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Zambia Transport Study

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Zambia Transport Study

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Abstract
From March through July 2014, the USAID | DELIVER PROJECT worked with Medical Stores Limited (MSL) to conduct a transport study utilizing Supply Chain Guru software. The study utilized data from the Choma and Chipata MSL hubs to generate models to inform optimal fleet requirements, site allocation, and routing guidance.

The survey assessed how the logistics systems managed selected family planning commodities at public health institutions. This report is based on the findings presented to Ministry of Health and USAID counterparts in July 2014. It describes the data and methodology used to create the model, the outputs from the modeling exercise, and recommendations for replicating this exercise in other hubs as they come online, if desired.

Cover photo: Medical Stores Limited vehicle being serviced in advance of scheduled deliveries from the Livingstone staging post, Choma, March 2014. Emma Stewart

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Contents

Figures

Tables

Acronyms

DHMT	District Health Management Team
DCHO	District Community Health Office
EMLIP	Essential Medicines Logistics Improvement Program
GIS	geographical information system
GPS	Global Positioning System
MSL	Medical Stores Limited
OSM	OpenStreetMap
SP	staging post
USAID	U.S. Agency for International Development

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Executive Summary

In order to fulfill Medical Stores Limited's (MSL) mandate to deliver commodities to all facilities in Zambia, a subnational warehousing approach has been adopted. This calls for the creation of hubs and associated staging posts to serve as cross-docking facilities to enable delivery of commodities to the health center level. The first of these facilities in Choma, Chipata, and now Mongu are operational. Based on the experiences at these hubs and their staging posts, what can be learned about how best to continue to roll-out this strategy? Using Supply Chain Guru modeling software, data inputs, and assumptions informed by key stakeholders, we can examine the Choma and Chipata experiences to inform decisions around fleet size, site allocation, and routing strategies.

To do this, two models were created in the software: a network model and Choma transport model. Following data collection from the hub and at MSL in Lusaka, as well as an assumption validation workshop, different scenarios were run within the model to inform current practices and future decisions. These scenarios covered fleet requirements for the entire country, with particular focus on the service area of the Choma hub, site allocation to hubs, and route recommendations for Choma. For each model and scenario, it has been noted what future data could better inform the model and resulting decisions. For the transport routing model in Choma, we have also noted the steps needed if this is to be replicated for other hubs. A summary of the three different analyses follows.

Fleet Requirement

In order to determine how many, and what types, of vehicles are needed to support direct delivery to health centers, it is necessary to know how much volume is being delivered to these health centers, how much volume each vehicle can accommodate, and how quickly it can distribute commodities and return to the hub. Based on MSL historical data on volumes of commodities flowing through the system, the study team factored in the peak volume, anticipated increase in order fill rate, and increase in boxes following the roll-out of the Essential Medicines Logistics Improvement Program (EMLIP) to determine the volume to be accommodated by the fleet. Since the fleet is intended to be comprised of 3.5-ton trucks and Land Cruisers, the carrying capacity for these vehicle types was used to determine the truckloads of volume being serviced by each hub or staging post.

In addition to the volume moving through the system, the other critical factor in determining the fleet requirements is how quickly vehicles can complete a delivery run and be restocked at the hub or staging post. This is informed by a number of factors, including distance traveled, volume per facility, and road conditions. Utilizing data from the Choma experience, the team extrapolated to determine the number of vehicle turns that could be completed by a 3.5-ton truck from each hub or staging post, based on the straight-line distance of the service area. As there are currently no Land Cruisers in the fleet, the vehicle turns for this type of vehicle are best estimates, and can be refined when more data is available. Based on the current hub structure where vehicles are shared between the hub and staging post, this methodology calculates that the current fleet requirement is 36 Land Cruisers and 33 3.5-ton trucks when all hubs and staging posts are open and operational. As order fill rates continue to increase, eventually reaching 80 percent for essential medicines and labs, these requirements will also increase to 46 Land Cruisers and 41 3.5 ton trucks.

Network Allocation

The network allocation analysis builds on previous modeling efforts to further refine the network strategy. This analysis builds on existing hub and staging post plans using available health facility–level location and demand data to determine allocation of individual health facilities to hubs and staging posts. By reallocating more than 200 facilities to a different hub or staging post than currently assigned, more than 18,000 km of distance (11 percent of the total current distance) can be saved. While distance is an important factor in terms of saving money through reduced fuel, maintenance, and per diem costs, it is only one factor in determining if a facility is allocated to its optimal hub. Additional considerations that were not included in the model are current and proposed road conditions, and current and potential human resources constraints of having a member of the District Health Management Team (DHMT) accompany hub staff on all deliveries, constraining all facilities within a district to the same hub. As these situations continue to evolve, the findings of the network refinement strategy can help inform which facilities could be reallocated to another hub or staging post.

Transport Route Optimization

Using data from MSL ledgers, Global Positioning System (GPS) units on hub vehicles, and hub manager expertise, the transport route optimization examined the possibility of determining routes that are more optimal than those currently being run. This means that all facilities are serviced by the hub in a timely manner, utilizing the best vehicle from the fleet. The model uses road network data (distance and road speed), data on facility accessibility, commodity volume by facility, and stop time at each facility to determine optimal routes. Since there is variability month to month, by comparing optimal routes across time it is possible to identify anchor sites around which the routes should be planned. These anchor sites provide the hub manager with some guidance on how to plan the routes, without having to start over each month, but allows for adjustments as needed based on variability. As with the network allocation analysis, this analysis was not constrained by district boundaries, and as such the anchor sites identified differ somewhat from the routes currently being run from the Choma hub. While they can be considered by the hub manager under current conditions to see if there are some routes to be altered, this guidance will be most useful in determining baseline routes if the involvement of the DHMT staff in deliveries changes in the future. Additionally, the methodology used for the Choma analysis can be used as other hubs are developed to help determine baseline routes, which can then be further refined as additional road network data is collected by hub vehicles.

Background and Methodology

Medical Stores Limited (MSL) has received a mandate to distribute commodities to every health facility in Zambia through regional hubs. This is a change from the current distribution model where MSL distributes commodities to the district level (district community health office [DCHO]) and all hospitals. From the DCHO, the district and facilities organize transport to the health center and health post level. The change will mean that MSL will deliver to over 1,800 facilities where previously they were delivering to approximately 200. To achieve this level of distribution, MSL plans to establish a number of hubs and staging posts (SP) to act as cross-docking distribution points.

This strategy falls within the draft *National Supply Chain Strategy for Essential Medicines and Medical Supplies*, under the Logistics strategic pillar, which identifies the expert implementation and professional management of storage, transport, and distribution of medical supplies to consumers as a strategic imperative of the public health sector. Under this pillar, objective 3 calls specifically for improving access to medical commodities through decentralizing the distribution of medical commodities and supplies through the establishment of regional hub where last mile distribution is led by MSL. This study seeks to support Strategic Intervention 3 under Thematic Area 3: Commodity Distribution- optimize transport resources and routing for distribution.

MSL has already begun the process of rolling out the hub strategy. Two prior studies were conducted to determine the locations and service areas for the hubs and SPs and estimate fleet requirements. When the study commenced in March 2014, Choma and Chipata hubs were open and operational. Since the study began, the Mongu hub has also opened. The Choma hub has an associated SP in Livingstone, and the Chipata hub's SP is located in Chama. The Mongu hub will not have an affiliated SP. The timing of the study was planned such that the real experiences in the established hubs could inform decisions for the remaining hubs.

The USAID | DELIVER PROJECT has partnered with LLamasoft, Inc. to provide supply chain network design and modeling to countries that seek to improve service delivery, manage costs, and increase efficiency of existing supply chain resources. Supply Chain Guru is proprietary software of LLamasoft that can be used to model various scenarios in order to provide insight and answers to supply chain questions. In the context of subnational hubs in Zambia, these questions include: what transportation routes would be optimal to cover last mile delivery? Can the national fleet requirements be informed by the experiences in Choma and Chipata? Are facilities optimally allocated to the hubs?

Study Objectives

To answer these questions, the study undertook three objectives: fleet requirement analysis, network strategy refinement, and transportation route optimization. Given that the Choma hub has been operational the longest, providing the greatest amount of data, findings from these analyses will be at a detailed level for the Choma hub and at a higher level for the remainder of the hubs. Based on the experience in Choma, the study will also provide guidance on how these analyses can be carried out and refined as other hubs open, should MSL want to pursue that.

