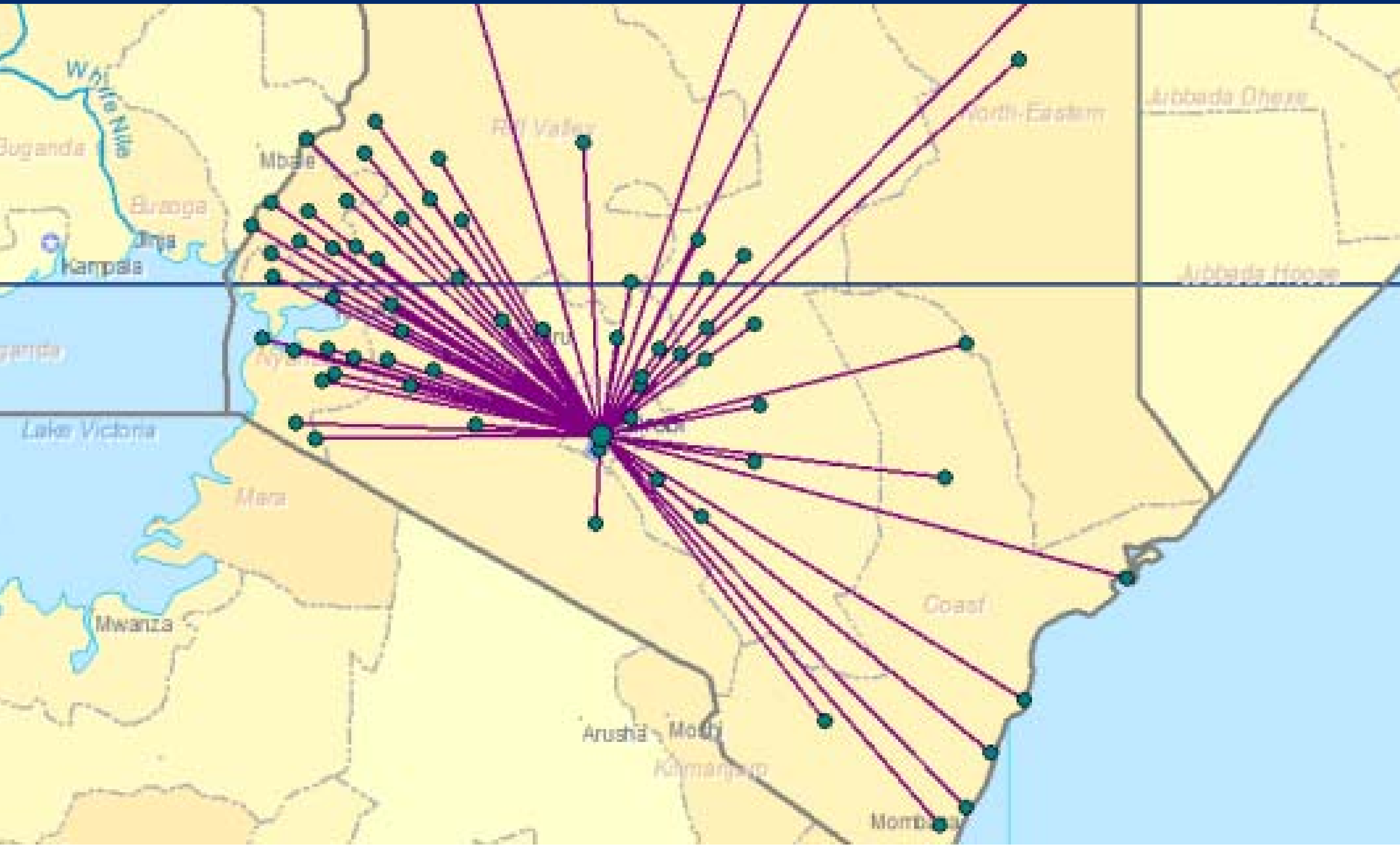
Kenya: 2020 Supply Chain Modeling Extension

Forecasting Demand from 2020–2024



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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.

In *Kenya: 2020 Supply Chain Modeling*, the application of the model to understand and analyze the current and future state (2020–2024) supply chain requirements for procuring and distributing essential medical commodities in Kenya was discussed. The following report is an extension of the initial report in which additional scenarios are analyzed.

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Cover photo: Current network structure in Kenya.

