand the most likely and possible situations facing them in 10 years.

The project objectives were accomplished by modeling the relationships between key public health variables including population, disease prevalence, and economic conditions, along with the resulting health supply material requirements. The modeling framework consisted of three separate but interlinked models: 1) a health model for predicting the location and quantity of treatable health conditions of interest in the future, 2) a material requirements model for translating the project health conditions into delivery needs for the supply system, and 3) a supply chain model that generates metrics of interest by modeling the pull and flow of generated material requirements through a defined supply chain network.

Together, the interlinked framework, which represents the three models of the system (health, material requirements, and supply chain), and a data gathering tool allow for the model to be built and applied quickly and flexibly for other scenarios, time frames, and countries. For example, a change made in the material requirements model simulating a potential future state scenario automatically cascades through to the supply chain model and is taken into account in the supply chain optimization. The data gathering template guides a modeler to extract and use the appropriate data. Substantial legwork for populating the health, material requirements, and supply chain models with accurate data has been completed as part of this project; this will reduce the time investment needed to generate these models for future projects that use the same framework.

This study found that if Kenya's network structure does not change to accommodate the growing population, the proportion of need met by the Kenya Medical Supplies Agency will decrease from 35 percent in 2010 to 28.5 percent in 2024. Multiple future state scenarios were assessed to determine in what ways the network could be restructured in a cost-effective manner to increase service levels, and the study found that the most cost-effective implementation would be to increase the number of replenishments each year. The main conclusion is that if nothing is done to address the increased demand, the majority of the public sector will not be serviced, resulting in loss of lives. As such, it is essential that stakeholders understand the importance of investing in the supply chain network and the timing of delivery.

Background

Overview

Public health supply chains deliver essential medical commodities to underserved communities in the developing world. As such, logistical shortcomings can have a serious impact on the quality of human health care. In some situations, it can literally mean the difference between life and death. By strengthening the existing supply chain systems, the availability of essential commodities to health care providers and consumers is greatly increased, resulting in improved health for communities in underserved areas. Today, with increased health needs due to the world's growing population and changing disease burdens, it is imperative that public health systems are optimized to ensure cost-effective and reliable supply chains to meet those demands.

The USAID | DELIVER PROJECT, in collaboration with LLamasoft, Inc., has undertaken the 2020 Supply Chain Modeling project as a means to develop a reusable framework to forecast developing countries' public health supply chain needs for future time periods. Here, the framework has been applied to Kenya for the years 2020 through 2024 to enable policymakers to strengthen the logistics situation. The 2020 model is designed so that it can be applied quickly to any country for any future time frame, helping policymakers to accurately visualize and understand the most likely and possible situations facing them, and to make informed decisions about how to design effective supply chains to meet those demands.

Project Objectives

The goal of this project is to predict future supply chain needs and performance metrics over a five-year period (2020–2024) in order to inform Kenyan policymakers and improve their long-range strategic planning processes. The three main objectives are—

1. To develop a general and reusable methodology for creating three interlinked models: a health model, a material requirements model, and a supply chain model.
2. To apply the health, material requirements, and supply chain models to understand and analyze the current and future state (2020–2024) supply chain requirements for procuring and distributing essential medical commodities in Kenya.
3. To determine the most robust supply chain network in Kenya by applying multiple future state scenarios to the modeling framework.

Modeling Framework

The approach for this study employed a modeling framework that consisted of three separate but interlinked models: 1) a health model for predicting the location and quantity of treatable health conditions of interest in the future, 2) a material requirements model for translating the health conditions into delivery needs for the supply system, and 3) a supply chain model that generates metrics of interest by modeling the pull and flow of generated material requirements through a defined supply chain network. Forecasting of essential health commodities was accomplished by analyzing the relationships between the three interdependent models.

Health Model

In line with the United Nation's Millennium Development Goals (MDGs) 4, 5, and 6 (child health, maternal health, and combat HIV and AIDS, respectively), the emphasis for the conditions included in the health model was on reducing child mortality, improving maternal health, and combating HIV and AIDS, malaria, and other serious diseases that have the greatest long-term detrimental effects on lifetime human potential contribution. Conditions modeled for reducing child mortality included measles, vitamin A deficiency, diarrhea, worms, and respiratory infections. Sexually transmitted infection prevalence, maternal mortality, and pregnancy and birth rates were modeled in accordance with MDG 5 to improve maternal health. HIV and AIDS, malaria, tuberculosis, and leprosy were included for MDG 6 as these are very serious diseases that can result in severe illness or death. In addition to conditions within the MDGs, selected lifestyle diseases, including cardiovascular diseases, hypertension, diabetes, and asthma, were included in the health model. It is expected that their prevalence rates will significantly increase in developing countries over the coming years. Furthermore, the World Health Organization (WHO) Global Burden of Disease work was reviewed, and the Pareto principle, also known as the 80-20 rule, was applied to this data. Greater emphasis was placed on keeping diseases in the model that represent the 20 percent of diseases that cause 80 percent of disability-adjusted life years and mortalities for the MDG region of sub-Saharan Africa.

Prevalence rates were obtained for each of the conditions described previously and broken down by age group when possible. Additionally, geocoded population data for Kenya was acquired at the district level. As the main components of the health model, the prevalence rates and population data were used to derive the number of people who need treatment for these conditions and diseases, and how the treatment should be distributed across Kenya.

Material Requirements Model

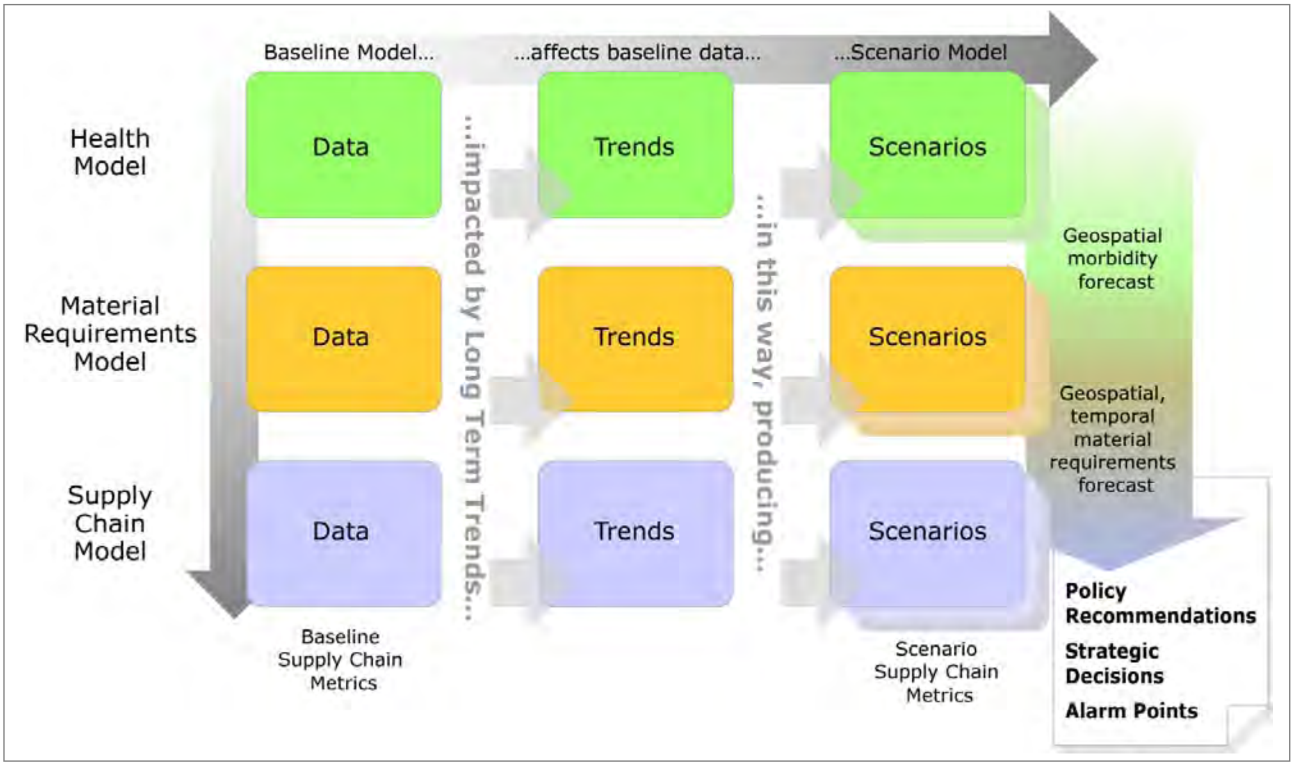
The materials for the material requirements model focus on key pharmaceuticals needed to treat a person who suffers from one of the in-scope conditions. In addition to medicines required to treat conditions, diagnostic and preventive commodities like HIV and malaria test kits, bed nets, vaccine packages, family planning commodities, and mother-child health-related items were included. Another component of the material requirements model is treatment rates for each disease; not everyone who suffers from a disease receives treatment, which needs to be taken into account when determining the overall material needs for a country. An additional bundle of essential medicines was also determined to be required to cover other disease and conditions not identified specifically. For each included health commodity, the price, quantity, weight, and volume were used as characteristic definitions.

Supply Chain Model

The supply chain model was defined by the following parameters: procurement and supply chain financials (warehouse operating, administrative, labor, and transportation), supply chain configuration (warehouse location, available warehouse space and capacity, and transportation capacity), and service requirements (percentage of need satisfied, and service distance and hours). The network was modeled at an aggregated district level based on demand-driven flows of the material needs that are determined through the material requirements model. Overall supply chain budget can be modeled both as a constraint and as a variable to be tested.

With this approach, observed trends for any of the three models of the framework can be easily incorporated to create different scenarios and compare the overall effects on the supply chain model outputs. The framework is illustrated in figure 1.

Figure 1. Visual Overview of the Interdependent Model Framework, Which Utilizes a Country's "Health State" to Determine Supply Chain Recommendations by Taking into Account Observed or Expected Trends



Future State Scenario

In this study, two main questions were considered for future state analyses. First, if the network structure does not change from its current operating state, how will this affect the service levels in 2020–2024? Additionally, what budget will be necessary for procurement and supply chain operations? Second, if the network was to change to meet the needs of the Kenyan population, what are ways to restructure the network in a cost-effective manner that increases service levels? Multiple options were considered, and those researched included 1) increased replenishment rate, 2) expansion of the central warehouse, 3) additional tier in the supply chain (i.e., regional warehouses), 4) Kenya Medical Supplies Agency (KEMSA)-owned fleet rather than using third-party logistics providers (3PLs), and 5) assessing multiple variables simultaneously.

Methodology

Overview

The project team first collected the required data from available sources to use as inputs for the health, material requirements, and supply chain models, which together makeup the modeling framework. The team then determined the necessary assumptions for both the baseline and future state scenarios. Next, the Public Health Network Optimization and Modeling (PHeNOM) tool, a rapid supply chain optimization and analysis tool developed by LLamasoft, Inc., was employed to determine the key supply chain, service, and financial metrics for the baseline and future state supply chain scenarios. Finally, the results were analyzed and summarized.

Data Collection

The following data was collected for Kenya to be used as inputs for the health model, material requirements model, and supply chain model.

Health Model

Census data for 1999 and projections for 2000 to 2010 available from the Kenya National Bureau of Statistics were used to predict the expected Kenyan population for the years 2020–2024. The census data is available down to the district level (Kenya had 69 districts in 1999) and is split by gender and age. The population numbers for 2010 and 2020 by district can be found in Appendix A.

The prevalence rates for the in-scope conditions were taken from sources such as the Kenyan Ministry of Public Health and Sanitation, WHO and U.S. President's Emergency Plan for AIDS Relief reports, peer-reviewed publications, and conference abstracts. An overview of the resources used and a description of what the rate/number represents for each condition are listed in Appendix B; the actual numbers for the prevalence rates by region can be found in Appendix C.

The number of cases for a certain condition was then calculated from the prevalence rates and projected population data. Appendix D is an example of these results, listing the number of cases by district in 2020 for HIV, tuberculosis, and malaria.

Material Requirements Model

The material requirements model is a compilation of all the information needed to derive a country's health supply needs from its health model. This entails gathering data on what treatment a person with an in-scope condition should receive, as required by age and gender. Appendices E, F, G, and H summarize the material requirements model. Appendix E contains the resources used for the model, Appendix F lists the treatments for each condition, the assumptions made for the material requirements are gathered by condition in Appendix G, and Appendix H lists the assumed treatment rates by condition for 2010 and 2020–2024.

The total material needs of a country were then calculated based on the health model and the treatments from the material requirements model. The treatment rates were applied to predict the total forecasted demand.

Supply Chain Model

The Kenya public health supply chain is operated by KEMSA. From previous LLamasoft in-country work in Kenya and KEMSA data, it is known that there is currently one central warehouse where supplies are imported, which has been at capacity since 2009. In addition to the central warehouse, there are eight smaller warehouses (depots) in the capital cities of the regions (provinces); however, these are mainly used to store larger pieces of equipment. All transportation occurs through 3PLs as KEMSA does not own its own vehicle fleet.