Approach

The study utilized Supply Chain Guru software to create models of various scenarios that can inform the answers to the study questions. To gather the data inputs for the model, the study team met with MSL representatives and toured the central warehouse in Lusaka. The team also visited the Choma hub in March 2014 to observe the facility and operations, as well as meet with the hub manager. In addition to visiting the hub, the team visited four facilities to solicit feedback from the end users on their experience of the hub to date. Detailed information on the hub and facility visits can be found in appendix A. Upon returning from Choma, the team hosted a workshop with key stakeholders to assess and validate the assumptions and data to be input into the modeling software. For a list of workshop participants, consult appendix A. Following the workshop, additional data was collected with the help of MSL staff as well as GPS trackers on hub vehicles. All of this data was input into the software to create two models: a network model of all facilities and hubs in the country, and a transport optimization model of the Choma service area with more detailed inputs. Figure 1 represents some of the data that must be collected, organized and analyzed to create the models. A list of data and assumptions can be found in appendix C. From the models created, recommendations were generated for high-level national fleet requirements, suggested sites for reallocation, and identification of anchor sites to guide routing decisions for the Choma hub.

Figure 1. Data from a variety of sources must be collected and organized in order to be analyzed using modeling software.

Fleet Requirement Analysis

The fleet requirement analysis seeks to determine the number and type of vehicles required to accomplish last mile delivery to all health facilities in Zambia by assessing volumes of commodities moving through the system, the volume of commodities that each type of vehicle can accommodate, and how quickly a vehicle can service facilities and return to the stocking point (hub or SP).

Data Inputs

The data required to determine the national fleet size include the number of truckloads of commodities flowing through the system and how quickly a vehicle can be turned (go out for delivery and return to the hub). By dividing the number of turns into the number of truckloads being distributed, we are able to determine the number of vehicles needed.

Number of truckloads (volume)

÷

Number of turns

=

Number of vehicles

For the fleet analysis we considered two different scenarios. In scenario 1, each hub and SP has dedicated transportation assets that can be used throughout the month. In scenario 2, the transportation assets are shared between the hub and its associated SP (see table 1). In this scenario, it was assumed the vehicles spend three weeks at the hub and one week at the SP. The exception to this case is Kabompo and Zambezi SPs, which are located relatively close to one another but quite far from the Luanshya hub. Based on input from MSL, we assumed that the two SPs shared transportation assets, which are distinct from the Luanshya hub, and each SP had the assets for two weeks each out of the month.

Table 1. Hub and Staging Post Pairings

Hub	Associated Staging Post (SP)
Chipata Hub	Chama SP
Choma Hub	Livingstone SP
Kasama Hub	Mansa SP
Luanshya Hub	Solwezi SP
	Zambezi SP, Kabompo SP
Lusaka Hub	Mkushi SP
Mongu Hub	n/a

In addition to examining the two scenarios described, we have factored in planned increases in order fill rate. Currently, MSL is reporting order fill rates of 39 percent for lab commodities and 66 percent for essential medicines. MSL plans to be able to fill 80 percent of all orders in the future. This planned increase in volume flowing through the system will impact the fleet requirements. As such, we've examined the two scenarios described with both the current order fill rates as well as the proposed order fill rates.

Calculating Number of Truckloads

To calculate the number of truckloads of commodities moving through the system we need to know the following information: facilities within each service area and volume going to each facility. We know that monthly shipments of commodities are not always consistent in their volume and we want to be sure the fleet can accommodate the highest volume periods. To do this, we analyzed volume data from 2012 (as a re-racking exercise at MSL in 2013 has skewed some of the data), and found that the peak volume is 1.21 times the average. We have applied that peak factor throughout the analysis to ensure that there are sufficient vehicles to service all facilities in the highest volume periods.

Additionally, we know that the hub roll-out is planned to be followed by a roll-out of the Essential Medicines Logistics Improvement Program (EMLIP). Since commodities will be picked and packed at MSL in Lusaka for each facility, rather than packed for the whole district and broken down later, it is expected that there will be a greater number of smaller volume boxes moving through the system. To determine how much of an impact this new packaging will have, we examined the volume data for three districts pre and post roll-out of EMLIP. This analysis showed between 20 and 25 percent increase in volume following the roll-out of EMLIP. Comparing the data from 2012 and 2013, we saw an overall increase in volume of 13 percent across all facilities, which leads us to believe that the increase attributable to EMLIP is somewhere between 12 and 25 percent. For the fleet requirements, we have used 20 percent as the volume increase resulting from EMLIP roll-out.

The fleet requirements analysis covered two vehicle types: 3.5-ton trucks (4×2 or 4×4) and Land Cruisers. Currently MSL has 12 3.5-ton trucks, and one Land Cruiser for the existing hubs. Going forward, MSL envisions having more Land Cruisers in the fleet in order to more efficiently reach facilities with limited access due to poor roads, terrain, and seasonal factors. The carrying capacity of the 3.5-ton trucks is estimated to be 14.4 m^3, while the Land Cruisers can carry 4.6 m^3 of commodities.

Calculating Number of Vehicle Turns

A vehicle turn is a round trip delivery run by a vehicle to and from the hub in a one-month period. The more vehicle turns you are able to accomplish in one delivery period (month), the fewer vehicles are required to execute all of your routes. There are a number of factors that influence vehicle turns, including: distance between the hub and the facility, distance between facilities, facility accessibility, and volume flowing to each facility. If facilities are far from the hub, or far from one another, it requires more time to reach each facility and reduces how quickly the vehicle can return to the hub. Facilities with limited accessibility due to poor road conditions also take longer to access, and reduce vehicle turns. As volumes increase, each facility's shipments require more space on the truck, which can result in fewer facilities visited, but more vehicle turns. This is the case when a vehicle services high volume facilities near to the hub. If there are high volume facilities far from the hub or many small volume facilities, these routes will take longer to execute, resulting in fewer vehicle turns within the month.

From the ledgers of the Choma hub, we know that they are turning vehicles four times per month. Currently the entire fleet in Choma is comprised of 3.5-ton trucks. To determine how quickly vehicles can be turned in other hub service areas, we determined the average distance within the service area (straight-line distance) and extrapolated from the Choma experience (see table 2).

Table 2. Calculating Implied Vehicle Turns

Hub or Staging Post	Average of Service Distance (miles)[1]	Implied Turns (closest integer) using Choma as base	Implied Turns after introduction of Land Cruisers
Lusaka Hub	59	5	6
Luanshya Hub	55	6	7
Chipata Hub	100	3	4
Kasama Hub	139	2	3
Choma Hub	77	4	5
Mansa SP	107	3	4
Mkushi SP	90	3	4
Mongu Hub	85	4	5
Solwezi SP	110	3	4
Livingstone SP	102	3	4
Zambezi SP	35	9	10
Chama SP	114	3	4
Kabompo SP	28	11	12

Since the vehicle turns in Choma reflect the 3.5-ton trucks that are currently accessing all facilities, including those determined to have limited access as a result of terrain and road conditions, we assumed that with the introduction of Land Cruisers that will service these hard to reach locations, the 3.5-ton trucks will be able to accomplish one additional turn each month. There is no historical data available from the existing hubs on vehicle turns for Land Cruisers since they are not yet in use. Given that these vehicles are expected to service difficult to reach facilities, we have made an assumption that they are able to turn four times each month. This would amount to one route per week.

Findings

Detailed Choma Hub Fleet Requirements

Since the Choma fleet is operational we have current information on their transportation needs: volume flowing through the hub and Livingstone SP, identified limited access facilities, and vehicle turns. The hub manager has identified that all facilities in Shangombo, Sesheke, and Mulobezi would

[1] The default setting in Supply Chain Guru is English Standard (miles). Where additional road information was not gathered (Network Model) outputs remain in miles. Since distance calculations are all relative to the Choma hub (also in miles) there is no impact on the fleet requirement outputs.

be better served by a Land Cruiser. This accounts for about 45 percent of facilities served out of the Livingstone SP, and 30 percent of the volume moving from this SP. Knowing that the transport assets are shared between the Choma hub and Livingstone SP, how many facilities are limited access, and how quickly vehicles are currently being turned, we found that given the current order fill rates (39 percent for lab, 66 percent for essential medicines) the recommended fleet for Choma is four 3.5-ton trucks and five Land Cruisers. When MSL is able to meet the target fill rate of 80 percent for all commodities, the Choma hub will require an additional 3.5-ton truck and two additional Land Cruisers.

Based on feedback from MSL following the debrief on the network strategy refinement results, the fleet requirements for Choma were revised to reflect the needs of the hub if the identified facilities in Mazabuka were reallocated to the Lusaka hub. This would reduce the average service area in Choma from 77 miles to 63 miles, and increase turns from the Choma hub from four turns to five turns per month. This would not, however, have an impact on the overall fleet requirements. Under scenario 1, the Choma hub would require two 3.5-ton trucks, with or without Mazabuka facilities. Under scenario 2, the reallocation of Mazabuka would reduce the need for 3.5-ton trucks at the Choma hub from three to two, but what is driving the recommendation in this scenario is the number of 3.5-ton trucks required by the associated SP in Livingstone (4), see table 3 for details.