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Acronyms

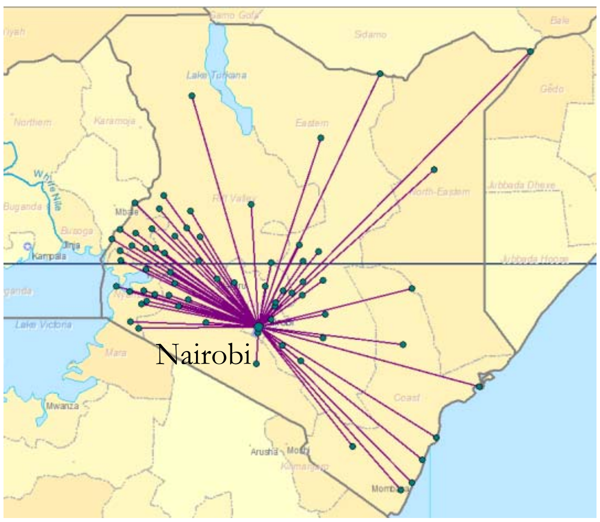
CPR	contraceptive prevalence rate
PHeNOM	Public Health Network Optimization and Modeling tool

Additional Scenario Analysis

Update to the Baseline Analysis

As detailed in the main report, the first step in the modeling process is to build a baseline model that depicts the current situation. Figure 1 depicts the current network structure in Kenya. The central warehouse is located in Nairobi, which delivers products directly 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 1. Current Network Structure in Kenya



Since the original report was written, there has been some additional information that has come to light about the current health practices in Kenya. In order to have an accurate baseline, a few minor updates were made to the baseline model. These updates included changing the diabetes prevalence rate for each year in question and increasing the treatment rate for hypertension. These changes were made based on epidemiological studies and are detailed in Appendix B. Apart from these changes, no others were made and all assumptions outlined previously still apply.

As shown in table 1, these updates to the baseline did not have a significant impact on the costs. The plus sign in the percent difference column indicates the increase in cost in the updated model. Although there is a slight change in handling and transportation costs, the overall effect is only 0.5 percent, a figure that corresponds to a cost difference of less than $30,000. All additional scenarios analyzed in this amendment are based on this version of the baseline model.

Table 1. Effects of the Updates to the Baseline (U.S. Dollars)

	PHeNOM Output 2010 (U.S. Dollars)	PHeNOM Output 2011 (U.S. Dollars)	Percent Difference (%)
Total transportation cost	$2,624,702	$2,633,399.36	+0.33
Total facility cost	$1,414,500	$1,414,500.00	0
Total administrative cost	$269,306	$272,524.05	+1.19
Total warehousing cost	$1,359,146	$1,375,385.35	+1.19
Total supply chain cost	$5,667,654	$5,695,808.76	+0.50

PHeNOM, Public Health Network Optimization and Modeling tool.

Additional Future State Analysis

The following future state scenarios explore the effects of varying characteristics of the health model on the supply chain costs. The Kenya Medical Supplies Agency currently uses the services of a third-party logistics provider for transportation, and it was determined from a previous analysis that unless the Kenya Medical Supplies Agency could maintain the vehicles appropriately, a third-party logistics provider was a better option. Therefore, all of the following scenarios have been analyzed assuming that all transportation services are provided by a third-party logistics provider.

In addition to that, all of the scenarios related to the changes in health model have been modeled under a centralized network structure, with the central warehouse located in Nairobi. However, because the capacity of the central warehouse as is stands is insufficient, the previous analysis was used to determine the capacity level and operating cost of the warehouse. Therefore, in addition to the costs that are mentioned in the scenario analyses that follow, the cost of the expanded warehouse must also be taken into account.

Changes to the Supply Chain Structure

In the previous analysis of the supply chain structure, one of the scenarios analyzed was a multi-echelon structure. This included a structure with a central warehouse in Nairobi and several variations of the number of additional facilities that were to act as district warehouses. In order to determine the location of the additional facilities, a greenfield analysis (or location-allocation analysis) was performed. This analysis retuned the proposed locations for distribution centers given the demand distribution across the districts and the number of facilities to add. The results from this analysis were also used for the following scenarios.