In order to build the Kenya supply chain model, the following data elements were gathered. First, latitude and longitude values for the district capitals were obtained and used for distance calculations and to distribute medical supplies based on population (using the population data gathered in the health model). Next, the volume and weight for one package of each commodity in the material requirements model was determined as well as the commodity cost. When available, this was taken from the historical shipment data; for those not available, the International Drug Price Indicator Guide (Management Sciences for Health 2008), Logistics Fact Sheet: ARV Drugs (DELIVER 2008), or Logistics Fact Sheet: HIV Test Kits (DELIVER 2008) were used.

Historical shipment data for the year 2009-2010 was provided by KEMSA, detailing the amount and value of commodities shipped out of the central warehouse by date. This data was used to 1) create an additional commodity in the supply chain model that represents the other essential medicines which are not yet specifically modeled as part of the disease- and program-specific commodities identified in the material requirements model, 2) determine what fraction of commodities go down to the lowest level of the supply chain (modeled as the district capitals in the supply chain model) and which commodities stay at a higher echelon (modeled as the region capitals in the supply chain model), and 3) calculate the 2009 average fill rate of orders, which is between 60 percent and 70 percent.

Additionally, an itemized budget for the logistics operations in 2009-2010 was obtained from KEMSA and included administrative, transportation, warehousing, order management, inventory, and procurement costs. The KEMSA budget was used to 1) derive 3PL transportation costs, on a per cubic meter per kilometer basis; 2) calculate the cost to lease a square foot of warehouse space; 3) determine the average handling rate with which items are received and shipped by an employee at the central warehouse; and 4) calculate the per unit administrative cost associated with ordering commodities. The historical shipment and itemized budget were used to calibrate and validate the model that was built for 2010, which functions as the baseline to compare the results for the 2020–2024 future state models.

Baseline and Future Projection Assumptions

General Assumptions

The following assumptions were made across the modeling framework:

- The exchange rate for Kenyan shilling to U.S. dollar was assumed to be 81.8:1, which was the rate as of June 4, 2010.

- No inflation is assumed so that the monetary values reported in the model reflect constant prices.

Health Model Assumptions

The following assumptions were made across the health model framework:

- Population growth rate was assumed equal for all districts.
- Current condition prevalence rates were assumed for 2020–2024.

Material Requirements Model Assumptions

The following assumptions were made across the material requirements model framework:

- The assumptions made for treatments by condition are summarized in Appendix G.
- The treatments (number of tablets/vials of medicine per person per year) are assumed to be the same between the baseline and 2020–2024, with the exception of the assumption that a new vaccine package that is bulkier and more expensive will be used for 2020–2024.
- Based on *The Business of Health in Africa* (International Finance Corporation 2008), 50 percent of health supply needs in sub-Saharan countries is fulfilled by the private sector and the other 50 percent by the public sector. Due to KEMSA's fill rate of 60 percent to 70 percent (calculated from historical shipment data), it is assumed that KEMSA currently fulfills 35 percent of the country's total need.

Supply Chain Model Assumptions

The following assumptions were made across the supply chain model framework:

- The derived per square foot warehouse leasing cost is used for the central warehouse and any new warehouses considered in the 2020–2024 scenarios.
- The derived administrative cost per commodity unit is applied at the central warehouse in the baseline and future state scenarios; however, it is not applied at any regional warehouses considered in future state scenarios.
- The derived 3PL transportation rate is used for both the baseline and future state scenarios for which 3PLs are considered.
- The derived handling rate is used in the future state scenarios at the central warehouse and any new warehouses that are considered.
- Warehouse employee annual wages are estimated at US$9,700 based on wages from WHO-Choosing Interventions that are Cost-Effective: 10 percent of logistics supply manager wage plus 90 percent of logistics storekeeper wage.
- Vehicle driver annual wages are estimated at US$7,700 based on wages from WHO-Choosing Interventions that are Cost-Effective: 10 percent of transportation manager wage plus 90 percent of driver wages.
- For future state scenarios where a KEMSA-owned vehicle fleet is considered, the vehicle characteristics are summarized in Appendix I.

Quantification Analysis

First, using PHeNOM, a public health–oriented supply chain modeling and optimization tool developed by LLamasoft, Inc., the modeling framework was used to generate a baseline set of metrics given current conditions and the most likely expected trends based on current trajectories. The baseline was used to analyze how the system is currently operating. It is important as a first step to validate that the model is able to reproduce current conditions so that the future state scenarios can be run with confidence. It was necessary to consider donated commodities in the baseline model to calculate the current state costs. The model included 69 district facilities and 130 total products.

Next, the modeling framework was reapplied under a scenario analysis approach, with key variables adjusted and relationships tested, in order to forecast a range of possible future state supply chain metrics utilizing a variety of possible conditions. For each scenario, there were three main types of output: financials, service metrics, and supply chain metrics. The financial metrics include supply chain costs (transportation, vehicle, facility operating, warehousing, and administrative), procurement costs, safety stock investment, and supply chain cost rate (percentage of supply chain cost compared with value of delivered goods). The supply chain cost rate begins to examine the effectiveness of a supply chain; in other words, how the supply chain costs compare to the value of goods that is flowing through this supply chain. However, it is only useful if there is a baseline value or data from multiple scenarios to compare.

The service metrics include met and unmet need, warehouse in-stock fill rates, service time and distance to the customers, delivered value (value of goods delivered countrywide), and delivered value per person (delivered value divided by the country's population).

Lastly, supply chain metrics contain warehouse data (type, number, location, size, number of employees, and cost), vehicle data (number, number of drivers, and cost), and safety stock levels needed to reach in-stock fill rates. The output metrics from the future state scenarios were analyzed and consolidated to provide actionable information for policymakers, who can in turn make decisions and plans that encourage one set of metric outcomes and potentially avoid other less desirable sets.

A description of the outputs the framework generates and what is included in each output is detailed in Appendix J.

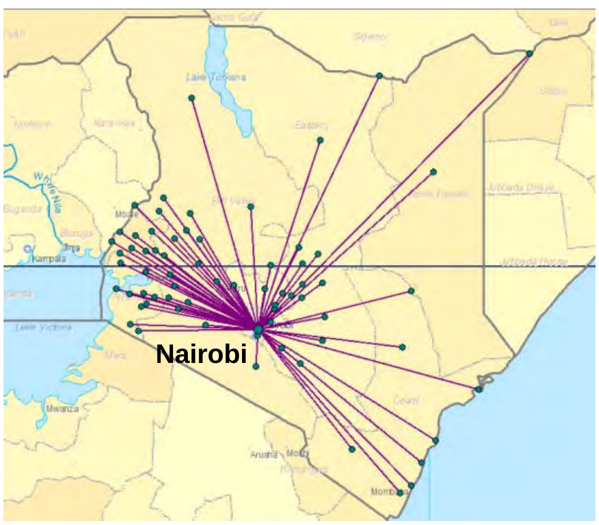
Key Findings

Baseline Analysis

The first step in any modeling exercise is to provide a benchmark for the software and verify that the tool can reproduce the known data. Once the software is able to meet this requirement, the user can have confidence in the tool's ability to predict future state scenarios. PHeNOM was validated for the Kenyan 2020 project by building a model using known 2009-2010 data and comparing the model outputs to 2009-2010 actual metrics (provided by KEMSA). The supply chain warehouse space was calibrated to its actual value and as previously mentioned, it was assumed that this public health network serves 35 percent of the population.

Figure 2 depicts the current network structure in Kenya. The central warehouse is located in Nairobi, which delivers products directly out to the districts (these lanes are represented by purple lines). As illustrated by the greater number of district warehouses, the majority of the Kenyan population is focused in the south/southwest of the country.

Figure 2. Current Network Structure in Kenya



As shown in table 1, the supply chain costs predicted by PHeNOM range from within 0.0 percent to 2.9 percent of the actual cost, and the total cost is within 1.7 percent. The numbers indicate that the assumptions used in the model are valid and PHeNOM is capable of reproducing the 2009 current state in Kenya. This analysis also demonstrates that the largest cost currently facing KEMSA is transportation at 46.3 percent of the current budget. This is nearly double the second largest cost (facility at 25.0 percent). The calculated supply chain metrics for the baseline model are provided in table 2. The delivered value is much higher than the total procurement cost because HIV, malaria, and tuberculosis medicine was donated by various organizations. Procurement cost captures only the cost of commodities actually paid for by KEMSA; delivered value also includes the value of the donated goods. The delivered value per person and supply chain cost rate will be compared to future state scenarios. The cost to procure the medicine and diagnostic and preventive commodities in 2009-2010 was quite high at U.S.$72 million.

Table 1. Baseline Supply Chain Cost Comparison

	PHeNOM Output	Percent of Total Budget (%)	KEMSA Data	Percent Difference Predicted versus Actual (%)
Total transportation cost	US$2,624,702	46.3	US$2,704,126	2.9
Total facility cost	US$1,414,500	25.0	US$1,414,463	0.0
Total administrative cost	US$269,306	4.7	US$272,406	1.1
Total warehousing cost	$1,359,146	24.0	$1,375,891	1.2
Total supply chain cost	**$5,667,654**	-	**$5,766,886**	1.7

Table 2. Baseline Supply Chain Metrics

Total safety stock investment	US$12,170,104.40
Total procurement cost	US$72,771,526.44
Delivered value	US$287,137,385.66
Delivered value per person	US$7.17
Supply chain cost rate (%)	1.97

Future State Analysis

The following future state scenarios explored two key questions. First, if the network structure does not change from its current operating state but the population continues to grow over time, how will this affect the service levels? Second, how can the supply chain network be restructured to account for additional demand and increased service levels? Multiple options were considered and included: 1) increased replenishment rate, 2) expansion of the central warehouse, 3) additional tier in the supply chain (i.e., regional warehouses), 4) KEMSA-owned fleet rather than using 3PLs, and 5) assessing multiple variables simultaneously.

Network Structure Remains the Same

The first future state scenario examined how population growth in 2020–2024 would affect service level if the supply chain network structure remained unchanged. The Kenyan population was predicted for the years 2020–2024 using projections from historical data; the population is expected to increase from 19.1 percent to 25.1 percent, from 40.0 million in 2010 to 49.5 million in 2020, 50.5 million in 2021, 51.5 million in 2022, 52.4 million in 2023, and 53.4 million in 2024. Figure 3 shows the proportion of the population's need that will be served by KEMSA in 2020–2024 if the network remains the same. As illustrated in the graph, the need satisfied by KEMSA will decrease from 35 percent in 2010 to 28.5 percent in 2024. Hence, only 28.5 percent of the Kenyan population will receive life-saving medicine and diagnostic and preventive commodities through the public sector. The 71.5 percent (38.2 million people) not served by KEMSA in 2024 will have to receive service from the private sector or will not receive health care at all.

Figure 3. Supply Chain Metrics for 2010 and 2020–2024

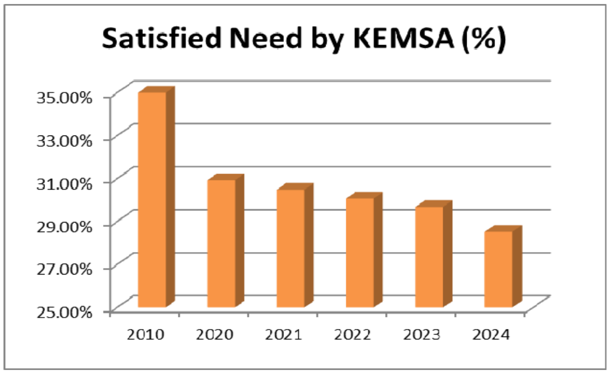


Figure 4A shows the delivered value per person for 2020–2024 compared to the baseline state in 2010. As expected, the delivered value per person decreases from US$7.17 in 2010 to US$6.82 in 2020 and continues to decrease over the next four years. Although demand is increasing, the throughput of products remains the same. Figure 4B demonstrates the delivered value for 2010 and 2020–2024. This graph is a bit misleading in the respect that it shows the delivered value increasing over time. In reality, this is an artifact of the modeling software; the tool optimizes on revenue so it chooses commodities with the highest revenue but lowest cost to deliver. However, it does demonstrate a real-world situation. If the network does not change to accommodate the increased demand, there will not be enough space to house all of the necessary commodities nor will there be enough budget for procurement of the goods or supply chain costs to push the goods through the network. As such, it will be necessary for KEMSA to choose which commodities to procure, and a decision will be made that will neglect a certain group or groups.

This point is illustrated in table 3, which shows the commodities for which KEMSA meets less than 25 percent of the need in this scenario (for some commodities, the need met by KEMSA decreases even more than the aggregated need met by KEMSA of 28.5 percent). Hence, in this situation, a patient that required aminophylline as an asthma treatment would not receive it. In this analysis, the PHeNOM tool has dealt with the issue of supply chain infrastructure that cannot serve all demand by choosing to distribute products that have the highest value. In reality, this situation shows that, without investment to increase supply chain capacity, government officials will face increasingly difficult choices about which populations to serve and which conditions to treat.