Table 3. 3.5-ton Trucks Needed in Choma Service Area Under Different Scenarios

	Current Choma Service Area		**Choma Service Area - Mazabuka Facilities Allocated to Lusaka**	
	Scenario 1	**Scenario 2**	**Scenario 1**	**Scenario 2**
Choma Hub	2	3	2	2
Livingstone SP	1	4	1	4
Recommended	**3** (total)	**4** (driven by SP)	**3** (total)	**4** (driven by SP)

Summary of National Fleet Requirements

While data from the Choma hub is readily available, we relied on assumptions drawn from the Choma and Chipata experiences to determine the fleet requirements for the other hubs. The major assumptions factoring into these calculations are the percentages of volume flowing to limited access facilities (11.8 percent from SPs and 30 percent from hubs) and how quickly vehicles can be turned. Since terrain and road conditions vary across the country, these assumptions may not be accurate across all hubs. See table 4 for summary fleet requirements for both current and projected order fill rates.

Table 4. Summary Fleet Requirements

	Current Order Fill Rate		Increased Order Fill Rate	
	Land Cruiser	**3.5-ton truck**	**Land Cruiser**	**3.5-ton truck**
Scenario 1 All storage facilities have dedicated vehicles	27	30	29	38
Scenario 2 Vehicles are shared between hub and associated SP	36	33	46	41

Considerations

Additionally, detailed road network information is not currently available for the entire country. As a result, we relied upon straight-line distance between the hub and each facility to extrapolate from the Choma experience. When actual road network data is available, there may be changes from the current average service area distance. This will be dependent on how much the road network varies from the straight-line projection. For example, in Choma, the estimated straight-line distance is 77 miles (123 km) whereas the actual road network average is 90 miles (145 km). Once actual service area distances are known, the calculations in the fleet requirements should be adjusted, and can be done easily by updating the service distance data in "Comparing Hubs for Turns" in the Calculations for Fleet Requirements spreadsheet, and subsequently updating the number of turns in the scenarios. This will apply only to 3.5-ton trucks, as all turns for Land Cruisers were assumed to be four. These distances will vary from those in the transport optimization as they do not calculate distance between facilities served by the hub. Detailed calculations for the national fleet requirement can be found in appendix D.

Network Refinement Strategy

The objective of the network refinement strategy analysis was to build on existing hub and SP plans using available health facility–level location and demand data to determine allocation of individual health facilities to hubs and SPs. Previous analyses were conducted to determine the placement of the hubs and SPs, as well as the facilities allocated to each. Under the current structure, members of the DHMT are accompanying the deliveries to facilities in order to conduct other tasks. As such, the service areas of each hub include all facilities within a given district.

In the future, it may no longer be the case that DHMT members accompany the hub delivery team. If this is the case, there are possible savings to be had in terms of distance traveled if some facilities within particular districts are reassigned to another hub or SP. In addition to the district structure, the current allocation of facilities to hubs accounts for current road conditions. While some districts are known to be closer to another hub, they are currently allocated to a hub that has better road access to the district. In addition to any changes in the involvement of the DHMT, completion of planned and ongoing road projects could be an appropriate time to revisit the facility allocation.

Data Inputs

To analyze the current network allocation, GPS coordinates of all health facilities in the network, as well as estimated locations of the hubs and SPs, were input into the model. Since the exact GPS coordinates of unbuilt hubs was unknown, locations were selected in their named town locations near local hospitals or medical administration offices. Similarly, SPs were located at representative DHO locations.

To determine the optimal allocation of facilities to hubs/SPs, the team considered only the straight-line distance between the facility and a given distribution point. The analysis was done by running two different scenarios in Supply Chain Guru and comparing the results. In one scenario, health facilities were linked to their currently assigned hub or SP. In the second scenario, this constraint was removed, and the model was able to allocate facilities to the hub or SP of its choosing. The team compared the two scenarios, identified discrepancies, and recorded the distance saved by allocating the facility chosen by the model.

Findings

Detailed Choma Hub Findings

For the Choma hub service area, it was determined that facilities within Mazabuka, and Shangombo could be reallocated for a combined savings of 4,593 miles. At this time it is not feasible to reallocate the Shangombo facilities from the Livingstone SP to the Mongu hub as the bridge connecting the two areas is not yet complete. This reallocation could be revisited when the road construction is complete. At this time, serving the facilities within Mazabuka from Lusaka rather than the Choma hub would save 2,570 miles. Although this would save time for distribution from the hub, as discussed earlier, the distance savings would not impact the Choma fleet requirements.

National Findings

At the national level, there are 229 facilities that could be reassigned to another hub or SP to save distance, and likely time. While the model helps to identify what facilities might be reallocated, each one will need to be examined for other factors before taking any action to reallocate. Table 5 identifies the districts with facilities that could be reallocated if the network strategy is re-examined. Details at the facility level can be found in appendix E.

Table 5. Districts from Which Facilities Could be Reassigned

Current Distribution Source	Proposed Distribution Source	Distance Saved (miles)	Districts from Which Facilities Could be Reallocated
Chama Staging Post	Kasama Hub	727	
Chipata Hub	Chama Staging Post	4,705	Lundazi
	Mkushi Staging Post	204	
Choma Hub	Lusaka Hub	2,570	Mazabuka
Kasama Hub	Chama Staging Post	2,269	Isoka, Mafinga, Mpika, Nkonde
	Mansa Staging Post	223	
Livingstone Staging Post	Choma Hub	103	
	Mongu Hub	2,023	Shangombo
Luanshya Hub	Solwezi Staging Post	1,570	
Lusaka Hub	Choma Hub	48	
Mansa Staging Post	Kasama Hub	813	
Mkushi Staging Post	Lusaka Hub	905	
Mongu Hub	Livingstone Staging Post	92	
	Zambezi Staging Post	167	
Solwezi Staging Post	Kabompo Staging Post	1,936	Mufumbwe, Mwinilunga
	Luanshya Hub	129	
	Mongu Hub	74	
Grand Total		**18,559**	

Considerations

It is understood that not all of the facilities identified by the model for reallocation can or should reallocated at this time, based on current human resources and road network constraints. Each should be evaluated for feasibility before making any administrative changes. Additionally, the distances saved, similar to the fleet requirements, do not calculate distance between facilities served by the hub but, rather, the distance between the hub and facility. Proximity to other facilities should be factored into any decisions. This additional level of detail is included in transport optimization modeling. If scaled to other hubs, this type of model can further inform network allocation decisions.

Transportation Route Optimization

The objective of the transportation route optimization analysis was to provide recommendations for optimal multi-stop delivery routes for the Choma hub and Livingstone SP service areas as well as provide guidance on how similar analyses could be conducted for other hubs as they come online.

Data Inputs

To determine optimal transport routes, the team relied on data provided by the hub as well as from MSL in Lusaka. The hub manager was able to provide an up-to-date facility list that included all facilities to be serviced by both the Choma hub and associated Livingstone SP. This list was developed in consultation with the DHMT. The hub manager also identified "limited access" facilities within the service area. These are facilities that, due to terrain and road conditions, would be better served by a Land Cruiser than a 3.5-ton truck. Also provided by the hub manager was a ledger of recent shipments. The trucks at the Choma hub were outfitted with GPS units that detail the location of the truck at two-minute intervals. This data was used to enhance the generic road network information the team obtained from OpenStreetMap (OSM) as well as to determine the average stop time of vehicles at facilities while making deliveries.

Of critical importance, MSL in Lusaka was able to provide the team with data on the number of cartons moving from Lusaka to the facilities served by the hub. This data reflects shipments in both 2012 and 2013, before and after the implementation of the hub. Knowing how many cartons were moving through the system, the team was able to calculate the volume of commodities. Antiretrovirals are in 10-L boxes, whereas other commodities are stored in 40-L boxes.

Commercial applications of modeling software rely on running the model for each delivery period to find the most optimal route each time. This isn't feasible or desired as part of the transport study. Instead, we looked to identify stable routes that can be run routinely without needing to consult the model each period. By identifying "anchor sites" there can be planned routes that are optimal but flexible enough to accommodate deliveries to other facilities.

To identify anchor sites we looked for stability in the routes month to month. The main drivers of instability are fluctuations in volume and in stop time. Additional factors include distance and accessibility, which are more difficult to control but can exacerbate any changes caused by variable volume and stop time.

The transport optimization model relied on facility location data, volume of commodities going to each facility, and data from the GPS trackers which showed how long vehicles were stopped at each facility.

Findings

Choma Hub Routing

The transportation optimization model was only run for the Choma service areas, as there is not currently detailed enough road network data for the other service areas. The model indicates that approximately 40 percent of Choma sites are stable, when the stop times are consistent. The model used 10-minutes stops at each site. A number of facilities were not shown to receive shipments each month. Once the shipments are more consistent, it's possible that additional anchor sites can be identified. While the GPS trackers show some variability in stop time, the mode of the stops was between 5 and 15 minutes. A list of the anchor sites with their associated routes can be found in appendix F.