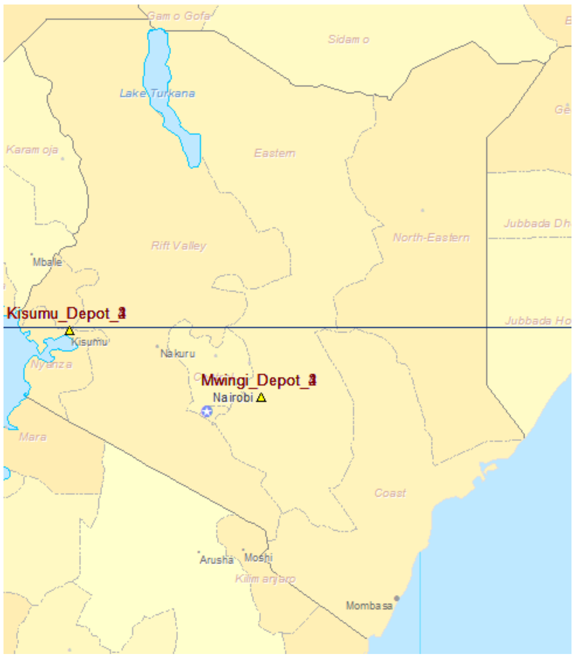
Decentralized Network

The following scenarios analyzed the changes to the supply chain costs under varied decentralized networks. In the following scenarios, the central warehouse in Nairobi is no longer used and bypassed, and scenarios with two, three, and four distribution centers are analyzed and compared.

Decentralized Network: Two Distribution Centers

As mentioned, the greenfield analysis conducted previously identified the depots in Kisumu and Mwingi to be used as the warehouse and distribution centers. Figure 2 shows the location of these two facilities on a map of Kenya.

Figure 2. Decentralized Network with Two Distribution Centers



Under this scenario, each of the facilities would need to be able to handle nearly 100,000 cubic meters in throughput and the cost structure for 2020 would be as shown in table 2.

Table 2. Cost Structure with Two Distribution Centers (U.S. Dollars)

Total logistics cost	$15,699,077
Total transportation cost	$5,482,488
Total facility cost	$5,138,584
Total administrative cost	$839,778
Total warehousing cost	$4,238,227

Decentralized Network: Three Distribution Centers

Under this scenario, the three distributions centers were located in Bamburi, Kisumu, and Nyeri. Figure 3 shows the location of these three facilities on a map of Kenya.

Figure 3. Decentralized Network with Three Distribution Centers

Under this scenario, the Nyeri and Kisumu facilities would need to be able to handle nearly 90,000 cubic meters in throughput; the Bamburi depot would need to handle approximately 20,000 cubic meters of throughput. The cost structure for 2020 would be as shown in table 3.

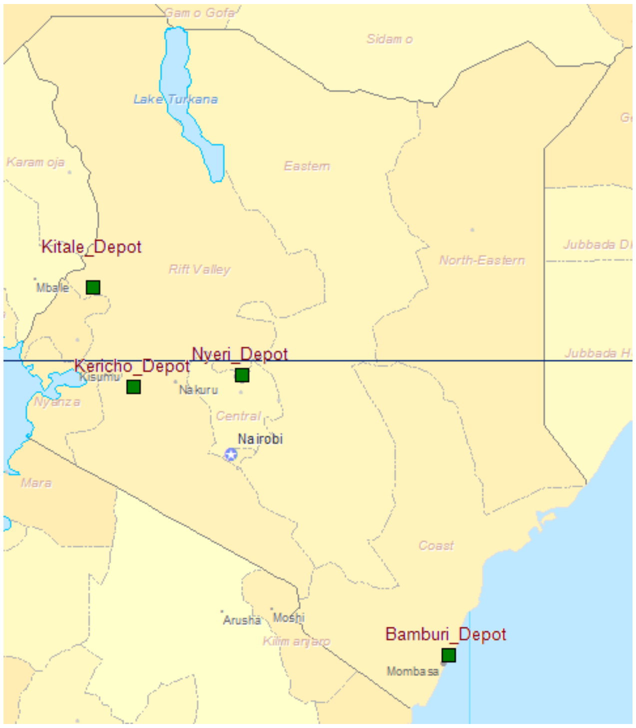
Table 3. Cost Structure with Three Distribution Centers (U.S. Dollars)

Total logistics cost	$17,227,503
Total transportation cost	$4,441,617
Total facility cost	$7,707,876
Total administrative cost	$839,779
Total warehousing cost	$4,238,231

Decentralized Network: Four Distribution Centers

In the final scenario for decentralized networks, four distributions centers were analyzed. These were located in Bamburi, Kitale, Kericho, and Nyeri. Figure 4 shows the location of these four facilities on a map of Kenya.

Figure 4. Decentralized Network with Four Distribution Centers



When the model is asked to use four distribution centers, the throughput needed is approximate 20,000, 45,000, 55,000, and 80,000 cubic meters at Bamburi, Kitale, Kericho, and Nyeri, respectively. The cost structure for 2020 would be as shown in table 4.