Figure 4. Supply Chain Metrics for 2010 and 2020–2024

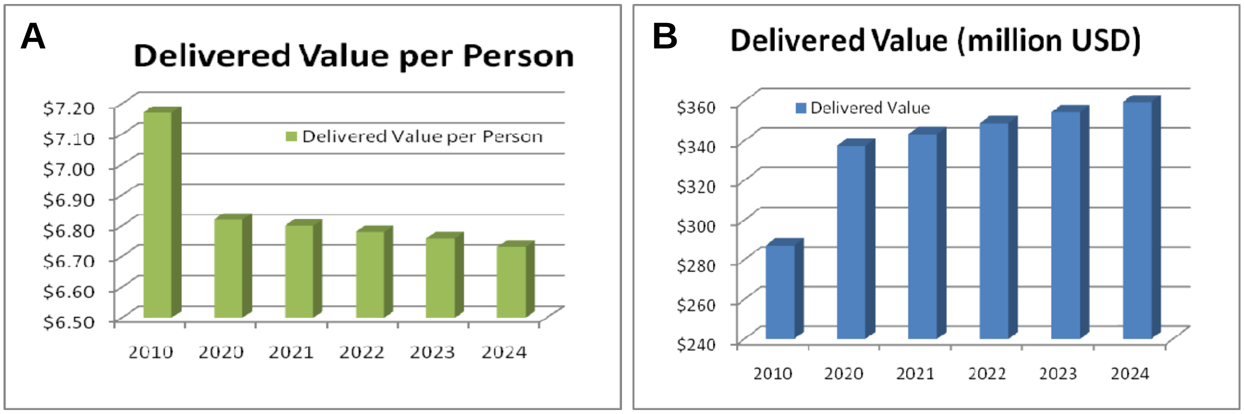


Table 3. Commodities Resulting in an Unmet Need of 75 Percent or Greater

Commodity	Condition	Proportion of Need Served by the Kenya Medical Supplies Agency
Aminophylline 25 mg/mL, 10 mL	Asthma	0
Determine HIV rapid test kits, 100 tests	HIV and AIDS	0
Stavudine 30mg/lamivudine/nevirapine (30 mg/150 mg/200 mg), 60 tabs/bottle	HIV and AIDS	4
Salbutamol 2 mg/5 mL, 100 mL, syrup	Respiratory infection/asthma	11
Zidovudine 150 mg, 100 caps	HIV and AIDS	14
Cotrimoxazole 240 mg/5 mL, 100 mL	HIV and AIDS/respiratory infection/diarrhea	14
Other essential medicines	Other	14

The total procurement and supply chain costs for 2024 were calculated by PHeNOM and found to be U.S.$359.54 million and U.S.$5.76 million, respectively. To compare back to the current 2009-2010 costs (U.S.$72.77 million for total procurement and U.S.$5.67 million for supply chain costs), the supply chain cost remains relatively the same (this is expected as the network has not changed and remains at maximum capacity) while the procurement cost increases by U.S.$286.77 million. The procurement cost is higher because it is assumed that commodities will not be donated as they were in 2009 and that KEMSA must pay for all commodities. This demonstrates that even if more supplies are procured or donated, they will not be delivered without investment in the network structure. If the need is not being met now and the proper investment is not made in supply chain costs, it will not be possible to fulfill an even greater need (which will occur due to population growth). It is important to not only push supplies into the country but also to invest in the supply chain network to handle the increased demand flow.

Restructuring the Supply Chain

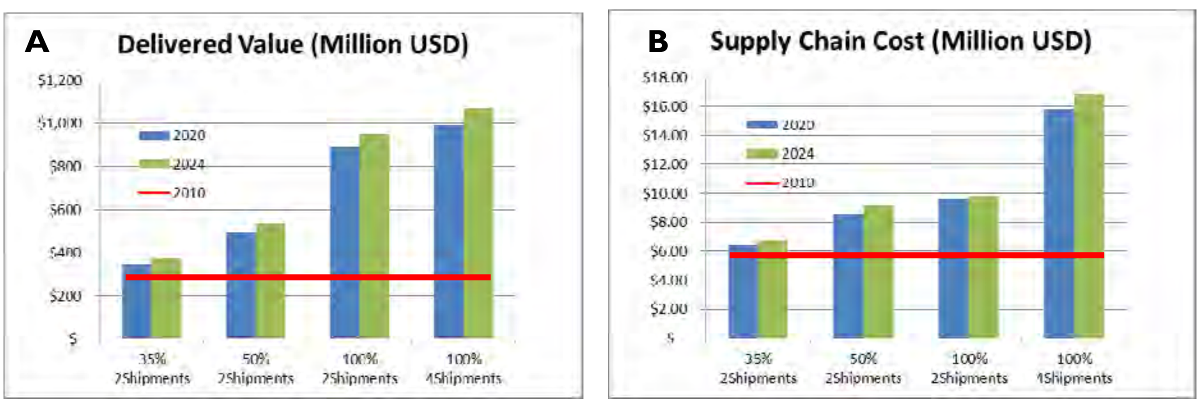
The following future state scenarios (2020–2024) examined the effect of restructuring the current network structure to account for the additional demand flowing through the system. In the scenarios, fulfilling 35 percent, 50 percent, or 100 percent of the countrywide need was utilized.

Increased Replenishment Rate

In the current situation, KEMSA receives a shipment of goods once per year and stores the commodities in the central warehouse in Nairobi. Here, the effect of increased replenishments, two or four yearly shipments, in 2020–2024 was examined. When fulfilling 35 percent or 50 percent of the demand, only two shipments are necessary per year. For a requirement of 100 percent demand, if two shipments are utilized, only 63 percent to 66 percent (2020–2024) of the need will be satisfied. Hence, 33 percent to 37 percent of the Kenyan population will not receive essential life-saving medicine and diagnostic and preventive commodities. However, 100 percent of the demand can be fulfilled if four shipments are utilized.

Figures 5A and 5B demonstrate the delivered value and supply chain cost as compared to the baseline (2010). It was determined from the baseline model (2010) that the total logistics cost is currently US$5,667,654. As such, there is a need for a 17 percent, 38 percent, and 42 percent investment into the supply chain logistics cost to meet 35 percent, 50 percent, and 100 percent of demand in 2024, respectively. Data is provided for 100 percent demand and two shipments in figure 5, but this does not provide the full picture as four shipments would be necessary to actually fulfill 100 percent demand. This scenario demonstrates the importance of investing in the supply chain and the timing of delivery.

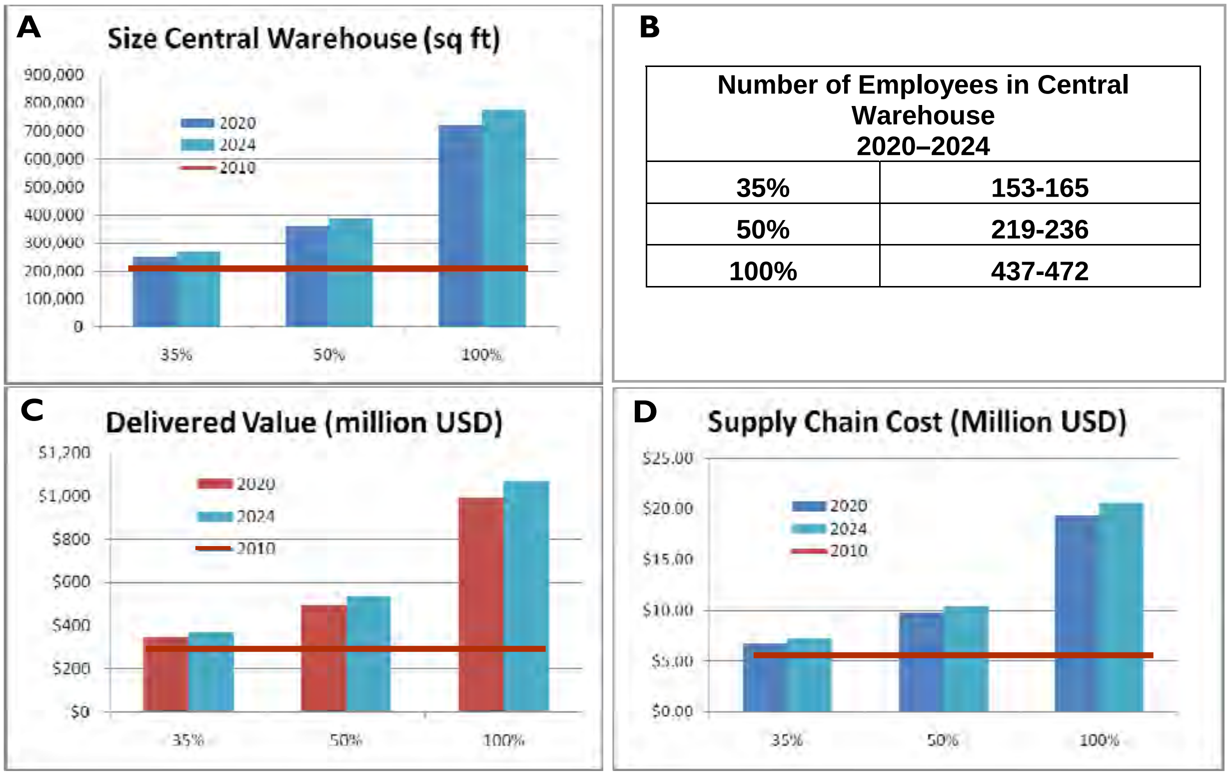
Figure 5. Supply Chain Metrics for 2010 and 2020–2024



Central Warehouse Expansion

In this scenario, the effect of allowing the central warehouse to expand and accommodate 35 percent, 50 percent, and 100 percent of the 2020–2024 predicted demand was examined. All other aspects of the network remained as is. The current size of the central warehouse is 204,894 square feet; however, it is already at capacity. Figure 6A shows the increase in the central warehouse that is necessary in order to meet 35 percent, 50 percent, and 100 percent of the need of the Kenyan population. For 35 percent, it must be expanded 22 percent (average over 2020–2024); for 50 percent, an expansion of 45 percent is necessary (average over 2020–2024); to meet 100 percent of the need, 75 percent growth is required (average over 2020–2024). From this data, it is apparent that in order to meet the increased need, the central warehouse needs to expand significantly. PHeNOM also predicted the number of warehouse employees that would be required to ensure the warehouse is running efficiently at the increased capacity, as provided in figure 6B. Figures 6C and 6D show the delivered value and supply chain cost as compared to the baseline (2010). As in the previous scenario, it is apparent from the increased supply chain cost that it is necessary to invest in the supply chain network in order to fulfill the future state demand.

Figure 6. Supply Chain Metrics for 2010 and 2020–2024



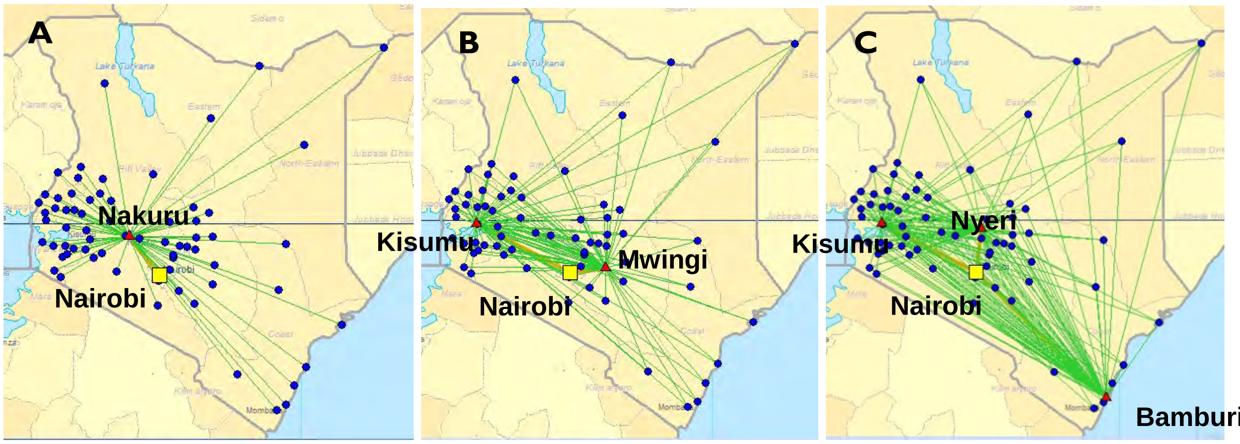
Number of Employees in Central Warehouse 2020–2024	
35%	153-165
50%	219-236
100%	437-472

Addition of Regional Warehouses

The next scenario examined the benefits of adding regional warehouses to the network. In this "decentralized" supply chain structure, the goods are first delivered to the central warehouse in Nairobi and then flow through regional warehouses rather than directly to the districts. This creates an intermediary holding facility, reducing the amount of supply stored at the central warehouse. From the regional warehouses, all shipments are routed to the districts. There can be multiple benefits to adding regional warehouses. First, there is the ability to pool products from central to regional warehouses on larger trucks rather than utilize more frequent shipments on smaller trucks, which can lower the transportation cost. Second, as the regional warehouses are, for the most part, closer to the districts than the central warehouse, a decentralized network would move stock closer to the population, reducing the service distance and hence, delivery times.