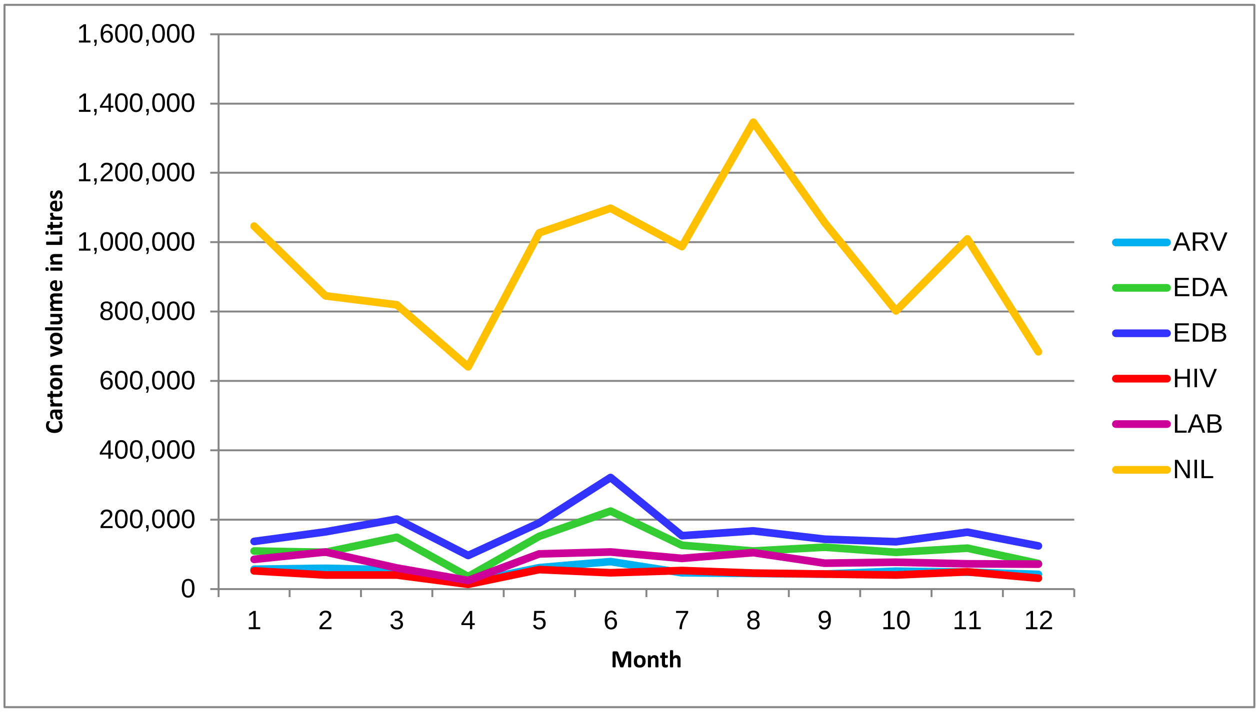
The Choma hub is currently running 25 routine routes. When comparing the anchor sites to the distribution lists provided by the hub manager, we see that many of the anchor sites fall outside of current routes. This is, in part, because the model was not constrained by district boundaries. The suggested anchor sites can only inform the routing patterns if the district personnel no longer accompany deliveries, or if they agree to accompany deliveries that are outside of their district. In consultation with the hub manager it is possible to use his or her knowledge along with the model to determine the optimal anchor routes.

Considerations

Variability in Volume

The carton data provided by MSL shows six categories of commodities handled by the system: antiretroviral (*ARV*) essential drugs (*EDA, EDB*), HIV test kits (*HIV*), laboratory commodities (*LAB*), and other (*NIL*). As shown in figure 2, approximately 60 percent of all volume moving through the system is classified as NIL. These are non-EMLIP essential medicines and equipment.

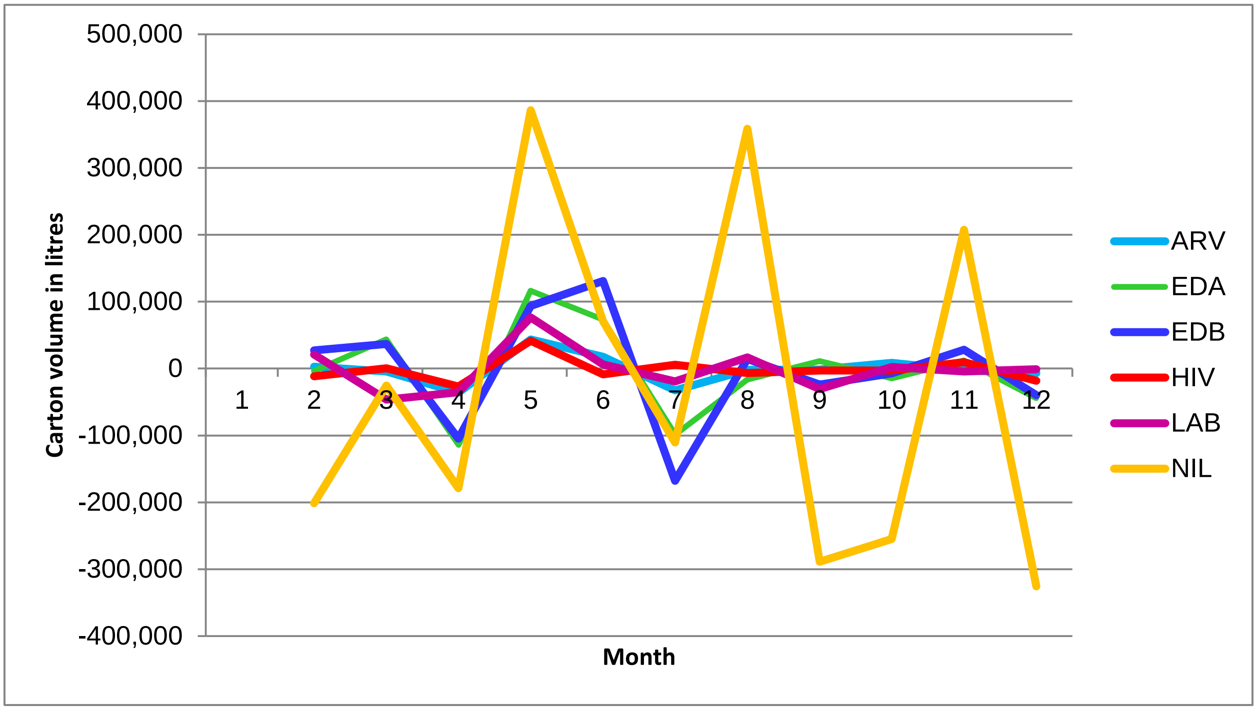
Figure 2. Volume by commodity type (national 2013).



Analysis of the carton data provided by MSL shows that most of the variability in volume moving through the system is driven by these non-EMLIP essential medicines and equipment (see NIL in figure 3). When volume is unpredictable, planning for stable routes around anchor sites becomes increasingly difficult. This difficulty is exacerbated if the facilities receiving highly variable quantities are far from the hub, or identified as limited access, as this decreases the number of vehicle turns. Since limited access facilities are being served by smaller vehicles, there is also less room to adjust the volume before having to resort to another or an additional route.

Moving more districts and products into established logistics systems (i.e., EMLIP) will help reduce the variability. Since the planned hub roll-out will be followed by EMLIP roll-out to these same facilities, this will reduce some of the variability. If more products can also be added into the system, as they come into full supply, this will further reduce the variability and assist in optimal route planning.

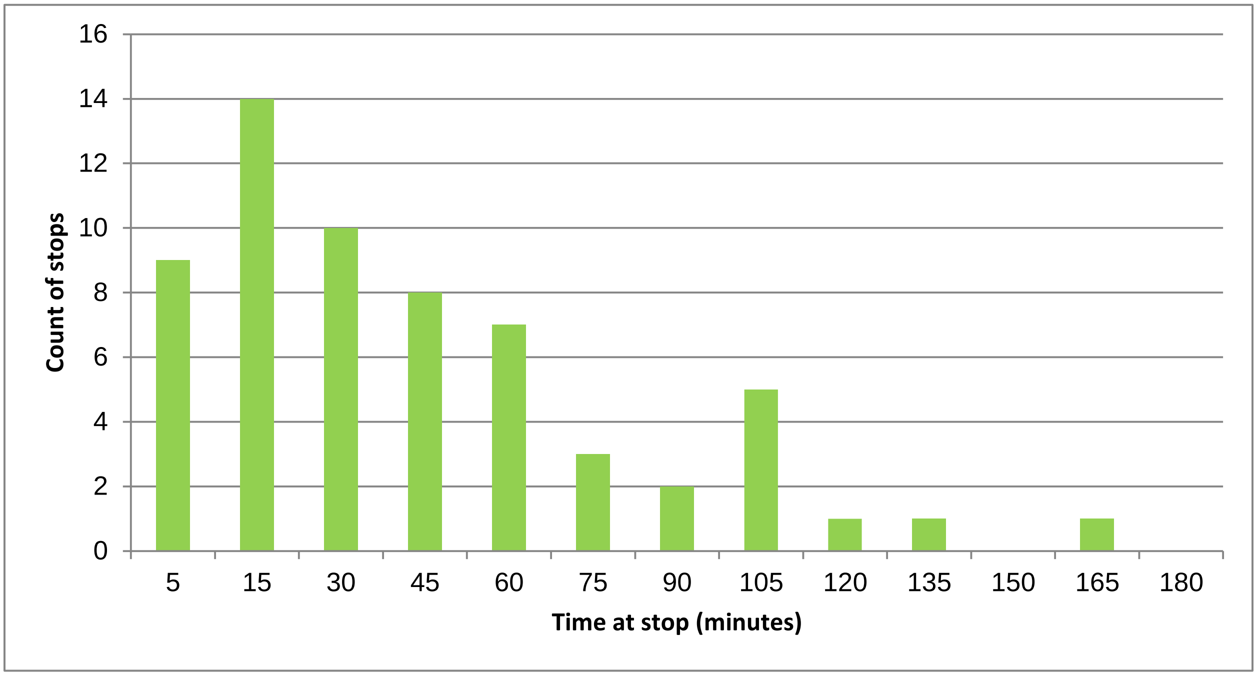
Figure 3. Difference from previous month (national 2013).