Table 4. Cost Structure with Four Distribution Centers (U.S. Dollars)

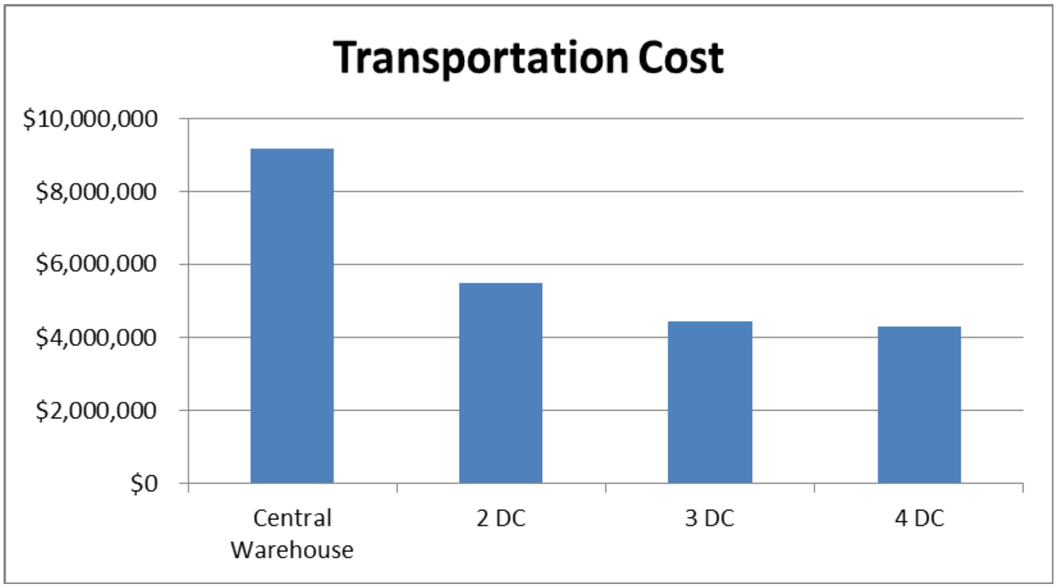
Total logistics cost	$19,667,024
Total transportation cost	$4,311,848
Total facility cost	$10,277,167
Total administrative cost	$839,779
Total warehousing cost	$4,238,230

Decentralized Network: Summary

One of the main tradeoffs analyzed in this scenario is the one between the transportation costs and the facility operating costs. The inbound transportation costs to the distribution centers (from air or sea ports) are not taken into account. This would be accurate under the assumption that each of the distribution centers would conduct its own procurement. The facility operating costs account for fixed operating costs based on the square footage of the facility and the wages of personnel needed to operate a facility of a particular size. The property value of the land at the different sites and the road networks are not taken into account at this level of analysis.

Figure 5 shows the transportation costs for the year 2020 under the centralized and three decentralized scenarios. Although there is a decrease in the transportation costs with the increasing number of distribution centers, the most significant cost reduction is seen in the scenario with two distributions centers. A caveat of this is that the transportation costs arising from interfacility flows are not accounted for. In the case of a stockout of a particular product at one the locations, a transfer of that product between the facilities would take place. This would depend on where the safety stock, a topic discussed later in the report, would be located.

Figure 5. Transportation Costs for Decentralized Network in 2020



The facility costs for 2020 under the various network structures are shown in figure 6. When the administrative costs (of putting in an order, managing inventory, etc.) and the handling costs at the warehouse are assigned per unit, they remain identical across the scenarios in the absence of a change in the demand. For the decentralized scenarios, although it may not be required, each facility is assumed to be a standard size that can handle 100,000 cubic meters of throughput. Hence, the central warehouse (handling 200,000 cubic meters of volume) and the two distribution center model have the same facility cost.

