Supply Chain Optimization of Specialized Nutritious Foods in Zambia

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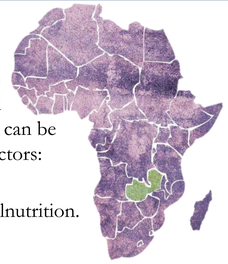
MOTIVATION



Zambia is one of the world's poorest countries with highest rate of under-nutrition, and still continues to face high level of child malnutrition that remained stagnant since 1999. This deficiency rate can be measured based on comparisons of 3 factors:

Underweight (low weight for age):
- A composite of chronic and acute malnutrition. Prevalence of **15%**.

Wasting (low weight for height):
- *Acute malnutrition,* usually caused by low energy intake and high loss of nutrients. Prevalence of **5%**.

Stunting (low height for age):
- *Chronic malnutrition,* best measures malnutrition in the long term. Prevalence of **45%** that has persisted over 2 decades.
- At least **1 out of 3** children in every household is stunted.

Malnutrition Rate Comparison Among African Countries

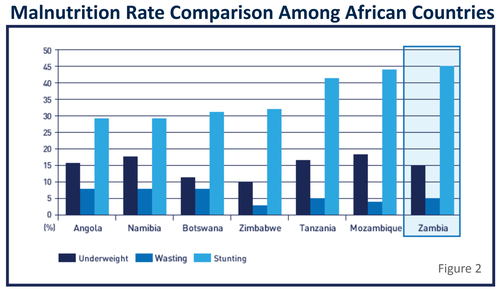


Figure 2

DECENTRALIZED SUPPLY CHAIN

District Warehouse System Optimization

In the current district warehouse system, central warehouse (CW) obtains the aggregate SNF demands of all distribution locations (DL) at each district through district warehouses (DW). There is at most 1 district warehouse representing every district in Zambia. SNF commodities are transported by single vehicles and the allocation decisions need to be made twice: CW → DW and DW → DL.

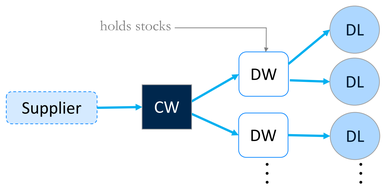


Figure 6

Similar to the centralized model, district warehouse system optimization also minimizes the sum of expected shortage, expiry, and transportation cost across the system for all scenarios. However, the model now includes the fixed cost of ordering rather than transportation costs from CW to DW for every demand allocated since no hubs exist.

OBJECTIVE

In 2013, six tons of SNF products were inefficiently distributed, causing high number of unsatisfied demands from targeted population. This eventually results in high prevalence of malnutrition and increasing rate of food insecurity especially among children under 5 years of age.

The goal of this research is to improve the efficiency of specialized nutritious foods supply chain in Zambia by optimizing inventory allocation policy. The Ministry of Health in Zambia currently utilizes district warehouse (decentralized) system to allocate SNF stocks from the central warehouse to over 15,000 beneficiaries.

To further improve the existing allocation policy, we developed centralized (hub system) and decentralized optimization model. The objectives in this process include minimization of commodity waste, unsatisfied demand and system-wide costs, which ultimately aims to decrease high malnutrition rate in Zambia.

Valuating both models, the hub system results in 17% less expiration and 5% less shortage of SNF commodities. With this optimized model, we will propose implementation of the hub system to the Ministry of Health in Zambia for more efficient and robust inventory allocation policies of SNF. The next steps in this research may include developing case studies and finding optimal inventory policy that minimizes logistical cost using both centralized and decentralized structures.

Key Stakeholders in SNF Supply Chain in Zambia

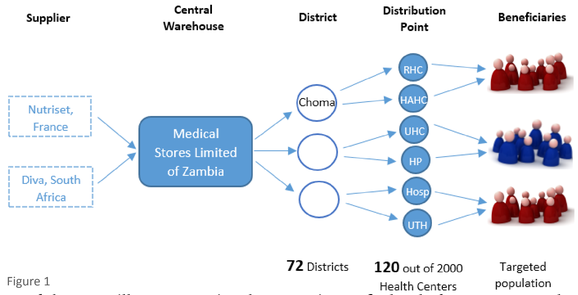
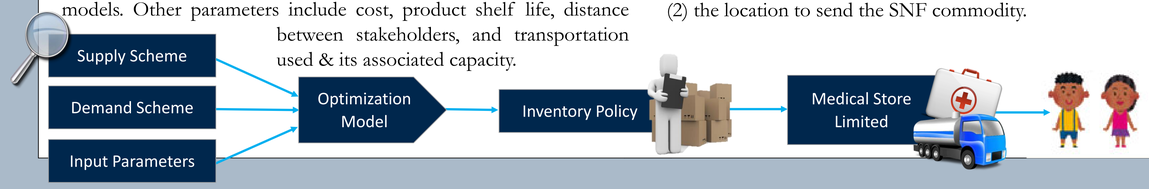