Variability in Stop Time

The GPS units on the hub vehicles track their location every two minutes. Using this data we are able to see how long a vehicle is stopped at a given facility. Analyzing the data from two months, the stop times are quite variable, as seen in figure 4. By reducing this variability and shortening stop times, it will be easier to predict how many facilities can be serviced on a given route. It is likely that when the vehicle is stopped for 60 minutes, this is the scheduled driver break, which has separately been factored into the model. At times, the vehicles remained at a location for more than six hours. It was assumed that this was an overnight stop for the vehicle rather than a delivery, and that time was not factored in. While most of the stops are less than 30 minutes, some lasted well over an hour. This length of stop would make it difficult to visit many facilities in one day, and should be controlled for where possible. Looking at the data by facility type, we did not find any trends. It was originally assumed that stop times at hospitals would be longer than at health centers, but that was not supported by the data.

Figure 4. Stop time at facilities as recorded by GPS trackers.



Distance and Limited Accessibility

Some factors that contribute to variability are more difficult to control, but are important to note. These include distance between the facility and hub, as well as distance between facilities, and limited accessibility due to road conditions. The distance between the hub and facility is difficult to control without a network reallocation; however, this can exacerbate the impact that variability in volume and variability in stop time have on forming standard routes. For instance, if a facility requires 5 percent of the space on the truck for its commodities one month, but 111 percent of a truck the next month, it cannot be identified as an anchor site. Additionally, while it can be added to an existing route one month, it will require its own separate route the following month. If the facility is located far from the hub, this prevents that vehicle from serving other facilities, and reduces the vehicle turns.

Limited access facilities are those that have been identified as better served by a smaller vehicle (Land Cruiser) than 3.5-ton truck. Most of these facilities are in remote locations with difficult terrain. Since they are likely scattered in relation to one another, variability in stop time will make it more difficult to reach all of the facilities within a delivery period. Additionally, variability in volume will be difficult to accommodate given the smaller carrying capacity of the vehicle. Many of these facilities are served by the staging post, which under the current model has only one week to make all scheduled deliveries. Although the smaller vehicle provides greater access to these facilities, the tradeoff is less flexibility. In areas served by Land Cruisers (i.e., Shangombo and Sesheke), controlling variability will be key in making all deliveries within the set delivery period.

Lessons Learned

Since this transport study was the first modeling exercise undertaken with a hub operational, there were many lessons learned that can help inform future efforts. As with any modeling exercise, the more high quality data that can be input into the model, the more likely that the outputs will be high quality and informative. One action that can improve data quality is utilization of a unique identifier for each facility that is linked to as many pieces of data during routine data collection as possible. In the Zambia context, this is the facility code assigned to each facility. As the service network is constantly changing as new facilities are added, maintaining a repository of these codes is critical, but only useful when that information is used to update other data collection efforts. In the two models created for this study, the facility code was critical in: identifying location sites with GPS coordinates, linking facilities to the box data maintained in the warehouse management information system MACS, and identifying facilities that are cutoff due to seasonal rains. Keeping facility codes for each of these data sources up to date will ease future modeling efforts.

Another lesson learned from this exercise is that having high quality data is critical. This is particularly important for both the volume data as well as the road network data. Before the box information was able to be extracted from MACS, the team tried various approaches to approximate the volume of commodity flowing to each facility. These methods relied on a large number of assumptions about catchment area, and services provided. Having the box data from MACS that reflects the historical throughput to each facility is crucial in accurately estimating both the fleet requirements and routing options. Digital road data, while available, is incomplete in that it does not capture all roads in the country nor does it convey road speeds for the various roads. By adding the GPS tracking units to the vehicles, the road network data for the Choma service area was greatly enhanced, improving the quality of the model outputs. Going forward, modeling efforts will benefit from GPS tracking units on all MSL vehicles.

In order for the model to help determine the most optimal routes that can be routinely run, it is important to increase the predictability of volume moving through the system as well as to manage stop times at each facility. These two factors greatly increase the ability to identify many anchor sites around which routes can be planned. Since most variability in volume is currently driven by essential medicines and equipment that are not part of a formal logistics system, moving these commodities into a formal system where they are routinely available will improve volume predictability. When variability in the system is reduced it becomes much easier to identify issues and take action.

One of the tasks of the hub manager should be to work with the team of drivers, and the DHO staff accompanying the deliveries, to standardize the stop time at facilities. The current variation in stop time makes it difficult to predict optimal routes, since the GPS data is not linked to the unique facility code. Rather than matching stop time for more than 300 facilities, the team relied on a standard stop time at each site. To identify sites that routinely exceed expected stop times, linking the data with facility code will improve the analysis, and resulting operational decisions.

Scaling to Other Hubs

If MSL chooses to use the modeling software to do additional analyses as other hubs open, some of the data can be entered in advance to inform the baseline routes and then further refined as more data becomes available. The initial data inputs include:

- All facilities in service area with GPS coordinates and unique facility code
  - The facility code should be linked to as many of the data points as possible as it will make linking the information much easier.
- Historical volume from MACS by facility
  - This will be number of boxes and can be converted to volume using the same methodology from Choma if the commodity type is known.
- Facilities known to be difficult to access
- The latest digital road network available from OSM

This information can inform baseline routes to run in the initial months of hub operation. If GPS units are added to the facilities, the detailed road speed and distance information they collect can help to further develop the road network in the model. Once this information is known, the model can be run again to determine the optimal anchor sites around which to plan future routes. Table 6 shows the information needed to update the modeling software for other hubs.

Table 6. Data Inputs for Scaling to Other Hubs

Data Needed	Location	Responsible Party	Frequency	Use
Facility list with code	Hub distribution list drawn from interactions with DHMTs	Hub manager	Once	Determine service area Serve as master list against which other data is checked
GPS coordinates of facilities	Sites table GPS units on vehicles	Ministry of Health	Once	Plot service area on map

Road network	OSM (osm.org)	GIS advisor	Once	Update existing road network
Limited access facilities (require Land Cruiser to access)		Hub manager	Once	Link facility to vehicle type to ensure delivery
Number of boxes by commodity type	MACs Hub ledger	MSL Hub manager	One year of data optimal	Calculate volume flowing to each facility
Travel distance and speed	GPS units on vehicles Hub vehicle logs Riders for Health	JSI MSL team Hub manager Riders for Health	Weekly as hub begins to deliver to facilities	Determine road conditions/travel times

References

Ministry of Health. 2013. *National Supply Chain Strategy for Essential Medicines and Medical Supplies (draft)*. Lusaka, Zambia.