A "greenfield" analysis was conducted to determine the optimal location for one, two, or three regional warehouse(s) based on the overall demand in the network. The analysis determined that Nakuru would be the ideal location if only a single warehouse were to be added (figure 7A), Kisumu and Mwingi if two warehouses were utilized (figure 7B), and Kisumu, Nyeri, and Bamburi if three warehouses were added (figure 7C). However, the feasibility of the locations would be dependent on land availability and economic and political considerations, which are beyond the scope of this study. An interesting finding is that the location of all the regional warehouses is predicted to be concentrated in the south of the country. This is not too surprising, however, because the majority of the Kenyan population is focused in the south/southwest of the country.

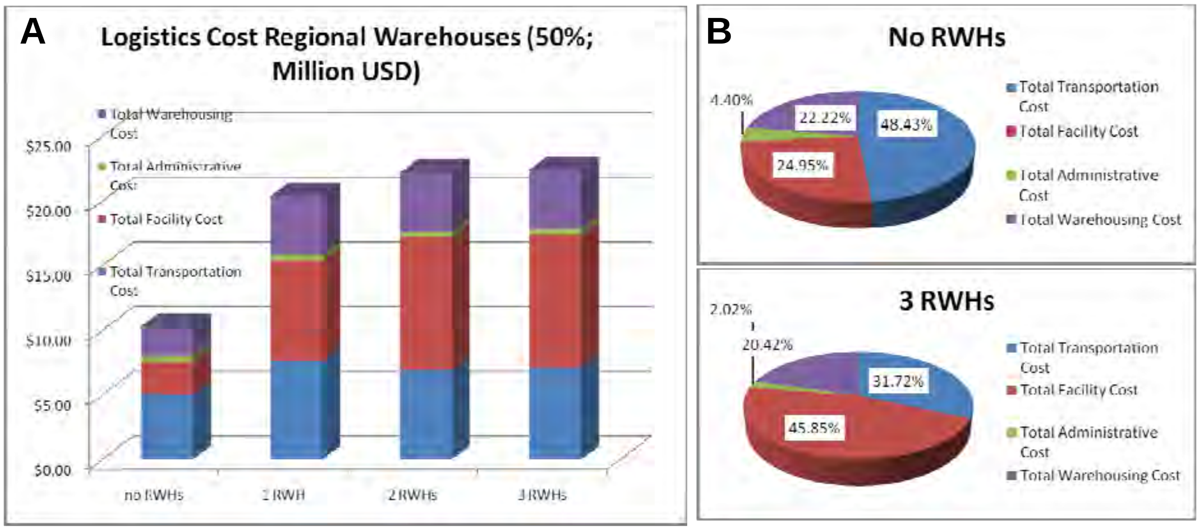
Figure 7. Results of Greenfield Analysis



Central warehouse is shown in yellow, predicted regional warehouses in red, and district customers in blue. The green lines indicate the flow of demand from the central warehouse to the regional warehouses to the districts. A) Location of a single regional warehouse. B) Location of two regional warehouses. C) Location of three regional warehouses.

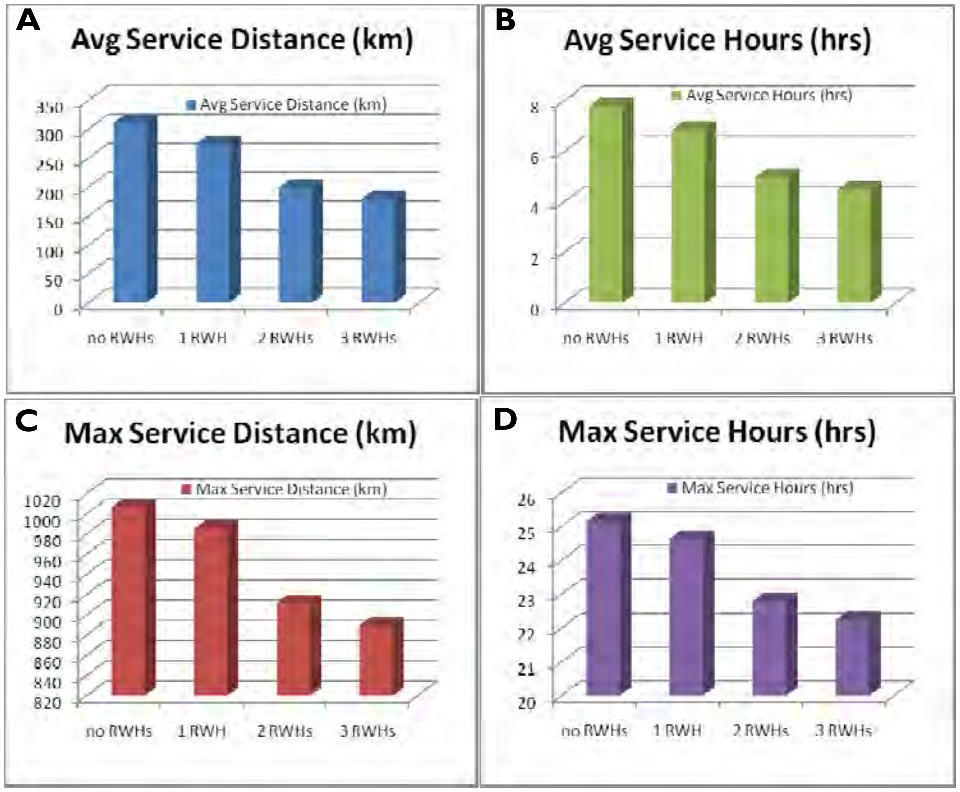
Figures 8A and 8B provide the supply chain financials for the baseline (no regional warehouses) compared to future state scenarios with one, two, or three regional warehouses being utilized in the network. For this scenario, only fulfilling 50 percent of the countrywide need was examined. As shown in figure 8A, the total logistics cost almost doubles between the baseline (no regional warehouse) and when a single regional warehouse is utilized. However, there is marginal cost difference between adding a single regional warehouse compared to two or three regional warehouses. In figure 8B, the percentage for each component of the logistics cost is given for the baseline versus three regional warehouses being utilized; the largest cost shifts from transportation in the baseline to facility costs when regional warehouses are added.

Figure 8. Supply Chain Financials for Baseline and Adding Regional Warehouse Scenarios



To determine if the large investment necessary for the addition of regional warehouses is worthwhile, the resulting supply chain service metrics were examined. The average service distance and hours for the baseline compared to the three regional warehouse scenarios is provided in figures 9A and 9B, and the maximum service distance and hours is provided in figures 9C and 9D. As demonstrated by this data, the service levels do not improve significantly with the addition of intermediate facilities. Hence, the marginal service improvements do not justify the large investment necessary for the supply chain logistics. LLamasoft's experience in other countries, in addition to these results, suggests that country size is a good indicator of whether an additional warehouse layer would be beneficial to the supply chain network. Based on this analysis, Kenya is not large enough to justify the investments needed for additional intermediate facilities.

Figure 9. Supply Chain Service Metrics for Baseline and Adding Regional Warehouse Scenarios



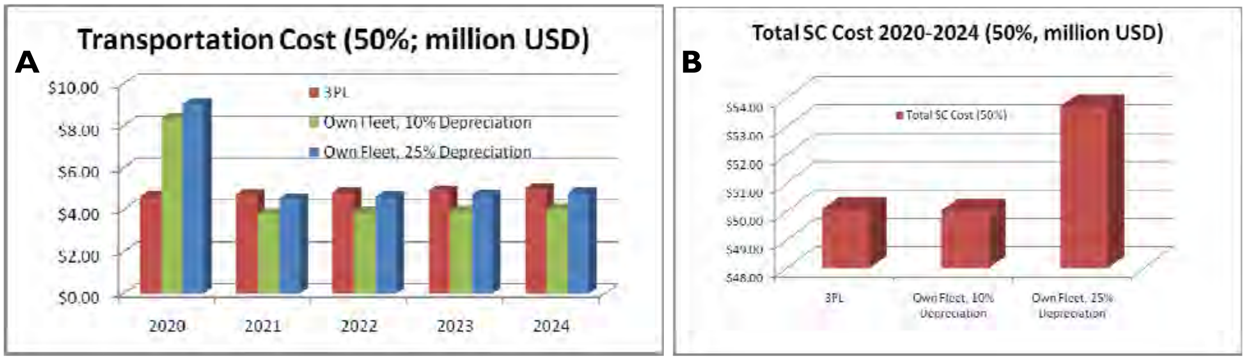
Kenya Medical Supplies Agency–Owned Fleet

In the current supply chain network, the largest cost facing KEMSA is transportation between the central warehouse and districts. To date, a 3PL is being utilized to deliver the goods. Here, it was assessed whether it is beneficial for KEMSA to own a vehicle fleet. For this scenario, only fulfilling 50 percent of the countrywide need was examined.

Figure 10A shows the transportation cost required for 3PLs and a KEMSA-owned fleet over 2020–2024. For the KEMSA-owned fleet, two depreciation rates were examined: 10 percent and 25 percent. In the best operating conditions, the vehicle fleet is well maintained, drivers are highly trained, and roads have been improved. However, in reality this is rarely the case in sub-Saharan Africa, and a higher depreciation rate such as 25 percent is more applicable. In this study, both 10 percent and 25 percent were examined to determine the cost effects of depreciation over time. The motivation was to assess the savings that could result from better maintenance of the vehicles, in addition to providing information on the cost of KEMSA owning its own vehicle fleet.

As shown in figure 10A, there is a large upfront investment to own a vehicle fleet, but it becomes cost-effective over time. If the vehicles are well maintained and a 10 percent depreciation rate can be assumed, it is actually cheaper over time for KEMSA to own its own fleet rather than outsourcing to a 3PL. PHeNOM also calculated that it would be necessary for KEMSA to purchase 99 to 107 vehicles and employ 94 to 102 drivers. As demonstrated by figure 10B, the total supply chain costs summed over five years, maintenance of the vehicle fleet is extremely important. If a 25 percent depreciation rate is assumed, there is a US$3.7 million difference over five years from the 10 percent depreciation rate data, and the cost savings versus 3PL transportation becomes negligible.

Figure 10. Supply Chain Metrics



A breakdown of the transportation cost is provided in table 4. In 2020, for the KEMSA-owned fleet, the largest component is the vehicle purchase (56 percent of the cost for 10 percent depreciation; 52 percent of the cost for 25 percent depreciation); fuel cost is second (24 percent of the cost for 10 percent depreciation; 22 percent of the cost for 25 percent depreciation). However, in 2024, fuel cost becomes most expensive as the vehicle cost significantly drops after the initial investment was made (53 percent of the cost for 10 percent depreciation; 44 percent of the cost for 25 percent depreciation). So, while there is a large cost associated with owning a vehicle fleet in the first year to purchase the vehicles, this becomes a cost-effective option for KEMSA as long as the vehicles are properly maintained over time. If the vehicles are not properly maintained, then the currently employed 3PL option is relatively the same cost. Experience of publicly owned transport fleets suggests that maintenance is typically a weakness in the public sector.