Figure 6. Facility Costs for Decentralized Network in 2020

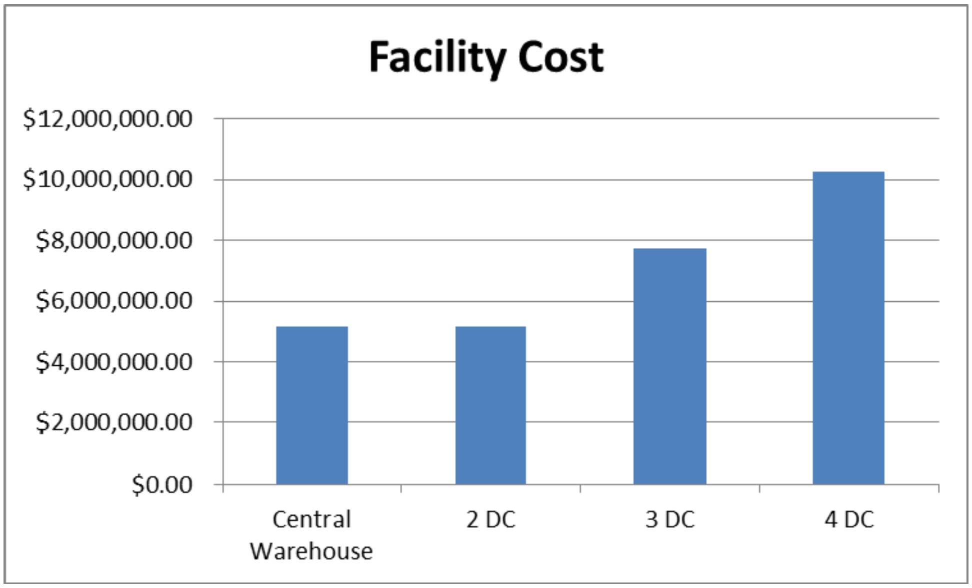
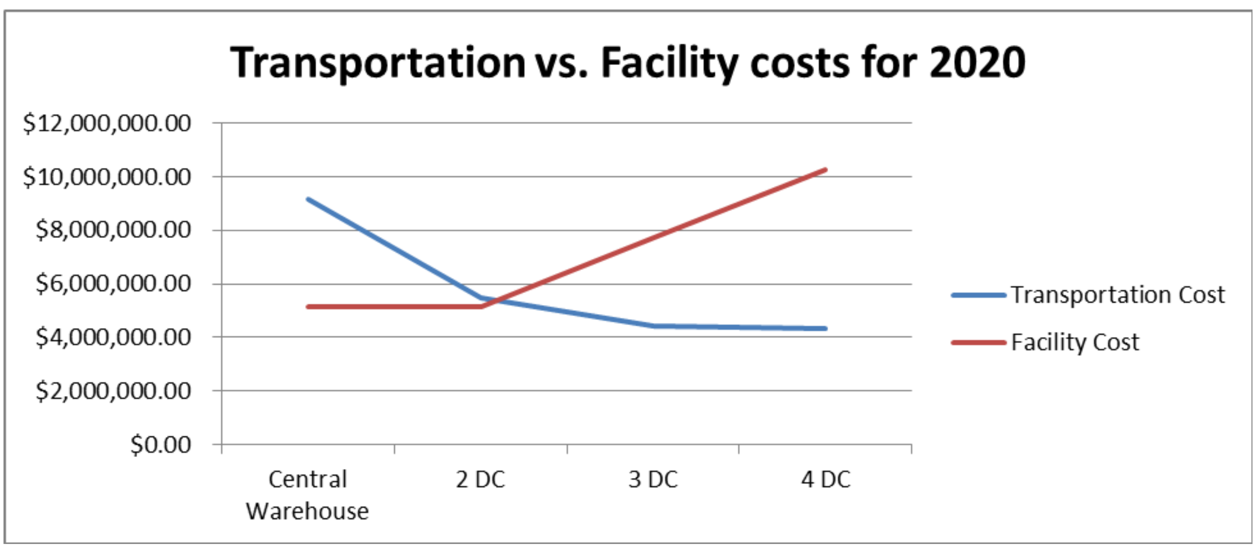


Figure 7 compares the facility costs with the transportation costs using the year 2020 as an example. While there can be more accuracy in the methodology to calculate the facility cost, it can be seen that there is a point where the benefits from reducing the transportation costs are outweighed by the costs from operating additional facilities.

Figure 7. Transportation versus Facility Costs for 2020



Safety Stock

One notable assumption in the decentralized network analysis is that the safety stock would remain centralized. This means that the safety stock would be stored at only one of the facilities and would be shipped either to the customer or the facility facing a stockout, as needed. As mentioned previously, the additional transportation cost associated with interfacility shipments is not considered in this model.

The safety stock investment is calculated based on the forecast error assigned to the demand, the supplier lead time, and the error in the supplier lead time. The forecast error of the demand is estimated to be a conservative percentage of 25 percent. A sensitivity analysis of this value shows that this does not vary the safety stock investment level significantly. The supplier lead time of 91 days is used to represent quarterly shipments that are currently in place. However, because these shipments are not always exactly on schedule, the baseline model uses a supplier lead time error of 25 percent. Table 5 shows the variation in safety stock investment with the supplier lead time error.