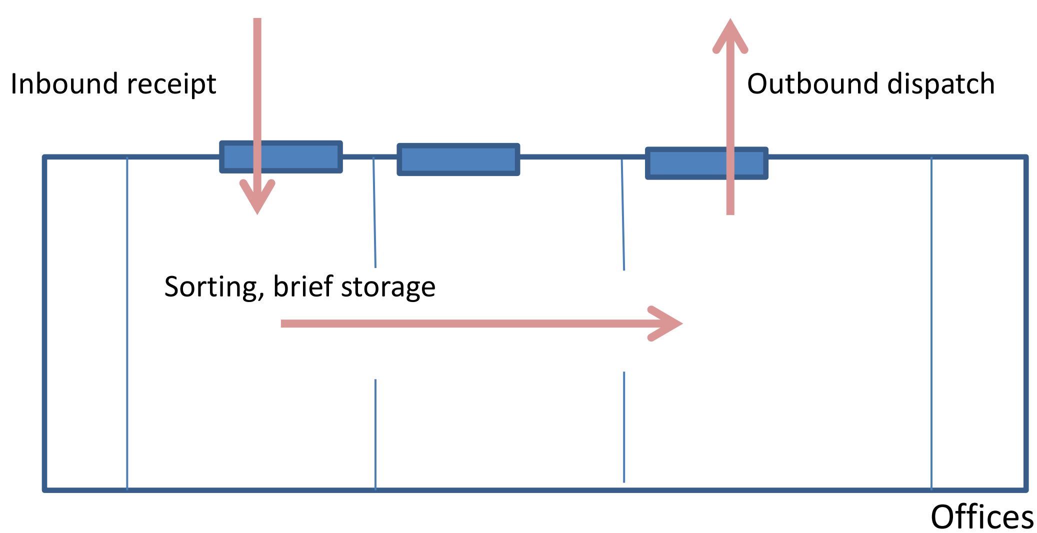
Appendix A. Choma Hub Visit

In March 2014, the transport study team visited the Choma hub to gather data for the study. While in Choma, the team also visited four facilities to gather feedback from end users on their experiences with the hub. The Choma hub operates 300 m^3 of storage space with separate loading bays for inbound receipt and outbound dispatch. At the time of the visit, the hub was serving more than 200 facilities in 10 districts on a monthly basis. When fully operational, the hub (including the Livingstone SP) expects to serve nearly 300 facilities. See figure 5 for a sketch of the Choma hub layout.

Client Satisfaction

The team visited four facilities being served by the Choma hub to determine the impressions of the end users on the hub delivery system. Due to time constraints, the facilities visited are all part of the Choma district, and were visited with DHMT staff. They range in distance from the hub from a few kilometers (Shampande) to 71 km (Masuku Terminal). While not a quantitative (or representative) survey, the team was able to get the opinions of facility staff on four indicator areas: lead time, predictability, order fulfillment, and MSL interactions. Overall, DHMT and facility staff are satisfied with the service of the hub, citing decreased lead times for order fulfillment (from five to six weeks to four to five weeks), greater predictability of when orders will arrive, and increased interactions with MSL staff (previously there were none). Predictability of order arrival is improved since the hub has dedicated vehicles and the district is no longer required to organize transport and fuel to deliver commodities. Additionally, the hub manager shares a delivery schedule with each facility; however, no facility was able to easily locate the schedule. Order fulfillment remains constrained by national stock levels under the new distribution strategy.

Figure 5. Sketch of Choma hub layout.



Appendix B. Assumption Validation Workshop Participants

Table 7. Assumption Validation Workshop Participants

Chikuta Mbewe	Deputy Director Logistics, Ministry of Health
John Ngosa	Director of Logistics, MSL
Chipopa Kazuma	MSL
Wambua Nzioki	MSL
Richard Chitembeya	Transport Manager, MSL
Maxwell Kasonde	Senior Pharmacist, RH Logistics Coordinator MCDMCH
Constance Chilbiliti	Riders for Health
Wendy Nicodemus	Deputy Director Data and Information Systems, DELIVER/ SCMS
Yapoma Nkhoma	Senior Public Health Logistics Advisor, DELIVER/SCMS
Deus Mwale	Public Health Logistics Advisor, DELIVER/SCMS
Fred Tembo	Public Health Logistics Officer, DELIVER/SCMS
Nathan Sichangwa	Public Health Logistics Officer, DELIVER/SCMS

Appendix C. Modeling Assumptions

Table 8. Modeling Assumptions

Product:	List of products hub manages provided by MSL, by commodity type
Product volume:	Total volume of delivery – represents all commodities delivered by hub/SP as cubic space (m^3), disaggregated by facility Volumes assigned by commodity type: 10 m^3 for antiretrovirals, 40 m^3 for all others, based on observations of box sizes
Locations:	Existing health facility names, latitudes, and longitudes provided by DELIVER/SCMS staff based on continuous updating of original JICA effort.
	Unbuilt hub locations sited in their named town locations near local hospitals or medical administration offices. Staging posts sited at representative DMO locations.
Road network:	Network model: straight-line distance based on facility location Transport optimization model: Shapefile obtained from public sources and cleaned by GIS advisor; updated using local driver review and GPS data obtained from vehicle trackers
Shipments frequency:	Occur on monthly delivery cycle
Vehicle types:	Mitsubishi/Fuso Canter 4×4 box truck (also 4×2s at Choma and Chipata) Land Cruiser
Carrying capacity:	14.4 m^3 Mitsubishi/ Fuso Canter 4.6 m^3 Land Cruiser
Fuel economy:	12.331 miles per gallon (5.24 km/L) (http://www.mitfuso.com/en-us/Canter-Advantage/Fuel-Economy) Fuel cost per km = (9.2 ZMK/5.24 km) = 1.76 ZMK/km
Fuel tank size:	Total 250 L (after supplementary tanks)
Vehicle prices:	370,000 Rand FOB South Africa excluding VAT (Fuso Canter)
Driver salaries:	4,300/ month (Kwacha)
Local fuel price:	9.2 ZKW/L diesel (U.S.$1.53/L as of March 15, 2014)
Vehicle economic working lives:	Four years is standard accounting life.
Vehicle load and unload times:	Loading time: one day Unloading time: 10 minutes—average based on GPS tracking data
Driver breaks:	One 60-minute break per shift

Road speeds:	GPS data from vehicles used to determine speeds along four different road classifications: tarmac, secondary, local, and local major (tarmac road through an urban area) For roads where speed was recorded, actual speed used For roads without GPS tracking data, the average speed in that district (by road type) was assigned
Site availability:	8:00 – 16:30
Exchange rates:	U.S.$1 = 6 Zambia Kwacha (as of March 15, 2014)
Vehicle insurance:	Annual cost at 8% of vehicle value (industry standard)
Maintenance:	Small repairs handled by drivers; large repairs and routine maintenance done in Lusaka
Maintenance timing:	Three days/month or 5000 km (aligns with monthly)
Maintenance costs:	0.79 ZMK per km (45% of fuel costs per kilometer traveled—comparable Tanzania study)

Appendix D. Fleet Requirements Calculations

Table 9. Scenario 1 Land Cruisers

Hub/SP	% of Volume going to INACCESSIBLE Facilities	Volume for Land Cruisers	Land Cruiser Truckloads	Number of Turns	Number of Land Cruisers
Chama SP	30%	7	1.4	4	1.0
Chipata Hub	12%	24	5.3	4	2.0
Choma Hub	12%	19	4.1	4	2.0
Kabompo SP	30%	6	1.3	4	1.0
Kasama Hub	12%	21	4.5	4	2.0
Livingstone SP	30%	22	4.9	4	2.0
Luanshya Hub	12%	39	8.5	4	3.0
Lusaka Hub	12%	57	12.3	4	4.0
Mansa SP	30%	48	10.3	4	3.0
Mkushi SP	30%	41	8.9	4	3.0
Mongu Hub	12%	15	3.2	4	1.0
Solwezi SP	30%	31	6.8	4	2.0
Zambezi SP	30%	7	1.5	4	1.0
				Total	**27**

Table 10. Scenario 1 3.5-ton Trucks

Hub/SP	% Going by 3.5-ton Truck	Volume for 3.5-ton Trucks	Number of 3.5-ton Truckloads	Number of Turns	Number of 3.5-ton Vehicles
Chama SP	70%	15.3	1.1	4	1.0
Chipata Hub	88%	182.7	12.7	4	4.0
Choma Hub	88%	140.0	9.7	5	2.0
Kabompo SP	70%	13.9	1.0	12	1.0
Kasama Hub	88%	155.4	10.8	3	4.0
Livingstone SP	70%	52.3	3.6	4	1.0
Luanshya Hub	88%	293.3	20.4	7	3.0
Lusaka Hub	88%	424.5	29.5	6	5.0
Mansa SP	70%	110.9	7.7	4	2.0
Mkushi SP	70%	95.4	6.6	4	2.0
Mongu Hub	88%	109.7	7.6	5	2.0
Solwezi SP	70%	72.5	5.0	4	2.0
Zambezi SP	70%	15.7	1.1	10	1.0
				Total	**30**

In tables 11 and 12, cells highlighted in yellow indicate the figure used to calculate the total. The higher figure was chosen between each hub and associated SP.