Figure 1

METHODOLOGY

- Conduct quantitative & qualitative data analysis to draw relationship between different factors and variables used in the optimization model, such as stunting prevalence (Figure 3), SNF distribution routing and locations (Figure 4), and demand statistics of SNF (Figure 5). Pattern observations will help determine optimal inventory policy for SNF allocation.
- Obtain supply and demand scheme to be fed into optimization models. Other parameters include cost, product shelf life, distance between stakeholders, and transportation used & its associated capacity.
- Identify each demand scheme is identified with the number of batches needed for certain SNF at every period for a given timespan. The model will take in a number of scenarios for both supply and demand. Data for each scenario can be randomly generated using simulation.
- Output of the model is an optimal inventory policy, that provides: (1) the type and quantity of SNF to deliver (based on product age), (2) the location to send the SNF commodity.



CENTRALIZED SUPPLY CHAIN

Hub System Optimization

The centralized model is a supply chain structure where central warehouse (CW) receives and allocates demand to district warehouses through 'cross-dock' hubs. The Medical Store Limited, which acts as the central warehouse, supplies all SNF stocks to each distribution location (DL) using multiple transportations to hubs, but only single vehicle to DLs. To determine the inventory policy, hub locations would need to be decided first before the allocations to each DL.

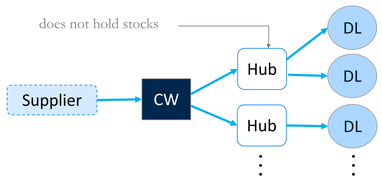


Figure 7

Objective: minimize the sum of expected shortage, expiry, and transportation cost across the system for all scenarios.

$$\text{Min} \sum_{t\in T}\sum_{s\in S} \text{probability of each scenario } s \times \Big\{ \sum_{i\in D} \big(\text{shortage cost per unit} \times \text{amount of unit lost} + \text{expiry cost per unit} \times \text{amount of unit expired in DL } i \big) + \sum_{i\in D}\sum_{k\in K} \big(\text{transportation cost per vehicle} \times \text{amount of vehicles used from CW to DL } i \big) + \sum_{u\in D}\sum_{v\in D} \big(\text{fixed ordering cost} \times \text{ordering decision var from hub } u \text{ to DL } v \big) + \text{expiry cost per unit} \times \text{amount of unit expired in central warehouse} \Big\}$$

Main decision var: amount of SNF commodity of age *j* allocated to from central warehouse to distribution location *i* at period *t*.

Constraints: 3 months to 2 years of shelf life, limited amount of commodity at each distribution, transportation routing, and allocation update.

DATA ANALYSIS

The stunting prevalence near the central and north-eastern region of Zambia is considerably higher than that in the western region. The increasing pattern of nutrient deficiency is positively correlated to the number of special nutritional food demands across the country. As seen in Figure 4, district hospitals also have higher density in the areas such as the southern and north-eastern region of Zambia where demands are higher. The primary routes for allocating SNF follow this consistency.

Stunting Prevalence in 2008

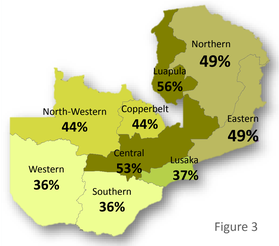


Figure 3

Logistics Routing for SNF

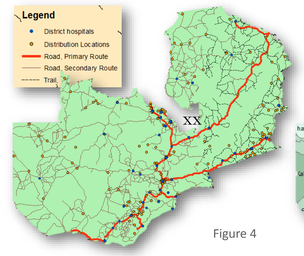


Figure 4

RUTF Demand Statistics in 2008

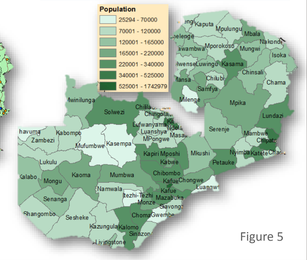


Figure 5

POLICY VALUATION

Models Comparison in Commodity Shortage & Expiration

Range	District Warehouse System		Hub System	
	Shortage	***Expiration***	***Shortage***	***Expiration***
Min	7.52%	6.14%	3.21%	0.28%
Max	61.71%	29.66%	12.12%	9.42%
Average	36.16%	17.30%	7.52%	4.77%

Centralized optimization model results in a much lower number of shortage and expired SNF commodities. This causes the cost of hub system implementation to be higher than the current decentralized model (see below).

Models Comparison in Costs for Structure Change

System	Expiration cost	Shortage cost	Transportation cost	Overall
Hub	0.00%	0.00%	+ 4.93%	0.00%
DW	+ 7.83%	+ 16.42%	0.00%	+ 10.57%

Switching to hub system completely results in 10.57% more cost than using the existing district warehouse system.