Table 5. Relationship between Supplier Lead Time Error and Safety Stock Investment

Supplier Lead Time Error	Safety Stock Investment (U.S. Dollars)	Safety Stock as a Percentage of Total Procurement (%)
25%	$101,932,580	14.2
10%	$41,920,253	5.8
5%	$22,891,702	3.2

Changes to the Health Model

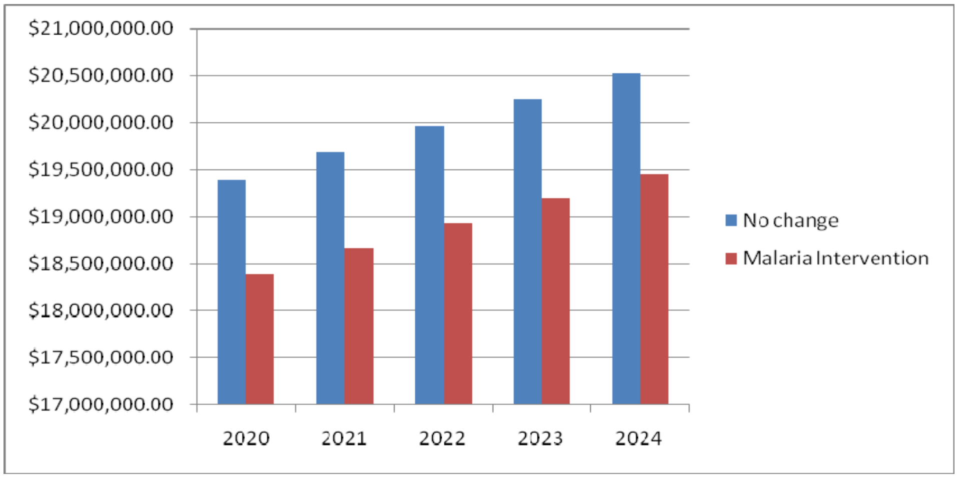
One of the main assumptions made during previous analyses was that disease prevalence rates for 2020 to 2024 would be the same as the prevalence rates from 2010. While this was necessary to understand the effects of growing population and the robustness of the current infrastructure, there are likely to be significant changes to various disease characteristics over the next decade. The following scenarios analyze the effect of potential changes in specific disease prevalence rates and treatment rates that are predicted. Appendix B lists the sources for the predicted changes.

Effects of Malaria Intervention

In this scenario, it is assumed that multiple types of malaria interventions that take place now will result in a 50 percent reduction in malaria incidence by the year 2020. Therefore, the prevalence rate for malaria is reduced by 50 percent and there were no changes made to the 34 percent treatment rate.

This resulted in a 9 percent reduction in the overall procurement cost during 2020 to 2025, meaning an average saving of approximately US$90 million per year. Figure 8 shows the resulting decrease in logistics cost from 2020 to 2025. This translates to logistics savings of nearly US$1 million per year, or a 5 percent decrease in logistics cost. The majority of this decrease (nearly 85 percent) is accounted for by the decrease in transportation costs.

Figure 8. Logistics Costs for Reduced Malaria Prevalence, 2020 to 2025



Effects of Economic Development on Disease Profiles

It is theorized that with economic development and increased urbanization, the prevalence and treatment of lifestyle diseases such as diabetes and cardiovascular diseases increases. In this scenario, the prevalence rates for both of the diseases have been adjusted based on epidemiological studies (outlined in Appendix B). In addition to this, the treatment rate for diabetes was increased from 5 percent to 20 percent. This was made under the assumption that urbanization and economic development would lead to more doctors' office visits and early detection and treatment of the condition. Table 6 outlines the specific prevalence rates used for the two diseases.

Table 6. Updated Prevalence Rates for Diabetes and Hypertension, by Year

Disease Condition	2020	2021	2022	2023	2024
Hypertension/cardiovascular	37%	38%	38%	39%	40%
Diabetes	3.75%	3.85%	3.94%	4.04%	4.13%

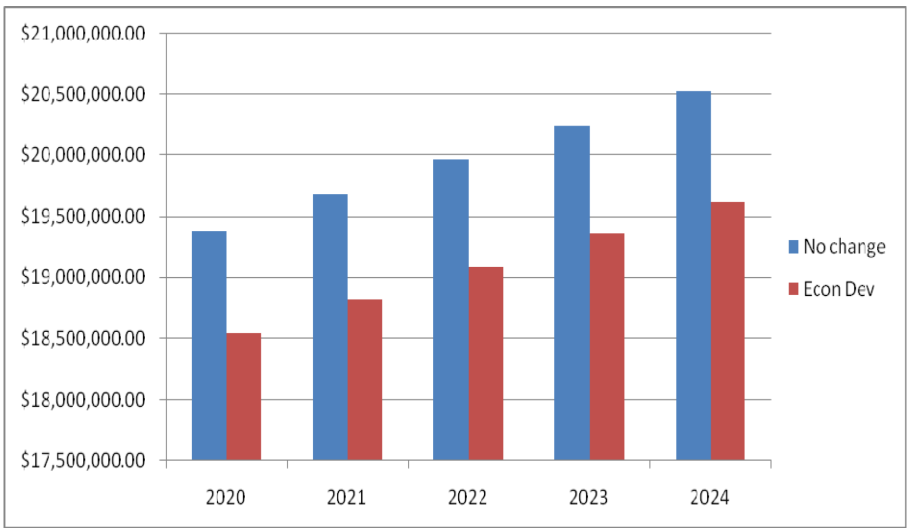
Given the lower volume of products used for treating these diseases, as compared with malaria, the difference in the costs was less significant for this scenario. Although there was an increase in both logistics and procurement costs, the difference only amounted to a 1 percent increase. These numbers, however, do not take into account new medications (volume, type, or cost) that would be required for the treatment of these diseases.