Table 4. Comparison of Transportation Cost Components (U.S. Dollars)

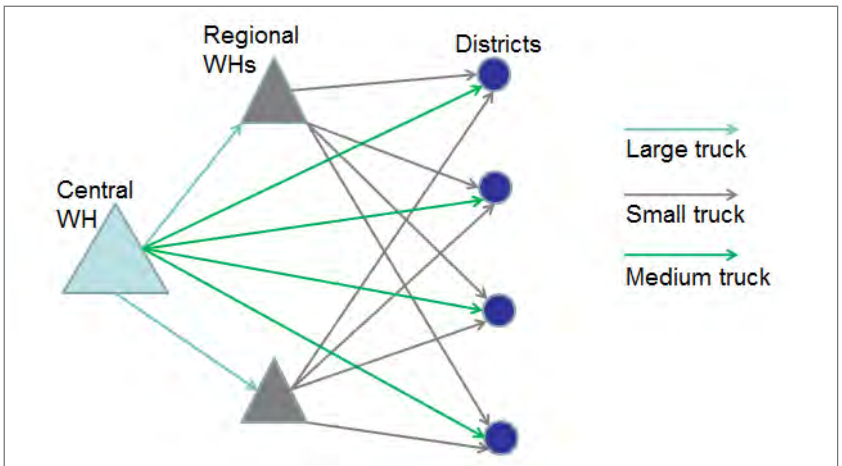
2020	Third-Party Logistics Provider (3PL)	Own Fleet, 10 Percent Depreciation	Own Fleet, 25 Percent Depreciation
3PL	$4,619,254		
Vehicle purchase		$4,708,559	$4,708,478
Vehicle fixed cost		$936,755	$1,643,011
Vehicle fuel cost		$1,962,488	$1,962,454
Vehicle driver wages		$726,498	$726,486
Total transportation cost	**$4,619,254**	**$8,334,300**	**$9,040,429**

2020	Third-Party Logistics Provider (3PL)	Own Fleet, 10 Percent Depreciation	Own Fleet, 25 Percent Depreciation
2024			
3PL	$4,988,436		
Vehicle purchase		$97,379	$97,291
Vehicle fixed cost		$1,011,623	$1,774,324
Vehicle fuel cost		$2,119,335	$2,119,298
Vehicle driver wages		$784,562	$784,548
Total transportation cost	**$4,988,436**	**$4,012,899**	**$4,775,461**

Assessing Multiple Variables

In the final scenario, three variables were examined in combination: addition of regional warehouses, multiple replenishment schedule (six shipments per year), and a KEMSA-owned fleet (small-, medium-, and large-sized trucks; 10 percent depreciation rate of the vehicles). For this scenario, only fulfilling 100 percent of the countrywide need was examined. Figure 11 shows a graphical representation of the future state network. PHeNOM was allowed to choose between two delivery methods: 1) central warehouse directly to districts (on medium-sized trucks) and 2) central warehouse to regional warehouse (on large-sized trucks) to districts (on small-sized trucks). The different transportation lanes are colored according to the size truck being utilized.

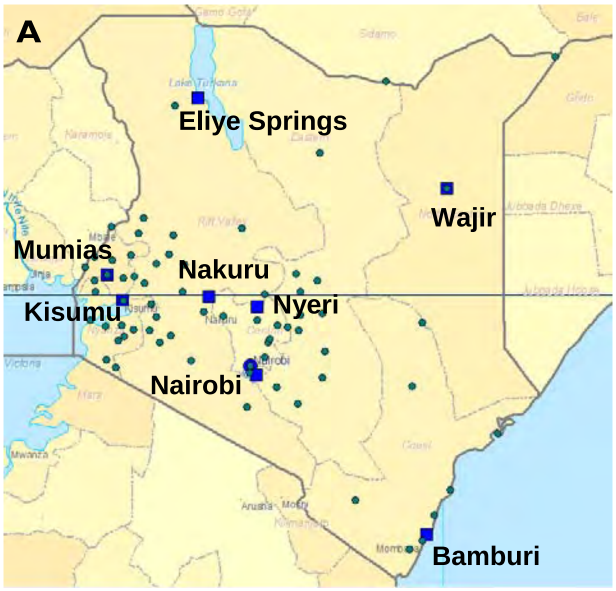
Figure 11. Future State Supply Chain Network



WH - warehouse.

A greenfield analysis was again conducted to determine the optimal locations for regional warehouses based on the overall demand in the network. In this scenario, eight regional warehouses were assessed but only seven were utilized by PHeNOM (Nyeri, Nakuru, Kisumu, Mumias, Eliye Springs, and Wajir), as shown in figure 12A. As previously mentioned, the feasibility of the locations would be dependent on land availability and economic and political considerations, which are beyond the scope of this study. Warehouses were added in the north part of the country, unlike the previous scenario. The size of each warehouse is provided in figure 12B. As expected, the largest warehouse is the central warehouse in Nairobi for both 2020 and 2024, as all goods must first flow through here. The next largest warehouse is predicted to be Mumias for both 2020 and 2024; Mumias is centered in an area in the southwest heavily populated by district customers. The Nyeri regional warehouse was only opened in 2024, when an increased amount of demand flows through the system.

Figure 12. Results of Greenfield Analysis



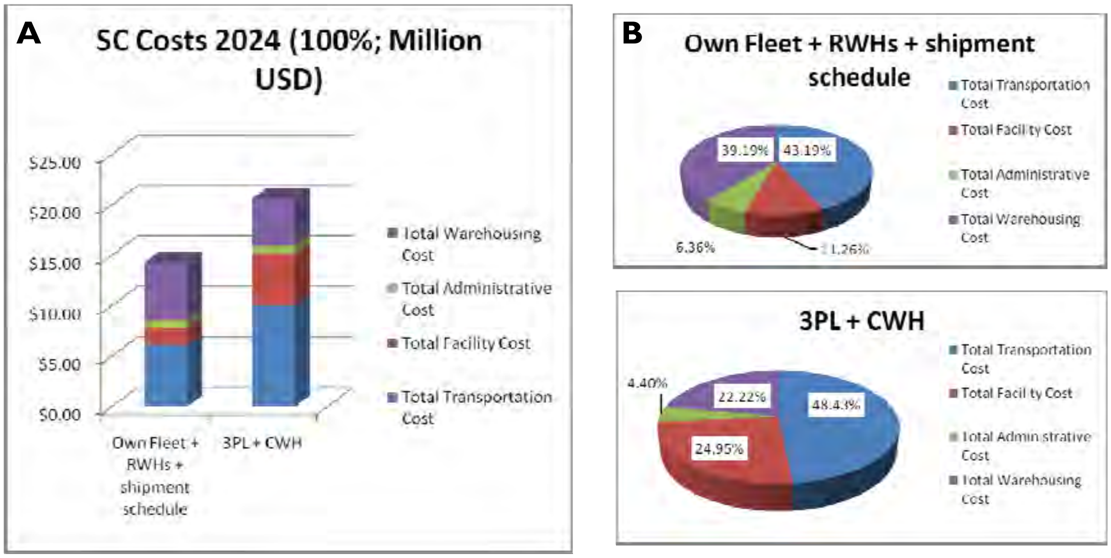
B

Size (sq ft)	2020	2024
Nairobi central warehouse	718,967	776,429
Bamburi depot	46,692	50,424
Nyeri depot	0	6,513
Kisumu depot	49,382	53,329
Wajir depot	6,209	6,706
Eliye Springs depot	9,238	9,976
Mumias depot	78,442	84,711
Nakuru depot	41,031	44,310

A) Locations of the predicted regional warehouses. Warehouses are shown in blue and district customers in green. B) Size of warehouses for 2020 and 2024.

Figures 13A and 13B provide the supply chain financials for the scenario "expanding the central warehouse" (3PL and the central warehouse) compared to "assessing multiple variables" (KEMSA-owned fleet, regional warehouses, and shipment schedule). For this scenario, fulfilling 100 percent of the countrywide need was examined. As shown in figure 13A, the total logistics cost is significantly cheaper for the assessing multiple variables scenario than only expanding the central warehouse. This suggests that multiple changes to the network may be necessary to reduce the supply chain costs. In figure 13B, the percentage for each component of the logistics cost is given for the scenario "expanding the central warehouse" (3PL and the central warehouse) compared to "assessing multiple variables" (KEMSA-owned fleet, regional warehouses, and shipment schedule). The majority of the cost when only expanding the central warehouse is from transportation. However, for the assessing multiple variables scenario, both transportation and warehousing costs contribute the most to the overall supply chain costs. The addition of regional warehouses drives up the warehouse cost.

Figure 13. Supply Chain Financials Comparing Multiple Scenarios: Expansion of Central Warehouse (3PL and the Central Warehouse) versus Assessing Multiple Variables (KEMSA-owned Fleet, Regional Warehouses, and Shipment Schedule)



Supply chain metrics and service metrics are compared for two scenarios in table 5: assessing multiple variables and KEMSA-owned fleet (central warehouse only). In the assessing multiple variables scenario, small-, medium-, and large-sized trucks were utilized, and the number of trucks and drivers necessary to fulfill 100 percent of the demand varies between 33 to 37, 102 to 109, and 22 to 24 for trucks, respectively, and 150 to 162 drivers. The most interesting finding is that the addition of regional warehouses improves the service time. The average service distance decreases from 310.7 kilometers to 243.6 kilometers, and the average service hours (this includes driving time only, not loading/unloading of the vehicle) from 6.2 hours to 4.9 hours.

Table 5. Supply Chain and Service Metrics

100 Percent, 2020–2024	Central and Regional Warehouses and Kenya Medical Supplies Agency–Owned Fleet	Only Central Warehouse and Kenya Medical Supplies Agency–Owned Fleet
Number of small trucks	33–37	0
Number of medium trucks	102–109	198–214
Number of large trucks	22–24	0
Number of vehicle drivers	150–162	189–204
Maximum service distance (kilometers)	1,006.2	1,006.2
Average service distance (kilometers)	**243.6**	**310.7**
Maximum service hours	20.1	20.1

100 Percent, 2020–2024	Central and Regional Warehouses and Kenya Medical Supplies Agency–Owned Fleet	Only Central Warehouse and Kenya Medical Supplies Agency–Owned Fleet
Average service hours	**4.9**	**6.2**

Discussion

The focus of this project was to build a general modeling framework that can be used to forecast the public health supply chains for any country for any future time frame. Here, it was applied to Kenya for the years 2020 through 2024 to demonstrate how the modeling approach can be utilized to help policymakers accurately visualize and understand the most likely and possible situations facing them in 10 years. However, it can be applied to any country to help make informed decisions about how to design a cost-effective supply chain that fulfills the necessary future demands.

Multiple future state scenarios were conducted to demonstrate the various ways a supply chain network could be restructured to account for additional demand and increased service levels. However, this is by no means a comprehensive list of the different variables that can be assessed. For example, the effect of varying prevalence rates, the implementation of new vaccines/treatments, or adding another import point in Mombasa could also be examined.

Table 6 shows a summary of total supply chain and procurement budgets for all scenarios across the various levels of demand fulfillment (35 percent, 50 percent, and 100 percent). In general, the most cost-effective implementation would be to increase the number of replenishments each year. It would, however, require coordination between multiple stakeholders to accomplish a replenishment schedule. In most cases, other scenarios are very similar in their total supply chain budget. Table 6 also demonstrates that to improve service levels, it is necessary to double (50 percent) or quadruple (100 percent) the supply chain budget from the baseline cost.

Table 6. Summary of Total Supply Chain and Procurement Budgets (U.S. Dollars)

Percent (%)		Total Supply Chain Budget (2024)	Total Procurement Budget (2024)
	Baseline (2010)	$5,667,654	$73 million
35	Central warehouse and increased replenishments (two shipments)	$6,825,746	$375 million
35	Central warehouse and third-party logistics provider (3PL)	$7,209,749	
35	Central warehouse and Kenya Medical Supplies Agency (KEMSA)-owned fleet (10% depreciation)	$6,502,979	
35	Central warehouse KEMSA-owned fleet (25% depreciation)	$7,036,754	
50	Central warehouse and increased replenishments (two shipments)	$9,144,845	$533 million
50	Central warehouse and 3PL	$10,299,637	
50	Central warehouse and KEMSA-owned fleet (10% depreciation)	$9,323,892	
50	Central warehouse and KEMSA-owned fleet (25% depreciation)	$10,086,427	
50	Central and two regional warehouses, and 3PL	$22,191,007	
100	Central warehouse and increased replenishments (four shipments)	$16,875,195	$1,067 million
100	Central warehouse and 3PL	$20,599,278	
100	Central warehouse and KEMSA-owned fleet (10% depreciation)	$18,647,790	
100	Central warehouse and KEMSA-owned fleet (25% depreciation)	$20,172,859	
100	Central and regional warehouses, and KEMSA-owned fleet (shipments every two months)	$14,265,173	

Conclusion

The modeling framework was developed and tested by applying it to analyze Kenya and its current and future supply chain states. Having done the groundwork and overcoming the challenges along the way, a robust framework now exists that can be easily reused and applied to other countries and scenarios. The interlinked modeling framework, which represents the health, material requirements, and supply chain models, and a data gathering tool allow for future models to be built and applied quickly and flexibly. The substantial legwork performed in order to shape the current software structure and populate it with accurate data will significantly reduce the time and effort needed to create models for future projects using this robust framework. The developed data gathering template will serve as a guideline for a modeler to extract and use the appropriate data.

Based on the analysis work conducted, the following results should be highlighted. First, if the Kenyan population continues to grow at a steady pace and the supply chain network remains as is, proportion of need met by KEMSA will decrease from 35 percent in 2010 to 28.5 percent in 2024. Additionally, it is important to not only push supplies into the country but to also invest in the supply chain network to handle the increased flow. The forecasted supply chain and procurement budget in 2024 is U.S.$5.76 million and U.S.$359.54 million, respectively.