Table 11. Scenario 2 Land Cruisers

Hub/SP	% of Volume going to INACCESSIBLE Facilities	Volume for Land Cruisers	Land Cruiser Truckloads	Number of Turns	Number of Land Cruisers
Chama SP	30%	7	1.43	1.00	2
Chipata Hub	12%	24	5.32	3.00	2
Choma Hub	12%	19	4.07	3.00	2
Livingstone SP	30%	22	4.87	1.00	5
Kabompo SP	30%	6	1.29	2.00	1
Zambezi SP	30%	7	1.46	2.00	1
Kasama Hub	12%	21	4.52	3.00	2
Mansa SP	30%	48	10.33	1.00	11
Luanshya Hub	12%	39	8.53	3.00	3
Solwezi SP	30%	31	6.75	1.00	7
Lusaka Hub	12%	57	12.35	3.00	5
Mkushi SP	30%	41	8.89	1.00	9
Mongu Hub	12%	15	3.19	4.00	1
				Total	**36**

Table 12. Scenario 2 3.5-ton Trucks

Hub/SP	% Going by 3.5-ton Truck	Volume for 3.5-ton Trucks	Number of 3.5-ton Truckloads	Number of Turns	Number of 3.5-ton Vehicles
Chama SP	70%	15	1.1	1.0	2.0
Chipata Hub	88%	183	12.7	3.0	5.0
Choma Hub	88%	140	9.7	3.8	3.0
Livingstone SP	70%	52	3.6	1.0	4.0
Kabompo SP	70%	14	1.0	6.0	1.0
Zambezi SP	70%	16	1.1	5.0	1.0
Kasama Hub	88%	155	10.8	2.3	5.0
Mansa SP	70%	111	7.7	1.0	8.0
Luanshya Hub	88%	293	20.4	5.3	4.0
Solwezi SP	70%	72	5.0	1.0	6.0
Lusaka Hub	88%	424	29.5	4.5	7.0
Mkushi SP	70%	95	6.6	1.0	7.0
Mongu Hub	88%	110	7.6	5.0	2.0
				Total	**33.0**

Appendix E. Detailed Network Reallocation Findings

District	Current hub or staging post	Proposed hub or staging post	Facility Code and Name
Chama	Chama Staging Post	Kasama Hub	302011 Chibale Rural Health Center
			302016 Lundu Rural Health Center
			302018 Mulilo Rural Health Center
			302022 Chilubanama Rural Health Center
Chilubi	Mansa Staging Post	Kasama Hub	601013 Fube Rural Health Center
			601015 Mayuka Rural Health Center
Chingola	Luanshya Hub	Solwezi Staging Post	202018 Mutenda Rural Health Center
Ikelenge	Luanshya Hub	Solwezi Staging Post	705001 Kalene Mission Hospital
			705012 Ikelenge Rural Health Center
			705013 Jimbe Rural Health Center
			705014 Kafweku Rural Health Center
			705022 Mukangala Rural Health Center
			705025 Sachibondu Rural Health Center
			705027 Salujinga Rural Health Center
			705033 Kayipaka Rural Health Center
			705099 Kawota Rural Health Center
Isoka	Kasama Hub	Chama Staging Post	603013 Kampumbu Rural Health Center
			603016 Nachisitu Rural Health Center
			603020 Nzoche Health Post
Itezhi-tezhi	Lusaka Hub	Choma Hub	803001 Itezhi-tezhi District Hospital
Kabwe	Mkushi Staging Post	Lusaka Hub	102001 Kabwe Mine Hospital
			102002 Kabwe General Hospital
			102010 Bwacha Urban Health Center
			102011 Kabwe Zambia Railways (Rayton) Urban Health Center
			102012 Railway Surgery Urban Health Center
			102015 Mahatma Gandhi Urban Health Center
			102016 Makululu Urban Health Center
			102019 Mukobeko Township Urban Health Center
			102020 Nakoli Urban Health Center
			102021 Natuseko Urban Health Center
			102022 Ngungu Urban Health Center
			102023 Pollen Urban Health Center
			102027 Chowa Urban Health Center
			102028 Kasanda Urban Health Center
			102032 Nkhruma Teachers College Health

			Post
			102033 Kawama Urban Health Center
			102035 Kasavasa Rural Health Center
			102038 KIFCO Health Post
			102039 Kang'omba Health Post
			102041 Katondo Urban Health Center
			102098 Kabwe General Hospital HAHC
			102099 Kabwe Mine Hospital HAHC
			1020A9 Chowa Railway Home Based Care
			1020AA Chreso Ministries - Kabwe
			1020B9 Dackana Home Based Care
			1020D9 Lukanga Home Based Care
			1020G9 Ngungu Home Based Care
			1020J9 Kang'ombe Urban Health Center
			1020K9 Munga Health Post
			1020L9 Highridge Urban Health Centre
			1020M9 Ranchhod Urban Health Center
			1020V9 Mukuni Insurace Clinic
			1020X9 DATF Kabwe
			1020Y9 Kabwe Medical Center
Kapiri-Mposhi	Mkushi Staging Post	Lusaka Hub	103003 Chibwe Rural Health Center
			103004 Chilumba Rural Health Center
			103005 Chilwa Rural Health Center
			103009 Luanshimba Rural Health Center
			103010 Lunsemfwa Rural Health Center
			103011 Mukonchi Rural Health Center
			103012 Mukubwe Rural Health Center
			103013 Mulungushi Rural Health Center
			103014 Mpunde Mission Rural Health Center
			103015 Ngabwe Rural Health Center
			103017 Mulungshi University Rural Health Center
			103018 St. Pauls Rural Health Center
			103019 Waya Rural Health Center
			103020 Kampumba Rural Health Center
			1030B9 Chitaba Rural Health Center
			1030I9 Chapusha Health Post
Kaputa	Mansa Staging Post	Kasama Hub	604013 Mukupa Katandula Rural Health Center
			604019 Kalaba Rural Health Center
Kasama	Kasama Hub	Mansa Staging Post	6050F9 Mumbi Mukulu Health Post
Kazungula	Livingstone Staging Post	Choma Hub	805022 Nyawa Rural Health Center
			805025 Kauwe Rural Health Center
Lukulu	Mongu Hub	Zambezi Staging Post	903017 Sikunduko Rural Health Center
Lundazi	Chipata Hub	Chama Staging Post	305011 Mwase Lundazi Zonal Rural Health Center
			305012 Kanyanga Rural Health Center

			305013 Munyukwa Rural Health Center
			305014 Lunzi Rural Health Center
			305015 Mtwalo Rural Health Center
			305016 Malandula Rural Health Center
			305017 Chasefu Rural Health Center
			305018 Nkhanga Rural Health Center
			305019 ZASP Health Post
			305020 Phikamalaza Rural Health Center
			305021 Lusuntha Rural Health Center
			305023 Kapichila Rural Health Center
			305024 Zumwanda Rural Health Center
			305027 Mwanya Rural Health Center
			305028 Chitungulu Rural Health Center
			305029 Kazembe Rural Health Center
			305032 Lundazi District Hospital
			305033 Chijemu Health Post
			305034 Kamsaro Health Post
			305035 Mucheleka Health Post
			305040 Lukwizizi Health Post
			305041 Mkasanga Health Post
			305099 Lundazi District Hospital HAHC
			3050B9 Egichikeni RHC
			3050C9 Hoya Health Post
			3050D9 Mkomba Health Post
			3050G9 Lundazi Urban Health Center
			3050H9 Zokwe Rural Health Center
			3050I9 Thandizane Health Center
			3050X9 DATF - Lundazi
Luwingu	Kasama Hub	Mansa Staging Post	606001 Luwingu District Hospital
			606010 Chungu Rural Health Center
			606011 Ipusukilo Rural Health Center
			606012 Katuta Rural Health Center
			606013 Luena Rural Health Center
			606014 Namukolo Urban Health Center
			606015 Ndoki Rural Health Center
			606016 Nsombo Rural Health Center
			606018 Tungati Rural Health Center
			606019 Lufubu Health Post
			606020 Mwando Health Post
			606021 Lundu Health Post
Mafinga	Kasama Hub	Chama Staging Post	603014 Mulekatembo Rural Health Center
			603015 Muyombe Rural Health Center
			603017 Thendere Rural Health Center
			603018 Kalyamani Health Post
			603019 Mweniwisi Health Post
			603025 Chanama Health Post
Mazabuka	Choma Hub	Lusaka Hub	807001 Mazabuka District Hospital
			807002 Chikankata Mission Hospital

			807003 Kafue Gorge Hospital
			807010 Cheeba Rural Health Center
			807011 Chikokomene Rural Health Center
			807012 Chikombola Rural Health Center
			807013 Chingangauka Rural Health Center
			807014 Chivuna Rural Health Center
			807015 Hanjalika Health Post
			807016 Hanzala Rural Health Center
			807017 Itebe Rural Health Center
			807018 Kafue Gorge Urban Health Center
			807019 Kalama Rural Health Center
			807020 Kasco Urban Health Center
			807021 Kaleya Urban Health Center
			807022 Kaonga Urban Health Center
			807023 NKonkola Rural Health Center
			807024 Lubombo Rural Health Center
			807025 Magoye Rural Health Center
			807026 Mbaya Msuma Rural Health Center
			807027 Mugoto Rural Health Center
			807028 Mukuyu Rural Health Center
			807029 Munenga Rural Health Center
			807030 Munjile Rural Health Center
			807031 Nadezwe Rural Health Center
			807033 Nakambala Urban Health Center
			807034 Naluama Rural Health Center
			807035 Nameembo Rural Health Center
			807036 Nanga Rural Health Center
			807037 Nega Nega Rural Health Center
			807038 Research Station Urban Health Center
			807039 Riverside Farm Rural Health Center
			807040 Moobe Health Post
			807041 Musuma Health Post
			807042 Nanduba Health Post
			807043 Namaila Rural Health Center
			807044 Mubuyu Health Post
			807045 Makuku Health Post
			807046 Kanjira Health Post
			807047 Chibote Health Post
			807098 Chikankanta Mission Hospital HAHC
			807099 Mazabuka Hospital HAHC
			8070F9 Chuula - Mazabuka
			8070H9 Lubomba Homebased Care
			8070J9 Chikani Health Post
			8070L9 Terranvova
			8070V9 Manyonyo Health Post
Mkushi	Mkushi Staging Post	Lusaka Hub	104012 Chimika Rural Health Center
			104018 Mboshya Rural Health Center