Economic Development Combined with Malaria Intervention

While the previous scenarios analyze the effect of the decreasing prevalence on one disease (malaria) and the increasing prevalence of others (diabetes and cardiovascular) individually, this scenario will take into account both of the changes together. This scenario analyzes the cost structure of a situation with a steady set of malaria interventions over the next decade and increasing urbanization and economic development.

As expected, the resulting savings in logistics and procurement costs under this combined scenario is less than that seen in the scenario with the malaria interventions alone. Figure 9 shows the difference in logistics costs, which are reduced by a little over 4 percent or nearly US$880,000, on average.

Figure 9. Logistics Costs for Economic Development Combined with Decreased Malaria Prevalence, 2020–2025



Introduction of Rotarix® Vaccine

The rotavirus is known to cause about 40 percent of all hospitalizations for diarrhea in children under the age of five. The Rotarix vaccine was found to be 78 percent efficacious against the rotavirus. Hence, the introduction of the Rotarix vaccine would result in a 78 percent decrease in 40 percent of childhood diarrhea cases. This scenario analyzes the change in logistics and procurement costs occurring as a result of this link between the vaccine and the prevalence rate. It is assumed for the scenario that the Rotarix vaccine is already taken into account under the vaccine bundle that has been modeled. Additional costs for the procurement of this vaccine or the cold chain storage are not taken into account.

Using a rate of 21 percent for childhood diarrhea prevalence and an increased treatment rate of 50 percent, a new baseline specific to this scenario was created. In order to account for the effects of the Rotarix vaccine under this scenario, the prevalence was reduced to 14.45 percent (accounting for the 78 percent efficacy in the 40 percent of diarrhea cases caused by the rotavirus). While the procurement costs saw a reduction of less than 1 percent, the total logistics costs were reduced by 3 percent. The majority of this reduction, over 60 percent, was in the form of reduced handling costs. The reduction in transportation costs accounted for a little less than a third of the 3 percent reduction in total costs. Because the procurement and potential cold-chain costs are not explicitly taken into account in this scenario, the introduction of the Rotarix vaccine may prove to be more expensive from a supply chain perspective, but it is a life-saving intervention.

Effects of Increasing the Contraceptive Prevalence Rate

There is a significant unmet demand for family planning needs in Africa. A study by the Futures Group studied the impact of population growth if all unmet needs for family planning were met (Moreland, Smith, and Sharma 2010). The study determined that if contraceptive prevalence rates (CPRs) increased at an optimistic yet realistic rate from 2005 to 2050, medium population estimates by the United Nations would not be impacted during the modeling period, "because of the dynamics of population momentum, the unmet need scenario's population projection approximates the UN medium projection." Therefore, for this scenario, an increase in population was not modeled, but the increase in CPR requirements did show an impact on the supply chain.

The CPR projections from the report were used to model this scenario. It was assumed that the proportion of contraceptive projected would remain the same. The CPRs are outlined in table 7.

Table 7. Assumed Kenya Contraceptive Prevalence Rates, 2005 to 2050

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Kenya contraceptive prevalence rate	28.4	33.3	38.2	43.1	48	52.9	57.8	62.7	67.6	72.5

In the event that there is limited capacity in the system, the model is set-up to prioritize products related to certain disease conditions. This is done by assigning each treatment category the following three values: critical fraction, standard fraction, and non-critical fraction. The critical fraction refers to the fraction of the total demand for the category that is of the highest importance to satisfy, while the standard and non-critical refer to the portion of the demand that are of average and low importance, respectively. For instance, 70 percent of all malaria, tuberculosis, and HIV drugs were assigned highest priority, as compared to 50 percent of all family planning and maternal health products that were assigned highest priority. For several other treatment categories (such as hypertension, diabetes, and others), only 30 percent of the total demand is deemed to be of highest importance.