Multiple cost-effective ways to restructure the supply chain network were examined in order to meet the needs of the growing Kenyan population over the years 2020–2024. In the first scenario, it was found that two replenishments per year would be necessary to meet 35 percent and 50 percent of the total demand, while four replenishments would be needed for 100 percent. In the second scenario, expansion of the central warehouse, the central warehouse must be expanded 22 percent (average over 2020–2024) to meet 35 percent of the future demand, an expansion of 45 percent is necessary (average over 2020–2024) for 50 percent, and 75 percent growth is required (average over 2020–2024) to meet 100 percent of the need. Additionally, a decentralization scenario was conducted where regional warehouses are utilized. This scenario demonstrated that a large investment would be necessary and only result in marginal service improvements. Although there would be shorter service distance and time to districts, Kenya as a country is small enough that the impact on costs and overall network efficiency would be minimal.

Additionally, it was assessed whether it would be cost-effective for KEMSA to utilize an in-house vehicle fleet. The analysis found that although there would be a large upfront investment to own a vehicle fleet, it becomes cost-effective over time. Furthermore, if the vehicles are well maintained and a 10 percent depreciation rate can be assumed, it is actually cheaper over time for KEMSA to own its own fleet rather than outsourcing to a 3PL. However, if a 25 percent depreciation rate is assumed, there is a US$3.5 million difference over five years from the 10 percent depreciation rate data, and utilizing a 3PL is relatively the same cost. This study demonstrates the importance of vehicle maintenance and how much of a factor it can play into supply chain transportation costs.

In the last scenario, multiple variables were assessed together. Here, decreased overall supply chain costs were found; for fulfilling 100 percent of the demand, it was the cheapest option. This suggests that multiple changes to the network may be necessary to significantly reduce the supply chain costs and increase service levels. The majority of the cost when only expanding the central warehouse is from transportation. However, for the assessing multiple variables scenario, both transportation and warehousing costs together contribute the most to the overall supply chain costs.

In general, the most cost-effective implementation would be to increase the number of replenishments each year. The power of PHeNOM is the ability to predict and visualize the future. Changes to strengthen the logistics situation are required, but they can be manageable if policymakers understand the most likely and possible situations facing them. If nothing is done to address the increased demand due to a growing Kenyan population, the public sector will not be serviced, which ultimately can result in loss of lives. The key message from this study is that stakeholders must understand the importance of investing in supply chain and the timing of delivery.

Future opportunities with PHeNOM building on the framework developed for this project exist and include applying the framework to multiple other countries to compare and identify regional trends. Additionally, information could be obtained, such as the typical benchmark numbers for the supply chain cost rate and other service metrics. Furthermore, additional scenarios could be conducted and include (among others) the following: 1) other network structures to consider; 2) the effect of higher fuel prices; 3) the effect of changing demographics due to urbanization, and economic/political changes and events; 4) the effect of changing prevalence rates due to vaccine introduction, disease outbreaks, and disease eradication; and 5) the effect of feedback loops such as lower maternal morbidity leads to higher birth rates and therefore larger population on the supply chain needs of a country. Lastly, PHeNOM could be employed to investigate the relation of supply chain service metrics to health outcomes. For example, how does the number of patients that are treated/untreated translate into quality-adjusted life years/disability-adjusted life years?

Appendix A

Kenya Population Data 2010 & 2020

Name	Province	District	Admin Level	2010	2020
KENYA			Country	40,046,566	49,458,956
KENYA_CENTRAL	CENTRAL		Province	5,198,935	6,420,870
KENYA_CENTRAL_KIAMBU	CENTRAL	KIAMBU	District	1,038,638	1,282,757
KENYA_CENTRAL_KIRINYAGA	CENTRAL	KIRINYAGA	District	638,117	788,095
KENYA_CENTRAL_MARAGUA	CENTRAL	MARAGUA	District	541,610	668,910
KENYA_CENTRAL_MURANG'A	CENTRAL	MURANG'A	District	486,232	600,513
KENYA_CENTRAL_NYANDARUA	CENTRAL	NYANDARUA	District	669,947	827,404
KENYA_CENTRAL_NYERI	CENTRAL	NYERI	District	922,972	1,139,910
KENYA_CENTRAL_THIKA	CENTRAL	THIKA	District	901,419	1,113,280
KENYA_COAST	COAST		Province	3,472,226	4,288,326
KENYA_COAST_KILIFI	COAST	KILIFI	District	759,848	938,442
KENYA_COAST_KWALE	COAST	KWALE	District	692,598	855,386
KENYA_COAST_LAMU	COAST	LAMU	District	101,474	125,322
KENYA_COAST_MALINDI	COAST	MALINDI	District	393,045	485,426
KENYA_COAST_MOMBASA	COAST	MOMBASA	District	928,371	1,146,567
KENYA_COAST_TAITA	COAST	TAITA	District	344,349	425,289
KENYA_COAST_TANA RIVER	COAST	TANA RIVER	District	252,541	311,895
KENYA_EASTERN	EASTERN		Province	6,465,973	7,985,711
KENYA_EASTERN_EMBU	EASTERN	EMBU	District	388,360	479,639
KENYA_EASTERN_ISIOLO	EASTERN	ISIOLO	District	140,803	173,897
KENYA_EASTERN_KITUI	EASTERN	KITUI	District	719,531	888,645
KENYA_EASTERN_MACHAKOS	EASTERN	MACHAKOS	District	1,265,678	1,563,161
KENYA_EASTERN_MAKUENI	EASTERN	MAKUENI	District	1,077,075	1,330,230
KENYA_EASTERN_MARSABIT	EASTERN	MARSABIT	District	169,583	209,435
KENYA_EASTERN_MBEERE	EASTERN	MBEERE	District	238,650	294,749
KENYA_EASTERN_MERU CENTRAL	EASTERN	MERU CENTRAL	District	696,442	860,128
KENYA_EASTERN_MERU NORTH	EASTERN	MERU NORTH	District	843,257	1,041,449
KENYA_EASTERN_MOYALE	EASTERN	MOYALE	District	74,655	92,205
KENYA_EASTERN_MWINGI	EASTERN	MWINGI	District	424,143	523,830

Name	Province	District	Admin Level	2010	2020
KENYA_EASTERN_NITHI (MERU SOUTH)	EASTERN	NITHI (MERU SOUTH)	District	286,814	354,222
KENYA_EASTERN_THARAKA	EASTERN	THARAKA	District	140,982	174,121
KENYA_NAIROBI AREA	NAIROBI AREA	PROVINCE	Province	2,991,987	3,695,213
KENYA_NAIROBI AREA_NAIROBI AREA	NAIROBI AREA	NAIROBI AREA	District	2,991,987	3,695,213
KENYA_NORTH-EASTERN	NORTH-EASTERN		Province	1,343,153	1,658,841
KENYA_NORTH-EASTERN_GARISSA	NORTH-EASTERN	GARISSA	District	547,946	676,727
KENYA_NORTH-EASTERN_MANDERA	NORTH-EASTERN	MANDERA	District	349,520	431,677
KENYA_NORTH-EASTERN_WAJIR	NORTH-EASTERN	WAJIR	District	445,687	550,438
KENYA_NYANZA	NYANZA		Province	6,131,514	7,572,642
KENYA_NYANZA_BONDO	NYANZA	BONDO	District	333,337	411,685
KENYA_NYANZA_GUCHA (SOUTH KISII)	NYANZA	GUCHA (SOUTH KISII)	District	643,475	794,714
KENYA_NYANZA_HOMA BAY	NYANZA	HOMA BAY	District	402,798	497,472
KENYA_NYANZA_KISII CENTRAL	NYANZA	KISII CENTRAL	District	686,536	847,894
KENYA_NYANZA_KISUMU	NYANZA	KISUMU	District	704,086	869,578
KENYA_NYANZA_KURIA	NYANZA	KURIA	District	212,035	261,864
KENYA_NYANZA_MIGORI	NYANZA	MIGORI	District	718,799	887,747
KENYA_NYANZA_NYAMIRA	NYANZA	NYAMIRA	District	695,352	858,783
KENYA_NYANZA_NYANDO	NYANZA	NYANDO	District	418,702	517,114
KENYA_NYANZA_RACHUONYO	NYANZA	RACHUONYO	District	428,749	529,516
KENYA_NYANZA_SIAYA	NYANZA	SIAYA	District	670,335	827,892
KENYA_NYANZA_SUBA	NYANZA	SUBA	District	217,310	268,383
KENYA_RIFT VALLEY	RIFT VALLEY		Province	9,753,920	12,046,445
KENYA_RIFT VALLEY_BARINGO	RIFT VALLEY	BARINGO	District	369,913	456,858
KENYA_RIFT VALLEY_BOMET	RIFT VALLEY	BOMET	District	534,379	659,976
KENYA_RIFT VALLEY_BURET	RIFT VALLEY	BURET	District	442,370	546,346
KENYA_RIFT VALLEY_EAST MARAKWET	RIFT VALLEY	EAST MARAKWET	District	196,316	242,457
KENYA_RIFT VALLEY_KAJIADO	RIFT VALLEY	KAJIADO	District	566,857	700,086
KENYA_RIFT VALLEY_KEIYO	RIFT VALLEY	KEIYO	District	200,831	248,036
KENYA_RIFT VALLEY_KERICHO	RIFT VALLEY	KERICHO	District	654,017	807,733
KENYA_RIFT VALLEY_KOIBATEK	RIFT VALLEY	KOIBATEK	District	192,880	238,211
KENYA_RIFT VALLEY_LAIKIPIA	RIFT VALLEY	LAIKIPIA	District	449,771	555,486
KENYA_RIFT VALLEY_NAKURU	RIFT VALLEY	NAKURU	District	1,657,107	2,046,589
KENYA_RIFT VALLEY_NANDI	RIFT VALLEY	NANDI	District	807,939	997,836
KENYA_RIFT VALLEY_NAROK	RIFT VALLEY	NAROK	District	510,591	630,594
KENYA_RIFT VALLEY_SAMBURU	RIFT VALLEY	SAMBURU	District	200,390	247,486
KENYA_RIFT VALLEY_TRANS MARA	RIFT VALLEY	TRANS MARA	District	238,141	294,124
KENYA_RIFT VALLEY_TRANS-NZOIA	RIFT VALLEY	TRANS-NZOIA	District	803,629	992,503
KENYA_RIFT VALLEY_TURKANA	RIFT VALLEY	TURKANA	District	629,397	777,334
KENYA_RIFT VALLEY_UASIN GISHU	RIFT VALLEY	UASIN GISHU	District	869,300	1,073,611

Name	Province	District	Admin Level	2010	2020
KENYA_RIFT VALLEY_WEST POKOT	RIFT VALLEY	WEST POKOT	District	430,092	531,179
KENYA_WESTERN	WESTERN		Province	4,688,858	5,790,908
KENYA_WESTERN_BUNGOMA	WESTERN	BUNGOMA	District	1,223,582	1,511,165
KENYA_WESTERN_BUSIA	WESTERN	BUSIA	District	517,372	638,972
KENYA_WESTERN_ELGON	WESTERN	ELGON	District	665,790	822,280
KENYA_WESTERN_KAKAMEGA	WESTERN	KAKAMEGA	District	842,382	1,040,367
KENYA_WESTERN_LUGARI	WESTERN	LUGARI	District	301,420	372,271
KENYA_WESTERN_SHIROTSA/MUMIAS	WESTERN	SHIROTSA/MUMIAS	District	188,509	232,814
KENYA_WESTERN_TESO	WESTERN	TESO	District	253,359	312,910
KENYA_WESTERN_VIHIGA	WESTERN	VIHIGA	District	696,444	860,130

Appendix B

Prevalence Rate Sources and Description

Condition	Source	Date	Description
HIV	HIV Spatial Data Repository, PEPFAR HIV Spatial Data webpage	2003	% prevalence of HIV, Men ages 15-45 & % prevalence of HIV, Women ages 15-45
Tuberculosis	*(a) Estimated epidemiological burden of TB, all forms* WHO, TB Data webpage	2008	Prevalence rate per 100,000
Number Births	World Health Statistics, 2009 WHO Report	2002	Live births in 2002 per 1,000 population
Measles	Kenya Reported Cases of Measles WHO Data Statistics and Graphs	2008	Total Cases reported
Malaria	Reported Malaria cases per 100,00 WHO spreadsheet	1990-2006	% Prevalence, average of 1990-2006 data
Leprosy	*Division of Leprosy, Tuberculosis, and Lung Disease – Kenya* Ministry of Public Health and Sanitation	2006	# cases in 2006 (only for 5 provinces given)
Childhood Diarrheal	*"Mortality Country Factsheet 2006"* WHO	2006	Assuming 25% for children and 10% for adults
Worms	*"Worms: Education and Health Externalities in Kenya"* National Bureau of Economic Research	2002	Adding 5% to worldwide rate of 25%
Respiratory Infections	*"Community Understanding of pneumonia in Kenya"* African Health Sciences, Vol 8	2008	Using Pneumonia as a proxy - Children 13% (Upper limit of Range); Adults: 10% (guess)
Syphilis	*"The epidemiology of gonorrhea, chlamydial infection and syphilis in four African cities."* *NLM Gateway*	2001	4%
Overall STI	*"Female condom introduction and STI prevalence" NLM Gateway*	2000	17%
Diabetes	*"Global prevalence of Diabetes: Estimates for the year 200 and projections for 2030"* Diabetes Care (Volume 27)	2004	3% (worldwide estimate)
HTN	*SECTION 1.02 "PREVALENCE, DETECTION, MANAGEMENT, AND CONTROL OF HYPERTENSION IN ASHANTI, WEST AFRICA"* SECTION 1.03 AMERICAN HEART ASSOCIATION	2004	30% (estimate from Ghana)
Asthma	*"Global Burden and management of Asthma in developing countries"* International Union Against Tuberculosis and Lung Disease		10% (estimate from neighboring countries)