Monze	Choma Hub	Lusaka Hub	808023 Banakaila Rural Health Center
			808024 Moonzwe Rural Health Center
Mpika	Kasama Hub	Chama Staging Post	608023 Nabwalya Rural Health Center
		Mansa Staging Post	608011 Chiunda Ponde Rural Health Center
			608015 Lukulu Rural Health Center
			608022 Muwele Rural Health Center
Mporokoso	Kasama Hub	Mansa Staging Post	609013 Chiwala Rural Health Center
			609020 Sunkutu Rural Health Center
			6090A9 Namukolo Clinic
Mufumbwe	Solwezi Staging Post	Kabompo Staging Post	704001 Mufumbwe District Hospital
			704010 Boma Rural Health Center
			704011 Jivundu Rural Health Center
			704013 Kabipupu Rural Health Center
			704014 Kalengwa Rural Health Center
			704016 Kashima Rural Health Center
			704017 Matushi Rural Health Center
			704018 Mufumbwe District Hospital HAHC
			704019 Munyambala Rural Health Center
			704020 Mushima Rural Health Center
			704021 Lubilo Rural Health Center
			7040J9 DATF - Mufumbwe
		Mongu Hub	7040B9 Miluji Health Post
Mwinilunga	Solwezi Staging Post	Kabompo Staging Post	705010 Chibwika Rural Health Center
			705011 Chiwoma Rural Health Center
			705016 Kamapanda Rural Health Center
			7050B9 Kanzenzi Health Post
		Luanshya Hub	705015 Kakoma Rural Health Center
Nakonde	Kasama Hub	Chama Staging Post	613014 Nakonde Rural Health Center
			613018 Chilolwa Rural Health Center
Nyimba	Chipata Hub	Mkushi Staging Post	3070D9 Nyimba Urban Clinic
Samfya	Mansa Staging Post	Kasama Hub	407027 Nsalushi Rural Health Center
Senanga	Mongu Hub	Livingstone Staging Post	905021 Mwanamwalye Rural Health Center
Sesheke	Livingstone Staging Post	Mongu Hub	906014 Kaywala Rural Health Center
Shan'gombo	Livingstone Staging Post	Mongu Hub	907011 Kaanja Rural Health Center
			907013 Kaunga Mashi Rural Health Center
			907018 Mbanda Rural Health Center
			907019 Mulonga Rural Health Center
			907021 Mutomena Rural Health Center
			907023 Nangweshi Rural Health Center
			907025 Shang'ombo Rural Health Center
			907027 Silowana Rural Health Center
			907028 Sinjembela Rural Health Center
			907030 Sioma Rural Health Center
			907031 Sipuma Rural Health Center
			907032 Sitoti Rural Health Center
			907034 Nalwashi Rural Health Center
			907035 Keyana Rural Health Center

			907036 Shang'ombo District Hospital
			9070B8 Lyabangu Health Post
			9070C9 Siwelewele Health Post
			9070I9 DATF - Shangombo
Solwezi	Solwezi Staging Post	Luanshya Hub	706023 Luanfula ZFDS Rural Health Center
			706027 Mapunga Rural Health Center
			706029 Mujimanjovu Rural Health Center
			706055 Kipushi Health Post
Zambezi	Zambezi Staging Post	Mongu Hub	707016 Mpindi Rural Health Center

Appendix F. Recommended Anchor Sites

Table 13. Recommended Anchor Sites

SiteName	Route ID
801010_Batoka Rural Health Center	2
801013_Jembo Rural Health Center	2
801020_Mapanza Rural Health Center	2
801015_Kanchomba Rural Health Center	2
801032_Chilalantambo Health Post	2
801027_Popota Rural Health Center	2
801011_Prisons Rural Health Center	2
801016_Kasiya Rural Health Center	2
801022_Mbabala Rural Health Center	2
801019_Mangunza Rural Health Center	2
801021_Masuku Mission Rural Health Center	2
801023_Mochipapa Rural Health Center	2
801026_Pemba Main Rural Health Center	3
801030_Sikalongo Rural Health Center	3
801035_Njase Rural Health Center	3
801034_Nakeempa Rural Health Center	3
801039_Nalube Health Post	3
801037_Masuku Mines Terminal Rural Health Center	3
801038_Railway Surgery Urban Health Center	3
802099_Gwembe District Hospital HAHC	4
8010R9_Simooya Health Post	4
802015_Lukonde Rural Health Center	4
802012_Sinafala Rural Health Center	4
8010P9_Demu Rural health Center	4
808016_Chisekesi Rural Health Center	4
804020_Mukwela Rural Health Center	5
804011_Sipatunyana Rural Health Center	5
804028_Namwianga Urban Health Center	5
804021_Choonga Rural Health Center	5
804012_Simwatachela Rural Health Center	5
804022_Naluja Rural Health Center	6
804026_Siabunkululu Rural Health Center	6
804024_Chilala Rural Health Center	6
804025_Mubanga Rural Health Center	6
802017_Bbondo Rural Health Center	7

802014_Nyanga/Chaamwe Rural Health Center	7
802016_Luumbo Rural Health Center	7
807003_Kafue Gorge Hospital	8
807011_Chikokomene Rural Health Center	8
807012_Chikombola Rural Health Center	9
807016_Hanzala Rural Health Center	9
807019_Kalama Rural Health Center	9
807018_Kafue Gorge Urban Health Center	9
807014_Chivuna Rural Health Center	9
807023_NKonkola Rural Health Center	9
807021_Kaleya Urban Health Center	9
807022_Kaonga Urban Health Center	9
807029_Munenga Rural Health Center	10
807044_Mubuyu Health Post	10
807035_Nameembo Rural Health Center	10
807036_Nanga Rural Health Center	10
807038_Research Station Urban Health Center	10
807040_Moobe Health Post	10
807037_Nega Nega Rural Health Center	10
808030_Monze Urban Health Center	11
809015_Kasenga Rural Health Center	12
809010_Baambwe Rural Health Center	12
809017_Maseele Urban Health Center	12
809098_Namwala Hospital HAHC	12
809001_Namwala District Hospital	12
809016_Maala Rural Health Center	12
809019_Muchila Rural Health Center	12
809012_Ichila Rural Health Center	12
809014_Kantengwa Rural Health Center	12
812014_Sinazeze Rural Health Center	13
812010_Maamba Hospital HAHC	13
812001_Maamba District Hospital	13
812015_Sinazongwe Rural Health Center	13
812012_Chiyabi Rural Health Center	13
806022_Mosi-oa-Tunya Health Center	14
806020_Mahatma Gandhi Urban Health Center	14
8060AA_Chreso Ministries Livingstone	14
8060C9_Libes Urban Health Center	14
806026_Hillcrest Health Post	14
8060B9_COH II Livingstone Site	14

806019_Airport Urban Health Center	14
8060D9_New Start Center-Livingstone	14
805022_Nyawa Rural Health Center	15
805017_Musokotwane Rural Health Center	15
805012_Kazungula Health Post	15
906013_Katima Mulilo Rural Health Center	16
906001_Mwandi Mission Hospital	16
906012_Kalobolelwa Rural Health Center	16
907030_Sioma Rural Health Center	17
907021_Mutomena Rural Health Center	17
907027_Silowana Rural Health Center	17
907019_Mulonga Rural Health Center	18
907023_Nangweshi Rural Health Center	18
907031_Sipuma Rural Health Center	19
907036_Shang'ombo District Hospital	19
9070C9_Siwelewele Health Post	19
801043_Simakutu Rural Health Center	20
801036_Pemba Sub Rural Health Center	20
8010G9_Chiyumbabenzu Health Post	20
8010F9_Harmony Clinic	20
801044_Kasikili Rural Health Center	20
801041_Macha Mission Hospital HAHC	20
801045_Sibanyati Rural Health Center	20
8010D9_Pangwe Rural Health Center	20
807031_Nadezwe Rural Health Center	21
807024_Lubombo Rural Health Center	21
807025_Magoye Rural Health Center	21

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