For this scenario, keeping in mind the goals to improve the CPR, the critical ratio for family planning was increased to 70 percent, thus putting it in the highest priority group along with malaria, tuberculosis, and HIV. In order to see the effects of elevating the priority of the family planning products on the current system, this scenario was modeled under the assumption that the central medical warehouse was not yet expanded.

Without the additional throughput at the central warehouse, the prioritization of the family planning products comes at the expense of other commodities. If CPR increases and there is an increase in use of contraceptives, the capacity to manage all other non-priority products will be adversely impacted, and these products may need to be rationed. Although in reality the decision as to which commodities would be sacrificed would be a carefully deliberated decision, the model made a selection based on the parameters given. In order to accommodate the additional 300,000 or more units of demand, the product titled "other essential medicines" was negatively affected. This is the bundle of medicines that was required to cover disease conditions that were not specifically modeled. However, this bundle contains several important antibiotics, as well as male and female sterilization products that would affect the family planning initiative.

The amount of the "other essential medicines" bundle sent through the system was reduced by nearly 40 percent. This was only seen for 9 of the 69 districts, with the 9 districts receiving less than 20 percent of the required amount of the bundle. In reality, this reduction would most likely be spread out across the districts. However, the transportation budget would then need to increase. Therefore, additional efforts for family planning activities must be adequately funded and the necessary infrastructure changes (expansion of the central warehouse) must be made in order to fulfill this need without sacrificing others.

Other Scenarios Not Modeled

Effects of Changes in Male Circumcision Rates on HIV Prevalence

There is some evidence that relates increased male circumcision rates to a reduction in the prevalence of HIV in both males and females. The relevant studies indicate that complete coverage of male circumcision would halve new HIV infections in sub-Saharan Africa. Given that the male circumcision rate is already at 85 percent in Kenya, a scenario assuming 100 percent male circumcision rates would make a very small (less than 1 percent) difference to the current prevalence rates (see Appendix A for prevalence rates). As this was unlikely to offer any significant insights into the supply chain structure, this scenario was not modeled.

Effects of Changing Demographics: The Migration from Rural to Urban Areas

Although total population numbers under the categories of urban and rural were available for the years 2020 to 2025, the breakdown by district was not available. In order to see the true effect on the network, migration patterns and total population changes by district would be needed. As the demand in the model is structured at the district level and this information was not present, this scenario was not modeled.

Appendix A

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
RespInf - Child	7%	7%	7%	7%	7%	7%	7%	7%
RespInf - 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 B

Sources of Health Model Changes

Disease Condition	Changes made	Source(s)
Diabetes	Prevalence Rates	IDF. Diabetes atlas (4th Edition). Brussles: International Diabetes Federation, 2009. http://www.diabetesatlas.org/
Hypertension/Cardiovascular	Prevalence Rates	1. Mensah, GA. "Epidemiology of stroke and high blood pressure in Africa". Heart 2008; 94: 697-705. 2. Mensah, GA. "Ischaemic heart disease in Africa". Heart 2008; 94: 836-843. 3. Addo, Juliet, et al. "Hypertension In Sub-Saharan Africa: A systematic Review". Hypertension. 2007; 50;1012-1018.
Malaria	Prevalence Rates	1. D'Acremont et al.: Reduction in the proportion of fevers associated with Plasmodium falciparum parasitaemia in Africa: A systematic review. Malaria Journal 2010, 9:240. 2. Bouyou-Akotet, et al.: Evidence of decline of malaria in the general hospital of Lireville, Gabon from 2000-2008. Malaria Journal 2009, 8:300. 3. Otten, et al.: Initial evidence of reduction of malaria cases and deaths in Rwanda and Ethiopia due to rapid scale-up of malaria prevention and treatment. Malaria Journal 2009, 8:14. 4. Barnes, et al.: Impact of the large-scale deployment of artemether/lumefantrine on the malaria disease burden in Africa: case studies of South Africa, Zambia and Ethiopia. Malaria Journal 2009, 8(Suppl 1):SB.
Diarrhea (Rotarix Vaccine)	Prevalence Rate	1. Pawinski, Robert, et al. Rotarix in Developing Countries: Paving the way for inclusion in National Childhood Immunization Programs in Africa. Journal of Infectious Disease. 2010; 202(S1):S80-S86. 2. Atherly, Deborah, et al. "Rotavirus Vaccination: Cost-effectiveness and impact on CHild Mortality in Developing Countries." Journal of Infectious Disease. 2009 200S28-38.
Contraceptive Prevalence rate (CPR)	CPR rate	1. Moreland, Scott, Ellen Smith and Suneeta Sharma. "World Population Prospects and Unmet Need for Family Planning". Futures Group. April 2010.

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

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