Appendix C

Kenya Prevalence Rates

	Region (Province)							
Condition	**Central**	**Coast**	**Eastern**	**Nairobi Area**	**North-Eastern**	**Nyanza**	**Rift Valley**	**Western**
HIV Men	2.00%	4.80%	1.50%	7.80%	0.00%	11.60%	3.60%	3.80%
HIV Women	7.60%	6.60%	6.10%	11.90%	0.00%	18.30%	6.90%	5.80%
Malaria	13.15%	13.15%	13.15%	13.15%	13.15%	13.15%	13.15%	13.15%
Tuberculosis	180	180	180	180	180	180	180	180
Measles	1282	1282	1282	1282	1282	1282	1282	1282
Number of Births	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Resp Inf - Child	7%	7%	7%	7%	7%	7%	7%	7%
Resp Inf - Adult	10%	10%	10%	10%	10%	10%	10%	10%
Diarrheal - Child	25%	25%	25%	25%	25%	25%	25%	25%
Diarrheal - Adult	10%	10%	10%	10%	10%	10%	10%	10%
Syphilis	4%	4%	4%	4%	4%	4%	4%	4%
Other STI	23%	23%	23%	23%	23%	23%	23%	23%
Leprosy	0	37	37	37	0	37	0	37
Vitamin A Def	100% Children 0-4	100% Children 0-4	100% Children 0-4	100% Children 0-4	100% Children 0-4	100% Children 0-4	100% Children 0-4	100% Children 0-4
Diabetes	3%	3%	3%	3%	3%	3%	3%	3%
Hypertension	30%	30%	30%	30%	30%	30%	30%	30%
Asthma	10%	10%	10%	10%	10%	10%	10%	10%
Ascariasis								
Richuriasis								
Worms	25%	25%	25%	25%	25%	25%	25%	25%

Appendix D

Number of HIV, Tuberculosis, and Malaria Cases in 2020

Country_Region_District	Tuberculosis	HIV	Malaria
KENYA	89,026	3,265,614	3,561,573
KENYA_CENTRAL	11,558	309,076	0
KENYA_CENTRAL_KIAMBU	2,309	61,162	0
KENYA_CENTRAL_KIRINYAGA	1,419	37,671	0
KENYA_CENTRAL_MARAGUA	1,204	32,657	0
KENYA_CENTRAL_MURANG'A	1,081	29,661	0
KENYA_CENTRAL_NYANDARUA	1,489	40,010	0
KENYA_CENTRAL_NYERI	2,052	55,141	0
KENYA_CENTRAL_THIKA	2,004	52,773	0
KENYA_COAST	7,719	243,527	127,881
KENYA_COAST_KILIFI	1,689	53,868	28,153
KENYA_COAST_KWALE	1,540	48,912	42,769
KENYA_COAST_LAMU	226	7,089	627
KENYA_COAST_MALINDI	874	27,664	14,563
KENYA_COAST_MOMBASA	2,064	64,053	34,397
KENYA_COAST_TAITA	766	24,195	4,253
KENYA_COAST_TANA RIVER	561	17,745	3,119
KENYA_EASTERN	14,374	307,382	30,346
KENYA_EASTERN_EMBU	863	18,264	0
KENYA_EASTERN_ISIOLO	313	6,497	869
KENYA_EASTERN_KITUI	1,600	34,874	4,443
KENYA_EASTERN_MACHAKOS	2,814	59,957	1,563
KENYA_EASTERN_MAKUENI	2,394	51,450	1,330
KENYA_EASTERN_MARSABIT	377	7,905	6,283
KENYA_EASTERN_MBEERE	531	11,445	1,474
KENYA_EASTERN_MERU CENTRAL	1,548	32,503	4,301
KENYA_EASTERN_MERU NORTH	1,875	39,966	5,207

Country_Region_District	Tuberculosis	HIV	Malaria
KENYA_EASTERN_MOYALE	166	3,501	2,766
KENYA_EASTERN_MWINGI	943	20,689	524
KENYA_EASTERN_NITHI (MERU SOUTH)	638	13,567	1,063
KENYA_EASTERN_THARAKA	313	6,763	522
KENYA_NAIROBI AREA	6,651	355,359	0
KENYA_NAIROBI AREA_NAIROBI AREA	6,651	355,359	0
KENYA_NORTH-EASTERN	2,986	0	9,519
KENYA_NORTH-EASTERN_GARISSA	1,218	0	6,767
KENYA_NORTH-EASTERN_MANDERA	777	0	0
KENYA_NORTH-EASTERN_WAJIR	991	0	2,752
KENYA_NYANZA	13,631	1,140,889	1,382,578
KENYA_NYANZA_BONDO	741	62,180	164,674
KENYA_NYANZA_GUCHA (SOUTH KISII)	1,430	119,614	3,974
KENYA_NYANZA_HOMA BAY	895	75,183	174,115
KENYA_NYANZA_KISII CENTRAL	1,526	127,775	4,239
KENYA_NYANZA_KISUMU	1,565	129,956	260,873
KENYA_NYANZA_KURIA	471	39,293	2,619
KENYA_NYANZA_MIGORI	1,598	133,661	8,877
KENYA_NYANZA_NYAMIRA	1,546	129,148	8,588
KENYA_NYANZA_NYANDO	931	77,588	129,278
KENYA_NYANZA_RACHUONYO	953	80,040	158,855
KENYA_NYANZA_SIAYA	1,490	126,083	372,552
KENYA_NYANZA_SUBA	483	40,368	93,934
KENYA_RIFT VALLEY	21,684	629,428	231,707
KENYA_RIFT VALLEY_BARINGO	822	24,061	1,371
KENYA_RIFT VALLEY_BOMET	1,188	34,850	2,640
KENYA_RIFT VALLEY_BURET	983	28,270	2,732
KENYA_RIFT VALLEY_EAST MARAKWET	436	12,766	1,212
KENYA_RIFT VALLEY_KAJIADO	1,260	36,363	2,800
KENYA_RIFT VALLEY_KEIYO	446	13,012	1,240
KENYA_RIFT VALLEY_KERICHO	1,454	41,975	4,039
KENYA_RIFT VALLEY_KOIBATEK	429	12,448	476
KENYA_RIFT VALLEY_LAIKIPIA	1,000	29,018	0
KENYA_RIFT VALLEY_NAKURU	3,684	106,575	0
KENYA_RIFT VALLEY_NANDI	1,796	52,125	8,981
KENYA_RIFT VALLEY_NAROK	1,135	32,912	2,522
KENYA_RIFT VALLEY_SAMBURU	445	13,108	990

Country_Region_District	Tuberculosis	HIV	Malaria
KENYA_RIFT VALLEY_TRANS MARA	529	15,474	1,471
KENYA_RIFT VALLEY_TRANS-NZOIA	1,787	51,977	29,775
KENYA_RIFT VALLEY_TURKANA	1,399	40,769	155,467
KENYA_RIFT VALLEY_UASIN GISHU	1,933	55,778	5,368
KENYA_RIFT VALLEY_WEST POKOT	956	27,947	10,624
KENYA_WESTERN	10,424	279,954	1,779,541
KENYA_WESTERN_BUNGOMA	2,720	72,813	453,349
KENYA_WESTERN_BUSIA	1,150	31,030	287,537
KENYA_WESTERN_ELGON	1,480	39,816	246,684
KENYA_WESTERN_KAKAMEGA	1,873	50,249	312,110
KENYA_WESTERN_LUGARI	670	17,931	11,168
KENYA_WESTERN_SHIROTSA/MUMIAS	419	11,177	69,844
KENYA_WESTERN_TESO	563	15,091	140,809
KENYA_WESTERN_VIHIGA	1,548	41,848	258,039

Appendix E

Resources Used for Material Requirements Model

Condition	Resource
Tuberculosis	For determining treatments: Treatment of Tuberculosis Guidelines, fourth Edition, WHO (http://whqlibdoc.who.int/publications/2010/9789241547833_eng.pdf)
	For determining percentage of patients requiring various treatments: Data collected from TB control programs and estimates generated by WHO (http://www.who.int/tb/country/data/download/en/index.html)
	Pharmaceutical product details: from STOP TB Product list (http://www.stoptb.org/gdf/drugsupply/drugs_available.asp)
STIs	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
HIV/AIDS	MSFs: Untangling the Web of Antiretroviral Drug Prices: http://utw.msfaccess.org/
	UNGASS 2010, country Report: http://data.unaids.org/pub/Report/2010/kenya_2010_country_progress_report_en.pdf
	Epidemiological Fact Sheet on HIV/AIDS 2008: http://apps.who.int/globalatlas/predefinedReports/EFS2008/full/EFS2008_KE.pdf
	PowerPoint presentation by WHO 2008 survey on ARV use: http://www.who.int/hiv/amds/who_survey_arv_use_2008_market_renaudthery.pdf
	"NEW WHO recommendations on ART regimen: Preliminary assumptions on future use of 1st and 2nd line regimen" PowerPoint (Rapid d4T example was used (2012)): http://www.who.int/hiv/amds/who_new_ar_recom_assump_future_renaudthery.pdf
	WHO Antiretroviral therapy of HIV infection in infants and children: http://www.who.int/hiv/pub/guidelines/paediatric020907.pdf
	WHO survey: ARV Use in 2008 and market trends in low and middle income countries: http://www.who.int/hiv/amds/who_survey_arv_use_2008_market_renaudthery.pdf
	Finalization of WHO ART Treatment Guidelines for Children: http://www.who.int/hiv/amds/who_paediatric_art_guidelines_crowley.pdf
	"Methodology and Assumptions used to estimate the Cost of Scaling Up Selected Child Health Interventions", WHO, March 2005.
	WHO survey: ARV Use in 2008 and market trends in low and middle income countries" http://www.who.int/hiv/amds/who_survey_arv_use_2008_market_renaudthery.pdf
	USAID | DELIVER PROJECT, Task Order 1. 2008. *Logistics Fact Sheets: ARV Drugs*. Arlington, Va.: USAID | DELIVER, PROJECT, Task Order 1. http://deliver.jsi.com/dlvr_content/resources/allpubs/factsheets/LogiFactShee_ARV_Comp.pdf
	USAID | DELIVER PROJECT, Task Order 1. *2008. Logistics Fact Sheets: HIV Test Kits*. Arlington, Va.: USAID | DELIVER PROJECT, Task Order 1. http://deliver.jsi.com/dlvr_content/resources/allpubs/factsheets/LogiFactShee_HIVT_Comp.pdf

Condition	Resource
Diarrhea	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
	Internal experts
Malaria	Guidelines for the Treatment of Malaria, Second edition, WHO, 2010.
Leprosy	National NTLP guidelines (http://www.nltp.co.ke/docs/National_NLTP_Guideline.pdf)
	Weekly epidemiological record (http://www.who.int/wer/2009/wer8433.pdf)
Worms	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
Respiratory Infections	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
	Internal experts
	"Methodology and Assumptions used to estimate the Cost of Scaling Up Selected Child Health Interventions", WHO, March 2005.
Family Planning	Profiles for Family Planning and Reproductive Health Programs, 2nd Edition by the Futures Group (http://www.policyproject.com/pubs/generalreport/Profiles116FP2ed.pdf)
	United Nations, Department of Economic and Social Affairs, Population Division: World Population Prospects DEMOBASE extract. 2007.
Vitamins	"Methodology and Assumptions used to estimate the Cost of Scaling Up Selected Child Health Interventions", WHO, March 2005.
	"Constraints to Scaling Up Health Related MDGs: Costing and Financial Gap Analysis:, WHO, September 2009.
Diabetes Mellitus	"Constraints to Scaling Up Health Related MDGs: Costing and Financial Gap Analysis:, WHO, September 2009.
	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
Maternal Health	"Constraints to Scaling Up Health Related MDGs: Costing and Financial Gap Analysis:, WHO, September 2009.
Hypertension & Cardiovascular Disease	"Constraints to Scaling Up Health Related MDGs: Costing and Financial Gap Analysis:, WHO, September 2009.
Asthma	Clinical Guidelines for Diagnosis and treatment of common Conditions in Kenya, 2002. (http://apps.who.int/medicinedocs/documents/s16427e/s16427e.pdf)
Vaccines	"Landscape Analysis: Trends in Vaccine Availability and Novel Vaccine Delivery technologies: 2008-2025", OPTIMIZE, July 2008.

Other Resources

International Finance Corporation. 2008. *Business of Health in Africa.* Washington, D.C.: International Finance Corporation.

Management Sciences for Health. 2008. *International Drug Price Indicator Guide.* Arlington, Va.: Management Sciences for Health.

Appendix F

Material Requirements Model: Treatments

Condition	Type	Treatment
Tuberculosis	1st line	2HRZE/4HR; likelihood of isoniazide resistance is low in African countries
	re-treatment	2HRZES/1HRZE/5HRE
	MDR-TB	Z, Km or Cm, Ofx, Eto, Cs
STIs	Genital Discharge	Norfloxacillin, doxycycline, metronidazole or clotrimazole pesaries
	Genital ulcer	Cotrimoxazole or ceftriaxone
	Syphilis	Benzathine or Procaine Penicillin Injection
HIV/AIDS - Adult	1st line	d4T/3TC NVP or EFV
		AZT/3TC NVP or EFV
		TDF/XTC with NVP or EFV
	2nd line	LPV/r
		ATV
		IDV/r or SQV/r
	with	TDF/XTC
		AZT/3TC
		AZT/XTC/TDF
		ABC/ddI
		d4T/3TC
	Note	XTC=3TC or FTC
HIV/AIDS - Pediatric	1st line	d4T/3TC/NVP
		AZT/3TC/NVP
		AZT/3TC/EFV
		d4T/3TC/EFV
		ABC/3TC/LPV/r
	2nd line:	ABC/d4T/LPV/r
		ABC/ddI/LPV/r
		d4T/3TC/ddI
		d4T/3TC/LPV/r

Condition	Type	Treatment
		3TC/ddI/LPV/r
		AZT/3TC/LPV/r
HIV/AIDS - PMTCT	Infants:	Breastfeeding: daily NVP from birth until 6 weeks of life
		Non-breastfeeding: daily AZT and NVP from birth until 6 weeks of age.
	Mothers (who do not qualify for ART) - option A	Ante partum AZT QD, starting at week 14
		sd-NVP at onset of labor and delivery
HIV/AIDS - PMTCT	Mothers (who do not qualify for ART) - option A	AZT/3TC during labor and delivery
		AZT/3TC for 7 days post-partum
	Mothers (who do not qualify for ART) - option B	AZT+ 3TC+ LPV/r
		AZT+ 3TC+ ABC
		AZT+ 3TC+ EFV
		TDF+ XTC+ EFV
	Note	All positive pediatrics and exposed infants until testing confirms negative results: co-trimoxazole
		All qualifying TB/HIV patients: co-trimoxazole
		RTKs: serial testing
Diarrhea		Majority on ORS and Normal saline (if needed) with zinc for pediatrics
		Antibiotics used: cotrimoxazole, metronidazole, erythromycin and nalidixic acid
Malaria	Uncomplicated	97% on coartem and 3% on SP, second-line: quinine and doxycycline
	Severe	Artesunate injection and coartem
	Pregnancy	Quinine, clindamycin, coartem and artesunate injection
		IPTp: SP
		RDTs
		ITNs
Leprosy	Paucibacillary	Dapsone and rifampicin
	Multi-bacillary	Dapsone, rifampicin and clofazimine
Worms	Acariasos	Mebendazole or albendazole
	Trichuriasis	Mebendazole or albendazole
	Hookworm	Mebendazole or albendazole
Respiratory Infections	Pediatrics	Outpatient: amoxicillin, Co-trimoxazole benzylpen, procain pen and/or chloramphenicol
		Inpatient: chloramphenicol, Benzylpenicillin,and/or gentamicin Discharged on: co-trimoxazole, amoxicillin, nebulized salbutamol and/or tablet
	Adult	Outpatient: amoxicillin, erythromycin, benzylpen, procain pen.
		Inpatient: crystalline penicillin, gentamicin, chloramphenical, and/or erythromycin

Condition	Type	Treatment
		discharge on: Amoxicillin or erythromycin
Family Planning		Oral Contraceptives
		Injectables
Family Planning		IUD Acceptors
		Condom (male)
		Vaginals
Vitamins		Measles and general pediatric supplementation: Vitamin A supplemented to all children at age 3, 9 and 15 months and every 6 months thereafter to age 5.
Diabetes Mellitus		Metformin and glibenclamide (glyburide) with 5% requiring insulin
Maternal Health		Eclampsia and severe pre-eclampsia: hydralazine and magnesium
		Ante-partem haemorrhage: ergometrine, iron and oxytocin
		Postpartum haemorrhage, manual removal of placenta and active management of the third stage of labor: oxytocin
Hypertensio n and cardivascular disease		Cardiovascular disease: hydrochlorothiazide, enalapril, simvastatins, atenolol and calcium channel blocker
		Congestive heart failure: digoxin, furosemide, enalapril and potassium
Asthma		Salbuterol and beconase; aminophylline injection for severe asthma
		Nebulizer treatment every 6 hours for total of 3 days
		Oral treatment for a total of 5 days
Vaccines		Basic package: BCG, DPT Hep B, oral polio (OPV), measles and tetanus.
		Possible future package: BCG or TB, DPT HepB Hib, Measles, seasonal Flu, Cholera, CMV, ETEC, HepA, HepE, HPV, Malaria, MCV-TT, MMR, PCV, Rotavirus RSV, Typhoid, YF, OPV.

Appendix G

Assumptions Material Requirements Model

Condition	Assumption
Tuberculosis	Co-trimoxazole therapy is given for all HIV positive patients.
	45% of TB patients tested for HIV were positive; increased this to 60% based on comments from advisors and other country examples.
	2.02% of TB patients had MDR TB
	Included all syringes and water for injection that would be required for the injections
STIs	Syndromic approach used for genital discharge and genital ulcer according to the national guidelines. Treatment for syphilis covers all forms and averages treatment durations.
HIV/AIDS - Adults	Most patients would be on WHO recommended treatments (for 1st-line)
	"NEW WHO recommendations on ART regimen: Preliminary assumptions on future use of 1st and 2nd line regimen" PowerPoint (Rapid transition from d4T example was used (2012)): http://www.who.int/hiv/amds/who_new_ar_recom_assump_future_renaudthery.pdf
	Where possible chosen a fixed-dose combination (FDC) assuming there will be more of a trend towards this.
	Assumed 80% on NVP and 20% on EFV based on 2006 survey of ART use: http://www.who.int/hiv/amds/ReportDemandForecastforARV2007-2008.pdf
HIV/AIDS - Pediatric	Taken out all d4T regimens and substitute with AZT.
	Combine all regimens for one total list of all 1st and 2nd line regimens.
	Overestimated needs for the 5-14 year old group, at times,to adult doses.
	Daily zinc (10mg) to prevent diarrhea in HIV positive pediatrics.
HIV/AIDS - PMTCT	Pregnant women that qualify for ART are covered under adult ART.
	Two options for PMTCT given in new WHO guidelines:
	Breastfeeding was assumed to be at 50% for option A and 50% for option B. Duration was assumed to be for 12 months (12 months from WHO document: HIV and infant feeding Revised Principles and Recommendations Rapid Advice, November 2009)
	There are four options for triple therapy in option B of PMTCT-mothers treatment. Choose 25% for each.
HIV/AIDS - Cotrimoxazole	Half the children between 0-4 would be taking syrup and the rest on tablets.
	Children 5-14 would be 25% on child dose and the rest on 400+80.
	TB/HIV adults should be placed on daily Cotrimoxazole preventative therapy.
Diarrhea	Average weight of 12 kg for children 0-4years old
	Average weight of 25kg for children 5-8 years old

Condition	Assumption
	Average weight of 35kg for children 8-14 years old
	Average weight of 60 kg for adults
	Assumed 20% of children between 5-14 will be on solutions and the other 80% on tablets/capsules
	For higher weight pediatric patients, did not go over the adult recommended dosage.
	For pediatric patients, rounded a treatment up to the nearest full bottle, since remaining medication cannot be stored once reconstituted.
Malaria	Coartem was used as a placeholder for the packaging of any ACT
Leprosy	Assume 50% un-supervised multi-bacillary leprosy treatments
	No treatments required for children under 15 years old
Worms	Within each age group the prevalence or incidence rate of disease is constant.
Worms	Mebendazole and Albendazole treatments are both recommended.
	Assume 50% of 0-4 year olds are 0-2 years old
	Assume all 0-4 year olds are taking solutions
	Assume 20% of 5-15 year olds are taking solutions.
Respiratory Infections	30% of men would need hospitalization
	5% of women would need hospitalization
	50% of children would need hospitalization
	3 days average hospital stay for adults and children, then discharged with oral meds for 10 days for a total of 13 days
	Of those who are not hospitalized, 50% receive an injection for the first dose of antibiotics and oral meds for a total of 10 days
	5% of adults have penicillin allergy
	Assumed 20% of children between 5-14 will be on solutions and the other 80% on tablets/capsules
	Patients 5 years and older can take tablets/capsules
	Used average weight of 12 kg for children 0-4 years old
	Used average weight of 30 kg for children 5-14 years old
Family Planning	Did not account for requirements needed for female and male sterilization as these medications will be covered in the general bundle of essential medicines.
Diabetes Mellitus	10ml vial of insulin is most likely used, with one vial per month as an average.
	Three injections per day for a 100/month
Maternal Health	All general essential medicines like IV solutions, lignocaine, diazepam and antibiotics have been taken out and will be assumed to be included as part of the essential medicines bundle.
Asthma	Epinephrine and prednisone would be included as part of the essential medicines bundle
	Average weight of 12 kg for children 0-4 years old
	Average weight of 25 kg for children 5-8 years old
	Average weight of 35 kg for children 8-14 years old
	Loading dose of Aminophylline=6mg/kg

Appendix H

Treatment Rates by Condition

Disease	Treatment Rate 2010	Treatment Rate 2020-2024
HIV/AIDS (first line/second line)	12.15%	49% / 1%
Malaria	34%	34%
Tuberculosis	85%	85%
Vaccines	85%	85%
Vitamin A	15%	85%
Diarrhea	20%	20%
Leprosy	20%	85%
Worms	35%	85%
Respiratory Infections	35%	35%
Syphilis	10%	85%
Other STI	10%	85%
Measles	20%	20%
Diabetes	5%	5%
Hypertension & cardiovascular disease	10%	10%
Asthma	5%	5%
Family Planning	39%	100%
Maternal Health	52%	100%
Other Essential Meds bundle	100%	100%

Appendix I

Vehicle Characteristics KEMSA Owned Fleet

Vehicle Type	I Ton vehicle	3.5 Ton vehicle	7 Ton vehicle	Notes
Example	Toyota Tundra /Tacoma	Nissan UD 40 /Mitsubishi Canter	Nissan UD 70 /Isuzu Van	
Maximum payload (kg)	1,085	3,150	6,300	I ton = 900 kg
Average weight per trip (kg)	543	1,575	5,670	50 or 90% of max payload
Purchase cost (USD)	$33,000.00	$47,500.00	$68,500.00	US Numbers from JSI
Fixed Cost (10% Depreciation)	$4,800.00	$9,450.00	$10,450.00	Maintenance / repair + 10% depreciation
Fixed Cost (25% Depreciation)	$9,750.00	$16,575.00	$20,725.00	Maintenance / repair + 25% depreciation
Maintenance /Repair	$1,500.00	$4,700.00	$3,600.00	Based on Malawi historical data
Depreciation (10%)	$3,300.00	$4,750.00	$6,850.00	10% of purchase cost
Depreciation (25%)	$8,250.00	$11,875.00	$17,125.00	25% of purchase cost
Per Distance Cost (fuel)	$0.32	$0.40	$0.49	Based on Malawi historical data
Average speed (km/hr.)	40	50	60	Estimates

Appendix J

Outputs Generated by Models and Scenarios

Output Cost / Metric Name	Description
Total Transportation Cost	For 3PL: total cost incurred for transportation based on per cubic meter per kilometer rate For KEMSA owned fleet: total cost incurred for transportation. This includes purchase of new vehicles, fixed costs for vehicles (maintenance, repair, depreciation), fuel costs (per kilometer), and labor costs for vehicle drivers
Total Facility Cost	This is the cost to operate the warehouse(s), which includes rent and electricity.
Total Administrative Cost	The total cost to order commodities, it is a per commodity unit cost that is applied.
Total Warehousing Cost	The cost of labor for warehouse employees shipping and receiving commodities
Total Supply Chain Cost	Sum of transportation, facility, administrative, and warehousing costs
Total Safety Stock Investment	The total investment needed to buy commodities to keep stocks are the recommended safety stock level, based on the fill-rate service requirement
Total Procurement Cost	The total investment needed to buy the needed commodities (price of commodities * # commodities)
Delivered Value	The total value of goods flowing through the supply chain (equals total procurement cost unless commodities are donated)
Delivered Value per Person	Delivered Value / country's population
Supply Chain Cost Rate (%)	Total Supply Chain Cost / Delivered Value (in %)

For more information, please visit deliver.jsi.com.

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